File No. 220036 **Committee Item No.** 3
Board Item No. ____________

COMMITTEE/BOARD OF SUPERVISORS

AGENDA PACKET CONTENTS LIST

Committee: Land Use and Transportation Committee **Date** June 13, 2022

Board of Supervisors Meeting **Date** ____________

Cmte	Board	
☐	☐	**Motion**
☐	☐	**Resolution**
☒	☐	**Ordinance**
☒	☐	**Legislative Digest**
☐	☐	**Budget and Legislative Analyst Report**
☐	☐	**Youth Commission Report**
☐	☐	**Introduction Form**
☐	☐	**Department/Agency Cover Letter and/or Report**
☐	☐	**MOU**
☐	☐	**Grant Information Form**
☐	☐	**Grant Budget**
☐	☐	**Subcontract Budget**
☐	☐	**Contract/Agreement**
☐	☐	**Form 126 – Ethics Commission**
☐	☐	**Award Letter**
☐	☐	**Application**
☐	☐	**Public Correspondence**

OTHER		**(Use back side if additional space is needed)**
☒	☐	2019 Emissions Inventory
☒	☐	CPUC Proposed Decision 060121
☒	☐	Emerging Best Practices for EV Charging Infrastructure 1017
☒	☐	IPCC Climate Change 2021
☒	☐	Proposed EV Roadmap for SF 0619
☒	☐	EV Charging Infrastructure 1020
☐	☐	Referral CEQA 011822
☐	☐	Referral PC 011822
☐	☐	Referral FYI 011822
☐	☐	CEQA Determination 021022
☐	☐	Reso No. 2202-03-COE
☐	☐	Referral FYI 051122
☐	☐	Referral CEQA 051122
☐	☐	Referral PC 051122
☐	☐	CEQA Determination 051222

(continued)

(continuation of Board File No. 220036 – June 13, 2022)

- ☐ ☐ PLN Transmittal 051722
- ☐ ☐ Executive Summary 041422
- ☐ ☐ PC Reso No. 21099 041422
- ☐ ☐ PLN Response 051722

Completed by: Erica Major **Date** June 9, 2022

Completed by: Erica Major **Date**

[Planning Code - Electric Vehicle Charging Locations]

Ordinance amending the Planning Code to create Electric Vehicle Charging Location and Fleet Charging as Automotive Uses, allow conversion of Automotive Service Stations to Electric Vehicle Charging Locations without Conditional Use authorization and principally permit conversion of other Automotive Uses to Electric Vehicle Charging Locations, revise zoning control tables to reflect these changes, and require annual reporting by the Planning Department regarding Electric Vehicle Charging Location and Fleet Charging project approvals; affirming the Planning Department's determination under the California Environmental Quality Act; and making findings of consistency with the General Plan, and the eight priority policies of Planning Code, Section 101.1, and findings of public necessity, convenience, and welfare under Planning Code, Section 302.

NOTE: **Unchanged Code text and uncodified text** are in plain Arial font.
Additions to Codes are in *single-underline italics Times New Roman font*.
Deletions to Codes are in ~~*strikethrough italics Times New Roman font*~~.
Board amendment additions are in double-underlined Arial font.
Board amendment deletions are in ~~strikethrough Arial font~~.
Asterisks (*   *   *   *) indicate the omission of unchanged Code subsections or parts of tables.

Be it ordained by the People of the City and County of San Francisco:

Section 1. Findings.

(a) The Planning Department has determined that the actions contemplated in this ordinance comply with the California Environmental Quality Act (California Public Resources Code Sections 21000 et seq.). Said determination is on file with the Clerk of the Board of

Supervisors in File No. 220036 and is incorporated herein by reference. The Board affirms this determination.

(b) On April 14, 2022, the Planning Commission, in Resolution No. 21099, adopted findings that the actions contemplated in this ordinance are consistent, on balance, with the City's General Plan and eight priority policies of Planning Code Section 101.1. The Board adopts these findings as its own. A copy of said Resolution is on file with the Clerk of the Board of Supervisors in File No. 220036, and is incorporated herein by reference.

(c) Pursuant to Planning Code Section 302, the Board of Supervisors finds that this ordinance will serve the public necessity, convenience, and welfare for the reasons set forth in Planning Commission Resolution No. 21099, and incorporates such reasons by this reference thereto. A copy of said Resolution is on file with the Clerk of the Board of Supervisors in File No. 220036, and is incorporated herein by reference.

(d) This ordinance is based on the following findings:

(1) In 2021, the Intergovernmental Panel on Climate Change issued a report further underscoring the need for urgent action to cut global greenhouse gas emissions (GHGs) in half by 2030 and reach net-zero emissions no later than 2050 to prevent the most catastrophic effects of climate change and reduce detrimental impacts to human health and ecosystems.

(2) San Francisco, the Bay Area, and the State of California are already suffering the effects of climate change in the form of droughts, air pollution, extreme heat, frequent wildfires, flooding, and other drastic impacts on weather and the environment.

(3) To address these urgent challenges, in 2021 Mayor London Breed sponsored legislation to update the City's climate action goals. As a result of Ordinance No. 117-21, San Francisco now has climate action goals to reduce emissions 61% below 1990 levels by 2030 and reach net-zero emissions by 2040.

(4) To achieve net-zero emissions by 2040, the updated climate action goals prioritize the City's Transit First policy and encourage a shift to low-carbon modes of transportation such as taking transit, walking, and biking. All remaining modes of transportation, including private and commercial vehicles, must be electrified to further reduce and eventually eliminate remaining transportation emissions.

(5) The City's climate action targets, per Ordinance No. 117-21, include the following transportation and land use goals:

(A) By 2030, 80% of trips taken by low-carbon modes such as walking, biking, transit, and shared Electric Vehicles (EVs).

(B) By 2030, increase vehicle electrification to at least 25% of all registered private vehicles, and, by 2040, to 100% of all such vehicles.

(6) As reported in the latest San Francisco GHG Emissions Inventory, San Francisco's 2019 emissions were 41% below 1990 levels—six years ahead of the previously established goal to reduce emissions 40% by 2025. However, additional efforts must be undertaken to ensure the net-zero commitment is met by 2050.

(7) As of 2019, nearly half (47%) of San Francisco's GHG emissions came from the transportation sector, with the vast majority (72%) of those emissions from privately owned cars and trucks. Despite the City's success in reducing overall emissions to date, GHG emissions from the transportation sector have remained relatively stable.

(8) In 2019, Mayor Breed released the Electric Vehicle Roadmap ("the Roadmap") to accelerate and advance EV adoption to reduce emissions and associated air pollution health impacts from the transportation sector. To date, EVs represent about 11% of new light-duty vehicle registrations in San Francisco. The Roadmap sets a 2030 goal of 100% of new passenger vehicle registrations with no increase in total vehicle registrations per household and an ambitious goal of 100% emission-free ground transportation by 2040.

These goals are aligned with California's targets to increase EV adoption and access to EV charging. In September 2020, Governor Gavin Newsom issued an executive order requiring only zero emission passenger cars to be sold in California by 2035. Additionally, the City's goals are aligned with the Biden Administration's goal that 50% of all new vehicles sold in the United States in 2030 be zero-emission vehicles.

(9) The rate of EV adoption is determined in large part by access to charging. The three greatest barriers at this time for drivers to buy EVs are cost of the EVs, lack of charging infrastructure, and the range of EVs, the latter two barriers are interrelated and result in "range anxiety," or the fear that EV owners won't be able to locate a charger or that if they do, someone else will be using it.

(10) Range anxiety is also an equity issue. Nearly 70% of San Francisco residents live in multi-unit buildings and most such residents do not have access to off-street parking or home charging. EV charging at home should not be a privilege available only to single-family home residents or those with EV charging available at the workplace. To provide expanded access to EV charging, in June 2021, the California Public Utilities Commission ruled that electrical corporations should prioritize their near-term investments to create charging options to customers without access to home charging.

(11) Publicly accessible EV charging stations—including public Level 2 (240 volt), DC fast ("superchargers"), and workplace chargers—are the most efficient and effective solution to meet anticipated demand for EV charging. San Francisco's combination of population density, small size, and resulting high land costs make it the perfect place to install fast-charging plazas that mimic the gas station experience that drivers have come to expect when fueling their vehicles. Fast-charging plazas are integral to San Francisco's developing a comprehensive public charging network. With a robust network of public charging stations, EV owners will be able to access fast charging as needed and close to their homes.

(12) Without this ordinance’s amendments of the Planning Code, further air quality and GHG degradation would occur because the ongoing inconvenience of finding EV charging stations would result in a low rate of adoption of EVs. Multiple studies have suggested a correlation between increasing the number of charging stations and higher EV adoption rates, as summarized in an October 2017 white paper by the International Council on Clean Transportation (ICCT). In addition, the EV Roadmap identified the expansion of publicly accessible Level 2 and fast charging infrastructure in San Francisco as a key strategy to increase EV adoption rates.

(13) In 2020, the ICCT completed a study on San Francisco’s EV charging needs in 2030 and 2040. The ICCT projects that by 2030, more than 170,000 light-duty EVs will be registered in the City. To meet that charging demand, the City must have six times more charging capacity than in 2019. The number of publicly accessible charging stations in San Francisco needs to increase from about 800 in 2019 to 2,000 by 2025, and over 5,000 by 2030, to meet this demand.

(14) Currently, EV charging is not defined in the Planning Code. As a result, applications to install EV charging projects require an EV service provider (EVSP) and the Planning Department or Commission to work out a permitting pathway, on a case-by-case basis, using Planning Code provisions designed for gas stations and auto service centers. The existing use categories are an imperfect fit for this new use. They impose limitations more appropriate for the facilities they were intended to address—conventional fueling facilities—rather than less-impactful EV charging stations, creating lengthy approval processes and bureaucratic delays that should be avoided for EV charging projects.

(15) By defining “Electric Vehicle Charging Location” as an “Automotive Use” in the Planning Code and establishing zones in the City in which stand-alone EV charging is permitted, this ordinance will make it easier to convert existing sites with “Automotive Uses” to

EV charging plazas or hubs. This will result in a clear approval path for EV charging projects, reducing delays and additional workflow in Planning, and expanding opportunities to deploy publicly accessible EV charging stations within San Francisco. This ordinance will expedite expansion of critical EV charging services, creating new public charging options for San Francisco residents and visitors, thus encouraging the adoption of EVs by a greater share of the population. This in turn will help the City meet its climate action goals to reduce emissions from the transportation sector.

Section 2. The Planning Code is hereby amended by revising Sections 102 (including placing new defined terms in alphabetical sequence with existing defined terms), 142, 187.1, 202.2, 202.5, 204, 210.1, 210.2, 210.3, 311,710, 711, and 713, and adding Sections 202.13 and 204.6, to read as follows:

SEC. 102. DEFINITIONS.

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A

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Automotive Use. A Commercial Use category that includes Automotive Repair, Ambulance Services, Automobile Sale or Rental, Automotive Service Station, Automotive Wash, *Electric Vehicle Charging Location, Fleet Charging,* Gas Station, Parcel Delivery Service, Private Parking Garage, Private Parking Lot, Public Parking Garage, Public Parking Lot, Vehicle Storage Garage, Vehicle Storage Lot, and Motor Vehicle Tow Service. All Automotive Uses that have Vehicular Use Areas defined in this Section of the Code shall meet the screening requirements for vehicular use areas in Section 142.

Automotive Use, Non-Retail. A subcategory of Automotive Use that includes Ambulance Services, *Fleet Charging,* Parcel Delivery Service, Private Parking Garage, Private Parking Lot, and Motor Vehicle Tow Service.

Automotive Use, Retail. A subcategory of Automotive Use that includes Automotive Repair, Automotive Sale or Rental, Automobile Service Station, Automotive Wash, *Electric Vehicle Charging Location,* Gas Station, Public Parking Garage, Public Parking Lot, Vehicle Storage Garage, and Vehicle Storage Lot.

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E

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Electric Vehicle Charging Location. *Automotive Use, Retail that provides electricity to electric motor vehicles through one or more Electric Vehicle Charging Stations on a retail basis to the general public as a primary use. Electric Vehicle Charging Locations may include up to one-third of the total Electric Vehicle Charging Stations dedicated to Fleet Charging as an accessory use per Section 204.6(a), and may include ancillary services, including but not limited to restrooms, self-service vending, and limited retail amenities primarily for the benefit of customers charging their vehicles.*

Electric Vehicle Charging Station. *An electric vehicle charging space served by an electric vehicle charger or other charging equipment.*

* * * *

F

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Fleet Charging. *Automotive Use, Non-Retail that provides electricity to electric motor vehicles through one or more Electric Vehicle Charging Stations that are dedicated or reserved for private parties pursuant to contract or other agreement and are not available to the general public.*

* * * *

SEC. 142. SCREENING AND GREENING OF PARKING AND VEHICULAR USE AREAS.

Off-street parking and Vehicular Use Areas adjacent to the public right-of-way shall be screened as provided in this Section *142*. *Where an existing Automotive Use converts to an Electric Vehicle Charging Location, the requirements of this Section shall not apply.*

* * * *

SEC. 187.1. AUTOMOTIVE SERVICE STATIONS*, ELECTRIC VEHICLE CHARGING LOCATIONS,* AND GAS STATIONS AS LEGAL NONCONFORMING USES.

(a) **Continuation as a Nonconforming Use.** Notwithstanding any other provision of this Code, an Automotive Service Station or a Gas Station as defined in Section 102 of this Code, located in a Residential district, and having legal nonconforming use status under the provisions of this Code on January 1, 1980, shall be regarded as a legal nonconforming use so long as the station *either: (1)* continues to sell and dispense gasoline and other motor fuels and lubricating fluids directly into motor vehicles*, or (2) transitions to an Electric Vehicle Charging Location*.

* * * *

SEC. 202.2. LOCATION AND OPERATING CONDITIONS.

* * * *

(b) Automotive Uses. The Automotive Uses listed below shall be subject to the corresponding conditions:

* * * *

(2) **Conditional Use Authorization Required for Establishments that Sell Beer or Wine with Motor Vehicle Fuel.** Any establishment that proposes to retail motor vehicle fuel and provide retail sale of beer or wine shall require Conditional Use authorization.

The Planning Commission may deny authorization or grant Conditional Use authorization to an applicant based upon the criteria set forth in Section 303(c) of this Code.

* * * *

(D) **Definitions.** For purposes of Subsection 202.2(b)(1) and (2), the following definitions shall apply:

(i) "Alcoholic beverages" shall be as defined in California Business and Professions Code Section 23004;

(ii) "Beer" and "wine" shall be as defined in California Business and Professions Code Section 23006 and Section 23007, respectively;

(iii) "Motor vehicle fuel" shall mean gasoline, other motor fuels *including electricity at an Electric Vehicle Charging Location*, and lubricating oil dispensed directly into motor vehicles; and

(iv) "Establishment" shall include an arrangement where a lot containing a business selling motor vehicle fuel provides direct access to another business selling alcoholic beverages on the same or adjacent lot.

* * * *

(3) **Automotive Wash.** Cleaning and polishing are required to be conducted within an enclosed building having no openings, other than fixed windows or exits required by law located within 50 feet of any R District, and that has an off-street waiting and storage area outside the building which accommodates at least one-quarter the hourly capacity in vehicles of the enclosed operations, provided: (1) that incidental noise is reasonably confined to the premises by adequate soundproofing or other device; and (2) that complete enclosure within a building may be required as a condition of approval, notwithstanding any other provision of this Code; but the foregoing provisions shall not preclude the imposition of any additional conditions pursuant to Section 303 of this Code.

*(4) **Electric Vehicle Charging Location.** At Electric Vehicle Charging Locations, the Electric Vehicle Charging Stations, including the charging space for the electric vehicle and all necessary charging equipment and infrastructure, may be located within any setbacks required by the underlying zoning district. Any structures associated with ancillary services, including restrooms or vending machines, must adhere to any underlying zoning setback requirements.*

*(5) **Fleet Charging and Electric Vehicle Charging Location Reporting Requirements.** Beginning on June 1, 2023, the Planning Department shall submit a report to the Board of Supervisors and the Mayor that includes the number and location of all Electric Vehicle Charging Locations and Fleet Charging locations that have been approved since the ordinance in Board File No. 220036 establishing this reporting requirement became effective. The Planning Department's report shall include: the address of each such charging location, number of charging stations at each location, prior use of the property, whether the charging location was principally permitted or conditionally permitted, and what percent of each station is dedicated to Fleet Charging. The Planning Department shall submit this report annually for five years, with the last report to be submitted on June 1, 2027.*

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SEC. 202.5. CONVERSION OF AUTOMOTIVE SERVICE STATIONS.

* * * *

(b) **Definitions.** Whenever used in this Section, unless a different meaning clearly appears from the context:

(1) "Automotive Service Station" or "service station" shall mean a retail automotive service use as defined in Section 102 of this Code.

(2) "Conversion" shall mean to change the use of a property from a service station use to a different type of use. *A change from Automotive Service Station to Electric Vehicle Charging Location is not a change to a different type of use and shall not be a "Conversion" subject to this Section.*

* * * *

SEC. 202.13. CONVERSION OF AUTOMOTIVE USE TO ELECTRIC VEHICLE CHARGING LOCATION.

Notwithstanding any other provisions of this Code, any Automotive Use, including Retail or Non-Retail uses, as defined in Section 102, shall be principally permitted to convert to an Electric Vehicle Charging Location, also as defined in Section 102, regardless of the underlying zoning district. Further, such conversion shall not be subject to the notification requirements outlined in Section 311.

SEC. 204. ACCESSORY USES, GENERAL.

This Section 204 and Sections 204.1 through 204.*6*~~5~~, shall regulate Accessory Uses, as defined in Section 102. Any use which does not qualify as an Accessory Use shall be classified as a Principal or Conditional Use, unless it qualifies as a temporary use under Sections 205 through 205.4 of this Code.

* * * *

SEC. 204.6. FLEET CHARGING ACCESSORY TO ELECTRIC VEHICLE CHARGING LOCATIONS.

In order for Fleet Charging to be a classified as an Accessory Use to an Electric Vehicle Charging Location, no more than one-third of the Electric Vehicle Charging Stations may be dedicated to Fleet Charging and two-thirds, or more, of the Electric Vehicle Charging Stations shall be available for general public use.

* * * *

SEC. 210.1. C-2 DISTRICTS: COMMUNITY BUSINESS.

* * * *

Table 210.1

ZONING CONTROL TABLE FOR C-2 DISTRICTS

Zoning Category	§ References	C-2

*   *   *   *

NON-RESIDENTIAL STANDARDS AND USES		
* * * *		
Automotive Use Category		
Automotive Repair	§ 102	NP
Automotive Sale/Rental	§ 102	P (3)
Automotive Service Station	§§ 102, 202.2(b), 202.5	P (2)
Automotive Wash	§§ 102, 202.2(b)	C (2)
Electric Vehicle Charging Location	*§§ 102, 202.2(b), 202.13*	*P*
Fleet Charging	*§ 102*	*C*

*   *   *   *

SEC. 210.2. C-3 DISTRICTS: DOWNTOWN COMMERCIAL.

*   *   *   *

Table 210.2

ZONING CONTROL TABLE FOR C-3 DISTRICTS

Zoning Category	§ References	C-3-O	C-3-O(SD)	C-3-R	C-3-G	C-3-S

*   *   *   *

NON-RESIDENTIAL STANDARDS AND USES

* * * *						
Automotive Use Category						
Automotive Repair	§ 102	NP	NP	NP	NP	P
Automotive Sale/Rental	§ 102	P (4)	P (4)	P (4)	P (3)	P (3)
Automotive Service Station	§§ 102, 202.2(b), 202.5	NP	NP	NP	P	P
Automotive Wash	§§ 102, 202.2(b)	NP	NP	NP	C	C
Electric Vehicle Charging Location	*§§ 102, 202.2(b), 202.13*	*C*	*C*	*C*	*C*	*C*
Fleet Charging	*§ 102*	*C*	*C*	*C*	*C*	*C*
Gas Station	§§ 102, 187.1, 202.2(b)	NP	NP	NP	*C*~~P~~	*C*~~P~~

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SEC. 210.3. PDR DISTRICTS.

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Table 210.3

ZONING CONTROL TABLE FOR PDR DISTRICTS

Zoning Category	§ References	PDR-1-B	PDR-1-D	PDR-1-G	PDR-2
* * * *					
NON-RESIDENTIAL STANDARDS AND USES					

* * * *					
Automotive Use Category					
Automotive Uses*	§ 102	NP	P	P	P
Automotive Repair	§ 102	P (3)	P	P	P
Automotive Sale/Rental	§ 102	P	P (4)	P	P
Automotive Service Station	§§ 102, 202.2(b), 202.5	P	P	P	P
Automotive Wash	§§ 102, 202.2(b)	P	P	P	P
Electric Vehicle Charging Location	*§§ 102, 202.2(b), 202.13*	*P*	*P*	*P*	*P*
Fleet Charging	*§ 102*	*C*	*P*	*P*	*P*

* * * *

SEC. 311. PERMIT REVIEW PROCEDURES.

(a) **Purpose.** The purpose of this Section 311 is to establish procedures for reviewing building permit applications to determine compatibility of the proposal with the neighborhood and for providing notice to property owners and residents on the site and neighboring the site of the proposed project and to interested neighborhood organizations, so that concerns about a project may be identified and resolved during the review of the permit.

(b) **Applicability.** Except as indicated herein, all building permit applications in Residential, NC, NCT, and Eastern Neighborhoods Mixed Use Districts for a change of use;

establishment of a Micro Wireless Telecommunications Services Facility; establishment of a Formula Retail Use; demolition, new construction, or alteration of buildings; and the removal of an authorized or unauthorized residential unit, shall be subject to the notification and review procedures required by this Section 311. In addition, all building permit applications that would establish Cannabis Retail or Medical Cannabis Dispensary uses, regardless of zoning district, shall be subject to the review procedures required by this Section 311. Notwithstanding the foregoing or any other requirement of this Section 311, a change of use to a Child Care Facility, as defined in Section 102, shall not be subject to the review requirements of this Section 311. Notwithstanding the foregoing or any other requirement of this Section 311, building permit applications to construct an Accessory Dwelling Unit pursuant to Section 207(c)(6) shall not be subject to the notification or review requirements of this Section 311. Notwithstanding the foregoing or any other requirement of this Section 311, a change of use to a principally permitted use in an NC or NCT District, or in a limited commercial use or a limited corner commercial use, as defined in Sections 186 and 231, respectively, shall not be subject to the review or notice requirements of this Section 311. *Notwithstanding the foregoing or any other requirement of this Section 311, building permit applications to change any existing Automotive Use to an Electric Vehicle Charging Location shall not be subject to the review or notification requirements of this Section 311.*

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SEC. 710. NC-1 – NEIGHBORHOOD COMMERCIAL CLUSTER DISTRICT.

*   *   *   *

Table 710. NEIGHBORHOOD COMMERCIAL CLUSTER DISTRICT NC-1

ZONING CONTROL TABLE

*   *   *   *

Zoning Category	§ References	Controls		
* * * *				
NON-RESIDENTIAL STANDARDS				
* * * *				
Non-Residential Uses		**Controls by Story**		
		1st	**2nd**	**3rd+**
* * * *				
Automotive Use Category				
Automotive Uses*	§ 102	NP	NP	NP
Electric Vehicle Charging Location	*§§ 102, 202.2(b), 202.13*	*C(12)*	*C(12)*	*C(12)*
Parking Garage, Private	§ 102	C	C	C

* * * *

(12) P where existing use is any Automotive Use.

* * * *

SEC. 711. NC-2 – SMALL-SCALE NEIGHBORHOOD COMMERCIAL DISTRICT.

* * * *

Table 711. SMALL-SCALE NEIGHBORHOOD COMMERCIAL DISTRICT NC-2

ZONING CONTROL TABLE

* * * *

Zoning Category	§ References	Controls
* * * *		

NON-RESIDENTIAL STANDARDS				
* * * *				
Non-Residential Uses		**Controls by Story**		
		1st	**2nd**	**3rd+**
* * * *				
Automotive Use Category				
Automotive Uses*	§ 102	NP	NP	NP
Automotive Repair	§ 102	C	NP	NP
Automotive Service Station	§§ 102, 202.2(b)	C	NP	NP
Electric Vehicle Charging Location	*§§ 102, 202.2(b), 202.13*	*C(13)*	*C(13)*	*C(13)*
Fleet Charging	*§ 102*	*C*	*C*	*C*
Gas Station	§§ 102, 187.1, 202.2(b)	C	NP	NP

* * * *

(13) P where existing use is any Automotive Use.

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SEC. 713. NC-S – NEIGHBORHOOD COMMERCIAL SHOPPING CENTER DISTRICT.

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Table 713. NEIGHBORHOOD COMMERCIAL SHOPPING CENTER DISTRICT NC-S ZONING CONTROL TABLE

* * * *

Zoning Category	§ References	Controls		
* * * *				
NON-RESIDENTIAL STANDARDS				
* * * *				
Non-Residential Uses		**Controls by Story**		
		1st	**2nd**	**3rd+**
* * * *				
Automotive Use Category				
Automotive Uses*	§ 102	NP	NP	NP
Automotive Sale/Rental	§ 102	C	NP	NP
Automotive Service Station	§§ 102, 202.2(b)	P	NP	NP
Automotive Wash	§§ 102, 202.2(b)	C	NP	NP
Electric Vehicle Charging Location	*§§ 102, 202.2(b), 202.13*	*C(9)*	*C(9)*	*C(9)*
Gas Station	§§ 102, 187.1, 202.2(b)	C	NP	NP

* * * *

(9) P where existing use is any Automotive Use.

Section 3. Amendment of Specific Zoning Control Tables.

Zoning Control Tables 712, 714, 715, 716, 717, 718, 719, 720, 721, 722, 723, 724, 725, 726, 727, 728, 729, 730, 731, 732, 733, 734, 735, 736, 737, 738, 739, 740, 741, 742, 743, 744, 745, 750, 751, 752, 753, 754, 755, 756, 757, 758, 759, 760, 761, 762, 763, and 764 are hereby amended identically to the amendment of Zoning Control Table 711 in Section 2 of this ordinance, to create “Electric Vehicle Charging Location” and “Fleet Charging” as new Non-Residential Uses within the Automotive Use Category, citing Planning Code Sections 102, 202.2(b) and 202.13 as references, identifying “C” as the zoning control, and including the note for “Electric Vehicle Charging Location” use (“*P where existing use is any Automotive Use.*”), provided that the note shall be numbered as appropriate for each table, as follows.

Zoning Control Table	Note #
712	12
714	9
715	8
716	8
717	7
718	8
719	10
720	6
721	6
722	14
723	10
724	7
725	7
726	8
727	3
728	8

729	6
730	6
731	7
732	7
733	7
734	7
735	3
736	3
737	5
738	3
739	8
740	5
741	3
742	3
743	3
744	4
745	4
750	10
751	8
752	8
753	6

754	9
755	7
756	7
757	11
758	10
759	9
760	5
761	7
762	8
763	8
764	10

Section 4. The Planning Code is hereby amended by revising Sections 810, 811, 812, 827, 829, 840, 841, 842, 843, 844, 845, 846, 847, and 848, to read as follows:

SEC. 810. CHINATOWN COMMUNITY BUSINESS DISTRICT.

* * * *

Table 810.

CHINATOWN COMMUNITY BUSINESS DISTRICT ZONING CONTROL TABLE

* * * *

Zoning Category	§ References	Controls		
NON-RESIDENTIAL USES		**Controls by Story**		
		1st	**2nd**	**3rd+**

* * * *				
Automotive Use Category				
Automotive Uses*	§§ 102, 202.5~~4~~	NP	NP	NP
Electric Vehicle Charging Location	*§§ 102, 202.2(b), 202.13*	*C(4)*	*C(4)*	*C(4)*
Parking Garage, Private	§ 102	C	C	C

* * * *

(4) P where existing use is any Automotive Use.

* * * *

SEC. 811. CHINATOWN VISITOR RETAIL DISTRICT.

* * * *

Table 811.

CHINATOWN VISITOR RETAIL DISTRICT ZONING CONTROL TABLE

* * * *

Zoning Category	§ References	Controls		
NON-RESIDENTIAL USES		**Controls by Story**		
		1st	**2nd**	**3rd+**
* * * *				
Automotive Use Category				
Automotive Uses*	§§ 102, 202.5~~4~~	NP	NP	NP
Electric Vehicle Charging Location	*§§ 102, 202.2(b), 202.13*	*C(3)*	*C(3)*	*C(3)*

Parking Garage, Private	§ 102	C	C	C

* * * *

(3) *P where existing use is any Automotive Use.*

* * * *

SEC. 812. CHINATOWN RESIDENTIAL NEIGHBORHOOD COMMERCIAL DISTRICT.

* * * *

Table 812.

CHINATOWN RESIDENTIAL NEIGHBORHOOD COMMERCIAL DISTRICT

ZONING CONTROL TABLE

* * * *

Zoning Category	§ References	Controls		
NON-RESIDENTIAL USES		**Controls by Story**		
		1st	**2nd**	**3rd+**
* * * *				
Automotive Use Category				
Automotive Uses*	§§ 102, 202.54	NP	NP	NP
Electric Vehicle Charging Location	*§§ 102, 202.2(b), 202.13*	*C(3)*	*C(3)*	*C(3)*
Parking Garage, Private	§ 102	C	C	C

* * * *

(3) *P where existing use is any Automotive Use.*

* * * *

SEC. 827. RINCON HILL DOWNTOWN RESIDENTIAL MIXED USE DISTRICT (RH-DTR).

* * * *

Table 827

RINCON HILL DOWNTOWN RESIDENTIAL MIXED USE DISTRICT

ZONING CONTROL TABLE

No.	Zoning Category	§ References	Rincon Hill Downtown Residential Mixed Use District Zoning Controls
* * * *			
Non-Residential Standards and Uses			
* * * *			
.40	Automotive Repair	§ 890.15	NP
.40a	*Electric Vehicle Charging Location*	*§§ 102, 202.2(b), 202.13*	*C*
.40b	*Fleet Charging*	*§ 102*	*NP*

* * * *

SEC. 829. SOUTH BEACH DOWNTOWN RESIDENTIAL MIXED USE DISTRICT (SB-DTR).

* * * *

Table 829

SOUTH BEACH DOWNTOWN RESIDENTIAL MIXED USE DISTRICT ZONING CONTROL TABLE

No.	Zoning Category	§ References	South Beach Downtown Residential Mixed Use District Zoning Controls
* * * *			
Non-Residential Standards and Uses			
* * * *			
.40	Automotive Repair	§ 890.15	NP
.40a	*Electric Vehicle Charging Location*	*§§ 102, 202.2(b), 202.13*	*C*
.40b	*Fleet Charging*	*§ 102*	*NP*

* * * *

SEC. 840. MUG – MIXED USE-GENERAL DISTRICT.

* * * *

Table 840

MUG – MIXED USE-GENERAL DISTRICT ZONING CONTROL TABLE

No.	Zoning Category	§ References	Mixed Use-General District Controls

* * * *			
Motor Vehicle Services			
* * * *			
840.75	Non-Auto Vehicle Sales or Rental	§ 890.69	P
840.76	*Electric Vehicle Charging Location*	*§§ 102, 202.2(b), 202.13*	*P*
840.77	*Fleet Charging*	*§ 102*	*C and must be within an enclosed building*

* * * *

SEC. 841. MUR – MIXED USE-RESIDENTIAL DISTRICT.

* * * *

Table 841

MUR – MIXED USE-RESIDENTIAL DISTRICT ZONING CONTROL TABLE

* * * *

No.	**Zoning Category**	**§ References**	**Mixed Use-Residential District Controls**
* * * *			
Motor Vehicle Services			
* * * *			

841.75	Non-Auto Vehicle Sales or Rental	§ 890.69	P
841.76	*Electric Vehicle Charging Location*	*§§ 102, 202.2(b), 202.13*	*P*
841.77	*Fleet Charging*	*§ 102*	*C and must be within an enclosed building*

* * * *

SEC. 842. MUO – MIXED USE-OFFICE DISTRICT.

* * * *

Table 842

MUO – MIXED USE-OFFICE DISTRICT ZONING CONTROL TABLE

No.	Zoning Category	§ References	Mixed Use-Office District Controls
* * * *			
Motor Vehicle Services			
* * * *			
842.75	Non-Auto Vehicle Sales or Rental	§ 890.69	P
842.76	*Electric Vehicle Charging Location*	*§§ 102, 202.2(b), 202.13*	*P*
842.77	*Fleet Charging*	*§ 102*	*C and must be within an enclosed building*

*   *   *   *

SEC. 843. UMU – URBAN MIXED USE DISTRICT.

*   *   *   *

Table 843

UMU – URBAN MIXED USE DISTRICT ZONING CONTROL TABLE

No.	**Zoning Category**	**§ References**	**Urban Mixed Use District Controls**
* * * *			
Motor Vehicle Services			
843.68	*Electric Vehicle Charging Location*	*§§ 102, 202.2(b), 202.13*	*P*
843.69	*Fleet Charging*	*§ 102*	*C and must be within an enclosed building*
843.70	Vehicle Storage - Open Lot	§ 890.131	NP

*   *   *   *

SEC. 844. WMUG – WSOMA MIXED USE-GENERAL DISTRICT.

*   *   *   *

Table 844

WMUG – WSOMA MIXED USE-GENERAL DISTRICT ZONING CONTROL TABLE

No.	Zoning Category	§ References	WSoMa Mixed Use-General District Controls
* * * *			
Motor Vehicle Services			
* * * *			
844.75	Non-Auto Vehicle Sales or Rental	§ 890.69	C
844.76	*Electric Vehicle Charging Location*	*§§ 102, 202.2(b), 202.13*	*P with no ingress/egress onto alleys, as defined in the Western SoMa Community Plan, within or along any RED or RED-MX Districts*
844.77	*Fleet Charging*	*§ 102*	*C and must be within an enclosed building with no ingress/egress onto alleys, as defined in the Western SoMa Community Plan, within or along any*

			<u>*RED or RED-MX Districts*</u>

*   *   *   *

SEC. 845. WMUO – WSOMA MIXED USE-OFFICE DISTRICT.

*   *   *   *

Table 845

WMUO – WSOMA MIXED USE-OFFICE DISTRICT ZONING CONTROL TABLE

No.	**Zoning Category**	**§ References**	**WSoMa Mixed Use-Office District Controls**
* * * *			
Motor Vehicle Services			
* * * *			
845.75	Non-Auto Vehicle Sales or Rental	§ 890.69	P
<u>*845.76*</u>	<u>*Electric Vehicle Charging Location*</u>	<u>*§§ 102, 202.2(b), 202.13*</u>	<u>*P*</u>
<u>*845.77*</u>	<u>*Fleet Charging*</u>	<u>*§ 102*</u>	<u>*C and must be within an enclosed building*</u>

*   *   *   *

SEC. 846. SALI – SERVICE/ARTS/LIGHT INDUSTRIAL DISTRICT.

*   *   *   *

Table 846

SALI – SERVICE/ARTS/LIGHT INDUSTRIAL DISTRICT ZONING CONTROL TABLE

No.	**Zoning Category**	**§ References**	**SALI District Controls**
* * * *			
Motor Vehicle Services			
* * * *			
846.75	Non-Auto Vehicle Sales or Rental	§ 890.69	P
846.76	*Electric Vehicle Charging Location*	*§§ 102, 202.2(b), 202.13*	*P*
846.77	*Fleet Charging*	*§ 102*	*C and must be within an enclosed building*

* * * *

SEC. 847. RED-MX – RESIDENTIAL ENCLAVE-MIXED DISTRICT.

* * * *

Table 847

RED-MX – RESIDENTIAL ENCLAVE-MIXED DISTRICT ZONING CONTROL TABLE

No.	**Zoning Category**	**§ References**	**Residential Enclave-Mixed Controls**
* * * *			

Automotive Services			
* * * *			
847.63	Public Transportation Facility	§ 890.80	NP
847.64	*Electric Vehicle Charging Location*	*§§ 102, 202.2(b), 202.13*	*NP*
847.65	*Fleet Charging*	*§ 102*	*NP*

* * * *

SEC. 848. CMUO-CENTRAL SOMA MIXED-USE OFFICE DISTRICT.

* * * *

Table 848 **CMUO-CENTRAL SOMA MIXED-USE OFFICE DISTRICT ZONING CONTROL TABLE**		
Central SoMa Mixed Use-Office District Controls		
Zoning Category	**§ References**	**Controls**
* * * *		
Automotive Use Category		
Automotive Uses*	§ 102	P
Electric Vehicle Charging Location	*§§ 102, 202.2(b), 202.13*	*P*

<u>Fleet Charging</u>	*<u>§ 102</u>*	*<u>C and must be within an enclosed building</u>*

* * * *

Section 5. Effective Date. This ordinance shall become effective 30 days after enactment. Enactment occurs when the Mayor signs the ordinance, the Mayor returns the ordinance unsigned or does not sign the ordinance within ten days of receiving it, or the Board of Supervisors overrides the Mayor's veto of the ordinance.

Section 6. Scope of Ordinance. In enacting this ordinance, the Board of Supervisors intends to amend only those words, phrases, paragraphs, subsections, sections, articles, numbers, punctuation marks, charts, diagrams, or any other constituent parts of the Municipal Code that are explicitly shown in this ordinance as additions, deletions, Board amendment additions, and Board amendment deletions in accordance with the "Note" that appears under the official title of the ordinance. The preceding sentence does not apply to Section 3 of the ordinance, which uses a different methodology for amending the sections of the Municipal Code to which it applies.

APPROVED AS TO FORM:
DAVID CHIU, City Attorney

By: _/s/ Robb Kapla_____
ROBB KAPLA
Deputy City Attorney

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FILE NO. 220036

REVISED LEGISLATIVE DIGEST
(Substituted, 5/3/2022)

[Planning Code - Electric Vehicle Charging Locations]

Ordinance amending the Planning Code to create Electric Vehicle Charging Location and Fleet Charging as Automotive Uses, allow conversion of Automotive Service Stations to Electric Vehicle Charging Locations without Conditional Use authorization and principally permit conversion of other Automotive Uses to Electric Vehicle Charging Locations, revise zoning control tables to reflect these changes, and require annual reporting by the Planning Department regarding Electric Vehicle Charging Location and Fleet Charging project approvals; affirming the Planning Department's determination under the California Environmental Quality Act; and making findings of consistency with the General Plan, and the eight priority policies of Planning Code, Section 101.1, and findings of public necessity, convenience, and welfare under Planning Code, Section 302.

Existing Law

The Planning Code does not contain definitions or zoning controls for electric vehicle charging locations, stations, or fleet charging. The Planning Code requires a conditional use authorization to convert an existing automobile service station to any other use and allows existing gas stations that do not conform with their zoning to remain in place as long as they continue to sell gasoline.

Amendments to Current Law

The Proposed Legislation would add three new definitions to the Planning Code: (1) Electric Vehicle Charging Station (EVCS)—the equipment to charge an electric vehicle; (2) Electric Vehicle Charging Location—a retail automotive use where the general public can pay to charge electric vehicles using EVCSs and access typical gas station services such as restrooms, snacks and refreshments, and vehicle necessities; and (3) Fleet Charging—EVCSs that are dedicated or reserved for specific users by contract or other arrangement and are not available for use by the general public. The Proposed Legislation would allow Electric Vehicle Charging Locations to dedicate up to one-third of their EVCSs to Fleet Charging use.

The Proposed Legislation would allow existing gas stations to convert to Electric Vehicle Charging Locations without needing conditional use authorization, including in areas where the existing gas station is nonconforming. Further, the Proposed Legislation would allow conversion of any existing Automotive Use to an Electric Vehicle Charging Location regardless of underlying zoning and without Section 311 notice.

The Proposed Legislation would also amend the zoning control tables for several non-residential districts across the City to allow Electric Vehicle Charging Locations by right (e.g., PDR and certain Mixed Use districts), pursuant to conditional use authorization (e.g., all Neighborhood Commercial and Chinatown Districts), or prohibit them (e.g., Residential-Enclave Mixed and all Residential Districts). Fleet Charging as a principal use (locations that have no retail EVCS access for the general public) would only be permitted by right in certain PDR districts and pursuant to conditional use authorization in Downtown Commercial Districts and certain Neighborhood Commercial, Eastern Neighborhoods Mixed Use, and Industrial Districts (but only when located within an enclosed building). Throughout the rest of the City, Fleet Charging as a principal use would not be permitted.

The Proposed Legislation would allow Electric Vehicle Charging Locations to charge vehicles and have EVCSs located within the setbacks of underlying zoning, but would require any ancillary structures—restrooms, vending machines or snack bars—adhere to any underlying setback requirements. The Proposed Legislation would also exempt Electric Vehicle Charging Locations from the notification provisions of Section 311 of the Planning Code.

Finally, the Proposed Legislation would require the Planning Department issue annual reports to the Board of Supervisors and Mayor’s Office detailing the location and approval of all retail Electric Vehicle Charging Locations and Fleet Charging locations approved since the zoning changes were enacted.

<u>Background Information</u>

This is a substitute ordinance, the original ordinance was introduced on January 11, 2022.

Local and state law streamline permitting for applicants installing EVCS equipment to existing uses, such as parking spaces serving office buildings, retail establishments, or private residences. But there is no explicit provision in the Planning Code that governs the establishment of electric vehicle charging as a principal use—where the parcel contains no commercial or residential use other than for customers to charge their electric vehicle and access ancillary services—like traditional gas stations. The Proposed Legislation would address this issue by (1) defining Electric Vehicle Charging Location and subject the use to similar zoning conditions as new and existing/non-conforming gas stations, and (2) defining Fleet Charging as an automotive use that may be accessory to Electric Vehicle Charging Locations, but as a principal use is generally confined to industrial and more intense mixed use districts. Finally, the annual reporting requirement will allow the City to monitor imbalances in geographic distribution, the effectiveness of the provisions in assisting the transition of gas to electric vehicles, and consistency with Transit-First policy.

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BOARD of SUPERVISORS

City Hall
1 Dr. Carlton B. Goodlett Place, Room 244
San Francisco, CA 94102-4689
Tel. No. (415) 554-5184
Fax No. (415) 554-5163
TDD/TTY No. (415) 554-5227

January 18, 2022

File No. 220036

Lisa Gibson
Environmental Review Officer
Planning Department
49 South Van Ness Avenue, Suite 1400
San Francisco, CA 94103

Dear Ms. Gibson:

On January 11, 2022, Mayor Breed submitted the following legislation:

File No. 220036

Ordinance amending the Planning Code to create Electric Vehicle Charging Location and Fleet Charging as Automotive Uses, allow conversion of Automotive Service Stations to Electric Vehicle Charging Locations without Conditional Use authorization, revise zoning control tables to reflect these changes, and require annual reporting by the Planning Department regarding Electric Vehicle Charging Location and Fleet Charging project approvals; affirming the Planning Department's determination under the California Environmental Quality Act; and making findings of consistency with the General Plan, and the eight priority policies of Planning Code, Section 101.1, and findings of public necessity, convenience, and welfare under Planning Code, Section 302.

This legislation is being transmitted to you for environmental review.

Angela Calvillo, Clerk of the Board

By: Erica Major, Assistant Clerk
Land Use and Transportation Committee

Attachment

c: Joy Navarrete, Environmental Planning
Don Lewis, Environmental Planning

Not defined as a project under CEQA Guidelines Sections 15378 and 15060(c)(2) because it would not result in a direct or indirect physical change in the environment. Individual projects will require environmental review.
02/10/2022

BOARD of SUPERVISORS

City Hall
1 Dr. Carlton B. Goodlett Place, Room 244
San Francisco, CA 94102-4689
Tel. No. (415) 554-5184
Fax No. (415) 554-5163
TDD/TTY No. (415) 554-5227

May 11, 2022

File No. 220036-2

Lisa Gibson
Environmental Review Officer
Planning Department
49 South Van Ness Avenue, Suite 1400
San Francisco, CA 94103

Dear Ms. Gibson:

On May 3, 2022, Mayor Breed submitted the following substitute legislation:

File No. 220036-2

Ordinance amending the Planning Code to create Electric Vehicle Charging Location and Fleet Charging as Automotive Uses, allow conversion of Automotive Service Stations to Electric Vehicle Charging Locations without Conditional Use authorization and principally permit conversion of other Automotive Uses to Electric Vehicle Charging Locations, revise zoning control tables to reflect these changes, and require annual reporting by the Planning Department regarding Electric Vehicle Charging Location and Fleet Charging project approvals; affirming the Planning Department's determination under the California Environmental Quality Act; and making findings of consistency with the General Plan, and the eight priority policies of Planning Code, Section 101.1, and findings of public necessity, convenience, and welfare under Planning Code, Section 302.

This legislation is being transmitted to you for environmental review.

Angela Calvillo, Clerk of the Board

By: Erica Major, Assistant Clerk
Land Use and Transportation Committee

Attachment

c: Joy Navarrete, Environmental Planning
Don Lewis, Environmental Planning

Not defined as a project under CEQA Guidelines Sections 15378 and 15060(c)(2) because it would not result in a direct or indirect physical change in the environment. Individual project will require separate environmental review.

05/12/2022

From:	Starr, Aaron (CPC)
To:	Paulino, Tom (MYR); Major, Erica (BOS)
Cc:	Owens, Sarah (MYR)
Subject:	Re: EV Charging Legislation BOS File No. 220036
Date:	Tuesday, May 17, 2022 4:11:29 PM
Attachments:	image001.png image002.png image003.png image004.png image005.png image006.png image007.png image008.png image009.png image010.png

---

Tom,

The changes in the revised ordinance were recommend by the Planning Commission, so no hearing is needed. I just got the Final Resolution back from the Commission Secretary and will be transmitting it to the Clerk shortly. This will allow the item to be calendar at committee.

Thanks,

Aaron Starr, MA
Manager of Legislative Affairs
San Francisco Planning
49 South Van Ness Avenue, Suite 1400, San Francisco, CA 94103
Direct: +1628-652-7533| sfplanning.org
Email: aaron.starr@sfgov.org
Web: www.sfplanning.org

From: "Paulino, Tom (MYR)" <tom.paulino@sfgov.org>
Date: Tuesday, May 17, 2022 at 4:02 PM
To: "Major, Erica (BOS)" <erica.major@sfgov.org>, Aaron Starr <aaron.starr@sfgov.org>
Cc: "Owens, Sarah (MYR)" <sarah.owens@sfgov.org>
Subject: RE: EV Charging Legislation BOS File No. 220036

Hi Erica,

Thank you for letting me know. Aaron, let us know either way.

Cheers,
Tom

From: Major, Erica (BOS)
Sent: Tuesday, May 17, 2022 3:56 PM
To: Starr, Aaron (CPC); Paulino, Tom (MYR)
Subject: FW: EV Charging Legislation BOS File No. 220036

FYI this was re-referred because it was substituted on May 3rd . I am not sure if the Commission will hear the substitute, I defer to Aaron .

ERICA MAJOR
Assistant Clerk
Board of Supervisors
1 Dr. Carlton B. Goodlett Place, City Hall, Room 244 San Francisco, CA 94102
Phone: (415) 554-4441 | Fax: (415) 554-5163
Erica.Major@sfgov.org | www.sfbos.org

(VIRTUAL APPOINTMENTS) To schedule a "virtual" meeting with me (on Microsoft Teams), please ask and I can answer your questions in real time.

Due to the current COVID-19 health emergency and the Shelter in Place Order, the Office of the Clerk of the Board is working remotely while providing complete access to the legislative process and our services.

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From: Kaitlin Sheber <ksheber@reubenlaw.com>
Sent: Monday, May 16, 2022 5:57 PM
To: Paulino, Tom (MYR) <tom.paulino@sfgov.org>; Ionin, Jonas (CPC) <jonas.ionin@sfgov.org>
Cc: Major, Erica (BOS) <erica.major@sfgov.org>
Subject: Re: EV Charging Legislation BOS File No. 220036

Hi Tom and Jonas,

Hope you both had a nice weekend. I wanted to reach out with a question because I saw the above legislation was maybe re-referred back to the Planning Commission. Will the Planning Commission need to hear this again or will it go to a Land Use Committee hearing next? Is there any idea for a date when the item will be heard next?

Really appreciate your help!

Best,

Kaitlin Sheber
Associate Attorney
T. (415) 567-9000
F. (415) 399-9480
C. (630) 981-4373
ksheber@reubenlaw.com

From: "Paulino, Tom (MYR)" <tom.paulino@sfgov.org>
Date: Wednesday, May 4, 2022 at 2:34 PM
To: Kaitlin Sheber <ksheber@reubenlaw.com>, "Major, Erica (BOS)" <erica.major@sfgov.org>
Subject: RE: EV Charging Legislation BOS File No. 220036

Hi Kaitlin,

Thank you for the email. We don't have a meeting date for when this item is scheduled just yet, but hope to bring it before the committee soon. Happy to keep you apprised when there it becomes clearer.

Cheers,

Tom Paulino
He/Him
Liaison to the Board of Supervisors
Office of the Mayor
City and County of San Francisco

From: Kaitlin Sheber <ksheber@reubenlaw.com>
Sent: Tuesday, May 3, 2022 2:29 PM
To: Major, Erica (BOS) <erica.major@sfgov.org>; Paulino, Tom (MYR) <tom.paulino@sfgov.org>
Subject: RE: EV Charging Legislation BOS File No. 220036

Thanks, Erica! Tom—do you know if there's a time that the above legislation is expected to be heard by the Land Use Committee?

Best,

Kaitlin Sheber
Associate Attorney
T. (415) 567-9000
F. (415) 399-9480
C. (630) 981-4373
ksheber@reubenlaw.com

From: Major, Erica (BOS) <erica.major@sfgov.org>
Sent: Wednesday, April 27, 2022 12:35 PM
To: Kaitlin Sheber <ksheber@reubenlaw.com>; Paulino, Tom (MYR) <tom.paulino@sfgov.org>
Subject: RE: EV Charging Legislation BOS File No. 220036

Hi Kaitlin,

Thanks, hope the same for you! I am not too sure, looping in the Mayor's staff for anticipated dates.

ERICA MAJOR
Assistant Clerk
Board of Supervisors
1 Dr. Carlton B. Goodlett Place, City Hall, Room 244 San Francisco, CA 94102
Phone: (415) 554-4441 | Fax: (415) 554-5163
Erica.Major@sfgov.org | www.sfbos.org

(VIRTUAL APPOINTMENTS) To schedule a "virtual" meeting with me (on Microsoft Teams), please ask and I can answer your questions in real time.

Due to the current COVID-19 health emergency and the Shelter in Place Order, the Office of the Clerk of the Board is working remotely while providing complete access to the legislative process and our services.

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The Legislative Research Center provides 24-hour access to Board of Supervisors legislation, and archived matters since August 1998.

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when they communicate with the Board of Supervisors and its committees. All written or oral communications that members of the public submit to the Clerk's Office regarding pending legislation or hearings will be made available to all members of the public for inspection and copying. The Clerk's Office does not redact any information from these submissions. This means that personal information—including names, phone numbers, addresses and similar information that a member of the public elects to submit to the Board and its committees—may appear on the Board of Supervisors website or in other public documents that members of the public may inspect or copy.

From: Kaitlin Sheber <ksheber@reubenlaw.com>
Sent: Monday, April 25, 2022 11:51 AM
To: Major, Erica (BOS) <erica.major@sfgov.org>
Subject: EV Charging Legislation BOS File No. 220036

This message is from outside the City email system. Do not open links or attachments from untrusted sources.

Hi Erica,

Hope you're doing well and had a nice weekend. Just wanted to follow up regarding the above referenced legislation—is there a time the legislation is expected to be heard by the Land Use Committee?

Thank you!

REUBEN, JUNIUS & ROSE, LLP

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Oakland, CA 94607

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May 17, 2022

Ms. Angela Calvillo, Clerk
Honorable Mayor Breed
Board of Supervisors
City and County of San Francisco
City Hall, Room 244
1 Dr. Carlton B. Goodlett Place
San Francisco, CA 94102

Re: Transmittal of Planning Department Case Number [Record Number]:
[Application Name]
Board File No. 220036

Planning Commission Recommendation: **Approval with Modification**

Dear Ms. Calvillo and Mayor Breed,

On April 14, 2022, the Planning Commission conducted a duly noticed public hearing at a regularly scheduled meeting to consider the proposed Ordinance, introduced by Mayor Breed that would amend the Planning Code to create the use definitions and corresponding land use controls for Electric Vehicle Charging Locations and Fleet Charging. At the hearing the Planning Commission recommended approval with modification.

The Commission's proposed modifications were as follows:

1. Require CU in all C-3 Districts for EV Charging Locations and change the code to make Gas Stations a CU in the two C-3 districts where they are currently principally permitted (C-3-G and C-3-S).
2. Exempt the conversion of existing automotive uses to EV Charging from Section 142 Screening requirements.
3. Prohibit Fleet Charging in RC Districts.
4. Add a new section to the Code explicitly allowing for the conversion of Automotive Uses to EV Charging Locations regardless of the underling zoning district.
5. Allow Fleet Charging with Conditional Use authorization in all NC Districts except NC-1 and NCT-1

The proposed amendments are not defined as a project under CEQA Guidelines Section 15060(c) and 15378 because they do not result in a physical change in the environment.

Mayor Breed, please advise the City Attorney at your earliest convenience if you wish to incorporate the changes recommended by the Commission.

Please find attached documents relating to the actions of the Commission. If you have any questions or require further information, please do not hesitate to contact me.

Sincerely,

Aaron D. Starr
Manager of Legislative Affairs

cc: Robb Kapla, Deputy City Attorney
Sarah Owens, Aide to Mayor Breed
Erica Major, Office of the Clerk of the Board

Attachments :
Planning Commission Resolution
Planning Department Executive Summary

San Francisco Planning

49 South Van Ness Avenue, Suite 1400
San Francisco, CA 94103
628.652.7600
www.sfplanning.org

PLANNING COMMISSION RESOLUTION NO. 21099

HEARING DATE: APRIL 14, 2022

Project Name: Electric Vehicle Charging Locations
Case Number: 2022-000549PCA [Board File No. 220036]
Initiated by: Mayor Breed / Introduced January 11, 2022
Staff Contact: aaron starr, Manager of Legislative Affairs
aaron.starr@sfgov.org, 628-652-7533

RESOLUTION APPROVING A PROPOSED ORDINANCE THAT WOULD AMEND THE PLANNING CODE TO CREATE ELECTRIC VEHICLE CHARGING LOCATION AND FLEET CHARGING AS AUTOMOTIVE USES, ALLOW CONVERSION OF AUTOMOTIVE SERVICE STATIONS TO ELECTRIC VEHICLE CHARGING LOCATIONS WITHOUT CONDITIONAL USE AUTHORIZATION, REVISE ZONING CONTROL TABLES TO REFLECT THESE CHANGES, AND REQUIRE ANNUAL REPORTING BY THE PLANNING DEPARTMENT REGARDING ELECTRIC VEHICLE CHARGING LOCATION AND FLEET CHARGING PROJECT APPROVALS; AFFIRMING THE PLANNING DEPARTMENT'S DETERMINATION UNDER THE CALIFORNIA ENVIRONMENTAL QUALITY ACT; AND MAKING FINDINGS OF CONSISTENCY WITH THE GENERAL PLAN, AND THE EIGHT PRIORITY POLICIES OF PLANNING CODE, SECTION 101.1, AND FINDINGS OF PUBLIC NECESSITY, CONVENIENCE, AND WELFARE UNDER PLANNING CODE, SECTION 302.

WHEREAS, on January 11, 2022 Mayor Breed introduced a proposed Ordinance under Board of Supervisors (hereinafter "Board") File Number 220036, which would which would amend the Planning Code to create Electric Vehicle Charging Location and Fleet Charging as Automotive Uses, allow conversion of Automotive Service Stations to Electric Vehicle Charging Locations without Conditional Use authorization, revise zoning control tables to reflect these changes, and require annual reporting by the Planning Department regarding Electric Vehicle Charging Location and Fleet Charging project approvals.

WHEREAS, The Planning Commission (hereinafter "Commission") conducted a duly noticed public hearing at a regularly scheduled meeting to consider the proposed Ordinance on April 14, 2022; and,

WHEREAS, the proposed amendments are not defined as a project under CEQA Guidelines Section 15060(c) and 15378 because they do not result in a physical change in the environment; and, WHEREAS, the Planning Commission has heard and considered the testimony presented to it at the public hearing and has further considered written materials and oral testimony presented on behalf of Department staff and other interested parties; and

WHEREAS, all pertinent documents may be found in the files of the Department, as the Custodian of Records, at 49 South Van Ness Avenue, Suite 1400, San Francisco; and

WHEREAS, the Planning Commission has reviewed the proposed Ordinance; and

WHEREAS, the Planning Commission finds from the facts presented that the public necessity, convenience, and general welfare require the proposed amendment; and

MOVED, that the Planning Commission hereby **approves with modifications** the proposed ordinance. The Commission's proposed recommendation(s) is/are as follows:

1. Require CU in all C-3 Districts for EV Charging Locations and change the code to make Gas Stations a CU in the two C-3 districts where they are currently principally permitted (C-3-G and C-3-S).

2. Exempt the conversion of existing automotive uses to EV Charging from Section 142 Screening requirements.

3. Prohibit Fleet Charging in RC Districts.

4. Add a new section to the Code explicitly allowing for the conversion of Automotive Uses to EV Charging Locations regardless of the underling zoning district. Example text:

   202.13 Conversion of Automotive Uses to EV Charging Locations

   Notwithstanding any other provisions of this Code, a change in use from an Automotive Use, as defined in Section 102, to an EV Charging Location, as defined in Section 102, shall be principally permitted regardless of the underling zoning district. Further, such a change in use shall not be subject to the notification requirements outlined in Planning Code Section 311.

5. Allow Fleet Charging with Conditional Use authorization in all NC Districts except NC-1 and NCT-1

Findings

Having reviewed the materials identified in the preamble above, and having heard all testimony and arguments, this Commission finds, concludes, and determines as follows:

The Commission supports the proposed ordinance because it sets clear definitions and regulations for EV Charging Locations and Fleet Charging that are consistent with existing land use regulations. Further, it prioritizes the conversion of existing auto infrastructure over creating new sites by allowing EV Charging locations as-of-right where there is an existing Automotive Use.

The Commission supports the proposed ordinance because it principally permits Fleet Charging in our industrial districts and requires conditional use in other areas where pedestrian safety and congestion can be properly analyzed; however, it also allows fleet charging as an accessory use to EV Charging location to ensure the use is more dispersed throughout the city.

General Plan Compliance

The proposed Ordinance and the Commission's recommended modifications are consistent with the following Objectives and Policies of the General Plan:

TRANSPORTATION ELEMENT

OBJECTIVE 1
MEET THE NEEDS OF ALL RESIDENTS AND VISITORS FOR SAFE, CONVENIENT AND INEXPENSIVE TRAVEL WITHIN SAN FRANCISCO AND BETWEEN THE CITY AND OTHER PARTS OF THE REGION WHILE MAINTAINING THE HIGH QUALITY LIVING ENVIRONMENT OF THE BAY AREA

POLICY 1.2
Ensure the safety and comfort of pedestrians throughout the city.

POLICY 1.3
Give priority to public transit and other alternatives to the private automobile as the means of meeting San Francisco's transportation needs, particularly those of commuters.

The proposed ordinance ensures that new automobile facilities will be reviewed to ensure that pedestrian safety and comfort can be considered prior to approval. Further, the proposed ordinance prioritizes the conversion of existing automotive uses to EV Charging installations, rather than creating new facilities. This is consistent with the giving priority to public transit and other alternatives to the private automobile.

COMMERCE AND INDUSTRY ELEMENT

OBJECTIVE 1
MANAGE ECONOMIC GROWTH AND CHANGE TO ENSURE ENHANCEMENT OF THE TOTAL CITY LIVING AND WORKING ENVIRONMENT.

Policy 1.1
Encourage development which provides substantial net benefits and minimizes undesirable consequences. Discourage development which has substantial undesirable consequences that cannot be mitigated.

The proposed Ordinance will facilitate the establishment of EV Charging Locations and Fleet Charging according to existing land us patterns and controls. Better regulations for these uses will provide substantial net benefits for the city, while minimizing any undesirable consequences.

OBJECTIVE 2
MAINTAIN AND ENHANCE A SOUND AND DIVERSE ECONOMIC BASE AND FISCAL STRUCTURE FOR THE CITY.

Policy 2.1
Seek to retain existing commercial and industrial activity and to attract new such activity to the city.

The proposed Ordinance allows new commercial activity, EV Charging Locations and Feet Charging, with controls that are appropriate for each district. This added commercial activity will help the city meet is Climate Change Goals and maintain a favorable social and cultural climate in San Francisco. This enhances San Francisco as a location for firms.

Planning Code Section 101 Findings

The proposed amendments to the Planning Code are consistent with the eight Priority Policies set forth in Section 101.1(b) of the Planning Code in that:

1. That existing neighborhood-serving retail uses be preserved and enhanced and future opportunities for resident employment in and ownership of such businesses enhanced;

   The proposed Ordinance would not have a negative effect on neighborhood serving retail uses and will not have a negative effect on opportunities for resident employment in and ownership of neighborhood-serving retail.

2. That existing housing and neighborhood character be conserved and protected in order to preserve the cultural and economic diversity of our neighborhoods;

   The proposed Ordinance would not have a negative effect on housing or neighborhood character.

3. That the City's supply of affordable housing be preserved and enhanced;

   The proposed Ordinance would not have an adverse effect on the City's supply of affordable housing.

4. That commuter traffic not impede MUNI transit service or overburden our streets or neighborhood parking;

   The proposed Ordinance would not result in commuter traffic impeding MUNI transit service or overburdening the streets or neighborhood parking.

5. That a diverse economic base be maintained by protecting our industrial and service sectors from displacement due to commercial office development, and that future opportunities for resident employment and ownership in these sectors be enhanced;

   The proposed Ordinance would not cause displacement of the industrial or service sectors due to office development, and future opportunities for resident employment or ownership in these sectors would not be impaired.

6. That the City achieve the greatest possible preparedness to protect against injury and loss of life in an earthquake;

The proposed Ordinance would not have an adverse effect on City's preparedness against injury and loss of life in an earthquake.

7. That the landmarks and historic buildings be preserved;

   The proposed Ordinance would not have an adverse effect on the City's Landmarks and historic buildings.

8. That our parks and open space and their access to sunlight and vistas be protected from development;

   The proposed Ordinance would not have an adverse effect on the City's parks and open space and their access to sunlight and vistas.

Planning Code Section 302 Findings.

The Planning Commission finds from the facts presented that the public necessity, convenience and general welfare require the proposed amendments to the Planning Code as set forth in Section 302.

NOW THEREFORE BE IT RESOLVED that the Commission hereby APPROVES WITH MODIFICATIONS the proposed Ordinance as described in this Resolution.

I hereby certify that the foregoing Resolution was adopted by the Commission at its meeting on April 14, 2022.

Jonas P. Ionin
Commission Secretary

AYES:	Diamond, Fung, Koppel, Tanner
NOES:	Ruiz, Imperial
ABSENT:	Moore
ADOPTED:	April 14, 2022

49 South Van Ness Avenue, Suite 1400
San Francisco, CA 94103
628.652.7600
www.sfplanning.org

EXECUTIVE SUMMARY
PLANNING CODE TEXT AMENDMENT

HEARING DATE: April 14, 2022

90-Day Deadline: April 18, 2022

Project Name: EV Charging Locations and Fleet Charging
Case Number: 2022-000549PCA [Board File No. 220036]
Initiated by: Mayor Breed / Introduced January 11, 2022
Staff Contact: Aaron Starr, Manager of Legislative Affairs
aaron.starr@sfgov.org, 628-652-7533

Recommendation: Approval with Modifications

Please note that this case report has been revised based on feedback from the last Planning Commission hearing on March 24, 2022. "The Way It Is" and "The Way It Would Be" section has been amended to correctly identify where Fleet Charging is allowed now and where it will be allowed should this ordinance pass; the "Racial and Social Equity" analysis has been expanded; a new section on Fleet Charging has been added; the recommendations have been revised to include recommendations presented at the last Planning Commission hearing; and new maps are included as Exhibits D-H.

Planning Code Amendment

The proposed Ordinance would amend the Planning Code to create Electric Vehicle Charging Location and Fleet Charging as Automotive Uses, allow conversion of Automotive Service Stations to Electric Vehicle Charging Locations without Conditional Use authorization, revise zoning control tables to reflect these changes, and require annual reporting by the Planning Department regarding Electric Vehicle Charging Location and Fleet Charging project approvals.

The Way It Is	The Way It Would Be
1. For the purposes of Planning approval, EV Charging Locations are regulated as Gas Stations. Gas Stations are permitted as follows: Not Permitted: Residential House (RH), Residential Mixed (RM), Residential Transit Oriented (RTO), some Neighborhood Commercial Districts (NCDs), Chinatown Districts, Residential Eastern Neighborhood Districts (except MUR), and Downtown Residential Districts (DTR). Conditional Use: Residential-Commercial (RC), Some Neighborhood Commercial Districts (NCDs), Downtown Districts C-3-O, C-3-O(SD), and C-3-R. Principally Permitted: Community Business Districts (C-2); Downtown Districts C-3-G and C-3-S; Production Distribution and Repair (Industrial or PDR) Districts; and all other Eastern Neighborhood Districts. (See Exhibit D)	1. The Planning Code would be amended to include a new use definition for EV Charging Locations, which will be categorized as an Automotive Use. Not Permitted: Residential House (RH), Residential Mixed (RM), Residential Transit Oriented (RTO), Chinatown Districts, Residential Eastern Neighborhood Districts (except MUR), and Downtown Residential Districts (DTR). Conditional Use: Residential-Commercial (RC), Neighborhood Commercial Districts (NCDs) Principally Permitted: Community Business Districts (C-2); all Downtown Districts (C-3); Production Distribution and Repair (Industrial or PDR) Districts; and all other Eastern Neighborhood Districts (See Exhibit E)
2. EV Charging Locations are permitted as-of-right where there is an existing gas station.	2. EV Charging Locations would be allowed as-of-right if they are replacing an existing Automotive Use as defined in Planning Code Section 102. (See Exhibit H)
3. For the purposes of Planning approval, Fleet Charging is primarily regulated as a Utility Installation. Utility installations require CU in most zoning districts; however, this use is prohibited in Eastern Neighborhood Districts, and are principally permitted in in C-2, C-3-G, C-3-S, PDR-1-D, PDR-1-G, and PDR-2. (See Exhibit F)	3. The Planning Code would be amended to include a new use definition for Fleet Charging, which will be categorized as an Automotive Use. Fleet Charging would be allowed as an accessory use with EV Charging location, otherwise the use would be permitted as follows: Not Permitted: Residential House (RH), Residential Mixed (RM), Residential Transit Oriented (RTO), Neighborhood Commercial Districts (NCD), Chinatown, Downtown Residential (DTR), and Residential Eastern

	Neighborhood Districts (except MUR). Conditional Use: Residential Commercial (RC), Community Business Districts (C-2), Downtown (C-3), Industrial Buffer Districts (PRD-1-B), Mixed Use Residential (MUR), and all other Non-Residential Easter Neighborhood Districts Principally Permitted: All other Industrial Districts (PDR-1-D, PRD-1-G, and PDR-2) (See Exhibit G)

Background

In 2019, Mayor Breed released the Electric Vehicle Roadmap ("the Roadmap") to accelerate and advance EV adoption to reduce emissions and associated air pollution health impacts from the transportation sector. To date, EVs represent about 11% of new light-duty vehicle registrations in San Francisco. The Roadmap sets a 2030 goal of 100% of new passenger vehicle registrations to be zero emissions with no increase in total vehicle registrations per household. It also set an ambitious goal of 100% emission-free ground transportation by 2040. These goals are aligned with California's targets to increase EV adoption and access to EV charging. In September 2020, Governor Gavin Newsom issued an executive order requiring only zero emission passenger cars to be sold in California by 2035. Additionally, the City's goals are aligned with the Biden Administration's goal that 50% of all new vehicles sold in the United States in 2030 be zero-emission vehicles.

The rate of EV adoption is determined in large part by access to charging. The three greatest barriers at this time for drivers to buy EVs are cost of the EVs, lack of charging infrastructure, and the range of EVs, the latter two barriers are interrelated and result in "range anxiety," or the fear that EV owners won't be able to locate a charger or that if they do, someone else will be using it.

Issues and Considerations

Addressing Climate Change

In 2021, the Intergovernmental Panel on Climate Change issued a report further underscoring the need for urgent action to cut global greenhouse gas emissions (GHGs) in half by 2030. It also reported that the world must meet net-zero emissions no later than 2050 to prevent the most catastrophic effects of climate change. San Francisco, the Bay Area, and the State of California are already suffering the effects of climate change in the form of droughts, air pollution, extreme heat, frequent wildfires, flooding, and other drastic impacts on weather and the environment.

In 2021 Mayor London Breed sponsored legislation to update the City's climate action goals to address these urgent challenges. As a result of Ordinance No. 117-21, San Francisco now has climate action goals to reduce emissions 61% below 1990 levels by 2030 and reach net-zero emissions by 2040. To achieve net-zero emissions by 2040, the updated climate action goals prioritize the City's Transit First policy and encourage a shift to low-carbon modes of transportation such as taking transit, walking, and biking. All remaining modes of transportation, including private and commercial vehicles, must be electrified to further reduce and eventually eliminate remaining transportation emissions.

> As of 2019, nearly half (47%) of San Francisco's GHG emissions came from the transportation sector, with the vast majority (72%) of those emissions from privately owned cars and trucks.

The City's climate action targets include the following transportation and land use goals:

- By 2030, 80% of trips taken by low-carbon modes such as walking, biking, transit, and shared Electric Vehicles (EVs).
- By 2030, increase vehicle electrification to at least 25% of all registered private vehicles, and, by 2040, to 100% of all such vehicles.

As reported in the latest San Francisco GHG Emissions Inventory, San Francisco's 2019 emissions were 41% below 1990 levels—six years ahead of the previously established goal to reduce emissions 40% by 2025. However, additional efforts must be undertaken to ensure the net-zero commitment is met by 2050. As of 2019, nearly half (47%) of San Francisco's GHG emissions came from the transportation sector, with the vast majority (72%) of those emissions from privately owned cars and trucks. Despite the City's success in reducing overall emissions to date, GHG emissions from the transportation sector have remained relatively stable.

Increasing EV Charging Capacity

> The number of publicly accessible charging stations in San Francisco needs to increase from about 800 in 2019 to 2,000 by 2025, and over 5,000 by 2030, to meet this demand.

In 2020, the International Council on Clean Transportation (ICCT) completed a study on San Francisco's EV charging needs in 2030 and 2040. The ICCT projects that by 2030, more than 170,000 light-duty EVs will be registered in the City. To meet that charging demand, the City must have six times more charging capacity than in 2019. The number of publicly accessible charging stations in San Francisco needs to increase from about 800 in 2019 to 2,000 by 2025, and over 5,000 by 2030, to meet this demand.

Currently, EV charging is not defined in the Planning Code. As a result, applications to install EV charging projects require an EV service provider (EVSP) and the Planning Department to work out a permitting pathway, on a case-by-case basis, using Planning Code provisions designed for gas stations and auto service centers. The existing use categories are an imperfect fit for this new use. They impose limitations more appropriate for the facilities they were intended to address—conventional fueling facilities—rather than less-impactful EV charging stations, creating lengthy approval processes and bureaucratic delays that should be avoided for EV charging projects.

> Multiple studies have suggested a correlation between increasing the number of charging stations and higher EV adoption rates…

Without this ordinance's amendments, further air quality and GHG degradation would occur because the ongoing inconvenience of finding EV charging stations would result in a low rate of adoption of EVs. Multiple studies have suggested a correlation between increasing the number of charging stations and higher EV adoption rates, as summarized in an October 2017 white paper by the International Council on Clean Transportation (ICCT). In addition, the EV Roadmap identified the expansion of publicly accessible Level 2 and fast charging infrastructure in San Francisco as a key strategy to increase EV adoption rates.

Publicly accessible EV charging stations—including public Level 2 (240 volt), DC fast ("superchargers"), and workplace chargers—are the most efficient and effective solution to meet anticipated demand for EV charging. San Francisco's combination of population density, small size, and resulting high land costs make it the perfect place to install fast-charging plazas that mimic the gas station experience drivers have come to expect when fueling their vehicles. Fast-charging plazas are integral to San Francisco's developing a comprehensive public charging network. With a robust network of public charging stations, EV owners will be able to access fast charging as needed and close to their homes.

Fleet Charging

EV Fleet Charging can apply to any type of fleet, such as parcel deliver providers like UPS, FedEx, Amazon and the USPS, taxi or ride hailing fleets, or sometime in the not-so-distant future, autonomous vehicle (AV) fleets. Staff believes that Fleet Charging is an intensive use mostly suited for industrial or mixed-use areas of the City. We estimated that AV Fleets could generate approximately 2 to 9 times more motorized trips per 1,000 square feet than a typical PDR use. The proposed ordinance allows this use as of right in our PDR districts but requires CU authorization in our Eastern Neighborhood mixed-use neighborhoods.

> It's estimated that we need to reduce VMT per capita by about 14 to 17 percent between 2018 and 2050. These estimates assume electrification of vehicles.

While we are familiar with traditional vehicle fleets, AV Fleets are somewhat of an unknown since the use doesn't fully exist yet. We don't know what sort of impact they will have on our streets, pedestrian safety, or adjacent communities, which is why this ordinance takes a more conservative approach to where they are permitted. AVs may have a similar impact on VMTs as ride hailing services such as Uber or Lyft. Each ride hailing vehicle generates more VMTs per trip than a privately owned vehicle, and studies show that approximately 40 percent of the VMTs from each vehicle would be generated without any passengers. As a state, we will not meet our long-term greenhouse gas reduction targets if we do not reduce VMTs. It's estimated that we need to reduce VMT per capita by about 14 to 17 percent between 2018 and 2050. These estimates assume electrification of vehicles.

General Plan Compliance

The proposed ordinance is consistent with policies in both the Transportation Element and the Commerce and Industry Element because allows for new commercial activity, but at the same time it prioritizes the conversion of existing automotive uses over the creation of new uses and places appropriate controls over the establishment of new auto-oriented facilities.

Racial and Social Equity Analysis

Lack of access to EV Charging is an equity issue. Nearly 70% of San Francisco residents live in multi-unit buildings and most such residents do not have access to off-street parking or home charging. EV charging at home should not be a privilege available only to single-family home residents who can afford to install their own systems, or those with EV charging available at the workplace. The proposed ordinance will enhance the availability of EV Charging throughout the City by better utilizing our increasingly obsolete network of gas stations, helping to assist the equal distribution of EV charging options through the city.

Converting our transportation system to zero emission vehicles will also have a positive effect on the health of marginalized communities. Often located in neighborhoods next to freeways, oil refineries and other industrial pollution sources, Black, Hispanic, and American Indian/Alaska Native communities bear the greatest burden from our reliance on fossil fuels. Black Americans are 1.5 times more likely to have asthma and three times more likely to die of asthma compared to White Americans[1]. There are many contributing factors that lead to health disparities in marginalized communities, but the legacy of environmental racism is especially significant. Reducing exposure to pollution by strengthening clean air policies, reducing transportation-related emissions, and transitioning to a clean energy economy are essential changes that San Francisco must make to help improve the health outcomes in these communities.

As proposed, Fleet Charging will be allowed primarily in the eastern and southeastern parts of the City. These areas of the City also contain some of our most vulnerable communities; however, the foundational issues related to industrial uses in this area were addressed when the City went through its 10+ year Eastern Neighborhoods rezoning effort. That planning process transitioned many areas away from industrial zoning, shifted many formerly industrial areas toward housing and office space, and created buffer zoning districts to protect new and establishing residential neighborhoods to lessen the impacts of nearby industrial uses. The process also created strong protections for the remaining industrial lands in San Francisco, which now represent less than 5% of City.

Heavy industry, petroleum-based vehicle fleets, and EV fleets already exist in our PDR Districts. Because of their non-residential, non-retail, and transportation-based nature, fleet charging of both EV and conventional types is most appropriate in our industrial areas. Since EVs will not produce emissions, Fleet Charging is less impactful on the surrounding communities than existing or future conventional fleet uses. Further, in our Easter Neighborhoods Mixed-Use Districts, where a healthy mix of housing, commercial and PDR uses is generally allowed, Fleet Charging locations will require CU authorization, ensuring that any impacts on adjacent communities will be considered prior to project approval.

Implementation

The Department has determined that this Ordinance will improve our current implementation procedures by setting a clear and consistent way to permit EV Charging Locations and Fleet Charging.

[1] Asthma Disparities - Reducing Burden on Racial and Ethnic Minorities | AAFA.org

Recommendation

The Department recommends that the Commission ***approve with modifications*** the proposed Ordinance and adopt the attached Draft Resolution to that effect. The Department's proposed recommendations are as follows:

1. Require CU in all C-3 Districts for EV Charging Locations and change the code to make Gas Stations a CU in the two C-3 districts where they are currently principally permitted(C-3-G and C-3-S).

2. Exempt the conversion of existing automotive uses to EV Charging from Section 142 Screening requirements.

3. Prohibit Fleet Charging in RC Districts.

4. Add a new section to the Code explicitly allowing for the conversion of Automotive Uses to EV Charging Locations regardless of the underling zoning district. Example text:

   ȣɢȣɣų Conversion of Automotive Uses to EV Charging Locations

   Notwithstanding any other provisions of this Code, a change in use from an Automotive Use, as defined in Section 102, to an EV Charging Location, as defined in Section 102, shall be principally permitted regardless of the underling zoning district. Further, such a change in use shall not be subject to the notification requirements outlined in Planning Code Section 311.

Basis for Recommendation

The Department supports the proposed ordinance because it sets clear definitions and regulations for EV Charging Locations and Fleet Charging that are consistent with existing land use regulations. Further, it prioritizes the conversion of existing auto infrastructure over creating new sites by allowing EV Charging locations as-of-right where there is an existing Automotive Use. For Fleet Charging, the ordinance principally permits this more intensive use in our industrial districts and requires conditional use in other areas where pedestrian safety and congestion can be properly analyzed; however, it also allows fleet charging as an accessory use to EV Charging location to ensure the use is more dispersed throughout the city. That said the Department does have the following amendments to the proposed ordinance that will rationalize existing and proposed regulations.

Recommendation 1: Require CU in all C-3 Districts for EV Charging Locations and change the code to make Gas Stations a CU in the two C-3 districts where they are currently principally permitted (C-3-G and C-3-S).
Staff recommends making this change because we want to encourage the conversion of existing auto infrastructure in our downtown area rather than encourage new locations. As currently drafted, EV Charging Locations are principally permitted in all downtown districts, while only two districts principally permit Gas Stations. The other three require CU authorization for Gas Stations. Requiring CU authorization for both uses will encourage the conversion of existing infrastructure to EV Charging and allow for individual analysis of new sites to ensure they do not impede transit or impact pedestrian safety in our downtown core.

Recommendation 2: Exempt the conversion of existing automotive uses to EV Charging from Section 142 Screening requirements.
Section 142 requires screening and greening for all new vehicular use areas. While this requirement helps improve the City's built environment by softening the presence of auto infrastructure, staff has found that it is difficult for existing automotive uses to come into conformance with these requirements. Mainly because they require a 5' planting area along the sidewalk, which can take up a significant portion of the lot depending on the current configuration. Since we want to encourage the conversion of existing automotive uses, we are recommending that this requirement be waived when an existing Automotive Use is being converted to an EV Charging Location.

Recommendation 3: Prohibit Fleet Charging in RC Districts.
As currently drafted the proposed ordinance allows Fleet Charging in RC Districts. This appears to be a drafting error that was noticed after the original case report was published. RC Districts are some of our densest urban areas and not conducive to intensive auto oriented uses like Fleet Charging. RC Districts are primarily residential, while provisions are made for supporting ground floor commercial uses that meet the frequent needs of nearby residents without generating excessive vehicular traffic. RC Districts are primarily found in the City's Tenderloin neighborhood, and along the Van Ness corridor. The Tenderloin has the highest density of children in the city, and along with Van Ness has the most high-injury corridors in the City[2]. Allowing fleet charging in RC Districts would only intensify auto traffic in these neighborhoods. Further, the Van Ness corridor recently saw the opening of the City's first BRT line, a significant transit investment intended to prioritize transit over automobiles.

Recommendation 4: Add a new section to the Code explicitly allowing for the conversion of Automotive Uses to EV Charging Locations regardless of the underling zoning district.
The intention with this ordinance was always to allow the conversion of any auto-orient use to an EV Charging Location; however, as currently drafted this provision does not extend to R Districts. The proposed language would clarify that the conversion is allowed regardless of the underling zoning district and that the conversion is not subject to 311 notification.

Required Commission Action

The proposed Ordinance is before the Commission so that it may approve it, reject it, or approve it with modifications.

Environmental Review

The proposed amendments are not defined as a project under CEQA Guidelines Section 15060(c) and 15378 because they do not result in a physical change in the environment.

Public Comment

Since the first hearing on March 24, the Planning Department received a letter from *Cruise* regarding the proposed Ordinance.

[2] Evaluating & Monitoring Our Progress | Vision Zero SF

Attachments:

Exhibit A:	Draft Planning Commission Resolution
Exhibit B:	Board of Supervisors File No. 220036
Exhibit C:	Public Comment Letters
Exhibit D:	Map: Existing Gas Station Controls
Exhibit E:	Map: Proposed EV Charging Location Controls
Exhibit F:	Map: Existing Utility Installation Controls
Exhibit G:	Map: Proposed Controls for Fleet Charging
Exhibit H:	Map: All Automotive Uses

San Francisco Planning
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PLANNING COMMISSION
DRAFT RESOLUTION

HEARING DATE: April 14, 2022

Project Name: Electric Vehicle Charging Locations
Case Number: 2022-000549PCA [Board File No. 220036]
Initiated by: Mayor Breed / Introduced January 11, 2022
Staff Contact: Aaron Starr, Manager of Legislative Affairs
aaron.starr@sfgov.org, 628-652-7533

RESOLUTION APPROVING A PROPOSED ORDINANCE THAT WOULD AMEND THE PLANNING CODE TO CREATE ELECTRIC VEHICLE CHARGING LOCATION AND FLEET CHARGING AS AUTOMOTIVE USES, ALLOW CONVERSION OF AUTOMOTIVE SERVICE STATIONS TO ELECTRIC VEHICLE CHARGING LOCATIONS WITHOUT CONDITIONAL USE AUTHORIZATION, REVISE ZONING CONTROL TABLES TO REFLECT THESE CHANGES, AND REQUIRE ANNUAL REPORTING BY THE PLANNING DEPARTMENT REGARDING ELECTRIC VEHICLE CHARGING LOCATION AND FLEET CHARGING PROJECT APPROVALS; AFFIRMING THE PLANNING DEPARTMENT'S DETERMINATION UNDER THE CALIFORNIA ENVIRONMENTAL QUALITY ACT; AND MAKING FINDINGS OF CONSISTENCY WITH THE GENERAL PLAN, AND THE EIGHT PRIORITY POLICIES OF PLANNING CODE, SECTION 101.1, AND FINDINGS OF PUBLIC NECESSITY, CONVENIENCE, AND WELFARE UNDER PLANNING CODE, SECTION 302.

WHEREAS, on January 11, 2022 Mayor Breed introduced a proposed Ordinance under Board of Supervisors (hereinafter "Board") File Number 220036, which would which would amend the Planning Code to create Electric Vehicle Charging Location and Fleet Charging as Automotive Uses, allow conversion of Automotive Service Stations to Electric Vehicle Charging Locations without Conditional Use authorization, revise zoning control tables to reflect these changes, and require annual reporting by the Planning Department regarding Electric Vehicle Charging Location and Fleet Charging project approvals.

WHEREAS, The Planning Commission (hereinafter "Commission") conducted a duly noticed public hearing at a regularly scheduled meeting to consider the proposed Ordinance on April 14, 2022; and,

WHEREAS, the proposed amendments are not defined as a project under CEQA Guidelines Section 15060(c) and 15378 because they do not result in a physical change in the environment; and, WHEREAS, the Planning Commission has heard and considered the testimony presented to it at the public hearing and has further considered written materials and oral testimony presented on behalf of Department staff and other interested parties; and

WHEREAS, all pertinent documents may be found in the files of the Department, as the custodian of records, at 49 South Van Ness Avenue, Suite 1400, San Francisco; and

WHEREAS, the Planning Commission has reviewed the proposed Ordinance; and

WHEREAS, the Planning Commission finds from the facts presented that the public necessity, convenience, and general welfare require the proposed amendment; and

MOVED, that the Planning Commission hereby approves with modifications the proposed ordinance. The Commission's proposed recommendation(s) is/are as follows:

1. Require CU in all C-3 Districts for EV Charging Locations and change the code to make Gas Stations a CU in the two C-3 districts where they are currently principally permitted (C-3-G and C-3-S).

2. Exempt the conversion of existing automotive uses to EV Charging from Section 142 Screening requirements.

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   Notwithstanding any other provisions of this Code, a change in use from an Automotive Use, as defined in Section 102, to an EV Charging Location, as defined in Section 102, shall be principally permitted regardless of the underling zoning district. Further, such a change in use shall not be subject to the notification requirements outlined in Planning Code Section 311.

Findings

Having reviewed the materials identified in the preamble above, and having heard all testimony and arguments, this Commission finds, concludes, and determines as follows:

The Commission supports the proposed ordinance because it sets clear definitions and regulations for EV Charging Locations and Fleet Charging that are consistent with existing land use regulations. Further, it prioritizes the conversion of existing auto infrastructure over creating new sites by allowing EV Charging locations as-of-right where there is an existing Automotive Use.

The Commission supports the proposed ordinance because it principally permits Fleet Charging in our industrial districts and requires conditional use in other areas where pedestrian safety and congestion can be properly analyzed; however, it also allows fleet charging as an accessory use to EV Charging location to ensure the use is more dispersed throughout the city.

General Plan Compliance

The proposed Ordinance and the Commission's recommended modifications are is consistent with the following Objectives and Policies of the General Plan:

TRANSPORTATION ELEMENT

OBJECTIVE 1
MEET THE NEEDS OF ALL RESIDENTS AND VISITORS FOR SAFE, CONVENIENT AND INEXPENSIVE TRAVEL WITHIN SAN FRANCISCO AND BETWEEN THE CITY AND OTHER PARTS OF THE REGION WHILE MAINTAINING THE HIGH QUALITY LIVING ENVIRONMENT OF THE BAY AREA

POLICY 1.2
Ensure the safety and comfort of pedestrians throughout the city.

POLICY 1.3
Give priority to public transit and other alternatives to the private automobile as the means of meeting San Francisco's transportation needs, particularly those of commuters.

The proposed ordinance ensures that new automobile facilities will be reviewed to ensure that pedestrian safety and comfort can be considered prior to approval. Further, the proposed ordinance prioritizes the conversion of existing automotive uses to EV Charging installations, rather than creating new facilities. This is consistent with the giving priority to public transit and other alternatives to the private automobile.

COMMERCE AND INDUSTRY ELEMENT

OBJECTIVE 1
MANAGE ECONOMIC GROWTH AND CHANGE TO ENSURE ENHANCEMENT OF THE TOTAL CITY LIVING AND WORKING ENVIRONMENT.

Policy 1.1
Encourage development which provides substantial net benefits and minimizes undesirable consequences. Discourage development which has substantial undesirable consequences that cannot be mitigated.

The proposed Ordinance will facilitate the establishment of EV Charging Locations and Fleet Charging according to existing land us patterns and controls. Better regulations for these uses will provide substantial net benefits for the city, while minimizing any undesirable consequences.

OBJECTIVE 2
MAINTAIN AND ENHANCE A SOUND AND DIVERSE ECONOMIC BASE AND FISCAL STRUCTURE FOR THE CITY.

Policy 2.1

Seek to retain existing commercial and industrial activity and to attract new such activity to the city.

The proposed Ordinance allows new commercial activity, EV Charging Locations and Feet Charging, with controls that are appropriate for each district. This added commercial activity will help the city meet is Climate Change Goals and maintain a favorable social and cultural climate in San Francisco. This enhances San Francisco as a location for firms.

Planning Code Section 101 Findings

The proposed amendments to the Planning Code are consistent with the eight Priority Policies set forth in Section 101.1(b) of the Planning Code in that:

1. That existing neighborhood-serving retail uses be preserved and enhanced and future opportunities for resident employment in and ownership of such businesses enhanced;

   The proposed Ordinance would not have a negative effect on neighborhood serving retail uses and will not have a negative effect on opportunities for resident employment in and ownership of neighborhood-serving retail.

2. That existing housing and neighborhood character be conserved and protected in order to preserve the cultural and economic diversity of our neighborhoods;

   The proposed Ordinance would not have a negative effect on housing or neighborhood character.

3. That the City's supply of affordable housing be preserved and enhanced;

   The proposed Ordinance would not have an adverse effect on the City's supply of affordable housing.

4. That commuter traffic not impede MUNI transit service or overburden our streets or neighborhood parking;

   The proposed Ordinance would not result in commuter traffic impeding MUNI transit service or overburdening the streets or neighborhood parking.

5. That a diverse economic base be maintained by protecting our industrial and service sectors from displacement due to commercial office development, and that future opportunities for resident employment and ownership in these sectors be enhanced;

   The proposed Ordinance would not cause displacement of the industrial or service sectors due to office development, and future opportunities for resident employment or ownership in these sectors would not be impaired.

6. That the City achieve the greatest possible preparedness to protect against injury and loss of life in an earthquake;

   The proposed Ordinance would not have an adverse effect on City's preparedness against injury and loss *of life in an earthquake.*

7. That the landmarks and historic buildings be preserved;

   The proposed Ordinance would not have an adverse effect on the City's Landmarks and historic buildings.

8. That our parks and open space and their access to sunlight and vistas be protected from development;

   The proposed Ordinance would not have an adverse effect on the City's parks and open space and their access to sunlight and vistas.

Planning Code Section 302 Findings.

The Planning Commission finds from the facts presented that the public necessity, convenience and general welfare require the proposed amendments to the Planning Code as set forth in Section 302.

NOW THEREFORE BE IT RESOLVED that the Commission hereby APPROVES WITH MODIFICATIONS the proposed Ordinance as described in this Resolution.

I hereby certify that the foregoing Resolution was adopted by the Commission at its meeting on April 14, 2022.

Jonas P. Ionin
Commission Secretary

AYES:

NOES:

ABSENT:

ADOPTED: April 14, 2022

[Planning Code - Electric Vehicle Charging Locations]

Ordinance amending the Planning Code to create Electric Vehicle Charging Location and Fleet Charging as Automotive Uses, allow conversion of Automotive Service Stations to Electric Vehicle Charging Locations without Conditional Use authorization, revise zoning control tables to reflect these changes, and require annual reporting by the Planning Department regarding Electric Vehicle Charging Location and Fleet Charging project approvals; affirming the Planning Department's determination under the California Environmental Quality Act; and making findings of consistency with the General Plan, and the eight priority policies of Planning Code, Section 101.1, and findings of public necessity, convenience, and welfare under Planning Code, Section 302.

NOTE: **Unchanged Code text and uncodified text** are in plain Arial font.
Additions to Codes are in *single-underline italics Times New Roman font*.
Deletions to Codes are in ~~*strikethrough italics Times New Roman font*~~.
Board amendment additions are in double-underlined Arial font.
Board amendment deletions are in ~~strikethrough Arial font~~.
Asterisks (* * * *) indicate the omission of unchanged Code subsections or parts of tables.

Be it ordained by the People of the City and County of San Francisco:

Section 1. Findings.

(a) The Planning Department has determined that the actions contemplated in this ordinance comply with the California Environmental Quality Act (California Public Resources Code Sections 21000 et seq.). Said determination is on file with the Clerk of the Board of Supervisors in File No. 220036 and is incorporated herein by reference. The Board affirms this determination.

(b) On __________, the Planning Commission, in Resolution No. __________, adopted findings that the actions contemplated in this ordinance are consistent, on balance, with the City's General Plan and eight priority policies of Planning Code Section 101.1. The Board adopts these findings as its own. A copy of said Resolution is on file with the Clerk of the Board of Supervisors in File No. __________, and is incorporated herein by reference.

(c) Pursuant to Planning Code Section 302, the Board of Supervisors finds that this ordinance will serve the public necessity, convenience, and welfare for the reasons set forth in Planning Commission Resolution No. ______, and incorporates such reasons by this reference thereto. A copy of said Resolution is on file with the Clerk of the Board of Supervisors in File No. ______, and is incorporated herein by reference.

(d) This ordinance is based on the following findings:

(1) In 2021, the Intergovernmental Panel on Climate Change issued a report further underscoring the need for urgent action to cut global greenhouse gas emissions (GHGs) in half by 2030 and reach net-zero emissions no later than 2050to prevent the most catastrophic effects of climate change and reduce detrimental impacts to human health and ecosystems.

(2) San Francisco, the Bay Area, and the State of California are already suffering the effects of climate change in the form of droughts, air pollution, extreme heat, frequent wildfires, flooding, and other drastic impacts on weather and the environment.

(3) To address these urgent challenges, in 2021 Mayor London Breed sponsored legislation to update the City's climate action goals. As a result of Ordinance No. 117-21, San Francisco now has climate action goals to reduce emissions 61% below 1990 levels by 2030 and reach net-zero emissions by 2040.

(4) To achieve net-zero emissions by 2040, the updated climate action goals prioritize the City's Transit First policy and encourage a shift to low-carbon modes of

transportation such as taking transit, walking, and biking. All remaining modes of transportation, including private and commercial vehicles, must be electrified to further reduce and eventually eliminate remaining transportation emissions.

(5) The City's climate action targets, per Ordinance No. 117-21, include the following transportation and land use goals:

(A) By 2030, 80% of trips taken by low-carbon modes such as walking, biking, transit, and shared Electric Vehicles (EVs).

(B) By 2030, increase vehicle electrification to at least 25% of all registered private vehicles, and, by 2040, to 100% of all such vehicles.

(6) As reported in the latest San Francisco GHG Emissions Inventory, San Francisco's 2019 emissions were 41% below 1990 levels—six years ahead of the previously established goal to reduce emissions 40% by 2025. However, additional efforts must be undertaken to ensure the net-zero commitment is met by 2050.

(7) As of 2019, nearly half (47%) of San Francisco's GHG emissions came from the transportation sector, with the vast majority (72%) of those emissions from privately owned cars and trucks. Despite the City's success in reducing overall emissions to date, GHG emissions from the transportation sector have remained relatively stable.

(8) In 2019, Mayor Breed released the Electric Vehicle Roadmap ("the Roadmap") to accelerate and advance EV adoption to reduce emissions and associated air pollution health impacts from the transportation sector. To date, EVs represent about 11% of new light-duty vehicle registrations in San Francisco. The Roadmap sets a 2030 goal of 100% of new passenger vehicle registrations with no increase in total vehicle registrations per household and an ambitious goal of 100% emission-free ground transportation by 2040. These goals are aligned with California's targets to increase EV adoption and access to EV charging. In September 2020, Governor Gavin Newsom issued an executive order requiring

only zero emission passenger cars to be sold in California by 2035. Additionally, the City's goals are aligned with the Biden Administration's goal that 50% of all new vehicles sold in the United States in 2030 be zero-emission vehicles.

(9) The rate of EV adoption is determined in large part by access to charging. The three greatest barriers at this time for drivers to buy EVs are cost of the EVs, lack of charging infrastructure, and the range of EVs, the latter two barriers are interrelated and result in "range anxiety," or the fear that EV owners won't be able to locate a charger or that if they do, someone else will be using it.

(10) Range anxiety is also an equity issue. Nearly 70% of San Francisco residents live in multi-unit buildings and most such residents do not have access to off-street parking or home charging. EV charging at home should not be a privilege available only to single-family home residents or those with EV charging available at the workplace. To provide expanded access to EV charging, in June 2021, the California Public Utilities Commission ruled that electrical corporations should prioritize their near-term investments to create charging options to customers without access to home charging.

(11) Publicly accessible EV charging stations—including public Level 2 (240 volt), DC fast ("superchargers"), and workplace chargers—are the most efficient and effective solution to meet anticipated demand for EV charging. San Francisco's combination of population density, small size, and resulting high land costs make it the perfect place to install fast-charging plazas that mimic the gas station experience that drivers have come to expect when fueling their vehicles. Fast-charging plazas are integral to San Francisco's developing a comprehensive public charging network. With a robust network of public charging stations, EV owners will be able to access fast charging as needed and close to their homes.

(12) Without this ordinance's amendments of the Planning Code, further air quality and GHG degradation would occur because the ongoing inconvenience of finding EV

charging stations would result in a low rate of adoption of EVs. Multiple studies have suggested a correlation between increasing the number of charging stations and higher EV adoption rates, as summarized in an October 2017 white paper by the International Council on Clean Transportation (ICCT). In addition, the EV Roadmap identified the expansion of publicly accessible Level 2 and fast charging infrastructure in San Francisco as a key strategy to increase EV adoption rates.

(13) In 2020, the ICCT completed a study on San Francisco's EV charging needs in 2030 and 2040. The ICCT projects that by 2030, more than 170,000 light-duty EVs will be registered in the City. To meet that charging demand, the City must have six times more charging capacity than in 2019. The number of publicly accessible charging stations in San Francisco needs to increase from about 800 in 2019 to 2,000 by 2025, and over 5,000 by 2030, to meet this demand.

(14) Currently, EV charging is not defined in the Planning Code. As a result, applications to install EV charging projects require an EV service provider (EVSP) and the Planning Department or Commission to work out a permitting pathway, on a case-by-case basis, using Planning Code provisions designed for gas stations and auto service centers. The existing use categories are an imperfect fit for this new use. They impose limitations more appropriate for the facilities they were intended to address—conventional fueling facilities—rather than less-impactful EV charging stations, creating lengthy approval processes and bureaucratic delays that should be avoided for EV charging projects.

(15) By defining "Electric Vehicle Charging Location" as an "Automotive Use" in the Planning Code and establishing zones in the City in which stand-alone EV charging is permitted, this ordinance will make it easier to convert existing sites with "Automotive Uses" to EV charging plazas or hubs. This will result in a clear approval path for EV charging projects, reducing delays and additional workflow in Planning, and expanding opportunities to deploy

publicly accessible EV charging stations within San Francisco. This ordinance will expedite expansion of critical EV charging services, creating new public charging options for San Francisco residents and visitors, thus encouraging the adoption of EVs by a greater share of the population. This in turn will help the City meet its climate action goals to reduce emissions from the transportation sector.

Section 2. The Planning Code is hereby amended by revising Sections 102 (including placing new defined terms in alphabetical sequence with existing defined terms), 187.1, 202.2, 202.5, 204, 210.1, 210.2, 210.3, 311, and 710, and adding Section 204.6, to read as follows:

SEC. 102. DEFINITIONS.

* * * *

A

* * * *

Automotive Use. A Commercial Use category that includes Automotive Repair, Ambulance Services, Automobile Sale or Rental, Automotive Service Station, Automotive Wash, *Electric Vehicle Charging Location, Fleet Charging,* Gas Station, Parcel Delivery Service, Private Parking Garage, Private Parking Lot, Public Parking Garage, Public Parking Lot, Vehicle Storage Garage, Vehicle Storage Lot, and Motor Vehicle Tow Service. All Automotive Uses that have Vehicular Use Areas defined in this Section of the Code shall meet the screening requirements for vehicular use areas in Section 142.

Automotive Use, Non-Retail. A subcategory of Automotive Use that includes Ambulance Services, *Fleet Charging,* Parcel Delivery Service, Private Parking Garage, Private Parking Lot, and Motor Vehicle Tow Service.

Automotive Use, Retail. A subcategory of Automotive Use that includes Automotive Repair, Automotive Sale or Rental, Automobile Service Station, Automotive Wash, *Electric Vehicle Charging Location,* Gas Station, Public Parking Garage, Public Parking Lot, Vehicle Storage Garage, and Vehicle Storage Lot.

* * * *

E

* * * *

Electric Vehicle Charging Location. *Automotive Use, Retail that provides electricity to electric motor vehicles through one or more Electric Vehicle Charging Stations on a retail basis to the general public as a primary use. Electric Vehicle Charging Locations may include up to one-third of the total Electric Vehicle Charging Stations dedicated to Fleet Charging as an accessory use per Section 204.6(a), and may include ancillary services, including but not limited to restrooms, self-service vending, and limited retail amenities primarily for the benefit of customers charging their vehicles.*

Electric Vehicle Charging Station. *An electric vehicle charging space served by an electric vehicle charger or other charging equipment.*

* * * *

F

* * * *

Fleet Charging. *Automotive Use, Non-Retail that provides electricity to electric motor vehicles through one or more Electric Vehicle Charging Stations that are dedicated or reserved for private parties pursuant to contract or other agreement and are not available to the general public.*

* * * *

SEC. 187.1. AUTOMOTIVE SERVICE STATIONS*, ELECTRIC VEHICLE CHARGING LOCATIONS,* AND GAS STATIONS AS LEGAL NONCONFORMING USES.

(a) **Continuation as a Nonconforming Use.** Notwithstanding any other provision of this Code, an Automotive Service Station or a Gas Station as defined in Section 102 of this Code, located in a Residential district, and having legal nonconforming use status under the provisions of this Code on January 1, 1980, shall be regarded as a legal nonconforming use so long as the station *either: (1)* continues to sell and dispense gasoline and other motor fuels and lubricating fluids directly into motor vehicles*, or (2) transitions to an Electric Vehicle Charging Location*.

*** * * ***

SEC. 202.2. LOCATION AND OPERATING CONDITIONS.

*** * * ***

(b) Automotive Uses. The Automotive Uses listed below shall be subject to the corresponding conditions:

*** * * ***

(2) **Conditional Use Authorization Required for Establishments that Sell Beer or Wine with Motor Vehicle Fuel.** Any establishment that proposes to retail motor vehicle fuel and provide retail sale of beer or wine shall require Conditional Use authorization. The Planning Commission may deny authorization or grant Conditional Use authorization to an applicant based upon the criteria set forth in Section 303(c) of this Code.

*** * * ***

(D) **Definitions.** For purposes of Subsection 202.2(b)(1) and (2), the following definitions shall apply:

(i) "Alcoholic beverages" shall be as defined in California Business and Professions Code Section 23004;

(ii) "Beer" and "wine" shall be as defined in California Business and Professions Code Section 23006 and Section 23007, respectively;

(iii) "Motor vehicle fuel" shall mean gasoline, other motor fuels *including electricity at an Electric Vehicle Charging Location*, and lubricating oil dispensed directly into motor vehicles; and

(iv) "Establishment" shall include an arrangement where a lot containing a business selling motor vehicle fuel provides direct access to another business selling alcoholic beverages on the same or adjacent lot.

* * * *

(3) **Automotive Wash.** Cleaning and polishing are required to be conducted within an enclosed building having no openings, other than fixed windows or exits required by law located within 50 feet of any R District, and that has an off-street waiting and storage area outside the building which accommodates at least one-quarter the hourly capacity in vehicles of the enclosed operations, provided: (1) that incidental noise is reasonably confined to the premises by adequate soundproofing or other device; and (2) that complete enclosure within a building may be required as a condition of approval, notwithstanding any other provision of this Code; but the foregoing provisions shall not preclude the imposition of any additional conditions pursuant to Section 303 of this Code.

*(4) **Electric Vehicle Charging Location.** At Electric Vehicle Charging Locations, the Electric Vehicle Charging Stations, including the charging space for the electric vehicle and all necessary charging equipment and infrastructure, may be located within any setbacks required by the underlying zoning district. Any structures associated with ancillary services, including restrooms or vending machines, must adhere to any underlying zoning setback requirements.*

*(5) **Fleet Charging and Electric Vehicle Charging Location Reporting Requirements.** Beginning on June 1, 2023, the Planning Department shall submit a report to the Board of Supervisors*

and the Mayor that includes the number and location of all Electric Vehicle Charging Locations and Fleet Charging locations that have been approved since the ordinance in Board File No. 220036 establishing this reporting requirement became effective. The Planning Department's report shall include: the address of each such charging location, number of charging stations at each location, prior use of the property, whether the charging location was principally permitted or conditionally permitted, and what percent of each station is dedicated to Fleet Charging. The Planning Department shall submit this report annually for five years, with the last report to be submitted on June 1, 2027.

*   *   *   *

SEC. 202.5. CONVERSION OF AUTOMOTIVE SERVICE STATIONS.

*   *   *   *

(b) **Definitions.** Whenever used in this Section, unless a different meaning clearly appears from the context:

(1) "Automotive Service Station" or "service station" shall mean a retail automotive service use as defined in Section 102 of this Code.

(2) "Conversion" shall mean to change the use of a property from a service station use to a different type of use. *A change from Automotive Service Station to Electric Vehicle Charging Location is not a change to a different type of use and shall not be a "Conversion" subject to this Section.*

*   *   *   *

SEC. 204. ACCESSORY USES, GENERAL.

This Section 204 and Sections 204.1 through 204.*6*~~5~~, shall regulate Accessory Uses, as defined in Section 102. Any use which does not qualify as an Accessory Use shall be classified as a Principal or Conditional Use, unless it qualifies as a temporary use under Sections 205 through 205.4 of this Code.

*   *   *   *

<u>SEC. 204.6. FLEET CHARGING ACCESSORY TO ELECTRIC VEHICLE CHARGING LOCATIONS.</u>

<u>In order for Fleet Charging to be a classified as an Accessory Use to an Electric Vehicle Charging Location, no more than one-third of the Electric Vehicle Charging Stations may be dedicated to Fleet Charging and two-thirds, or more, of the Electric Vehicle Charging Stations shall be available for general public use.</u>

* * * *

SEC. 210.1. C-2 DISTRICTS: COMMUNITY BUSINESS.

* * * *

Table 210.1

ZONING CONTROL TABLE FOR C-2 DISTRICTS

Zoning Category	§ References	C-2
* * * *		
NON-RESIDENTIAL STANDARDS AND USES		
* * * *		
Automotive Use Category		
Automotive Repair	§ 102	NP
Automotive Sale/Rental	§ 102	P (3)
Automotive Service Station	§§ 102, 202.2(b), 202.5	P (2)
Automotive Wash	§§ 102, 202.2(b)	C (2)
<u>Electric Vehicle Charging Location</u>	*<u>§§ 102, 202.2(b)</u>*	*<u>P</u>*

Fleet Charging	*§ 102*	*C*

* * * *

SEC. 210.2. C-3 DISTRICTS: DOWNTOWN COMMERCIAL.

* * * *

Table 210.2

ZONING CONTROL TABLE FOR C-3 DISTRICTS

Zoning Category	§ References	C-3-O	C-3-O(SD)	C-3-R	C-3-G	C-3-S
* * * *						
NON-RESIDENTIAL STANDARDS AND USES						
* * * *						
Automotive Use Category						
Automotive Repair	§ 102	NP	NP	NP	NP	P
Automotive Sale/Rental	§ 102	P (4)	P (4)	P (4)	P (3)	P (3)
Automotive Service Station	§§ 102, 202.2(b), 202.5	NP	NP	NP	P	P
Automotive Wash	§§ 102, 202.2(b)	NP	NP	NP	C	C
Electric Vehicle Charging Location	*§§ 102, 202.2(b)*	*P*	*P*	*P*	*P*	*P*
Fleet Charging	*§ 102*	*C*	*C*	*C*	*C*	*C*

* * * *

SEC. 210.3. PDR DISTRICTS.

* * * *

Table 210.3

ZONING CONTROL TABLE FOR PDR DISTRICTS

Zoning Category	§ References	PDR-1-B	PDR-1-D	PDR-1-G	PDR-2

* * * *

NON-RESIDENTIAL STANDARDS AND USES					
* * * *					
Automotive Use Category					
Automotive Uses*	§ 102	NP	P	P	P
Automotive Repair	§ 102	P (3)	P	P	P
Automotive Sale/Rental	§ 102	P	P (4)	P	P
Automotive Service Station	§§ 102, 202.2(b), 202.5	P	P	P	P
Automotive Wash	§§ 102, 202.2(b)	P	P	P	P
Electric Vehicle Charging Location	*§§ 102, 202.2(b)*	*P*	*P*	*P*	*P*
Fleet Charging	*§ 102*	*C*	*P*	*P*	*P*

* * * *

SEC. 311. PERMIT REVIEW PROCEDURES.

(a) **Purpose.** The purpose of this Section 311 is to establish procedures for reviewing building permit applications to determine compatibility of the proposal with the neighborhood and for providing notice to property owners and residents on the site and neighboring the site of the proposed project and to interested neighborhood organizations, so that concerns about a project may be identified and resolved during the review of the permit.

(b) **Applicability.** Except as indicated herein, all building permit applications in Residential, NC, NCT, and Eastern Neighborhoods Mixed Use Districts for a change of use; establishment of a Micro Wireless Telecommunications Services Facility; establishment of a Formula Retail Use; demolition, new construction, or alteration of buildings; and the removal of an authorized or unauthorized residential unit, shall be subject to the notification and review procedures required by this Section 311. In addition, all building permit applications that would establish Cannabis Retail or Medical Cannabis Dispensary uses, regardless of zoning district, shall be subject to the review procedures required by this Section 311. Notwithstanding the foregoing or any other requirement of this Section 311, a change of use to a Child Care Facility, as defined in Section 102, shall not be subject to the review requirements of this Section 311. Notwithstanding the foregoing or any other requirement of this Section 311, building permit applications to construct an Accessory Dwelling Unit pursuant to Section 207(c)(6) shall not be subject to the notification or review requirements of this Section 311. Notwithstanding the foregoing or any other requirement of this Section 311, a change of use to a principally permitted use in an NC or NCT District, or in a limited commercial use or a limited corner commercial use, as defined in Sections 186 and 231, respectively, shall not be subject to the review or notice requirements of this Section 311. *Notwithstanding the foregoing or any other requirement of this Section 311, building permit applications to change any existing*

Automotive Use to an Electric Vehicle Charging Location shall not be subject to the review or notification requirements of this Section 311.

* * * *

SEC. 710. NC-1 – NEIGHBORHOOD COMMERCIAL CLUSTER DISTRICT.

* * * *

Table 710. NEIGHBORHOOD COMMERCIAL CLUSTER DISTRICT NC-1

ZONING CONTROL TABLE

* * * *

Zoning Category	§ References	Controls		
* * * *				
NON-RESIDENTIAL STANDARDS				
* * * *				
Non-Residential Uses		**Controls by Story**		
		1st	**2nd**	**3rd+**
* * * *				
Automotive Use Category				
Automotive Uses*	§ 102	NP	NP	NP
Electric Vehicle Charging Location	*§ 102, 202.2(b)*	*C(12)*	*C(12)*	*C(12)*
Parking Garage, Private	§ 102	C	C	C

* * * *

(12) P where existing use is any Automotive Use.

* * * *

Section 3. Amendment of Specific Zoning Control Tables.

Zoning Control Tables 711, 712, 713, 714, 715, 716, 717, 718, 719, 720, 721, 722, 723, 724, 725, 726, 727, 728, 729, 730, 731, 732, 733, 734, 735, 736, 737, 738, 739, 740, 741, 742, 743, 744, 745, 750, 751, 752, 753, 754, 755, 756, 757, 758, 759, 760, 761, 762, 763, and 764 are hereby amended identically to the amendment of Zoning Control Table 710 in Section 2 of this ordinance, to create "Electric Vehicle Charging Location" as a new Non-Residential Use within the Automotive Use Category, citing Planning Code Sections 102 and 202.2(b) as references, identifying "C" as the zoning control, and including the note ("*P where existing use is any Automotive Use.*"), provided that the note shall be numbered as appropriate for each table, as follows.

Zoning Control Table	Note #
711	13
712	12
713	9
714	9
715	8
716	8
717	7
718	8
719	10
720	6
721	6

722	14
723	10
724	7
725	7
726	8
727	3
728	8
729	6
730	6
731	7
732	7
733	7
734	7
735	3
736	3
737	5
738	3
739	8
740	5
741	3
742	3

743	3
744	4
745	4
750	10
751	8
752	8
753	6
754	9
755	7
756	7
757	11
758	10
759	9
760	5
761	7
762	8
763	8
764	10

Section 4. The Planning Code is hereby amended by revising Sections 810, 811, 812, 827, 829, 840, 841, 842, 843, 844, 845, 846, 847, and 848, to read as follows:

SEC. 810. CHINATOWN COMMUNITY BUSINESS DISTRICT.

* * * *

Table 810.

CHINATOWN COMMUNITY BUSINESS DISTRICT ZONING CONTROL TABLE

* * * *

Zoning Category	§ References	Controls		
NON-RESIDENTIAL USES		**Controls by Story**		
		1st	**2nd**	**3rd+**
* * * *				
Automotive Use Category				
Automotive Uses*	§§ 102, 202.54	NP	NP	NP
Electric Vehicle Charging Location	*§§ 102, 202.2(b)*	*C(4)*	*C(4)*	*C(4)*
Parking Garage, Private	§ 102	C	C	C

* * * *

(4) P where existing use is any Automotive Use.

* * * *

SEC. 811. CHINATOWN VISITOR RETAIL DISTRICT.

* * * *

Table 811.

CHINATOWN VISITOR RETAIL DISTRICT ZONING CONTROL TABLE

* * * *

Zoning Category	§ References	Controls

NON-RESIDENTIAL USES		**Controls by Story**		
		1st	**2nd**	**3rd+**
* * * *				
Automotive Use Category				
Automotive Uses*	§§ 102, 202.*5*~~*4*~~	NP	NP	NP
Electric Vehicle Charging Location	*§§ 102, 202.2(b)*	*C(3)*	*C(3)*	*C(3)*
Parking Garage, Private	§ 102	C	C	C

* * * *

(3) P where existing use is any Automotive Use.

* * * *

SEC. 812. CHINATOWN RESIDENTIAL NEIGHBORHOOD COMMERCIAL DISTRICT.

* * * *

Table 812.

CHINATOWN RESIDENTIAL NEIGHBORHOOD COMMERCIAL DISTRICT

ZONING CONTROL TABLE

* * * *

Zoning Category	§ References	Controls		
NON-RESIDENTIAL USES		**Controls by Story**		
		1st	**2nd**	**3rd+**
* * * *				

Automotive Use Category				
Automotive Uses*	§§ 102, 202.5~~4~~	NP	NP	NP
Electric Vehicle Charging Location	*§§ 102, 202.2(b)*	*C(3)*	*C(3)*	*C(3)*
Parking Garage, Private	§ 102	C	C	C

* * * *

(3) P where existing use is any Automotive Use.

* * * *

SEC. 827. RINCON HILL DOWNTOWN RESIDENTIAL MIXED USE DISTRICT (RH-DTR).

* * * *

Table 827

RINCON HILL DOWNTOWN RESIDENTIAL MIXED USE DISTRICT

ZONING CONTROL TABLE

No.	Zoning Category	§ References	Rincon Hill Downtown Residential Mixed Use District Zoning Controls
* * * *			
Non-Residential Standards and Uses			
* * * *			

.40	Automotive Repair	§ 890.15	NP
.40a	Electric Vehicle Charging Location	§§ 102, 202.2(b)	C
.40b	Fleet Charging	§ 102	NP

* * * *

SEC. 829. SOUTH BEACH DOWNTOWN RESIDENTIAL MIXED USE DISTRICT (SB-DTR).

* * * *

Table 829

SOUTH BEACH DOWNTOWN RESIDENTIAL MIXED USE DISTRICT ZONING CONTROL TABLE

No.	Zoning Category	§ References	South Beach Downtown Residential Mixed Use District Zoning Controls
* * * *			
Non-Residential Standards and Uses			
* * * *			
.40	Automotive Repair	§ 890.15	NP
.40a	Electric Vehicle Charging Location	§§ 102, 202.2(b)	C
.40b	Fleet Charging	§ 102	NP

* * * *

SEC. 840. MUG – MIXED USE-GENERAL DISTRICT.

* * * *

Table 840

MUG – MIXED USE-GENERAL DISTRICT ZONING CONTROL TABLE

No.	Zoning Category	§ References	Mixed Use-General District Controls
* * * *			
Motor Vehicle Services			
* * * *			
840.75	Non-Auto Vehicle Sales or Rental	§ 890.69	P
840.76	*Electric Vehicle Charging Location*	*§§ 102, 202.2(b)*	*P*
840.77	*Fleet Charging*	*§ 102*	*C and must be within an enclosed building*

* * * *

SEC. 841. MUR – MIXED USE-RESIDENTIAL DISTRICT.

* * * *

Table 841

MUR – MIXED USE-RESIDENTIAL DISTRICT ZONING CONTROL TABLE

* * * *

No.	Zoning Category	§ References	Mixed Use-Residential District Controls
* * * *			
Motor Vehicle Services			
* * * *			
841.75	Non-Auto Vehicle Sales or Rental	§ 890.69	P
841.76	*Electric Vehicle Charging Location*	*§§ 102, 202.2(b)*	*P*
841.77	*Fleet Charging*	*§ 102*	*C and must be within an enclosed building*

* * * *

SEC. 842. MUO – MIXED USE-OFFICE DISTRICT.

* * * *

Table 842

MUO – MIXED USE-OFFICE DISTRICT ZONING CONTROL TABLE

No.	Zoning Category	§ References	Mixed Use-Office District Controls
* * * *			
Motor Vehicle Services			
* * * *			

842.75	Non-Auto Vehicle Sales or Rental	§ 890.69	P
842.76	*Electric Vehicle Charging Location*	*§§ 102, 202.2(b)*	*P*
842.77	*Fleet Charging*	*§ 102*	*C and must be within an enclosed building*

*   *   *   *

SEC. 843. UMU – URBAN MIXED USE DISTRICT.

*   *   *   *

Table 843

UMU – URBAN MIXED USE DISTRICT ZONING CONTROL TABLE

No.	Zoning Category	§ References	Urban Mixed Use District Controls
* * * *			
Motor Vehicle Services			
843.68	*Electric Vehicle Charging Location*	*§§ 102, 202.2(b)*	*P*
843.69	*Fleet Charging*	*§ 102*	*C and must be within an enclosed building*
843.70	Vehicle Storage - Open Lot	§ 890.131	NP

*   *   *   *

SEC. 844. WMUG – WSOMA MIXED USE-GENERAL DISTRICT.

*   *   *   *

Table 844

WMUG – WSOMA MIXED USE-GENERAL DISTRICT ZONING CONTROL TABLE

No.	**Zoning Category**	**§ References**	**WSoMa Mixed Use-General District Controls**
* * * *			
Motor Vehicle Services			
* * * *			
844.75	Non-Auto Vehicle Sales or Rental	§ 890.69	C
844.76	*Electric Vehicle Charging Location*	*§§ 102, 202.2(b)*	*P with no ingress/egress onto alleys, as defined in the Western SoMa Community Plan, within or along any RED or RED-MX Districts*
844.77	*Fleet Charging*	*§ 102*	*C and must be within an enclosed building with no ingress/egress onto alleys, as defined in the Western SoMa*

			Community Plan, within or along any RED or RED-MX Districts

*   *   *   *

SEC. 845. WMUO – WSOMA MIXED USE-OFFICE DISTRICT.

*   *   *   *

Table 845

WMUO – WSOMA MIXED USE-OFFICE DISTRICT ZONING CONTROL TABLE

No.	**Zoning Category**	**§ References**	**WSoMa Mixed Use-Office District Controls**
* * * *			
Motor Vehicle Services			
* * * *			
845.75	Non-Auto Vehicle Sales or Rental	§ 890.69	P
845.76	*Electric Vehicle Charging Location*	*§§ 102, 202.2(b)*	*P*
845.77	*Fleet Charging*	*§ 102*	*C and must be within an enclosed building*

*   *   *   *

SEC. 846. SALI – SERVICE/ARTS/LIGHT INDUSTRIAL DISTRICT.

*   *   *   *

Table 846

SALI – SERVICE/ARTS/LIGHT INDUSTRIAL DISTRICT ZONING CONTROL TABLE

No.	**Zoning Category**	**§ References**	**SALI District Controls**
* * * *			
Motor Vehicle Services			
* * * *			
846.75	Non-Auto Vehicle Sales or Rental	§ 890.69	P
<u>*846.76*</u>	<u>*Electric Vehicle Charging Location*</u>	<u>*§§ 102, 202.2(b)*</u>	<u>*P*</u>
<u>*846.77*</u>	<u>*Fleet Charging*</u>	<u>*§ 102*</u>	<u>*C and must be within an enclosed building*</u>

*   *   *   *

SEC. 847. RED-MX – RESIDENTIAL ENCLAVE-MIXED DISTRICT.

*   *   *   *

Table 847

RED-MX – RESIDENTIAL ENCLAVE-MIXED DISTRICT ZONING CONTROL TABLE

No.	**Zoning Category**	**§ References**	**Residential Enclave-Mixed Controls**
* * * *			

Automotive Services			
* * * *			
847.63	Public Transportation Facility	§ 890.80	NP
847.64	*Electric Vehicle Charging Location*	*§§ 102, 202.2(b)*	*NP*
847.65	*Fleet Charging*	*§ 102*	*NP*

* * * *

SEC. 848. CMUO-CENTRAL SOMA MIXED-USE OFFICE DISTRICT.

* * * *

Table 848 **CMUO-CENTRAL SOMA MIXED-USE OFFICE DISTRICT ZONING CONTROL TABLE**		
Central SoMa Mixed Use-Office District Controls		
Zoning Category	**§ References**	**Controls**
* * * *		
Automotive Use Category		
Automotive Uses*	§ 102	P
Electric Vehicle Charging Location	*§§ 102, 202.2(b)*	*P*
Fleet Charging	*§ 102*	*C and must be within an enclosed building*

*   *   *   *

Section 5. Effective Date. This ordinance shall become effective 30 days after enactment. Enactment occurs when the Mayor signs the ordinance, the Mayor returns the ordinance unsigned or does not sign the ordinance within ten days of receiving it, or the Board of Supervisors overrides the Mayor's veto of the ordinance.

Section 6. Scope of Ordinance. In enacting this ordinance, the Board of Supervisors intends to amend only those words, phrases, paragraphs, subsections, sections, articles, numbers, punctuation marks, charts, diagrams, or any other constituent parts of the Municipal Code that are explicitly shown in this ordinance as additions, deletions, Board amendment additions, and Board amendment deletions in accordance with the "Note" that appears under the official title of the ordinance. The preceding sentence does not apply to Section 3 of the ordinance, which uses a different methodology for amending the sections of the Municipal Code to which it applies.

APPROVED AS TO FORM:
DAVID CHIU, City Attorney

By: /s/ Robb Kapla _____
ROBB KAPLA
Deputy City Attorney

n:\legana\as2021\2100505\01574603.docx

cruise

Exhibit C

April 4, 2022

<u>Proposal on EV Zoning Legislation for Fleet Charging Activities</u>

Benefits of the Legislation: San Francisco has proposed legislation to codify electric vehicle (EV) charging - both publicly available and fleet charging - as official uses within Code. The intent of the legislation is sound, and represents a positive step forward for meeting the City's broader climate action and electrification goals in line with Mayor Breed's EV Roadmap. Every San Franciscan deserves access to clean transportation options.

Challenges of the Legislation: However, as written, the legislation creates undue restrictions on the ability for EV fleets to build and develop their own dedicated non-public charging stations, largely limiting these uses to existing PDR districts or constricting their use to 30% of public charging hubs (as an accessory use). Additionally, though the draft legislation–introduced over two months ago–allows Fleet Charging as a conditional use in the Residential Commercial (RC) zoning districts, staff has proposed a last-minute change to prohibit Fleet Charging in the RC districts. Any prohibition of fleet charging in RC districts would be a stark departure from current zoning, where almost all Automotive Uses and Utility Installation uses are permitted with approval of a Conditional Use Authorization.

Risks to City's Equity, Climate, and Inclusive Growth Goals: This legislation creates a number of extrinsic risks for broader electrification in San Francisco, including significant business uncertainty for EV fleets pursuing charging projects in RC districts, and broader adverse impacts on the city's equity, environmental justice, and inclusive growth goals. As written, the policy codifies geographic inequities that would lead to fleet charging stations being concentrated only in a few southern neighborhoods. At best, clean, zero-emission fleets will have to travel significant extra distance across the city, adding unneeded vehicle miles traveled. At worst, the narrow zoning for fleet charging locations could hinder the adoption of EVs in fleets, leading to greater air pollution in communities already overly and unfairly burdened. The policy as written could also unintentionally become a barrier to creating new, green jobs for organized labor and sharing the benefits of the EV transition with every San Franciscan.

Fleet charging provides tremendous public benefit in expanding EV access to all San Franciscans - regardless of EV ownership or access to a charger. It also creates new, green job opportunities and brings significant new investments in the community, like road safety and beautification improvements. For example, our proposed charging and R&D center on Cesar Chavez Street provides ~$25M in economic benefits to organized labor through new construction and maintenance jobs, which is why the San Francisco Building Trades and Construction Council has formally endorsed our project.

Proposal: Given these potential unintended consequences on the city's environmental, equity, and growth goals, Cruise proposes the following changes for the SF EV Ordinance legislation:

- The legislation should maintain the current provision of Fleet Charging uses within the RC districts as a conditional use.
- Allow fleet charging on properties that already have an existing Automotive Use, on the condition that such projects provide a neighborhood notice and are subject to Discretionary Review.
- Allow Fleet Charging as of right on any property for which a Project Application has been filed or a building permit has been issued to establish a new Fleet Charging use by April 18, 2022.

cruise

April 4, 2022

FAQs on Proposal:

Why can't fleet vehicles just drive back and forth to PDR zones in D10?
If all fleet charging occurs in D10, EV fleets will spend significant periods of time unnecessarily traversing the city, leading to deadhead miles and business inefficiencies, all of which will reduce incentives for fleets to adopt electric vehicle business models and delay the air quality benefits of EV fleet adoption for local communities.

Why can't fleet vehicles just share with public chargers? Isn't ⅓ enough?
The costs and operational needs for fleet charging are distinct from public charging stations. The ⅓ accessory use provision does not provide enough scale to accommodate fleet charging requirements, possibly hindering the adoption of clean vehicle fleets and risking achieving the City's climate goals. Additionally, many charging operators depend on fleet charging to generate a return as an anchor tenant and de-risk investment in charging hubs. Restricting this offtake to only ⅓ would make many charging hubs untenable based on today's level of EV adoption.

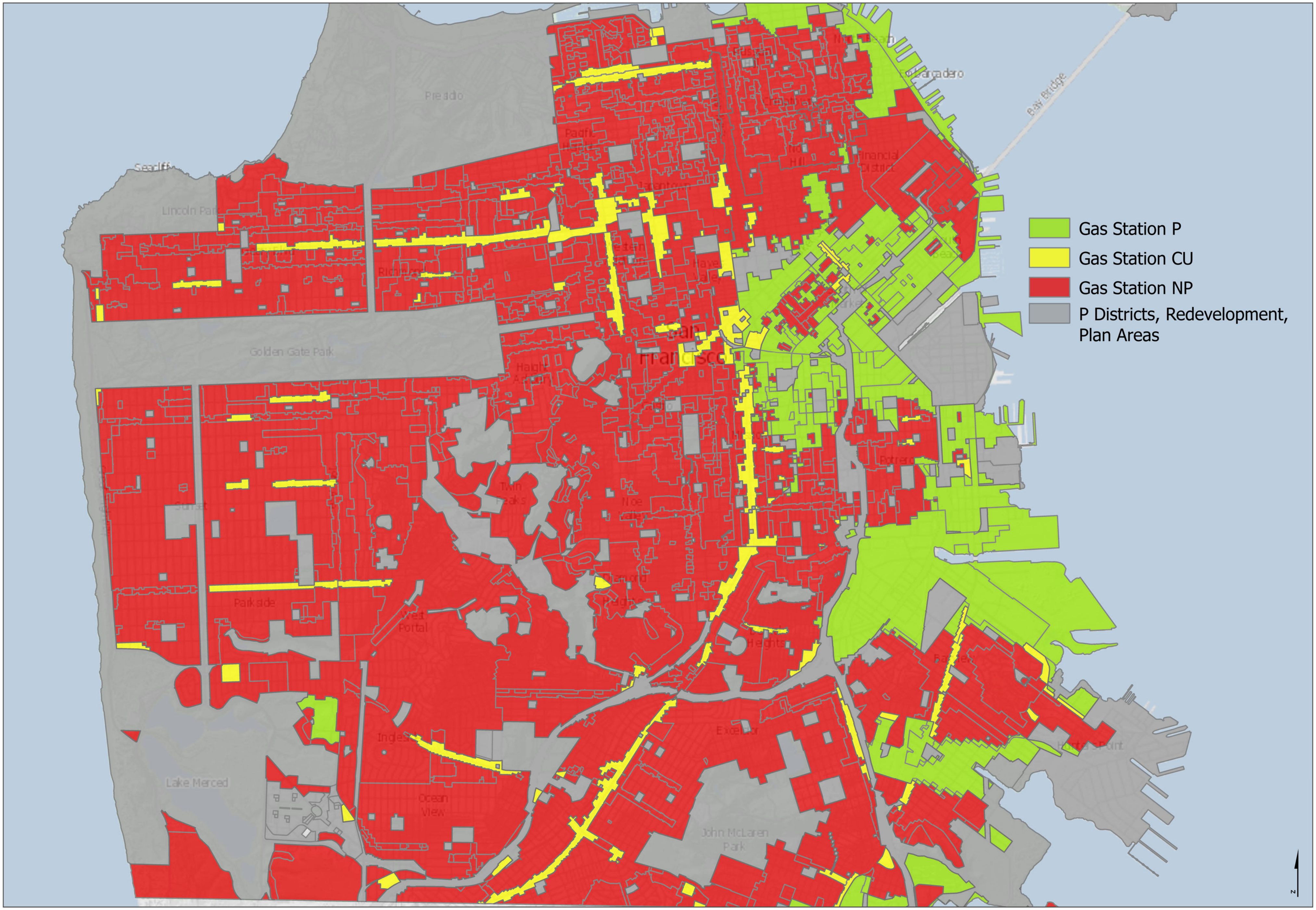
How will fleet charging sites operate? How intensive is this use?
While intensity will depend on the number of chargers, Cruise estimates vehicle traffic will be relatively minimal, consisting of almost exclusively light duty vehicles. Charging of light-duty fleet vehicles takes just as long as charging privately owned light duty vehicles, thus the usage pattern of the site is unlikely to change. Many charging hubs do require higher utilization in order to make it economically viable. Allowing fleet charging outside of the PDR zones with either a CU or discretionary review requirement will ensure that any potential location-specific impacts of a fleet charging site are thoughtfully considered and addressed.

How much space will fleet charging facilities need?
Most satellite charging locations will be at existing auto use sites like parking garages or auto service shops, and be contained within an existing building or site footprint. Charging also does not lead to intensification of use if the site is already an existing auto use. In fact, it is more likely a site will lose some capacity when adding charging due to having additional electrical switchgear and chargers.

Existing Gas Station Controls

Exhibit D

San Francisco Planning



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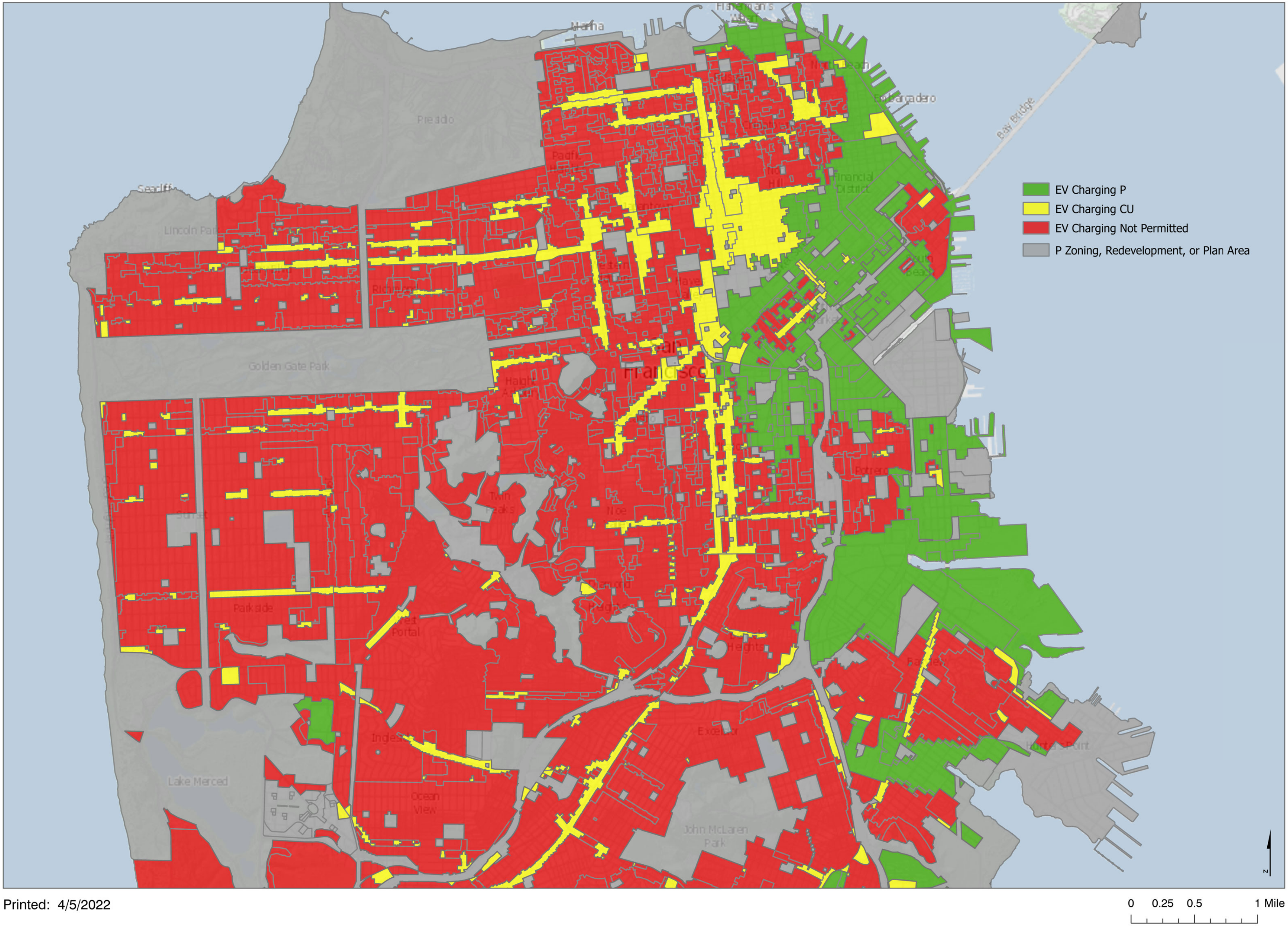
0 0.25 0.5 1 Mile

Proposed EV Charging Location Controls

Exhibit E

San Francisco Planning



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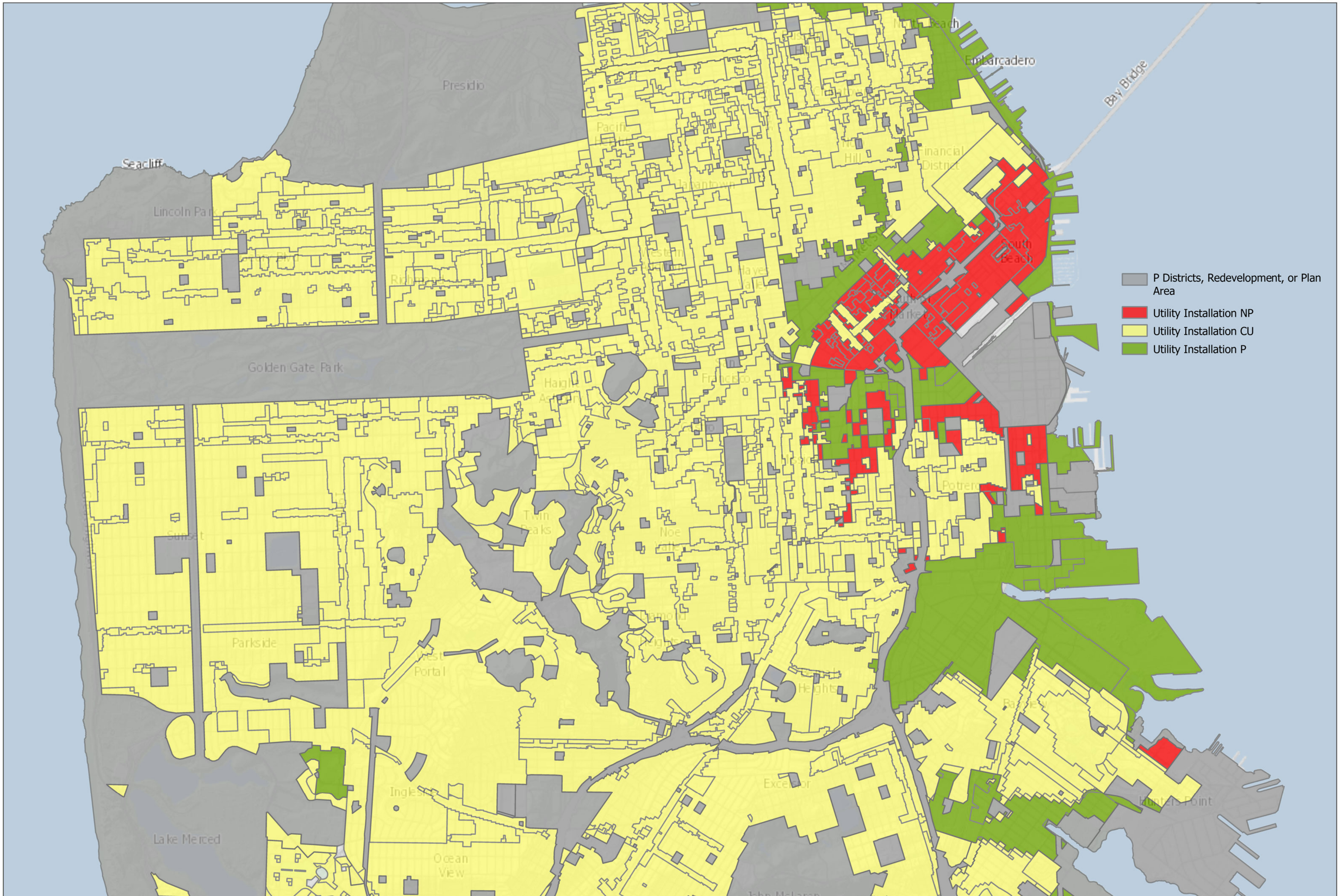
Existing Utility Installation Controls

Exhibit F

San Francisco Planning



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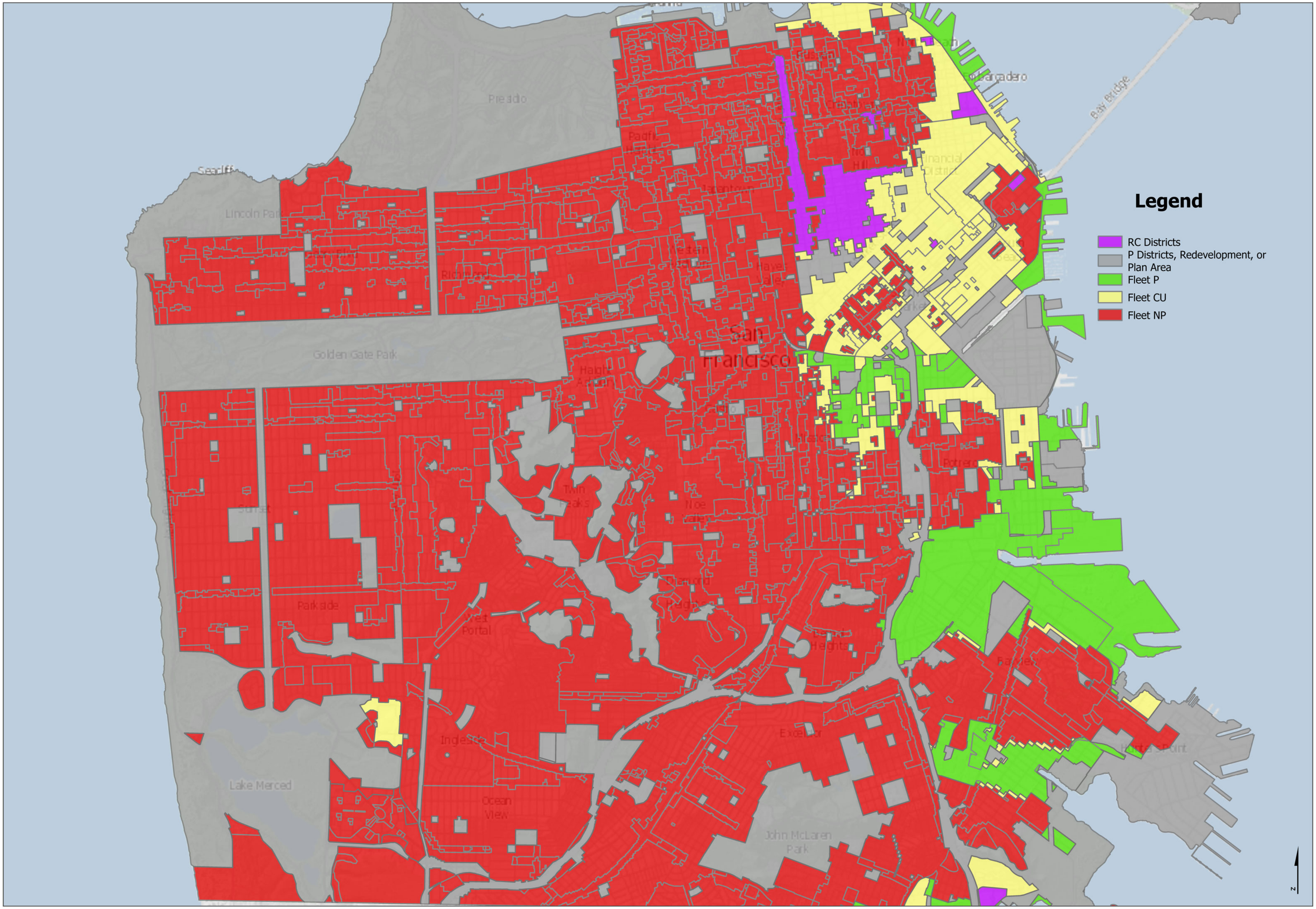
0 0.25 0.5 1 Mile

Proposed Fleet Charging Controls

Exhibit G

San Francisco Planning

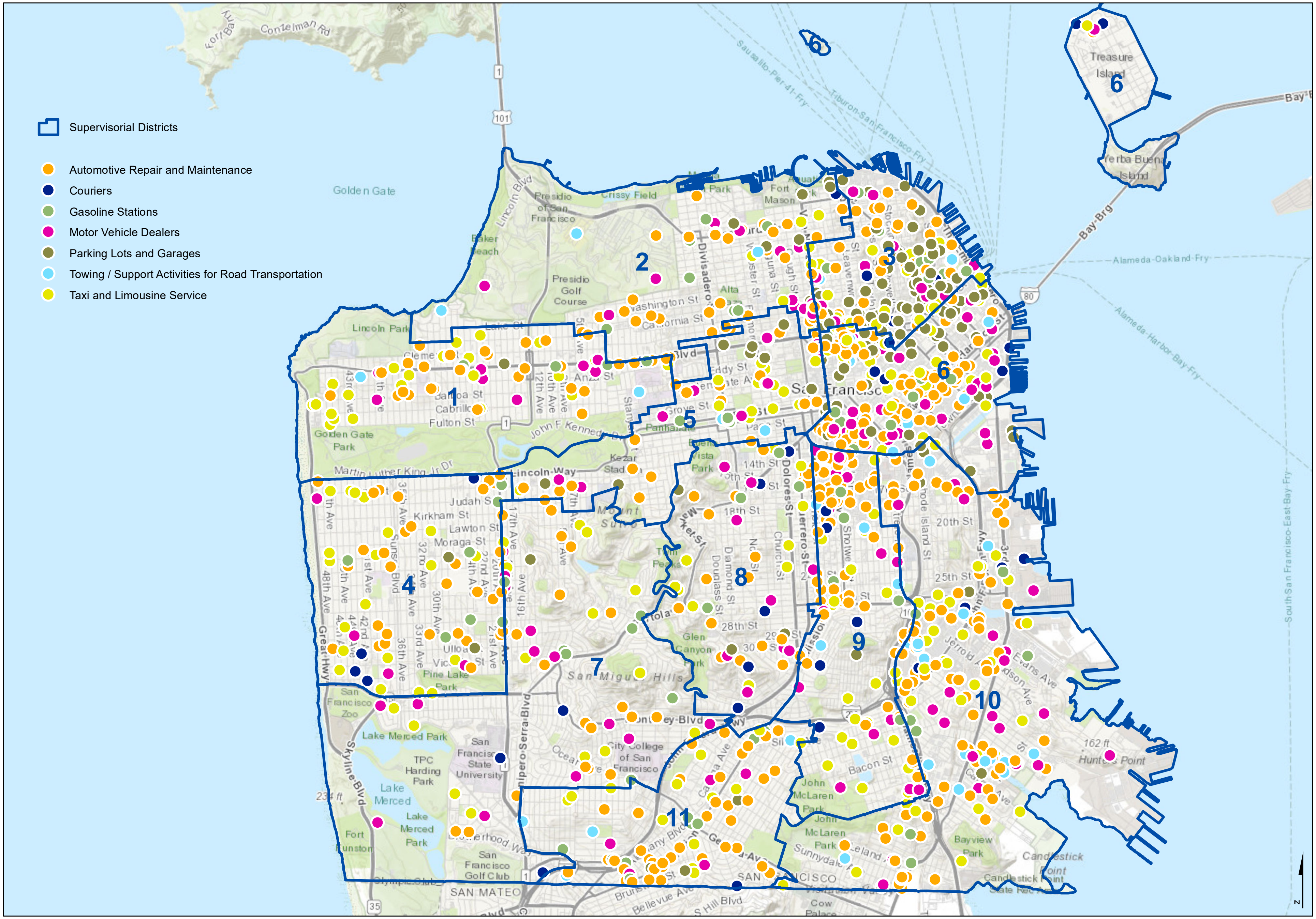


Printed: 4/5/2022

0 0.25 0.5 1 Mile

Automotive Uses and Supervisorial Districts

San Francisco Planning



0 0.25 0.5 1 Mile

23 March, 2022

[SAN FRANCISCO COMMISSION ON THE ENVIRONMENT RESOLUTION SUPPORTING ELECTRIC VEHICLE CHARGING LOCATIONS ORDINANCE]

WHEREAS, The Intergovernmental Panel on Climate Change issued a report in 2021 underscoring the need for urgent action to cut global greenhouse gas emissions (GHG) in half by 2030 and reach net-zero emissions no later than 2050 to prevent the most catastrophic effects of climate change and reduce detrimental impacts to human health and ecosystems; and

WHEREAS, San Francisco, the Bay Area, and the State of California are already suffering the effects of climate change in the form of droughts, air pollution, extreme heat, frequent wildfires, flooding, and other significant impacts on the environment; and

WHEREAS, Mayor London Breed sponsored legislation in 2021 to update the City's climate action goals to reduce emissions 61% below 1990 levels by 2030 and reach net-zero emissions by 2040; and

WHEREAS, The updated climate action goals prioritize the City's Transit First policy which encourages a shift to low-carbon modes of transportation such as taking transit, walking, and biking while all remaining modes of transportation must be electrified to eventually eliminate transportation emissions; and

WHEREAS, As of 2019, nearly half (47%) of San Francisco's GHG emissions came from the transportation sector, with the vast majority (72%) of those emissions from privately owned cars and trucks; and

WHEREAS, In 2019, Mayor Breed released the Electric Vehicle Roadmap to accelerate and advance EV adoption to reduce emissions and associated air pollution health impacts from the transportation sector; and

WHEREAS, The greatest barriers at this time for drivers to buy EVs are their costs and lack of convenient charging infrastructure; and

WHEREAS, 70% of San Franciscans live in multi-unit dwellings, many without access to home or workplace charging must depend on public charging to fuel their EV; and

WHEREAS, Publicly accessible EV charging stations—including public Level 2 (240 volt), DC fast, and workplace chargers—are the most efficient and effective solution to meet anticipated demand for EV charging; and

WHEREAS, Without this ordinance's amendments of the Planning Code, further air quality decline and GHG emission increases would occur because the ongoing inconvenience of finding EV charging stations would result in a low rate of adoption of EVs; and

WHEREAS, In 2020, the International Council on Clean Transportation (ICCT) completed a study on San Francisco's EV charging needs in 2030 and 2040, which projects that by 2030, more than 170,000 light-duty EVs will be registered in the City; and

WHEREAS, To meet projected charging demand, the City must have six times more charging capacity than in 2019 with the number of publicly accessible charging stations in San Francisco needing to increase from about 800 in 2019 to 2,000 by 2025, and over 5,000 by 2030; and

WHEREAS, Applications in San Francisco to install EV charging projects currently require an EV Service Provider (EVSP) and the Planning Department or Commission to work out a permitting pathway, on a case-by-case basis, using Planning Code provisions designed for gas stations and auto service centers, creating lengthy approval processes and bureaucratic delays that should be avoided; and

WHEREAS, By defining "Electric Vehicle Charging Location" as an "Automotive Use" in the Planning Code and establishing zones in the City in which stand-alone EV charging is permitted, this ordinance will make it easier for EVSP to convert existing sites with "Automotive Uses" to EV charging plazas or hubs; and

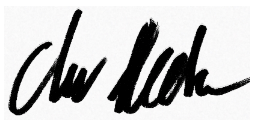
WHEREAS, This ordinance will expedite expansion of critical EV charging services, creating new public charging options for San Francisco residents, especially those in multi-unit dwellings, and visitors, thus encouraging the adoption of EVs by a greater share of the population while helping the City meet its climate action goals; now, therefore, be it

RESOLVED, That the Commission on the Environment urge the San Francisco Board of Supervisors to adopt the Ordinance amending the Planning Code to create Electric Vehicle Charging Location and Fleet Charging as Automotive Uses; and be it

FURTHER RESOLVED, That the Commission on the Environment underscores the importance of the ordinance because it allows conversion of

Automotive Service Stations to Electric Vehicle Charging Locations without Conditional Use authorization, revises zoning control tables to reflect these changes, and requires annual reporting by the Planning Department regarding Electric Vehicle Charging Location and Fleet Charging project approvals (File No. 220036), sponsored by Mayor London Breed.

I hereby certify that this Resolution was adopted by the Commission on the Environment at its meeting on March 22, 2022.



Charles Sheehan, Chief Policy and Public Affairs Officer

Vote: 7-0

Ayes: 7

Noes: 0

Absent: 0

The Mayor’s Electric Vehicle Working Group (EVWG)

Electric Mobility Subcommittee

Proposed Electric Vehicle Roadmap for San Francisco

June, 2019


BUS STOP
METRO STATION
PUBLIC PARKING
CHARGING STATION
GROCERY
RESTAURANT
BUS ONLY
OUTBOUND
6 MIN
INBOUND
AIRPORT
5 MIN
EAST BAY
LOS ANGELES
10 MIN
SACRAMENTO

Contents

Electric Mobility Subcommittee

The Electric Vehicle Roadmap was created by the Electric Mobility Subcommittee of the San Francisco Electric Vehicle Working Group (EVWG). The views and opinions expressed in this document are not necessarily representative of the views of individual participants and/or the organizations they represent.

Department/Organization	Participant
Bay Area Air Quality Management District	Ranyee Chiang/Karen Schkolnick/Mark Tang
Bloomberg New Energy Finance	Alejandro Zamorano
Brightline Defense Project	Eddie Ahn/Ivan Jimenez
ChargePoint	Anthony Harrison
Charge Across Town	Maureen Blanc
County Transportation Authority	Amber Crabbe
Department of Building Inspection	James Zhan
Department of Public Health	Maxwell Gara
Department of Public Works	Patrick Rivera
Department of the Environment	Lars Peters/Jessie Denver
General Motors	Jamie Hall
Governor's Office of Business and Economic	Gia Brazil-Vacin
Mayor's Office	Tyrone Jue
Mayor's Office on Disability	Arfaraz Khambatta
Metropolitan Transportation Commission	Krute Singa
Office of Economic and Workforce Development	Nara Babakhanyan/Marc Majors
Pacific Gas and Electric	David Sawaya/Cal Silcox
Planning Department	Lisa Fisher/Doug Johnson
Port of San Francisco	Richard Berman
Real Estate Division	Sachiko Tanikawa
Recreation and Park Department	Eric Pawlowski
San Francisco International Airport	Erin Cooke/Roger Hooson
San Francisco Municipal Transportation Agency	Tim Doherty
San Francisco Public Utilities Commission	Manuel Ramirez
Tesla	Francesca Wahl
The Greenlining Institute	Joel Espino
Veloz	Josh Boone

With support from speakers:

Mark Ferron, Cal ISO
Gillian Gillette, San Francisco Mayor's Office
Akshay Jaising, Maven
Grahm Satterwhite, San Francisco Municipal Transportation Agency
Bill Van Amberg, CALSTART

And City staff:

Josselyn Ivanov (PUC)
Suzanne Loosen (ENV)
Margaret McCarthy (ENV)
Emily Stefiuk (SFMTA)
Zac Thompson (ENV)

Terms and Abbreviations

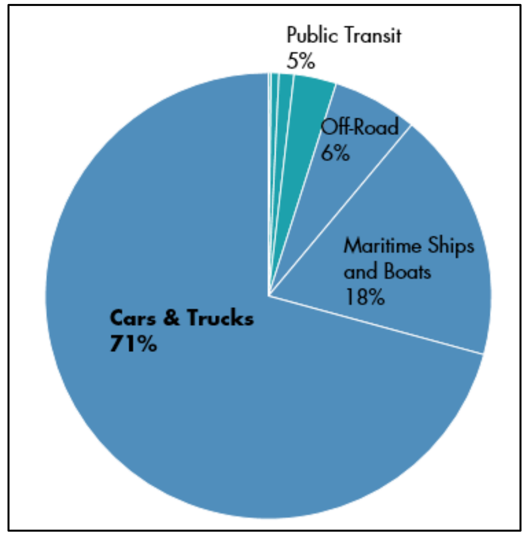
ADM	San Francisco Office of the City Administrator
AV	Autonomous Vehicle
BEV	Battery Electric Vehicle
CCA	Community Choice Aggregation
City	City and County of San Francisco
CO2e	Carbon dioxide equivalent
COPD	Chronic Obstructive Pulmonary Disease
CPUC	California Public Utilities Commission
CVRP	Clean Vehicle Rebate Project
DBI	San Francisco Department of Building Inspection
DCFC	Direct Current Fast Charger
DMV	California Department of Motor Vehicles
DPW	San Francisco Department of Public Works
Emerging Mobility	Innovations in transportation including ride-hailing services (Lyft and Uber), ride-pooling services (Chariot), bike share, autonomous vehicle technologies, and more.
ENV	San Francisco Department of the Environment
ERP	Electricity Resource Plan
EV	Electric Vehicle, including BEV, FCEV and PHEV
EV Roadmap	San Francisco Electric Vehicle Roadmap
EVSE	Electric Vehicle Supply Equipment
EVWG	Electric Vehicle Working Group
FCEV	Fuel Cell Electric Vehicle
GHG	Greenhouse Gas
HACTO	Healthy Air and Clean Transportation Ordinance
HOV	High Occupancy Vehicle
MPGe	Miles per gallon gasoline equivalent
SFMTA	San Francisco Municipal Transportation Agency
MUD	Multi-Unit Dwelling
NREL	National Renewable Energy Laboratory
OEWD	Office of Economic and Workforce Development
PG&E	Pacific Gas & Electric

PHEV	Plug-in Hybrid Electric Vehicle
PM	Particulate Matter
PM2.5	PM of less than 2.5 micrometers in diameter
PRT	Port of San Francisco
SFPUC	San Francisco Public Utilities Commission
RMI	Rocky Mountain Institute
SFCTA	San Francisco County Transportation Authority
SF Environment/SFE	San Francisco Department of the Environment
SFO	San Francisco International Airport
SF Planning	San Francisco Planning Department
SFTP	San Francisco Transportation Plan
Sustainable modes	Walking, bicycling, and public transit, as well as those modes that complement their use, like taxis and vehicle sharing
Sustainable trips	Trips using sustainable modes
TDM	Transportation Demand Management
TNC	Transportation Network Company
VMT	Vehicle Miles Traveled

1 Introduction and Summary

The City and County of San Francisco's ("City") rapidly evolving transportation sector is the primary emitter of heat trapping greenhouse gases (GHG) and the key cause of local air pollution and associated health problems. As of 2017, transportation emissions decreased by 10% since 1990,[2] making transportation responsible for 46% of the City's total GHG emissions today. The vast majority of these emissions is caused by private cars and trucks.

GHG Emissions from Transportation in San Francisco in 2017



San Francisco is a Transit First City

To create a more livable city, the City and County of San Francisco envisions[1] a city where:

- Numerous transportation and mobility options are available and affordable for all. There is less need for individually owned cars.
- The City's air is free from toxic vehicle exhaust, and people and goods are moved using renewable energy.
- There are seamless transit connections to local and regional destinations.
- Public right-of-way prioritizes sustainable transportation modes, improving safety and efficiency.
- Neighborhoods are safe, clean, and vibrant with many people walking and biking.

Public Transportation: Transit First

Increasing the share of sustainable trips

In line with its Transit First policy, the City is focused on getting people out of cars by increasing the share of trips made by transit, bicycling, and walking ("Sustainable trips"). San Francisco implemented the Muni Rapid Network of core bus routes providing nearly 70% of all riders with more frequent and reliable service, supported by dedicated "red" transit lanes. The City also built over 125 miles of bike lanes and established a citywide Transportation Demand Management (TDM) Program.[3] For 2030, the City set a goal to further grow the share of sustainable trips from 57% today to 80%.

Better vehicle technology in City vehicles

In addition to reducing car dependency through prioritizing sustainable trips, the City is leading by example in reducing emissions from its own vehicles. San Francisco has made great strides in using clean vehicle technology and low carbon fuel for its public transit vehicles, taxis, and the municipal fleet:

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[1] The long-term vision for transportation is described in more detail in *Connect SF,* an ongoing citywide effort to develop a 50-year vision for an effective, equitable, and sustainable transportation system that represents the City's long-term priorities, goals, and aspirations. https://connectsf.org/

[2] 2016 Emission Inventory SF Environment. "Carbon dioxide equivalent" or "CO2e" is a term for describing different greenhouse gases in a common unit. For any quantity and type of greenhouse gas, CO2e signifies the amount of CO2 which would have the equivalent global warming impact. MMT CO2e is Million Metric Ton CO2 equivalent.

[3] San Francisco's TDM program requires development projects to incorporate design features, incentives, and tools that support walking, biking and transit.

- San Francisco operates the largest electric trolley bus fleet in the U.S., powered by 100% renewable energy from its own municipal utility hydro-electric system.
- Taxis and bus fleets were modernized with fuel efficient hybrid electric vehicles.
- The diesel fuel supply of transit buses, municipal trucks, and ferries was switched to 100% Renewable Diesel.

Going forward, the City committed to electrify its non-emergency fleet sedans by 2022 and its remaining diesel transit buses by 2035.[4] And, with the electrification of Caltrain and BART's transition to renewable energy the City is now close to achieving an emission free public transit system.

Private Transportation: Cars and Trucks

While public transportation is well on its way to becoming emission free, private transportation poses unique challenges as the City is undergoing a transformation into a denser urban environment. Since 1990, San Francisco's economy grew by 166% and the City added 22% more people. Growth is expected to continue with 260,000 more jobs and 104,000 new units of housing being added in the coming decades.[5]

At the same time, the proliferation of smartphones and connected vehicle technologies is enabling the explosive growth of privately-owned ride-hailing vehicles and other forms of emerging mobility, such as shared bikes and electric scooters. These new services add new demands on streets and curbs, competing with the need to prioritize access for pedestrians, bicyclists, and transit vehicles. Soon autonomous vehicle technology may further and more drastically alter the transportation system.

Rapid growth in population and jobs combined with the explosive growth of ride hailing is increasing the number of cars on the road in San Francisco. Over 600,000 vehicles that are registered in or commute into the City are leading to increased congestion, road safety concerns, and traffic incidents[6] and slowing down the City's progress in reducing emissions.

Electric Vehicles: An Opportunity

The City recognizes that the best way to reduce emissions and congestion is to prioritize sustainable modes of transportation. While implementing this strategy, two technical breakthroughs offer an opportunity to more rapidly reduce and eventually eliminate emissions. First, electric vehicle (EV) technology is approaching a tipping point as new models are better performing and more affordable. [7] Second, generation of electricity for EVs is getting cleaner through the transition to renewable energy sources on the grid.[8] San Francisco aims to complete the transition to 100% renewable electrical power

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[4] SFMTA Board Resolution to all electric bus fleet by 2035: https://www.sfmta.com/press-releases/san-francisco-committs-all-electric -bus-fleet-2035
[5] Plan Bay Area 2040 projections. http://2040.planbayarea.org/what-is-plan-bay-area-2040
[6] More information: http://sfgov.org/scorecards/traffic-fatalities
[7] Electric drive trains include Plug-in Hybrid Electric Vehicles (PHEV) as well as Battery Electric Vehicles (BEV). Fuel Cell Electric Vehicles powered by hydrogen are included in the definition of EVs. This does not include other technology such as hybrid electric vehicles without a plug, or those running on CNG/LPG and renewable biofuels.
[8] Currently the power mix is 44% renewable (2016) - San Francisco Electric System Power Content and Greenhouse Gas Emissions Forecast.

by 2030, in line with the objectives of the City's 0-80-100 Climate Action framework.[9] When EVs, including Fuel Cell EVs (FCEV) powered by hydrogen, and renewable power are combined, these technologies provide a pathway to eliminate local air pollution as well as GHG emissions from transportation altogether.

EV Vision: 100% Emission-Free Transportation by 2040

In April 2018, San Francisco committed to accelerate GHG emission reductions and pledged to achieve net-zero GHG emissions by 2050. The pledge aligns with the goals adopted in the 2016 Paris Climate Agreement to take urgent action to limit global warming to under 1.5 Celsius/2.7 degrees F.[10]

It is in the context of this pledge, the changing transportation landscape, and the breakthroughs in EV and renewable energy technologies, that the City presents the San Francisco Electric Vehicle Roadmap ("EV Roadmap"). The EV Roadmap puts forward an accelerated path toward electrification of all forms of private transportation[11] and proposes a bold vision for the future: Make all transportation in San Francisco emission-free by 2040.

Interim Targets and Strategies

To inspire near term action and reduce emissions quickly, the EV Roadmap sets interim targets for 2025 and 2030. These targets aim to rapidly electrify vehicle miles traveled (VMT) while reducing total VMT by increasing the share of sustainable trips. The targets also aim to reduce the sale of new gasoline and diesel vehicles with all remaining new car sales being electric by 2030.[12]

To achieve these targets the EV Roadmap proposes six strategies, each addressing a key barrier to adoption of EV technology. The strategies and associated near term actions are described in detail further in this document. They were developed by City departments and agencies in collaboration with a diverse set of external stakeholders, including state and regional agencies, industry, and advocacy organizations. The City will work with these stakeholders, other local governments, and the community to implement the strategies and make the vision of emission-free transportation by 2040 a reality.

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[9] 0-80-100 refers to 0 Waste, 80% sustainable trips, 100% renewable energy.

[10] Members to The Paris Agreement agreed to pursue efforts to limit global warming to under 2.7 degrees Fahrenheit/1.5 degrees Celsius https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement.

[11] Private mobility, including cars, vans and medium- or heavy-duty trucks, taxis, paratransit, emerging mobility fleets, and commuter shuttles, as well as motorbikes and scooters, and by providing supporting infrastructure for electric bikes. The scope of the EV Roadmap encompasses all trips made by vehicles starting from, ending, or passing through San Francisco's boundaries.

[12]As defined by the Zero Emission Vehicle Mandate of the California Air Resources Board:
zero-emission or transitional zero-emission passenger cars and light-duty trucks..

The strategies are:

A. **Public Awareness**: Achieve broad public awareness, understanding and consideration of the options and benefits of electric mobility.
B. **Incentives:** Create a preference for electric mobility over gasoline and diesel vehicles.
C. **Charging Infrastructure:** Ensure that charging infrastructure for EVs is available and convenient for all residents, businesses, and visitors.
D. **Grid:** Integrate EV charging with the electrical grid to maximize the benefits of charging infrastructure and support the transition to a renewable energy future.
E. **Medium- and Heavy-Duty:** Lead the way in medium- and heavy-duty vehicle electrification.
F. **Emerging Mobility:** Advocate for and require emerging mobility options to be emission-free.

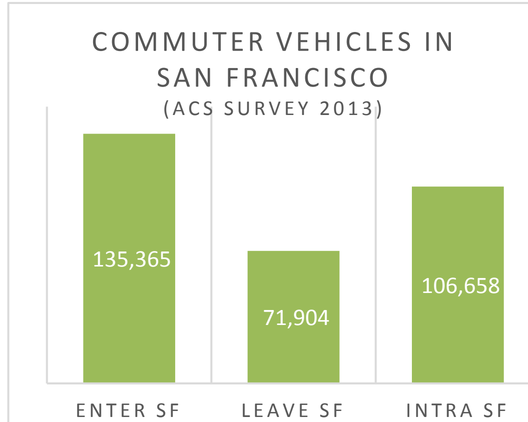
Alignment with City Plans and Goals

Through these six strategies and the supporting actions that are developed in this document, the EV Roadmap complements the City's Climate Action Plan, its Transit First policy, and its commitment to transition to renewable energy resources. The EV Roadmap also makes important contributions to equity, health, and economic vitality, in support of the overarching goal to create a more livable city. Clean, electric transportation provides cleaner air to all communities, especially benefiting vulnerable groups that are experiencing increased rates of asthma and other illnesses caused or worsened by air pollution. Investments in charging infrastructure and electric mobility provide new opportunities to build the sustainable economy of the future and a livable city for all.

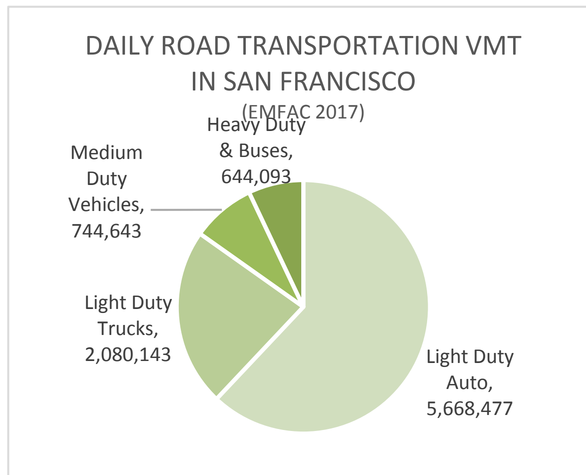
2 Private Transportation Emissions Today and a Vision for the Future

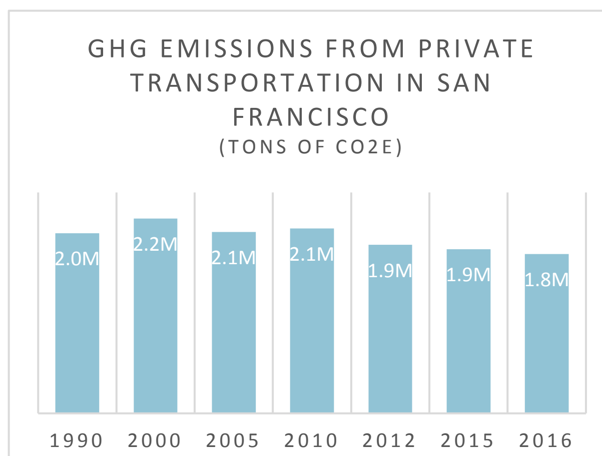
2.1 Private Transportation Emissions

Driven by rapid economic and population growth the San Francisco Bay Area now has the second-most traffic congestion in the U.S., after Los Angeles.[13] 430,000 light-duty cars and trucks and 33,000 medium- and heavy-duty trucks and buses are registered in San Francisco. In addition, 135,000 commuter cars drive into the City daily. Together these 600,000 vehicles drive over 9 million miles per day causing 1.8 million tons of GHG gases to be emitted over the year, or 32% of the City's GHG footprint in 2016.[14] Emissions in transportation have decreased by 10% compared to 1990, but the decrease has been slow and transportation has fallen behind when compared to reductions in other sectors.

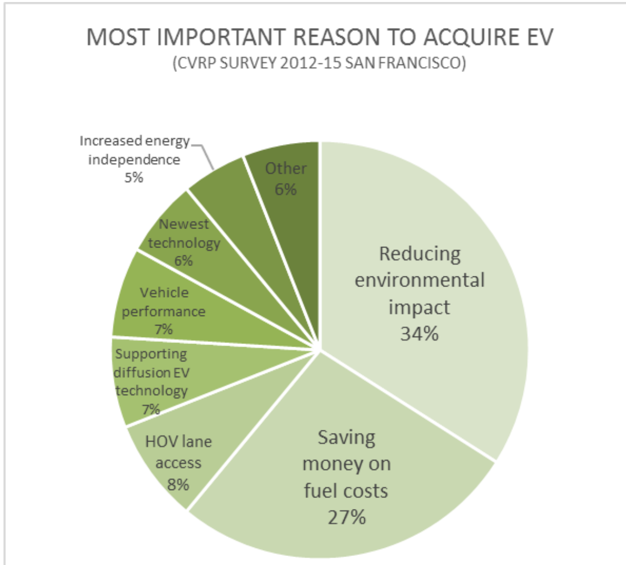


San Francisco is among the leading cities nationally, and the Bay Area is among the leading regions globally in EV adoption, but EVs still only make up a fraction of total vehicle registrations. In October 2018, 10,648 (2.3%) of the approximately 460,000 registered vehicles in San Francisco were EVs, varying widely by neighborhood.[15] Of new sales in San Francisco, EVs made up 6% in 2016, the last year for which the number is available. Early adoption of EV technology has been driven by environmental benefits and fuel cost savings as primary reasons for adoption.[16]

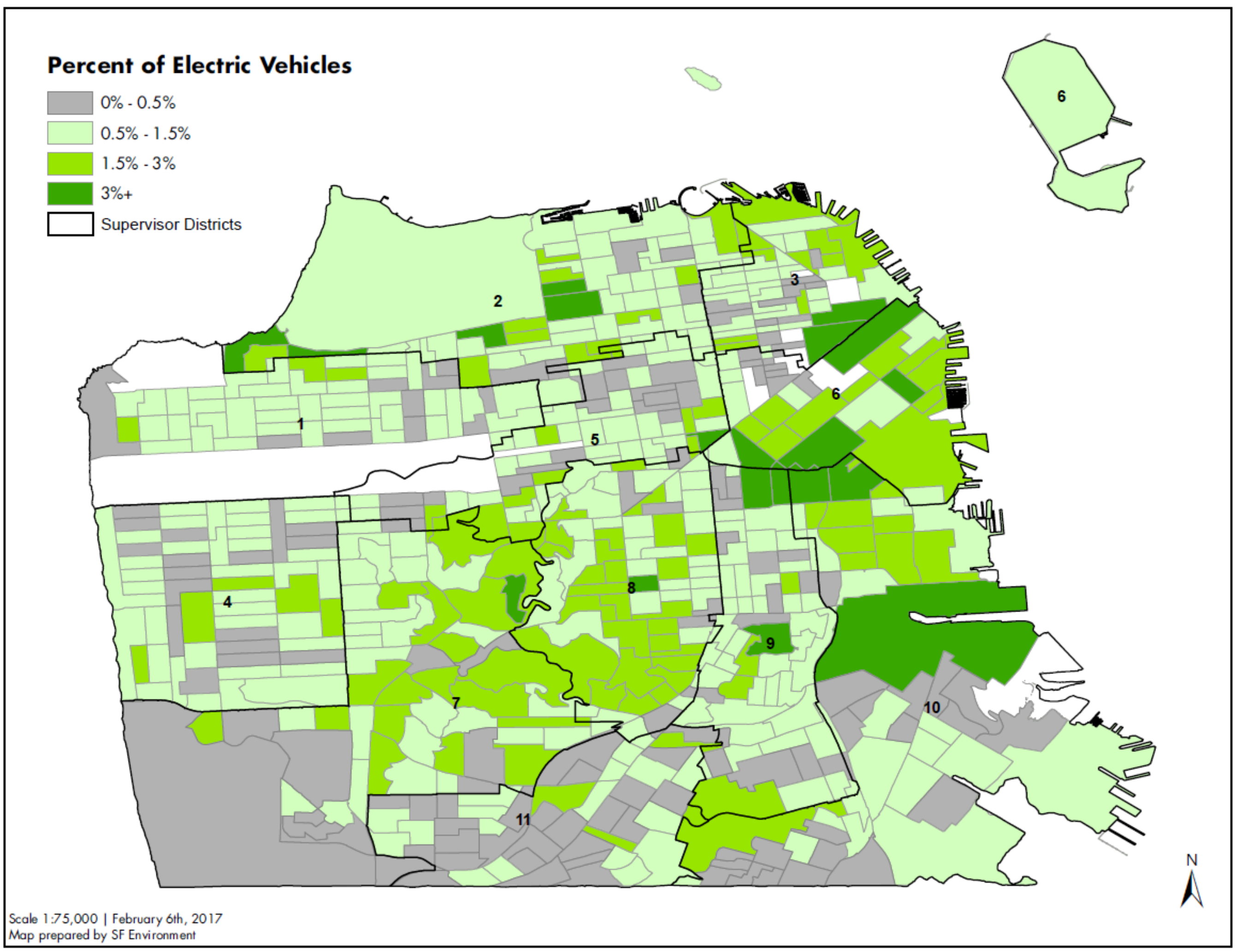




[13] https://www.tomtom.com/en_gb/trafficindex/list?citySize=LARGE&continent=ALL&country=ALL
[14] Source: 2016 GHG emission inventory SF Environment.
[15] DMV registrations October 2018.
[16] Clean Vehicle Rebate Project Survey 2012-2015 for San Francisco.



MOST IMPORTANT REASON TO ACQUIRE EV
(CVRP SURVEY 2012-15 SAN FRANCISCO)
Increased energy independence 5%
Other 6%
Newest technology 6%
Vehicle performance 7%
Supporting diffusion EV technology 7%
HOV lane access 8%
Saving money on fuel costs 27%
Reducing environmental impact 34%



Percent of Electric Vehicles
0% - 0.5%
0.5% - 1.5%
1.5% - 3%
3%+
Supervisor Districts
1
2
3
4
5
6
7
8
9
10
11
6
N
Scale 1:75,000 | February 6th, 2017
Map prepared by SF Environment

2.2 Background on Electric Vehicle Technology

EVs use electric drivetrains to power the wheels of the vehicle, eliminating tailpipe emissions. The electricity is stored in onboard batteries or in the case of FCEVs as hydrogen. Rather than refueling at gas stations, plug-in EV batteries recharge at electrical outlets and through electric vehicle charging equipment, typically installed in public and private parking garages or lots.

Benefits of Electric over Gasoline or Diesel-Powered Vehicles
● Environmental benefits: EVs eliminate harmful exhaust emissions at the tailpipe and over 75% of GHG emissions from operations today based on the City's current electrical grid. [17] The GHG reduction increases to 100% with a fully renewable energy supply by 2030. ● Lower fuel costs: Fuel costs for EVs can be as low as $0.03 per mile for passenger cars charging on an EV rate plan, 50% or more below the cost of gasoline per mile. ● Lower maintenance costs: EVs have fewer moving parts, no engine oil, and no transmission, reducing maintenance frequency and costs. ● Convenience: As long as daily driving ranges are within the battery capacity (100-300 miles for most Battery Electric Vehicles [BEVs]), EVs can be charged at home, at work, or at destination chargers, rather than visiting a gas station. On-the-road refueling at Direct Current Fast Chargers (DCFCs) is getting faster and more available as well. Higher-powered DCFC stations are being deployed that are capable of adding over 200 miles of range in 30 minutes of charging. ● Comfort: EVs offer quiet, quick and smooth accelerating power without shifting gears.

Vehicle types
Battery Electric Vehicles (BEVs) – 70% of EVs in San Francisco ● Powered by electric batteries only, between 60 and 315 miles of range before recharging is needed. ● All BEVs accept level 1 and 2 charging. Many modern BEVs also come with standard or optional fast charging (DCFC). ● Very efficient in conversion of electric power: 100-136 miles per gallon gasoline equivalent (MPGe reported by EPA). Local ("tailpipe") emissions are zero.
Plug-in Hybrid Electric Vehicles (PHEVs) – 30% of EVs in San Francisco ● Powered by electric charging and gasoline or diesel fueling. Most have an all-electric driving range of 10 - 50 miles. ● All electric driving speeds limited in some models requiring gasoline engine to be engaged at highway speeds. ● Since they have smaller batteries, PHEVs can often be fully charged overnight from a standard household socket (Level 1), but most also accept Level 2.
Hydrogen Fuel Cell Electric Vehicles (FCEVs) – Relatively new: 30-60 vehicles in San Francisco by 2017 ● FCEVs use a fuel cell to convert hydrogen into electric power within the vehicle. Driving range of 265 to 366 miles based on current models (three available today). ● Refueling takes only marginally longer than with gasoline: typically, 5 minutes for a passenger car. In San Francisco, three hydrogen fueling stations are being developed and will open in 2019. ● Efficient in power conversion, but not as efficient as BEVs: 49-67 MPGe (EPA). GHG emissions depend on how hydrogen was produced: Using renewable power creates a low footprint, natural gas a much higher one. Local 'tailpipe' emissions are only water vapor.

[17] PG&E grid mix

Charging types
Level 1: Standard household socket (110v) ● PHEV and low-mileage drivers often find a standard household socket sufficient for their daily charging needs. The charging cable often comes with the car to allow the driver to plug in anywhere.
Level 2: Most common for home and workplace charging (208-240v) ● For BEVs, especially with larger batteries, a full charge requires 6-12 hours. ● Typically, a charging station is mounted to a wall or on a pedestal. The station is hardwired or plugged in to an outlet and provides a charging cable. There are over 600 publicly available level 2 chargers in San Francisco. ● "Smart" Level 2 chargers provide control and monitoring features and allow charging speeds to be modulated, enabling power sharing and demand response to limit grid impact. ● New buildings in San Francisco need to be fully wired to support at least level 2 charging in 10% of parking spaces and have sufficient capacity on the electrical panel to supply shared charging to 100% of parking spaces.
Level 3: Direct Current Fast Charger (DCFC) for short duration of stay ● High-powered commercial charging stations along highway corridors to support road trips, and in urban areas to support high mileage use (Taxi/Transportation Network Company [TNC]), backup/emergency charging, and drivers without home charging access. ● Most BEVs on the market today ship with standard or optional DCFC capabilities. ● A full charge requires between 30-60 minutes depending on the charging speed of the station and the vehicle battery. ● DCFC requires significant investments and ample power, limiting its availability today. Currently there are 20 DCFCs in San Francisco.

2.3 A Vision for the Future: 100% Emission-Free Transportation by 2040

The end goal of the EV Roadmap is to achieve the vision of emission-free transportation by 2040 by electrifying all forms of private mobility, including cars, vans and medium- or heavy-duty trucks, taxis, paratransit, emerging mobility fleets, and commuter shuttles, as well as motorbikes, and scooters as well as by providing supporting infrastructure for electric bikes.[18]

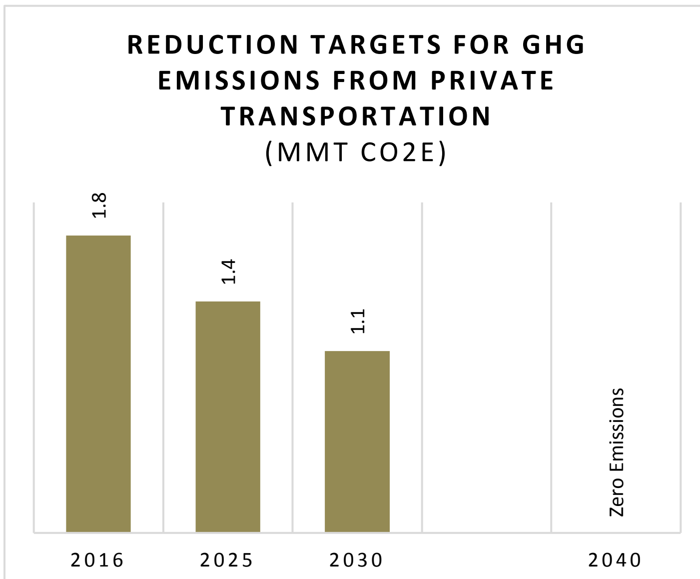
To put San Francisco on the path towards full electrification, the EV Roadmap proposes six strategies detailed in this document to eliminate barriers to adoption and bring about transformative change. Together they put the City on track to meet interim adoption and GHG reduction targets[19] for 2025 and 2030 specifically focused on new passenger vehicles, emerging mobility, medium- and heavy-duty fleets, and incoming commuters.

By 2040, electrification of all private transportation would result in a 29%[20] reduction of the City's overall emissions compared to the 1990 baseline, on top of the reductions that have already been achieved across all sectors – including transportation – to date. Such an achievement would be a major step toward the City's pledge of net-zero GHG emissions by 2050.

Strategy	Target Outcome 2020-2025
A: Public Awareness	• By 2020, drivers and the general public will be fully informed on key EV benefits so that electric options are always considered.
B: Incentives	• By 2020, clear price signals and other incentives will be in place to encourage electric mobility over gasoline and diesel.
C: Charging Infrastructure	• By 2022, there will be an effective and scalable range of charging options for all residents, fleets, and visitors across the City supporting full electrification.
D: Grid	• By 2025, most EVs will be powered by GHG-free electricity, and all will have access to electricity rates that make EVs an economical alternative to gasoline and diesel-powered transportation.
E: Medium- and Heavy-Duty	• From 2020 to 2025, the City will establish lighthouse projects of early adoption of EV technology for all major categories of medium- and heavy-duty transportation.
F: Emerging Mobility	• By 2020, shared and emerging mobility fleets will commit to a clear path to full electrification before 2025, and any new forms of mobility will be fully electric from the start.

[18] The scope of the EV Roadmap encompasses all trips made by vehicles starting from, ending, or passing through San Francisco's boundaries except for public transit, marine transport, and off-road vehicles such as drayage, forklifts, and airport logistical vehicles.
[19] Metric Ton CO2 equivalent. "Carbon dioxide equivalent" or "CO2e" is a term for describing different greenhouse gases in a common unit. For any quantity and type of greenhouse gas, CO2e signifies the amount of CO2 which would have the equivalent global warming impact.
[20] Private transportation emissions in 2016 as a % of 1990 baseline. Source: SF Environment Carbon Inventory.

Targets		
By 2025 EVs will be[21]	**By 2030 EVs will be**	**2040 Vision**
50% of new passenger vehicle registrations with no increase in total vehicle registrations per household 50% of emerging mobility vehicle miles traveled (VMT) 2,000 medium/heavy-duty commercial vehicles registered in the City 1/3 of incoming commuter vehicles	100% of new passenger vehicle registrations with no increase in total vehicle registrations per household[22] 100% of emerging mobility vehicle miles traveled (VMT) 10,000 medium/heavy-duty commercial vehicles registered in the City 2/3 of incoming commuter vehicles	All trips originating in, ending in or passing through San Francisco will be emission-free[23]



[21] For reference but outside of the scope of this document: 100% of City-owned light duty passenger sedan portfolio to be electrified by 2022 per the Municipal Zero Emission Vehicle (ZEV) Fleet Ordinance (2017).
[22] Examples of nationwide end of sales of internal combustion engine vehicles: China (no date), Netherlands new cars (2030) and Norway new cars (2025), France and UK new cars (2040).
[23] While San Francisco's goals are more stringent, they are consistent with and complement regional goals as defined in the 2017 Clean Air Plan and Plan Bay Area 2040.

3 Context and Purpose of the Electric Vehicle Roadmap

3.1 Mayor's EV Working Group and Electric Mobility Subcommittee

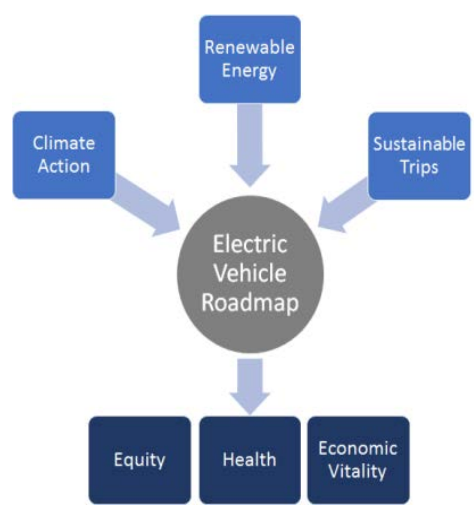
To achieve its policy goals such as cleaner air and reduction of GHG emissions, San Francisco has taken an active role in the promotion of EV technology for decades. The City installed dozens of first generation charging stations in the 1990s and in 2002 bought its first electric fleet vehicles. Since 2009, the City installed over 200 EV charging stations in municipal garages and lots and at San Francisco International Airport (SFO).

With EV technology becoming mainstream, the role of the City and the way it collaborates with the private sector on electrification is evolving. In January 2015, Mayor Ed Lee established the Electric Vehicle Working Group (EVWG) to identify actions and policies to accelerate EV adoption in San Francisco. The EVWG's objective is to ensure that EVs are available, affordable, and easy to use for all. Led by the Office of the City Administrator (ADM) and the San Francisco Department of the Environment (SF Environment), the EVWG was asked to develop recommendations and solutions to electrify the municipal fleet and transform the marketplace for EVs in private transportation.

Throughout 2016 and 2017, ADM and SF Environment staff worked to respond to the Mayor's initial requests, with City leaders unanimously passing the Municipal Zero Emission Vehicle Fleet Ordinance and the EV Readiness Ordinance for new construction and major renovations. The Mayor's Office also funded a study on worldwide best practices and recommendations to inform the City's next steps. On October 30, 2017 a summary of this work was presented that included high level opportunities for action. The EVWG agreed to establish a Subcommittee to lead the development of an EV Roadmap to accelerate electrification of private transportation.

The Subcommittee was formed in December 2017. Chaired by SF Environment, and co-chaired by the San Francisco Municipal Transportation Agency (SFMTA) and the San Francisco Public Utilities Commission (SFPUC), the Subcommittee includes broad representation from City departments and agencies, as well as key stakeholders from the private and non-profit sectors, and regional and state governmental agencies.

This EV Roadmap is the outcome of eight workshops in which the Subcommittee identified the most critical strategies and actions to electrify private transportation. In April and May 2018, the public was engaged for an initial consultation through Community Listening Sessions, in which City representatives gave brief presentations about electric mobility in San Francisco and collected feedback from the public on the best ways to increase awareness and to provide charging infrastructure for EVs.



The following sections describe how the EV Roadmap complements existing policy frameworks, programs, and initiatives, and how it contributes to equity, health, and economic vitality, in support of the overarching goal to create a more livable city.

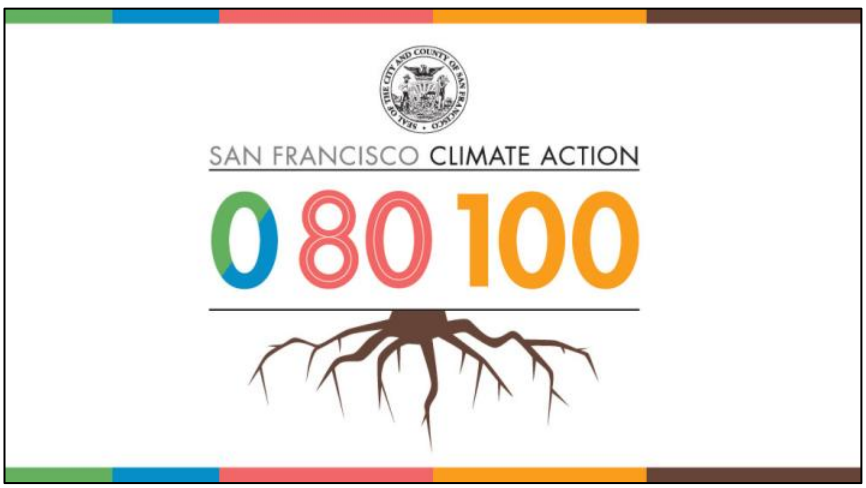
3.2 Existing Plans and Policies

Climate Action

San Francisco has long been a pioneer of innovative and responsible environmental policies and programs. The City has reduced annual GHG emissions 36% below 1990 by enforcing new green building standards, investing in renewable energy systems, pursuing rigorous energy efficiency improvements, increasing the share of sustainable trips and moving closer to zero waste being sent to landfill.

With the effects of climate change being felt sooner and stronger than expected, in 2013 San Francisco updated its *2004 Climate Action Plan* (to be updated again in 2020). The Plan provides a summary of progress, and outlines actions to be taken to meet the City's GHG reduction goals:

- 0: zero waste to landfill
- 80: a transportation system where 80% of all trips are sustainable trips
- 100: a built environment powered by 100% renewable electricity
- Roots: increased biodiversity, urban greening, and other carbon sequestration initiatives



To support the Climate Action Plan, in 2010 San Francisco updated its Environmental Code with the *Healthy Air and Clean Transportation Ordinance* (HACTO),[24] which calls for achieving GHG and air pollution reduction goals by transforming the market for energy efficient vehicles that produce zero or ultra-low emissions, and expanding alternative fueling infrastructure (including EV charging and hydrogen fuel pumps) community wide and at City facilities.

On April 19, 2018, San Francisco pledged net-zero GHG emissions by 2050, replacing the prior goal in the Climate Action Plan of an 80% reduction. With that pledge, the City joined 25 other cities from around the globe that have made the commitment to accelerate emission reduction plans. The pledge aligns with the 2016 Paris Climate Agreement and builds on San Francisco's track record of successfully reducing emissions while simultaneously growing its economy.

[24] HACTO is outlined in Chapter 4 of San Francisco's Environmental Code.

The Paris Climate Agreement, adopted on December 12, 2015, is an agreement within the United Nations Framework Convention on Climate Change (UNFCCC) that addresses GHG mitigation, adaptation, and finance starting in the year 2020. Representatives of 195 countries adopted this first-ever universal, and legally binding global climate treaty.

The Paris Agreement intends to hold the increase in the global average temperature to well below 3.6° Fahrenheit/2° C above pre-industrial levels and to pursue efforts to limit the temperature increase to 2.7° Fahrenheit/1.5 °C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change.

San Francisco's pledge to achieve carbon neutrality[25] by 2050 supports and goes beyond landmark legislation of the California State legislature: The California Global Warming Solutions Act of 2006 (AB 32) and Senate Bill 350 (S.B. 350), passed in 2015.

Renewable Energy

As a municipal utility with considerable power generation resources, the PUC has been a leader in the transition to a sustainable power grid, providing renewable power to municipal buildings, the airport, and Port, as well as the City's electric transit fleet for over 100 years.

In 2001, City leaders passed the *Human Health and Environmental Protections for New Electric Generation Ordinance* to consider all practical alternatives to fossil fuel electricity generation in San Francisco.

In 2002, the City released its first *Electricity Resource Plan* (ERP), which outlined actions to improve air quality in San Francisco and move the City toward reliance on renewable sources of electricity by closing the City's two remaining power plants and establishing the long-term goal of a GHG-free electricity sector for all of San Francisco.

With the release of its first *Strategic Sustainability Plan in* 2008, San Francisco set a course of action to ensure that the City's future electricity needs were met through maximizing energy efficiency, supplying the City's energy needs with renewable resources, eliminating GHG emissions associated with energy production and use, and basing energy decisions on the goal of creating a sustainable community.

In 2011 and 2012, the City took further steps to achieve the long-term goal of meeting its electricity needs through 100% renewable resources with City leaders adopting the *Updated Electricity Resource Plan.* The updated ERP identified three broad strategies and fourteen recommendations that San Francisco could take in order to have a GHG-free electric sector by 2030, generating all of its energy needs from the City's Hetch Hetchy hydro-electric project and other renewable energy resources.

In 2012, the Mayor's Office released the *Renewable Energy Task Force Recommendations Report*, which outlined how to maximize on-site distributed renewable generation, expand community-scale

[25] Carbon neutrality is a term used to describe the action of organizations, businesses, and individuals to remove as much carbon dioxide from the atmosphere as each added. The overall goal of carbon neutrality is to achieve a zero-carbon footprint.

renewable projects, explore renewable power purchasing options, and encourage the private sector to invest in renewable energy projects.

In addition to the municipal utility, the City launched *CleanPowerSF*, the City's Community Choice Aggregation (CCA) program, to significantly increase the proportion of electrical energy supplied to the San Francisco electrical grid from local renewable sources, decrease San Francisco's GHG emissions, and help combat global climate change. CleanPowerSF began automatically delivering cleaner energy to San Francisco residents and businesses in phases in May 2016 and will enroll all eligible San Francisco electricity customers by the end of 2019. CleanPowerSF is a not-for-profit entity that works in partnership with the local investor-owned utility, Pacific Gas & Electric (PG&E).

Sustainable Transportation

Since the 1970s, the City has been a national leader in the creation of a sustainable transportation system. The City's public transit, bike and pedestrian networks are vital elements of its strategy to build a more equitable, safe, sustainable, and affordable multimodal transportation system. Mode shift, from single occupancy vehicle trips to sustainable modes, is the City's primary strategy to reduce congestion, improve public health and safety, and reduce GHG emissions.

In 1973, City leaders enacted San Francisco's Transit First policy, which prioritizes the safe and efficient movement of people and goods to ensure quality of life and economic health in San Francisco. A key tenet of Transit First is the prioritization of the use of finite public street and sidewalk space by pedestrians, bicyclists, and public transit over private automobiles. The policy can be found in Appendix a). Implementation of the Transit First policy is a long-term strategic effort, requiring considerable and sustained investments in multimodal transportation infrastructure. In addition, the following key plans, strategies, and principles guide the City's transportation investments:

The *San Francisco Transportation Plan (SFTP)* is the countywide, long-range blueprint for San Francisco's multimodal transportation system. The SFTP outlines a diverse investment strategy and recommends policy actions to optimize investments.

The *SFMTA Strategic Plan* defines the purpose of the Agency and establishes goals and objectives to guide SFMTA's work for the next two years. It also outlines performance metrics and targets by which SFMTA's success will be measured and refines/updates strategic goals and objectives to better address the changing needs of the SFMTA and the City.

In 2017, the San Francisco County Transportation Authority (SFCTA) and the SFMTA adopted ten *Emerging Mobility Services and Technology Guiding Principles* to serve as a framework for evaluating emerging mobility services and technologies. Examples of emerging mobility services and technologies include ride-hail services, autonomous vehicles, bike share, and ride-pooling services. The Guiding Principles reflect adopted City policies, plans, and strategies, and are synthesized to relate to emerging mobility.

Vision Zero SF is the City's policy for building safety and livability into the City's streets, protecting the one million people who move about the City every day. Through implementation of Vision Zero, the City is committing to working together to prioritize street safety and eliminate traffic related injuries and deaths by 2024 in San Francisco.

The *2017 Transportation Sector Climate Action Strategy* provides a framework for the accelerated reduction of emissions from the transportation sector, and for building a more resilient transportation sector to mitigate climate impacts such as sea level rise.

Implementing the Transit First policy is a long-term strategic effort, requiring considerable and sustained investments in neighborhoods and transportation infrastructure. To that end, the City recently launched a citywide effort, *ConnectSF*, to develop a 50-year vision for an effective, equitable, and sustainable transportation system that represents the City's long-term priorities, goals, and aspirations.

3.3 Equity, Health, and Economic Vitality

Eliminating emissions from transportation through electrification contributes to equity, health, and economic vitality in support of the overarching goal to create a more livable City.

Equity

To ensure that the EV Roadmap helps build a more equitable San Francisco, it must:

- address inequities in the broader transportation system/access to electric mobility
- reduce pollution coming from congested corridors and medium- and heavy-duty traffic
- include a robust community outreach and engagement process

Equitable Access

Over the past century, transportation investments have prioritized automobiles over other modes. In many communities, the resulting transportation system created disparities in mobility choices and services along with health, safety, and environmental impacts on low-income and underserved communities[26] who have often been left out of decision-making and transportation planning processes.

San Francisco has been working on a number of initiatives to build a more equitable multimodal transportation system that reflects community priorities. Examples include the Muni Service Equity Strategy which benefits neighborhoods by implementing transit service improvements and improving connectivity to key destinations, reliability and frequency while reducing crowding. The City also coordinates with regional partners such as the Metropolitan Transportation Commission (MTC) to advance the Lifeline Transportation Program, which improves transportation choices for low income populations and addresses transportation gaps or barriers in low income and underserved communities within San Francisco and the region.

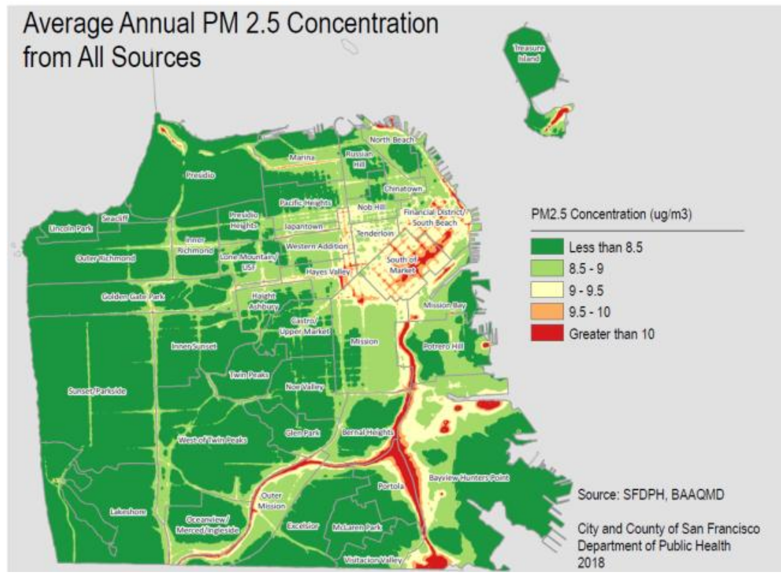
For San Francisco to be able to implement the EV Roadmap in an equitable way, the City needs to address the disparities in access to electric mobility that already exist. If access is unequal, the electric mobility revolution could lead to a growing rift in the already stratified mobility landscape between those who have personal, social, and economic opportunities and those who do not. California's current policy measures to accelerate transportation electrification include incentives such as EV access to

[26] "Underserved communities" will be defined in the context of specific actions and policies, leveraging MTC's Communities of Concern as being vulnerable and/or Department of Public Health's Community Resiliency Index (available at: https://sfclimatehealth.org/neighborhoods/).

carpool lanes, rebates, and special lease terms and electricity rates. Access to the benefits of electric mobility becomes increasingly important as the technology matures and policy makers propose new initiatives.

Clean Air

Creating equitable access to electric mobility options helps ensure that reductions in emissions directly benefit local communities, especially low-income and underserved communities disproportionately impacted by vehicle emissions. Notably, in areas with the worst air quality, emissions come predominantly from commuter traffic and medium- and heavy-duty vehicles on nearby arteries. Access to electric mobility options for local residents and businesses is therefore not enough. To improve air quality in the most affected communities, it is critical to reduce the emissions from incoming and outgoing commuter traffic as well as the diesel emissions from medium- and heavy-duty vehicles.



Community Engagement

For the EV Roadmap to succeed in creating more equitable outcomes, a robust plan for community engagement is essential to the implementation of the proposed actions. As an example of such engagement, the City is currently collaborating with residents and community groups through the Bayview community-based transportation planning process to identify multimodal transportation projects that meet specific needs identified by residents and businesses. These projects will emphasize sustainable modes and improve access and connectivity for transit-dependent groups.

The City also has partnered with the nonprofit GRID Alternatives for more than a decade to provide low income single family homeowners low to no cost roof replacements and rooftop solar installations. To date 255 photovoltaic systems have been installed which will result in $6M in long-term cost saving for low income homeowners. Additionally, San Francisco's energy efficiency programs have prioritized completion of upgrades in both affordable and market rate multi-family properties across the city resulting in more than 6 megawatts of energy savings for residents.

Health

Besides being the primary source of GHG emissions in San Francisco, private transportation is also a key source of local criteria air pollutants, including ozone and particulate matter (PM).[27] While representing a small percentage of all vehicles, medium- and heavy-duty vehicles are responsible for about half of transportation PM of less than 2.5 micrometers in diameter (PM2.5) emissions in the City.[28] Accordingly, air quality issues are concentrated in neighborhoods along the major traffic arteries, the central business district, areas zoned for commercial/industrial activities, and along highway corridors. These areas of lower air quality often overlap with low-income and underserved communities, placing a disproportionate public health burden on residents there.

Health problems associated with exposure to air pollution include:

- Aggravated Asthma: asthma is the leading chronic condition for children
- Chronic Obstructive Pulmonary Disease (COPD): COPD is the third leading cause of death in the United States
- Cancer: exposure to diesel exhaust is an established cause of lung cancer

Recent studies also indicate that exposure well below legal limits still causes increases in mortality,[29] suggesting there is no truly “safe level” for PM pollution.

The San Francisco Department of Public Health is tracking leading indicators such as asthma in vulnerable populations. In 2014, 21% of high school students in San Francisco were diagnosed with asthma, well above the national average of 10%.[30] Rates are even higher, 37.6%, among Black/African American high school students.[31]

Electrification is a key tool to reduce the negative impacts from transportation emissions on vulnerable communities. To achieve optimal air quality benefits, electrification needs to span all duty types, including medium- and heavy-duty fleets which are responsible for a large share of harmful criteria air pollutants.

Economic Vitality

San Francisco is proof that reductions in GHG emissions can go together with strong economic growth. The City’s emissions have been reduced by 36% from 1990 levels, while the local economy grew by

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[27] Vehicle emissions are responsible for over 50% of CO and over 30% of NOx emissions in the City (BAAQMD 2011) http://www.baaqmd.gov/~/media/Files/Planning%20and%20Research/Emission%20Inventory/BY2011_CAPSummary.ashx?la=en. In contrast with national trends, air quality in the San Francisco Bay Area is worsening rather than improving.. The Bay Area now ranks worse than LA in both short term and year-round particle pollution: http://www.lung.org/local-content/california/documents/state-of-the-air/2017/sota-2017-statewide-press-english.pd.

[28] 2017 EMFAC model - CARB; The San Francisco Indicator Project – SF Department of Public Health. PM2.5 is highlighted here for brevity and its strong adverse health impacts.

[29] Air Pollution and Mortality in the Medicare Population - 2017 - http://www.nejm.org/doi/full/10.1056/NEJMoa1702747#t=abstract.

[30] https://www.cdc.gov/asthma/most_recent_data.htm.

[31] San Francisco Community Health Needs Assessment – San Francisco Health Improvement Project.

166%,[32] and the population increased by 22%.[33] With the strategies and actions described in this EV Roadmap, the City will further accelerate the transition to a sustainable economy, create new jobs in the clean technology sector, and continue to foster a culture of innovation.

Electrification opens up new employment opportunities for car mechanics, electricians, contractors, and other workers needed to build out charging infrastructure and to service EVs. Many of these job types – specifically electricians and EV-service technicians – have been identified as important occupations for producing employment opportunities in underserved communities.[34]

San Francisco's Office of Economic and Workforce Development (OEWD) will lead the City in working with employers and workforce training partners to identify hiring needs associated with electric mobility. City College of San Francisco has begun EV labor pool development through the establishment of an EV technician training program. The program is free for all San Francisco residents, and trains students to maintain and repair EVs and EV charging stations. OEWD will work with City College and other workforce development programs to prepare a labor pool in support of the strategies put forward in this EV Roadmap.

In addition to the employment opportunities for individuals, the transition to electric mobility creates opportunities for businesses to accelerate their sustainability initiatives and for new initiatives to begin. The Bay Area is already home to globally leading companies in clean technology and emerging mobility. Expanding the City's status as a world leader in electric mobility will cement this leadership role and foster an environment for innovation to tackle the key global challenges in addressing climate change.

3.4 Implementation and Public Engagement

The EV Roadmap proposes six strategies and 33 actions across City departments to be initiated and/or completed in the 2018-2020 timeframe. To coordinate and detail the actions, City staff will create a detailed implementation plan, providing more detail on each action, specifying deliverables, timelines, and stakeholder involvement.

The implementation plan will also put forward a robust community outreach plan to guide implementation of the strategies and actions. It is vitally important to understand the needs of different communities throughout San Francisco so that the actions in the EV Roadmap are equitable and effective for all residents.

[32] Increase in GDP from 1990 to 2017
[33] 2017 – SF Environment
[34] https://www.ucsusa.org/clean-vehicles/electric-vehicles/freight-electrification#.WvI3qn9lCUk

Strategies

The next six sections describe each strategy in more detail, including relevant City context and challenges, and propose actions for 2018-2020 that provide City departments with concrete, near-term next steps.

Strategy		Proposed Actions
A	**Public Awareness**: Achieve broad public awareness, understanding and consideration of the options and benefits of electric mobility.	1. Awareness campaign 2. EV help desk 3. Extended test rides 4. TDM 5. Wayfinding and signage
B	**Incentives:** Create a preference for electric mobility over gasoline and diesel vehicles.	1. EV purchase/lease incentive 2. Regional highway system 3. SFO access and pricing 4. Garage parking policy and pricing 5. Street parking policy and pricing 6. Special zones 7. Transportation pricing
C	**Charging Infrastructure:** Ensure that charging infrastructure for EVs is available and convenient for all residents, businesses, and visitors.	1. Multi-Unit Dwellings (MUD) 2. Smart charging 3. DCFC masterplan 4. City garages 5. Private commercial garages 6. Curbside charging study 7. Workforce training 8. Charging experience
D	**Grid:** Integrate EV charging with the electrical grid to maximize the benefits of charging infrastructure and support the transition to a renewable energy future.	1. Infrastructure limitations solutions 2. Pricing evaluation 3. Stationary battery storage 4. Renewable power
E	**Medium- and Heavy-Duty:** Lead the way in medium- and heavy-duty electrification.	1. Fleet pilots 2. School transportation 3. Recology fleet 4. Port charging for heavy-duty applications 5. Incentives and regulations
F	**Emerging Mobility:** Advocate for and encourage emerging mobility options to be emission-free.	1. TNCs 2. Car share 3. Taxis 4. Car rentals 5. Autonomous Vehicles

Strategy A: Public Awareness

Achieve broad public awareness, understanding and consideration of the options and benefits of electric mobility.

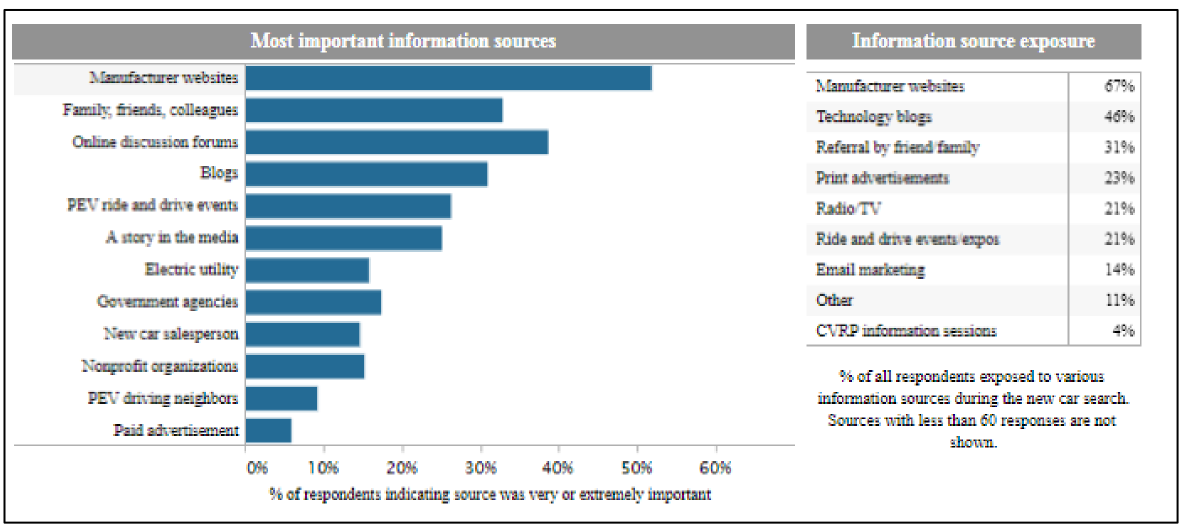
Context

Electric cars and trucks are being propelled into the mainstream by falling sticker prices on increasing model options, extended battery range and incentives. The electric mobility revolution is here, but perceptions that EVs are expensive or inconvenient persist.[35]

Often these concerns result from a lack of easily accessible information and technical assistance. The industry and dealerships were initially slow to catch up to the selling points and fueling requirements for EVs.[36] Early EV adopters therefore based their decisions almost entirely on online research and advice from family, friends, and colleagues.

Drivers and fleet owners may not be aware of incentives that reduce the upfront cost of EVs; the benefits electric mobility offers, such as reduced operation and maintenance expenses; or how to charge at home, work, and at other destinations. Citing concerns about affordability and charging availability, 79% of new car buyers do not yet consider an EV for their next car.[37]

California Clean Vehicle Rebate Project (CVRP) Survey Data for San Francisco 2012-2015



[35] The perception that "EVs are too expensive" is inaccurate for most drivers in California when incentives are considered. While the market price of EVs can be more expensive than traditional internal combustion engine vehicles, after incentives EVs are comparable if not more affordable than traditional vehicles. Furthermore, experiments show that marketing EVs at a price that reflects available tax credits and dealership incentives results in significantly higher sales.

[36] CVRP 2012-2015 for San Francisco: 33% of the time, dealerships offered to facilitate Electric Vehicle Supply Equipment (EVSE) installation; 37% offered assistance with tax/rebate applications; and 33% offered High Occupancy Vehicle (HOV) lane stickers at point of purchase.

[37] National Renewable Energy Laboratory (NREL) 2017 Barriers to acceptance of ZEVs: 79% applies to BEVs, adding PHEVs only slightly increases the pool that would consider an EV. FCEV was not tested as commercial availability was very limited at the time of the study.

Target Outcome and Actions

The following actions ensure that by 2020, drivers and the general public will be fully informed on key EV benefits, and that electric options are always considered when mobility investments and choices are made.

Proposed Actions for Strategy A: Public Awareness		**Lead**	**Support**
A1	Develop and fund a city **public awareness campaign** to increase awareness: • Develop and maintain a single online “one-stop-shop” landing page. • Partner with the retail car industry to display educational and promotional materials, such as posters and handouts aligned with state/regional messaging. • Fold in educational/promotional material at any point (online or offline) that an agency interacts with drivers or fleet owners.	ENV	SFMTA, SFPUC
A2	Develop and fund a city EV **Help Desk** providing information and technical assistance for residents and organizations with electric mobility questions.	ENV	
A3	Evaluate options to offer community groups/neighborhoods **extended test rides** in EVs.	ENV	
A4	Explore opportunities to align the City’s **Transportation Demand Management** Program and policies with electrification goals.	SF PLANNING, SFCTA, ENV, SFMTA	
A5	Develop wayfinding/branding and **signage** standards for EV charging infrastructure.	TBD City Staff	

Strategy B: Incentives

Create a preference for electric mobility over gasoline and diesel vehicles.

Affordability of EVs

Prices for EVs, especially long-range passenger car models, are rapidly decreasing and are expected to be comparable to gasoline-powered cars as soon as 2025.[38] Currently purchase and lease incentives bridge the price gap and have been effective in driving demand for EVs in the U.S. and globally. After incentives, some EVs are among the most affordable new car options on the market and used EVs, a rapidly growing market, are cheaper still. State and other programs targeting low-income consumers bring down costs even further.[39]

Vehicle Pricing Examples

Illustrative Pricing July 2017 (TMV/CarMax)	Nissan Leaf 2017	Chevrolet Bolt 2017	Used Nissan Leaf 2011-2015 (< 40,000 miles)
MSRP	$30,680	$36,620	
Dealer rebate	-$3,450	-$3,000	
MFG rebate	-$4,000		
Federal tax credit	-$7,500	-$7,500	
State rebate (CVRP)	-$2,500	-$2,500	
Qualifying low income CVRP	-$2,000	-$2,000	
Effective price (excluding tax)	$11,230	$21,620	$6,000 – $11,000

In addition to purchase incentives, lower operating costs are a key driver of EV adoption, saving many drivers $1,000 per year or more. These savings stem from a large difference in fueling and maintenance costs. To fuel an efficient car with gasoline costs between $0.07-0.14 per mile, but charging an EV at home can costs as little as $0.03-0.04 per mile.[40]

While the economics of owning and driving an EV can be favorable, as in the examples above, this is not the case for all residents or communities: affordable charging is not available to everyone, an issue that is addressed in detail the next chapter on Charging Infrastructure.

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[38] BNEF 2018 forecast BEV prices

[39] In addition, programs help provide indirect access to incentives through providing financing options for drivers with low credit ratings. For instance: Driving Clean https://drivingclean.chdcnr.com/.

[40] Assumptions: Fuel cost for a 35 MPG car based on local gasoline prices, which fluctuated between $2.46 and $4.74 per gallon over the last 5 years. EV drivers with access to home charging can take advantage of EV rate plans that offer electricity at a constant low price of $0.12 per kWh (off-peak). Electricity prices are more stable and predictable than prices of gasoline. In addition, EVs, especially BEVs, have lower ongoing maintenance costs. For example, BEVs do not have transmissions or require oil changes. Additionally, strong regenerative braking reduces wear and tear on brake pads reducing maintenance costs further. Individual cost savings vary by type of car and use, but can approach 50% or about $0.02-0.03 per mile, saving drivers several hundred dollars per year. For gasoline cars, the fueling cost makes up a significant share of total vehicle costs of $0.59 per mile for an average sedan. https://newsroom.aaa.com/tag/driving-cost-per-mile/.

And, while incentives are key to ensuring affordability, their future is uncertain. Many incentive programs change annually and the Federal Electric Vehicle Tax Credit of up to $7,500 per EV purchased began phasing out for top selling brands in 2018. In the transitional period leading up to price parity, incentives are critical to keeping EVs priced competitively when compared to gasoline or diesel vehicles.

Financial and Other Incentives

To make EVs an attractive alternative to gasoline and diesel vehicles, many cities successfully use transportation and parking pricing policies as well as non-financial incentives, such as access for EVs to preferred parking. The effectiveness of financial and non-financial incentives varies across individuals and groups and the level of EV adoption. Strong, non-financial incentives have been especially important to foster early adoption of EVs, potentially evolving over time as the technology matures.[41]

In evaluating these policy options for San Francisco, the City will look at effectiveness as well as safeguarding that outcomes are equitable, and policies maintain the preference for sustainable modes of transportation throughout the City.

[41]A key example of a non-financial incentive is the ability for EVs to access HOV (or carpool) lanes. HOV lane benefits for EVs are currently available throughout the state until 2022-2025. Zero emission zones are another example. In 2017 a group of 12 cities, including Los Angeles and Seattle, signed a declaration to ensure a major area of these cities is zero emission by 2030. According to CVRP 2012-2015 Survey, HOV lane access was the #1 reason for buying electric cars from 2012-2015 in Santa Clara County.

Target Outcome and Actions

The following actions put in place clear price signals and other incentives to encourage electric mobility over gasoline and diesel by 2020.

Proposed Actions for Strategy B: Incentives		Lead	Support
B1	Evaluate options for a city **EV purchase/lease incentive** for qualified vehicles and individuals.	ENV	
B2	Collaborate regionally to evaluate **EV lane access** policies on managed lanes[42]	SFCTA	SFMTA, ENV
B3	Evaluate incentives (pricing and priority access) for EVs on **SFO** roadways, in queues and in parking facilities.	SFO	ENV
B4	Evaluate options and develop recommendations to use **garage parking policy** (taxes, rates, space allocation) to create incentives to switch from gasoline or diesel vehicles to EVs.	SFMTA	ENV
B5	Evaluate opportunities and develop recommendations for EV **street parking policies and pricing** (including permit and metered spots) to create incentives to switch from gasoline or diesel vehicles to EVs.	SFMTA	ENV
B6	Evaluate opportunities and develop recommendations for low-emission or EV-only parking and/or driving **zones**.	SFMTA	SFCTA, ENV, SF PLANNING
B7	Evaluate **transportation pricing** strategies (congestion charges/VMT pricing/fuel pricing/tolling) that base fee structure on the emission factors of vehicles.	SFMTA, SFCTA	ENV

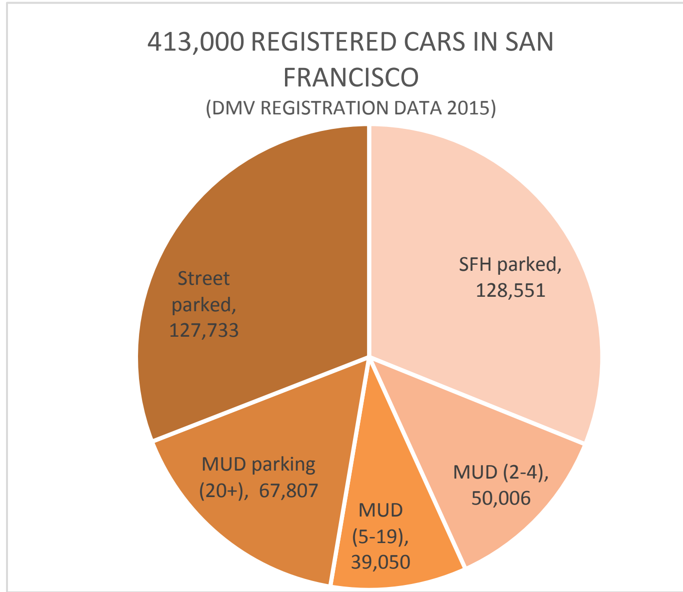
[42] Lane access regulations can include HOV lanes, transit lanes, and/or express lanes. http://2040.planbayarea.org/strategies-and-performance.

Strategy C: Charging Infrastructure

Ensure that charging and fueling infrastructure for EVs is available and convenient for all residents, businesses, and visitors.

Context

Access to convenient and affordable charging infrastructure is critical to supporting electrification. While charging needs vary, most charging for passenger cars is done at private charging stations at home, or secondly at work, with a more limited role for chargers that are accessible by the general public.[43]



Home charging is popular for its convenience, affordability, and guaranteed availability. Extended parking durations at home allow a full charge of large batteries with standard charging equipment at attractive electricity rates, especially when combined with an EV rate plan from the utility.

However, access to home charging depends on the housing type. Single family homes with on-site parking have the most flexibility and require the lowest investment,[44] but in San Francisco about one third of cars are parked in shared MUD garages, where charging station installation is much more complex. Another one third are parked on the street and if electric would rely exclusively on public or workplace charging.

Challenges in Multi-Unit Dwellings

The MUD sector is a large and diverse part of San Francisco's housing stock. There are approximately 179,000 units with 114,000 built-in parking spaces in buildings with 5 or more units.[45]

- Smaller scale (< 100 units) buildings built pre-1940 are the largest sub-segment with 86,000 units. These buildings often have just a few parking spaces, if any.
- At the other end of the scale are more than 120 newer MUDs with over 100 units per building and 24,000 units total in the City. These buildings typically have larger parking garages in line with the parking minimum policies at the time of construction.

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[43] https://www.inl.gov/article/charging-behavior-revealed-large-national-studies-analyze-ev-infrastructure-needs/

[44] Many homes have some excess capacity on the panel, electrical wiring distances are short and there is no need to restrict or manage access to the charger.

[45] Initial analysis focused on 5+ MUDs as challenges are more pronounced, but many of the findings may apply to smaller MUDs as well. Duplexes tend to be more similar to single family homes in that charging infrastructure installation is relatively more straightforward in most cases.

While specifics vary from building to building, residents and landlords face significant obstacles in almost all existing MUD developments with off-street parking[46]:

- MUDs have a shared and often fully utilized electrical capacity.[47]
- Many MUDs feature distributed ownership and control over common spaces and investments. Parking space is often deeded to individual units.
- In rent-controlled buildings there are limitations on the owner's ability to recoup capital improvements directly.
- Cost effectiveness requires a coordinated approach across many residents in a single building. It's often cost prohibitive to pay for charging station installation individually, versus electrifying multiple spaces at once to achieve economies of scale.

Map of MUDs with Five or More Units with Supervisor District Boundaries

Challenges for Street-Parked Vehicles

An estimated 128,000 vehicles are parked on the street overnight. Most of these vehicles are personal passenger cars, trucks or vans, but street parking is also used by permitted car share fleets and peer-to-peer car sharing companies.

On Street Parking Spaces in San Francisco (Estimates from SFMTA Parking Study)	
Metered street parking	24,000
Permit zones	78,000
Other street parking spaces	218,000
Total street parking	**320,000**

Today, street-parked vehicles can be charged at work or at publicly available Level 2 and DCFC networks, although availability and time required to charge are limiting factors. Alternatively, charging stations could be located on the curb where vehicles are parked throughout the day, overnight, or for 30-60 minutes in the case of DCFC. In some European cities with limited garage/lot parking, curbside charging is common,[48] while several U.S. cities have started to pilot curbside charging options (Level 2 and DCFC).[49]

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[46] San Francisco MUD challenges and opportunities – CEC financed study - April 2018.
[47] Where electrical capacity is limited technologies such as load sharing (common) or dynamic load balancing against the building load (novel) can serve as alternatives to expensive upgrades to the electrical supply.
[48] Amsterdam, a city with a similar number of residents but much lower level of car ownership, had over 2,000 curbside charging stations in 2016 and is planning to get to a total of 4,000 by 2018.
[49] In Los Angeles, over 200 Level 2 stations are planned to support the roll out of electric car share Blue LA https://www.bluela.com/.

The City will review the effectiveness of various charging options, as well as safeguarding that outcomes are equitable and policies maintain access to sustainable modes of transportation. Specifically, the City will consider the following:

- The role of the curb is evolving and needs to provide space for a range of uses such as biking, walking, transit, deliveries, passenger loading, and accessible services.
- Technology of charging infrastructure and battery capacities is rapidly improving with faster charging speeds coming to market in the near future.
- Preferences for when and how to charge vehicles may change as the mobility mix shifts to more sustainable and shared modes of transportation.
- Curbside charging would require the City to form public-private partnerships, and take on a role that is very different from the limited role the City has in permitting private fueling infrastructure for gasoline and diesel today.

Public Charging Infrastructure

San Francisco is among leading cities nationally in providing publicly available charging infrastructure, which is essential to supporting residents, businesses, and visitors. Approximately 750 publicly available Level 2 charging stations are in paid garages in the City center and at SFO.[50] Level 2 chargers need 5-10 hours to fully charge an EV. Additionally, 20 DCFCs are available for use by the public, many in retail parking lots.[51] These stations are highly utilized and take 30-60 minutes to fully charge a car.[52]

Public DCFC Supports Multiple Use Cases
• Range extension • Charging for residents (e.g., renters who depend on street parking or cannot install charging at a rental property), commuters who do not have access to charging at home or in the workplace, and visitors • Charging for high mileage vehicles that need to charge frequently (e.g., taxis and ride-hailing fleets) • A backup solution if regular charging is not yet installed, temporarily unavailable, travel plans change, or an EV missed a charging session • Charging options for medium- and heavy-duty trucks, vans, and buses that will be electrified in the near future

[50] DOE national AFDC database June 2019

[51] EVGo operates a total of 15 chargers at six Whole Foods/Walgreens parking lots, a Nissan dealership, and UC Hastings Law School. There are three Blink chargers and one ChargePoint charger. Currently many chargers are not available 24 hours per day/7 days per week, have time of stay restrictions (typically 30 minutes) or are retail customer parking access only. Charging speeds range from 24 kW to 50 kW. In addition, hydrogen fueling stations are needed to support FCEVs, refueling in approximately 5 minutes. There are 3 stations scheduled to be opened in San Francisco in 2019.

[52] Higher power DCFC stations, which are beginning to enter the market, will provide even faster recharging (<20 minutes).

While San Francisco's public EV charging network is ahead of most other cities, so is EV adoption. Significant investments are needed to keep up, but building and operating public charging infrastructure has low or even negative financial returns, discouraging private investment. The business model challenges are caused by a number of factors:

- High initial investments in electrical infrastructure upgrades and accessibility compliance
- Limited availability of parking space with often high monthly lease prices for premium locations
- Higher unit cost of electricity as compared to attractive residential EV-rate plans; compounded by peak demand charges for DCFC
- Low (initial) utilization

Public and Privately Owned Commercial Garages and Lots in San Francisco
• 113,000 spaces in private garages and lots • 56,000 parking spaces managed by local, state, and federal agencies • 20,000 spaces at SFO

Because of these challenges, much of the investment in public charging infrastructure in the City to date has come from grants and court settlements. With more EVs on the road, the utilization of charging stations is increasing, and car makers, fleet owners, and charging network companies are starting to invest. A key question facing policy makers is how the business model for public Level 2 and DCFC can be further improved to attract private investment, while keeping charging available to the general public and prices competitive.[53]

[53] Public charging, if not subsidized by an employer, municipality or OEM, is often significantly more expensive than home charging, making driving electric in some cases more expensive than driving on gas.

Target Outcome and Actions

The following actions ensure that by 2022 there will be an effective and scalable range of charging options for all residents, fleets, and visitors across the City supporting full electrification.

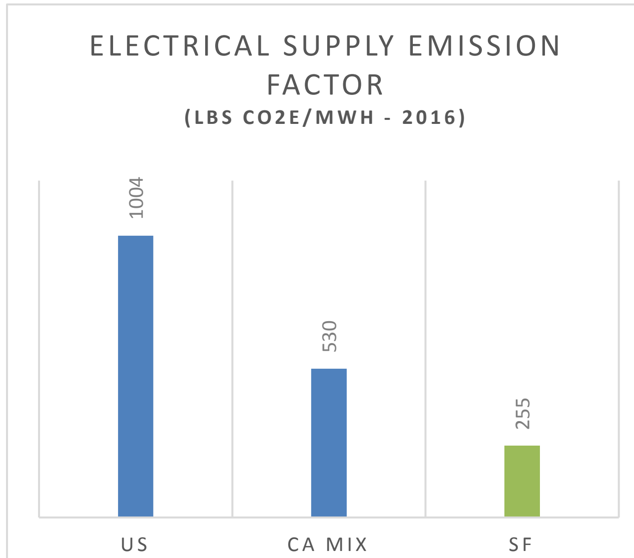
Proposed Actions for Strategy C: Charging Infrastructure		Lead	Support
PRIVATE CHARGING			
C1	Evaluate options for broad deployment of charging infrastructure in **multi-unit dwellings** through an incentive program and code and policy development.	ENV	DBI, SFPUC, SF PLANNING
C2	Develop a home/workplace **smart charging program** that optimizes grid-responsive charging through remote demand response and price incentives.	ENV	SFPUC
PUBLIC CHARGING			
C3	Develop a **DCFC Masterplan** to establish a citywide network to meet current and future demand.	ENV, SFMTA, SFPUC	Relevant City departments
C4	Evaluate options to install/expand publicly accessible charging infrastructure at **City owned parking** facilities and lots.	ENV, SFMTA, SFPUC	Relevant City departments
C5	Evaluate options to accelerate deployment of charging stations in **privately owned**, publicly accessible **garages** and lots.	ENV	
C6	Study **curbside** charging options (including support for micro-transit & e-bikeshare).	ENV, SFMTA, SFPUC, DPW	DBI
GENERAL			
C7	Develop a **workforce** training program to support charging infrastructure installation at scale. Ensure underserved community members have access to jobs by working with San Francisco City College and community-based organizations.	ECN	City College, ENV, DBI
C8	Evaluate options to make the **charging experience** across various vendors/owners and operators more seamless and investments future proof, reinforcing state-level initiatives on the use of standards.	ENV	

Strategy D: Grid

Integrate EV charging with the electrical grid to maximize the benefits of charging infrastructure and support the transition to a renewable energy future.

Context

Relying on renewable electricity to power the transportation system eliminates GHG, and criteria air pollutants. In San Francisco, electrification of the transportation sector is especially attractive because the power supplied to the City is almost 75% cleaner than the U.S. average.[54] Furthermore, the City has adopted a goal to use 100% renewable energy by 2030.[55]



Electrifying transportation will increase demand on the grid (see Appendix m). However, through planning when, where, and how to charge, EVs can help optimize the grid and thereby reduce the unit cost of electricity.[56] By using EVs to absorb excess solar and wind, utilities can avoid curtailment and increase the share of renewables in the electricity supply. [57]

While the potential of EVs to enhance grid reliability and optimize the use of renewables is promising, there are key hurdles slowing down the transition. It is critical that utilities and regulators ensure rates for EV charging reflect grid conditions, thereby guiding charging habits of drivers to the right time of day.

As discussed in the previous chapter on charging infrastructure, the profitability of public charging infrastructure is challenged by current rate structures that limit the availability of advantageous EV-rate plans to residential customers. In addition, peak demand charges pose significant challenges to the ability to profitably operate DCFC stations where demand charges can make up 70%+ of the electricity costs. To accelerate private sector investments, special rate plans may need to be considered that are more conductive to profitable DCFC business models but still allow appropriate cost recovery.

Increased electricity demand and consumption resulting from EV charging may also require costly upgrades to the electrical distribution system, including, but not limited to, new transformers. To unlock the full grid potential of EVs it is critical that:

[54] SF Environment analysis.
[55] The State of California has established a renewable energy mandate of 50% by 2030 and the State Legislature is currently proposing to raise that to 60% and adopt a new target of 100% by 2045.
[56] https://rmi.org/insights/reports/electric-vehicles-distributed-energy-resources/.
[57] Curtailment is a reduction in the output of a generator from what it could otherwise produce given available resources, typically on an involuntary basis.

- Wholesale price signals reach the end user through rates that accurately reflect the cost on the electric system and that are available to all customers.[58]
- Vehicles are plugged in when at rest through charging infrastructure connected and responsive to real time price signals.
- There is an efficient permitting pathway for onsite 'behind-the-meter' stationary battery storage.
- Hurdles in the distribution grid are addressed.

Target Outcome and Actions

The following actions ensure that by 2025, most EVs will be powered by GHG-free electricity, and all have access to electricity rates that make EVs an economical alternative to gasoline and diesel-powered transportation.

Proposed Actions Strategy D: Grid		**Lead**	**Support**
D1	Convene City agencies and PG&E to identify solutions to overcome neighborhood electrical **infrastructure limitations** to supplying EV charging infrastructure (for instance transformer placement).	ENV	DBI, DPW, SF PLANNING, PUC
D2	Evaluate **pricing** to customers for public and residential Level 2 and DCFC chargers, and identify options to make charging more affordable, including alternative rate structures for residential and commercial customers and DCFC.	ENV	PUC
D3	Study options to incentivize DCFC station providers to invest in onsite "**stationary battery storage"** to minimize impact on the grid and increase resiliency.	ENV	
D4	Require charging network providers operating on public land, in the public right-of-way (if and where permitted), or in public facilities to use **100% renewable or GHG-free power** where feasible.	ENV	SFPUC, SFMTA

[58] For home charging, a non-tiered EV rate plan exists, rewarding charging in the off-peak night hours with rates as low as $0.12 /kWh (equivalent to approx. $1.20/gallon gasoline). However, existing EV rate plans typically don't support commercial customers, MUD dwellers, and energy efficient households.

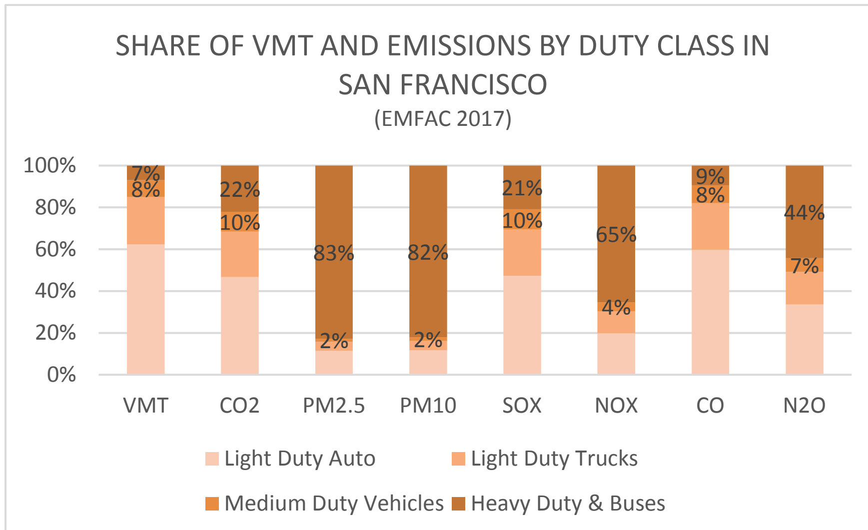
Strategy E: Medium- and Heavy-Duty Vehicles

Lead the way in medium- and heavy-duty electrification.

Context

Electrification provides an opportunity for medium- and heavy-duty fleets to significantly reduce the transportation expenses of their businesses through reduced fuel and maintenance costs. In addition, incentive programs help offset investments in vehicle conversion and support charging infrastructure installation. [59]

The emission reduction opportunity is very significant as well. Medium- and heavy-duty fleets active in San Francisco consist of 33,000 locally registered vehicles, as well as many vans, shuttles, trucks, and buses that drive into or through the City. While only responsible for 15% of VMT, this segment is responsible for 32% of GHG emissions, reflecting the higher fuel use of heavier vehicles. Since most medium- and heavy-duty vehicles are powered by diesel engines, they are responsible for a large share of local particulate emissions as well.



When compared to passenger cars, the availability of electric options for a wider range of duty types is still relatively new. Transit fleets are widely seen as the first adopters of both battery electric and fuel cell electric vehicle technology. Applications for medium-duty delivery vans, shuttles, and heavy-duty niches, such as drayage, are next. The general heavy-duty segment is following closely behind, leveraging many of the same vehicle technologies for electrification. For mainstream adoption, each new application needs to be extensively proven in order to create demonstration projects for these new applications that foster further adoption.

[59] For example https://www.californiahvip.org/

Target Outcome and Actions

The following actions ensure that from 2020 to 2025, the City establishes demonstration projects for early adoption of EV technology for all major categories of medium- and heavy-duty transportation.

Proposed Actions for Strategy E: Medium- and Heavy-Duty		Lead	Support
E1	Identify, catalog, and support **pilots** in medium- and heavy-duty fleets (e.g., delivery vans and trucks, commuter buses and shuttles, courtesy shuttles, and paratransit.	ENV	SFO, SFMTA
E2	Work with **SFUSD** to support electric transportation for students.	ENV	
E3	Work with **Recology** to expand pilots for electric trucks for waste operations.	ENV	
E4	Evaluate options to install charging infrastructure for trucks parked at **Port** property.	PRT	ENV
E5	Evaluate opportunities and develop recommendations for **incentives/regulations** for electrification of medium- and heavy- duty fleets.	SFMTA, ENV	

Strategy F: Emerging Mobility

Advocate for and encourage emerging mobility options to be emission-free.

Context

Emerging mobility services and technologies are changing how people get around in cities. Ride-hailing, shared vehicles, and rapid innovations in autonomous vehicle technology are just a few examples of how the transportation system continues to evolve. When shared, emerging mobility services and technologies could help reduce single occupancy vehicle trips and the need to own cars. At the same time, emerging mobility services may interfere with the City's goals for a sustainable transportation system by increasing overall VMT. As discussed in Section 3.2, the SFMTA and SFCTA recently developed a set of Guiding Principles to ensure that emerging mobility complements—not competes with—transit, bicycling, and walking options and that goals for emerging modes include sustainability.

In San Francisco, emerging mobility services currently include (not exhaustive):

- Autonomous Vehicles – GM Cruise, Zoox, Waymo
- Microtransit/private transit – Chariot
- Ridesharing/carpool – Waze/Scoop
- Bikeshare – Motivate/FordGoBike
- Courier Network Services – Postmates, Caviar, Eat 24, Uber Eats
- Scooter share – Scoot
- Stationless bikeshare – Social Bicycles/JUMP, Limebike
- Ride-hailing – Transportation Network Companies (TNCs) – Uber, Lyft
- Car share – Zipcar, Getaround, Maven, Turo
- One-way car share – GIG
- Shared use vehicle fleet – Fair, Hertz, Maven Gig
- Electric scooter boards – Bird, Lime, Spin

In addition, for the scope of the EV Roadmap:

- Car rentals
- Taxis

The ability of the City to implement these principles varies with the degree to which emerging mobility services are subject to local regulatory authority. Regardless of its role as regulator, the City always has authority to establish and enforce traffic laws on San Francisco streets and regulate access to the curb and off-street city-owned parking garages and lots.

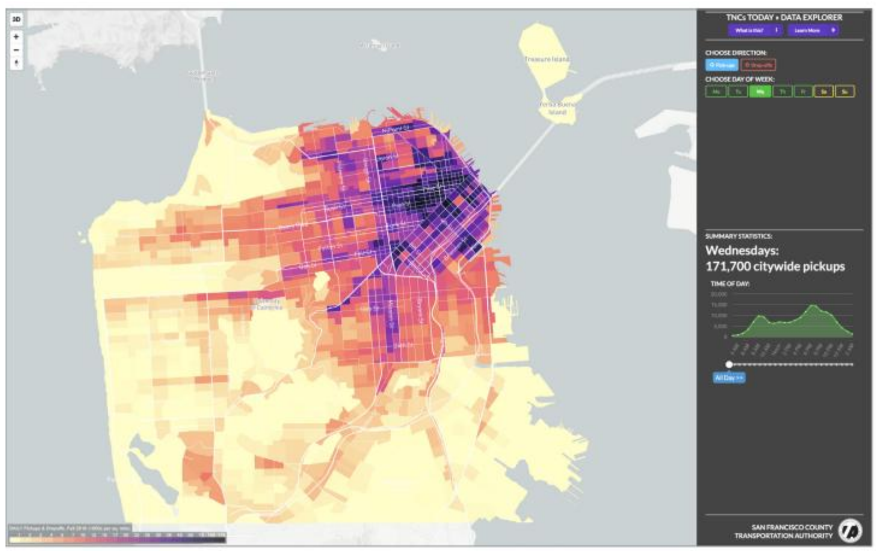
Agency	Authority
SFMTA permitted	• Electric moped parking (Scoot) • On-street car share • Stationed (Bay Wheels) and stationless (Jump) bike-share • Private transit vehicles (Chariot) and commuter shuttles
California Public Utilities Commission (CPUC) regulated	• Transportation network companies (TNCs), such as Uber and Lyft
Local regulation preempted by State or Federal Government	• Courier network services (Caviar, Postmates, Uber Eats) • Autonomous vehicles (potential pending legislation)

Electrification Challenges for Fleets

Today there are a number of emerging mobility services that operate on electricity such as mopeds, scooter boards, bicycles, car share, and most pilots with autonomous vehicles. The operators of these services manage their fleets to ensure their vehicles are available throughout the city and remain charged throughout the day. Maintaining a charge can be a challenge due to high usage and limited availability of charging facilities. Some operators have one or more private charging facilities and may offer incentives for users to bring vehicles to these hubs by offering free trips. Privately owned and operated car fleets also depend, in part, on public charging networks or home charging to operate in the City.

The limitations of charging infrastructure are a key constraint on the ability to expand fleet size and service coverage for all electric emerging mobility services. Operators are looking for opportunities to collaborate with the City and property owners to establish charging sites throughout the City, with a focus on the downtown core.

Growth of Ride-Hailing (TNCs)



Trips made by TNCs (Uber and Lyft) doubled from 2016 to 2017. By the end of 2016, TNC vehicles were making over 170,000 trips within San Francisco per day, which is 15% of all intra San Francisco trips, and about 20% of VMT.[60] TNC activity is particularly concentrated in the most congested and polluted areas of the City, making electrification of this sector even more urgent.

However, currently only approximately 1% of all TNC vehicles in California are electric.[61] Accelerated electrification of TNC vehicles could make a significant contribution to cleaner air and reduced GHG emissions in some of the most polluted areas of the City. In addition, a study from the Rocky Mountain Institute estimates that EVs could boost income for full-time drivers by $2,500-$5,200 per year due to reduced fuel expenses, and $2,700 per year in maintenance and repair cost savings compared to gasoline-powered vehicles. [62]

[60] TNCs today - June 2017 SFCTA.
[61] Electrifying the Ride-Sourcing Sector in California, April 2018 CPUC. The CPUC's definition includes both fully electric and plug-in hybrid electric vehicles. Similarly, approximately 1% of TNC total vehicle miles travelled in California, including deadheading, are made in electric vehicles.
[62] Rocky Mountain Institute study March 29, 2018 "Ride-Hailing Drivers are ideal candidates for Electric Vehicles." Fuel savings are based and dependent on access to residential EV charging rates.

Table 6: Overall Auto Mode Share over Time

Mode	2013	2014	2015	2016	2017
Drive Alone	26%	30%	27%	29%	28%
Carpool	22%	16%	21%	16%	15%
Total (Private Vehicles)	**48%**	**45%**	**48%**	**45%**	**43%**
Carshare	<1%	<1%	<1%	<1%	<1%
TNC	<1%	1%	1%	2%	4%
Taxi	2%	1%	1%	<1%	<1%
Total (All Vehicles)	**50%**	**48%**	**50%**	**48%**	**47%**

Source: Corey, Canapary & Galanis Research, 2017; Fehr & Peers, 2017

There are several challenges associated with the electrification of TNCs:

- To qualify as a TNC, the organization can't own or operate their own vehicle fleets. The vehicles are therefore owned by individual drivers or leased/rented from professional fleet management companies.
- TNC drivers' driving patterns and needs are different from the average EV driver. Pilot studies suggest[63] that a range of 200 miles or more is typically considered the minimal practical range for full time TNC use.[64]
- So-called "range anxiety" is exacerbated since TNC platforms currently do not tell drivers the trip length or destination until a trip has been accepted, and the ride matching software is not aware of the state of charge and/or range of the EV.
- Many TNC drivers may work part time or for a limited time period, making an investment in charging infrastructure and a fuel-efficient vehicle less certain to pay off.[65]
- Drivers often park on the street or in MUD garages where, even if they wish to install charging stations, the challenges discussed under Strategy C make it very difficult or impossible to install EV charging at home.
- Relying solely on public charging infrastructure is challenging today. As discussed in Strategy C, there are too few DCFC stations, the stations are not always accessible, and charging speeds are limited, requiring an hour or more for a full charge. Public DCFCs' higher kWh price may also reduce fuel cost savings that would be provided through home charging, negatively impacting the net hourly pay of the driver.

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[63] Uber study in London: http://www.energysavingtrust.org.uk/sites/default/files/reports/Uber%20EV%20Trial%20-%20Electric%20Private%20Hire%20Vehicles%20in%20London_1.pdf.

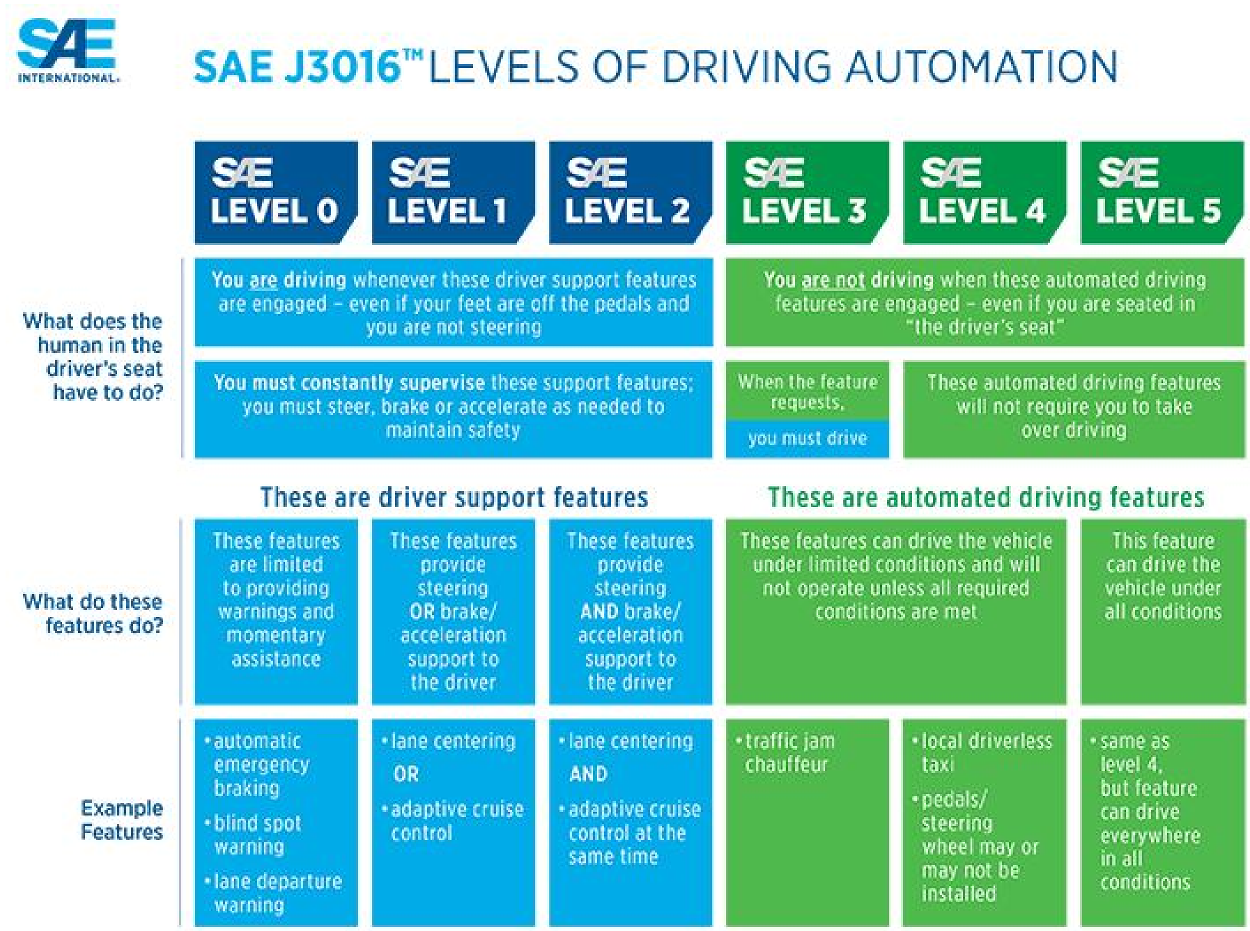
[64] Studies suggest that optimal range may go down for autonomous TNCs restricted to intra-city trips with plentiful charging infrastructure: https://pubs.acs.org/doi/full/10.1021/acs.est.7b04732.

[65] https://www.theinformation.com/articles/how-uber-will -combat-rising-driver-churn 4/20/2017.

Autonomous Vehicle Technology

A large majority of companies developing self-driving cars are either currently testing or working towards fully electric vehicles. However, some companies prefer hybrid technology in order to maximize vehicle mileage. To shift the industry towards electrification, charging infrastructure must be provided and regulatory frameworks must favor electrification. The charging needs for autonomous fleet vehicles will likely be very different from regular passenger EVs as autonomous vehicle (AV) fleets will need to recharge more frequently and will not be subject to factors affecting individual owners such as a desirable charging location or time of day

AVs are advancing rapidly and are being tested in such varied categories as luxury sedans, long haul trucking fleets that drive along open highways, and small shuttle buses that can navigate fixed routes inside low risk environments. As technology develops, AVs should be able to safely navigate more complex traffic scenarios and numerous variables such as road closures. While there is no certain date for when AVs will be deployed on public roads without a safety driver – as some companies are already beginning to test such vehicles without a safety driver today – it is speculated that deployment may begin in select cities between 2020 and 2030.



Mainstream availability of level 4 and 5 AV technology is widely anticipated to have a revolutionary impact on the transportation system overall and on private mobility in particular, potentially upending the private car ownership model. While it is hard to predict when the transition might take place and what form it will take, pilot initiatives are already underway today. The California Department of Motor Vehicles (DMV) recently passed regulations that allow for driverless testing and deployment of AVs, and the CPUC has proposed a pilot to allow AVs to be used for passenger service, both with and without safety operators.

Target Outcome and Actions

The following actions ensure that by 2020, emerging mobility fleets commit to a clear path to full electrification before 2025, and any new forms of mobility are fully electric from the start.

Proposed Strategic Actions for Strategy F: Emerging Mobility		**Lead**	**Support**
F1	Evaluate options and develop recommendations to electrify **TNCs** and similar light duty passenger fleets.	ENV, SFMTA, SFO, SFCTA	
F2	Evaluate options to electrify **vehicle sharing**. Evaluate opportunity to make associated charging infrastructure publicly accessible.	SFMTA, ENV	
F3	Evaluate options to electrify **taxi** fleets.	SFMTA	ENV
F4	Pilot electric **car rentals** at SFO. Evaluate options to expand to other car rental locations.	SFO, ENV	
F5	Set expectation and encourage AV test vehicles and level 4 and 5 commercially available **AV** fleets and private vehicles to be electric.	SFMTA, SFCTA	ENV

Appendices

a) Transit First Policy Directives

1. To ensure quality of life and economic health in San Francisco, the primary objective of the transportation system must be the safe and efficient movement of people and goods.
2. Public transit, including taxis and vanpools, is an economically and environmentally sound alternative to transportation by individual automobiles. Within San Francisco, travel by public transit, by bicycle and on foot must be an attractive alternative to travel by private automobile.
3. Decisions regarding the use of limited public street and sidewalk space shall encourage the use of public rights of way by pedestrians, bicyclists, and public transit, and shall strive to reduce traffic and improve public health and safety.
4. Transit priority improvements, such as designated transit lanes and streets and improved signalization, shall be made to expedite the movement of public transit vehicles (including taxis and vanpools) and to improve pedestrian safety.
5. Pedestrian areas shall be enhanced wherever possible to improve the safety and comfort of pedestrians and to encourage travel by foot.
6. Bicycling shall be promoted by encouraging safe streets for riding, convenient access to transit, bicycle lanes, and secure bicycle parking.
7. Parking policies for areas well served by public transit shall be designed to encourage travel by public transit and alternative transportation.
8. New transportation investment should be allocated to meet the demand for public transit generated by new public and private commercial and residential developments.
9. The ability of the City and County to reduce traffic congestion depends on the adequacy of regional public transportation. The City and County shall promote the use of regional mass transit and the continued development of an integrated, reliable, regional public transportation system.
10. The City and County shall encourage innovative solutions to meet public transportation needs wherever possible and where the provision of such service will not adversely affect the service provided by the Municipal Railway.

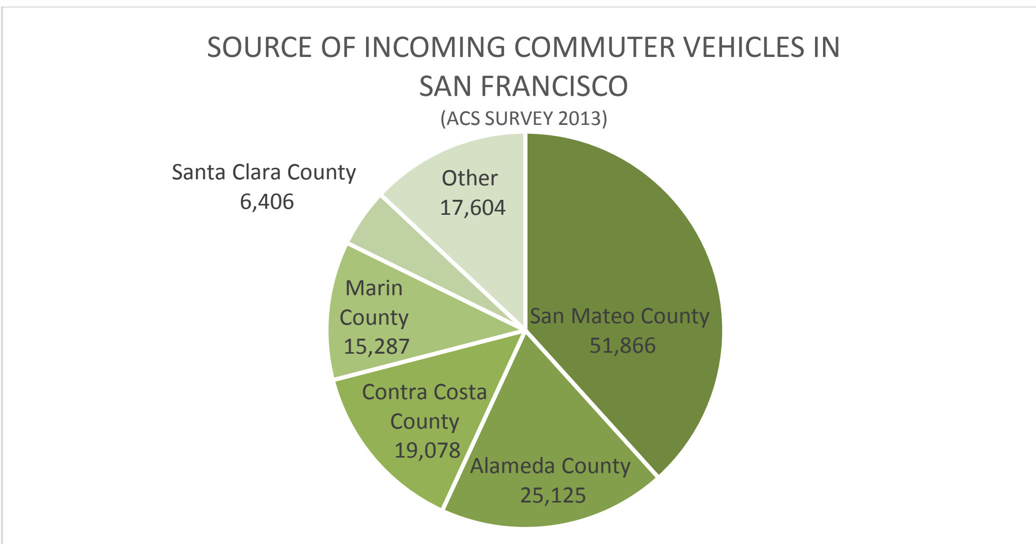
b) Charging Technology

Charger Type	Panel Breaker (Typical)	Kilowatts (Accepted by the Car)	Range added per Hour Typical (RPH)	Connector to the Car
Level 1: Standard household socket PHEV and low-mileage drivers often find a standard household socket sufficient for their daily charging needs. A charging cable often comes with the car, which allows the driver to plug in anywhere.	110-120 VAC 15-20 amp	1.3-1.9 kW	4-5 miles	J1772
Level 2: Common for home and workplace charging For BEVs, especially with larger batteries, a full charge requires 6-12 hours. Typically, a charging station is mounted to the wall or on a pedestal. The station is hardwired or plugged in to an outlet and provides a charging cable. Level 2 "smart chargers" provide control and monitoring features and allow charging speeds to be modulated, enabling power sharing and demand response to limit grid impact.	208-240 VAC 40-100 amp (comparable to an electrical dryer outlet)	6.6 – 7.2 kW (PHEV limited to 3.3/3.6)	20 miles	J1772 (or Tesla)
New buildings in San Francisco need to be equipped to support at least level 2 charging in 10% of spaces.		17 kW (Tesla 100D only)	50+ miles	J1772 (or Tesla)
Level 3: DC Fast Charger (DCFC) for short duration of stay High powered commercial charging stations along highway corridors to support road trips and in urban areas to support high mileage use (Taxi/TNC), backup/emergency charging, and drivers without home charging access.	480 VAC, 3- phase >100 Amp breaker	50 kW (most common) 150+ kW	75 miles per 30 minutes 225 + miles per 30 minutes	SAE Combo, ChaDeMo SAE Combo
Most BEVs on the market today ship with standard or optional DCFC capabilities. Currently there are 20 DCFCs in San Francisco.		72 (Urban Supercharger) -120 (Supercharger) kW	120 – 180 miles per 30 minutes	Tesla

c) Vehicle Registrations

CalEnviroscreen[66] 3.0 (Based on statewide percentiles)	Population (CalEnviroscreen)	Car Registrations in ZIP codes (Jan 2017)	EV Ownership
Overall SF	805,235	427,333	1.5%
ZIP codes containing at least one census tract with a 5% healthiest score	212,196 86,009 in census tracts	119,119	1.9%
ZIP codes containing at least one census tract with a 25% unhealthiest score[67]	122,118 40,455 in census tracts	68,872	1.4% (includes city and PG&E fleet registrations)
Zip code 94124 (Bayview-Hunters Point)	32,284	29,126	0.7%

d) Commuters to San Francisco



[66] CalEnviroScreen uses environmental, health, and socioeconomic information to produce scores for every census tract in the state. An area with a high score is one that experiences a much higher pollution burden than areas with low scores.

[67] ZIP codes in which at least one CalEnviroscreen 3.0 designated disadvantaged community is located: 94102 (Tenderloin), 94103 (SOMA), 94107 (Dogpatch/Potrero), 94124 (Bayview -Hunters Point), 94130 (Treasure Island).

e) Dealerships in San Francisco

EV Dealerships in San Francisco		
Dealership	**Address**	**BEV/FCEV 100+ Mile Range**
BMW of San Francisco	1675 Howard St.	I3
Mercedes-Benz of San Francisco	500 8th St.	B-Class
Nissan Infiniti of San Francisco	1395 Van Ness Ave.	Leaf
Royal Automotive Group (Volkswagen, Audi)	165 14th St.	e-Golf
Tesla	999 Van Ness Ave.	Model 3/S/X
Honda	10 S. Van Ness Ave	Clarity (FCEV)
Toyota	1701 Van Ness Ave.,	Mirai (FCEV)
Brands Not in San Francisco		
Ford		Focus
General Motors (Chevrolet)		Bolt
Hyundai/Kia		Ioniq

f) Multiple-Unit Dwelling Building Stock

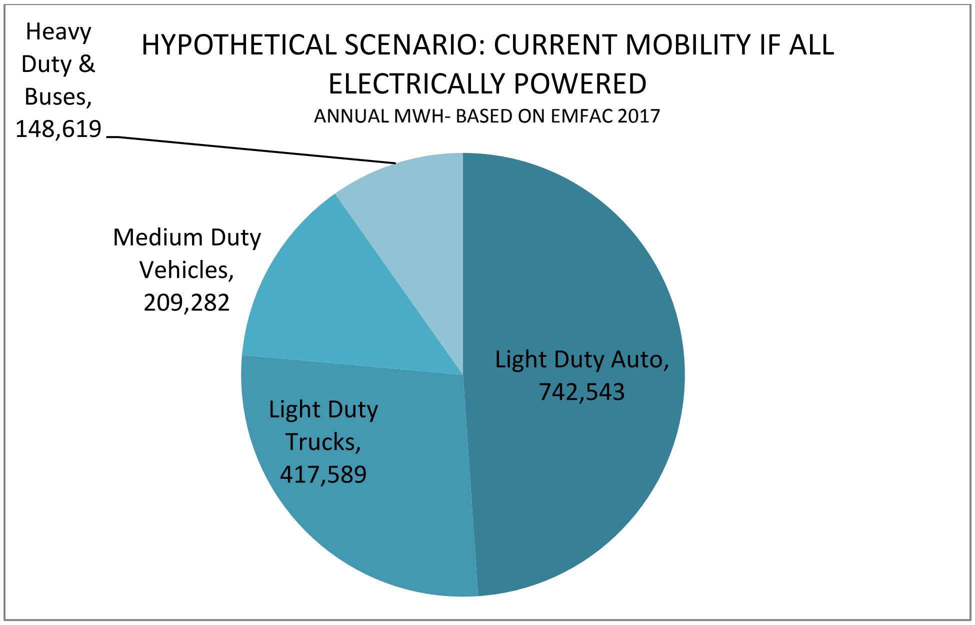
San Francisco MUD Parcels, Housing Units and Parking Spaces by Building Size and Construction Year

Construction Year	Units per Parcel	Number of Parcels	Number of Units	% of City-Wide Housing Units	Estimated Number of Parking Spaces	Average Parking Lot Size
Pre-1940	5-9	3,781	23,989	6%	16,792	4
	10-19	1,822	24,434	6%	6,353	3
	20-99	1,046	38,076	10%	9,900	9
	100+	55	8,005	2%	2,081	38
	Subtotal	**6,704**	**94,504**	**25%**	**35,126**	**5**
1940-1954	5-9	168	1,019	0%	713	4
	10-19	52	631	0%	164	3
	20-99	48	2,322	1%	604	13
	100+	12	3,179	1%	827	69
	Subtotal	**280**	**7,151**	**2%**	**2,308**	**8**
1955-1978	5-9	1,205	8,045	2%	9,574	8
	10-19	546	7,157	2%	5,153	9
	20-99	255	9,545	2%	9,545	37
	100+	50	10,340	3%	10,340	207
	Subtotal	**2,056**	**35,087**	**9%**	**34,612**	**17**
Post-1978	5-9	366	2,439	1%	2,902	8
	10-19	281	3,846	1%	2,769	10
	20-99	287	12,037	3%	12,037	42
	100+	122	24,123	6%	24,123	198
	Subtotal	**1,056**	**42,445**	**11%**	**41,832**	**40**
All construction years	5-9	5,520	35,492	9%	29,982	5
	10-19	2,701	36,068	9%	14,439	5
	20-99	1,636	61,980	16%	32,085	20
	100+	239	45,647	12%	37,371	156
Total		**10,096**	**179,187**	**47%**	**113,877**	**11**

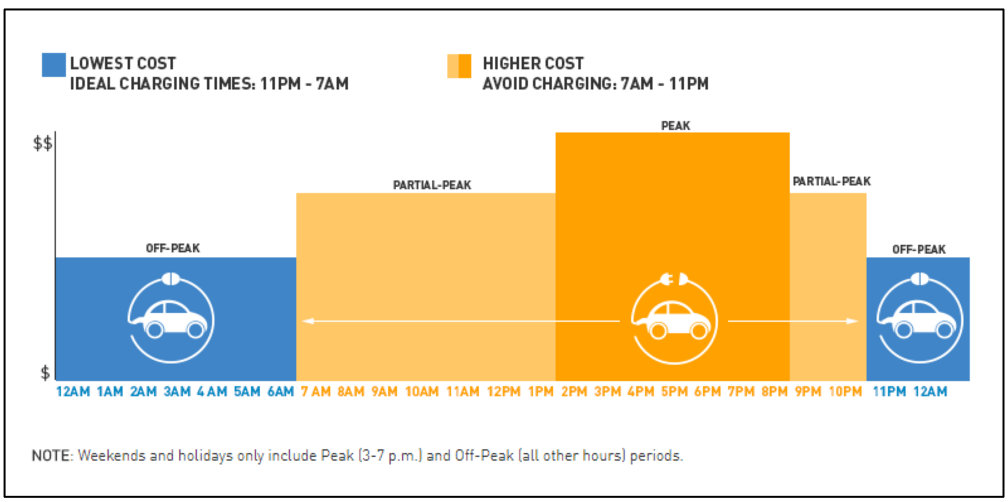
g) Commercial Garages/Municipal Properties

Non-Residential Off-Street Parking Spaces in San Francisco – 2011 (OpenDataSF)	
Owner	**Parking spaces**
SFO	20,000
SFMTA	16,600
Recreation & Parks Department	12,789
Port of San Francisco	3,887
City College of San Francisco	2,663
Department of Public Works	648
Police Department	494
San Francisco General Hospital	348
SFPUC	289
Redevelopment Agency	470
San Francisco Unified School District	233
Other	73
City and County of San Francisco	**58,494**
Presidio	5,061
University of California, San Francisco	4,210
San Francisco State University	3,172
Golden Gate National Recreation Area	1,305
Veterans Administration	1,214
United States Postal Service	703
Laguna Honda Hospital	532
UC	400
State of California	269
Golden Gate Bridge Authority	245
Caltrans	200
DMV	142
BART	53
Other	38
Regional, State and Federal	**17,544**
Private	**113,327**
Grand total	**189,365**

h) Full Electrification Hypothetical by Duty Class



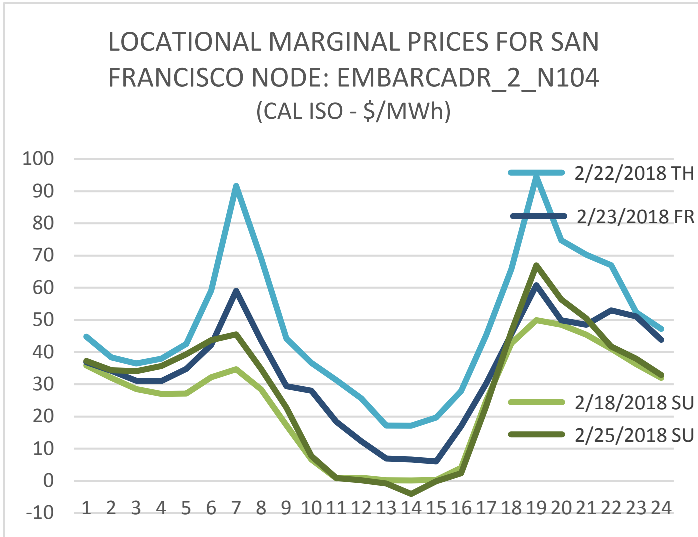
i) Current EV Rate Plan Challenges



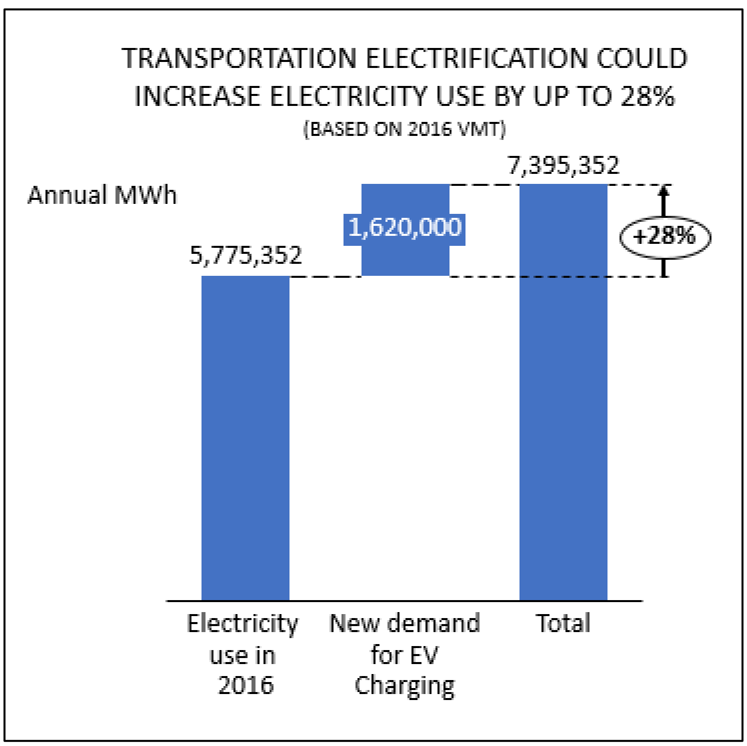
For home charging, a time-of-use EV rate plan rewards charging in the off-peak night hours with rates as low as $0.12/kWh (equivalent to $1.20/gallon gasoline). Uptake of EV specific rate plans is currently estimated at 30% among EV drivers today regionally. EV Rate plans do not reach all because:

- Lack of awareness of impact of EV charging on electricity use and importance of rate plans
- Energy efficient households with limited private mobility needs may prefer a tiered rate plan
- Lack of access to an independent meter – typical in MUD garages
- EV rate plans are not available for larger installations/commercial plans
- Current EV rate plans do not reward charging during peak availability of renewables in the day time

j) Wholesale Generation Prices for Electricity Supply - The Duck Curve



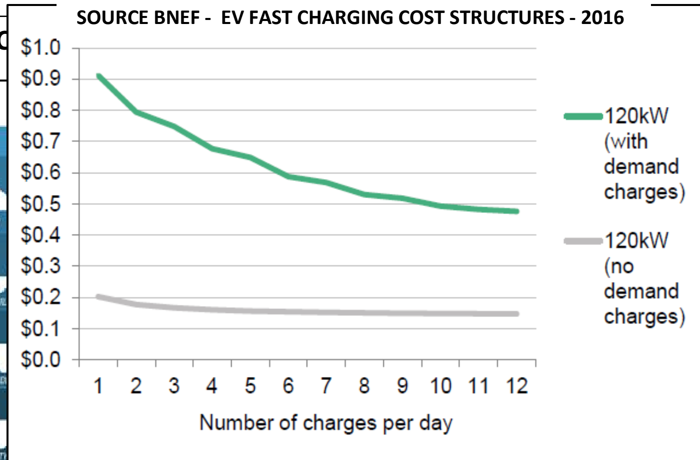
k) Electricity Demand Increase



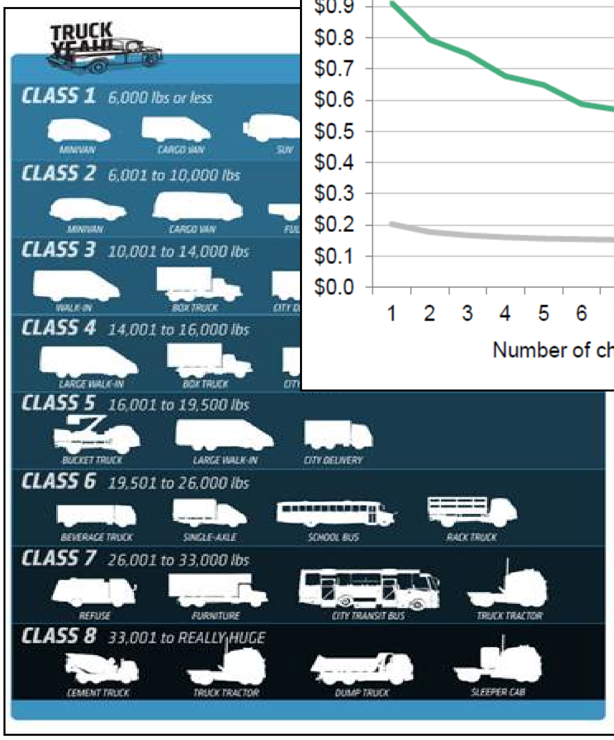
l) **Cost of Peak Demand Charges for DCFC**

m) **Medium- and Heavy-Duty Classes**

Cost Curve for DCFC



EMISSIONS BY VEHICLE C ... **mples of Electric Options**



		r 20 models -up: Workhorse
		rkHorse, Chanje, tiv, Zenith
	104,433	Buses: Blue Bird, Greenpower, Motiv, Navistar, Lion Trucks: BYD
	138,083	Buses: over 10 mfg: Proterra, BYD Trucks: BYD, Cummins, Tesla, Volvo

n) Mode Share

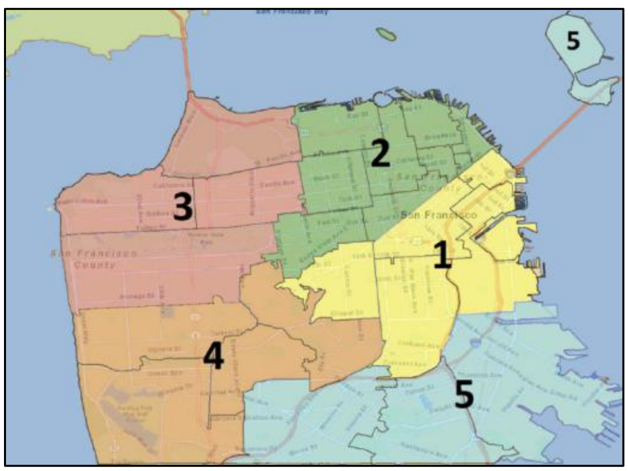
Mode Share by Zone

Table 11: Mode Share by Residential Location, Five Year Averages (2013 - 2017)

Place of Residence	Private Auto	TNC/ Taxi/ Carshare	Transit	Walk	Bike	Other
San Francisco	**44%**	**3%**	**23%**	**26%**	**3%**	**1%**
Zone 1	31%	5%	26%	33%	4%	1%
Zone 2	30%	5%	23%	38%	4%	1%
Zone 3	54%	2%	21%	21%	2%	1%
Zone 4	59%	1%	19%	19%	2%	<1%
Zone 5	54%	1%	27%	15%	4%	<1%
Outside of San Francisco	**52%**	**1%**	**30%**	**17%**	**<1%**	**<1%**
East Bay	37%	1%	40%	21%	<1%	<1%
North Bay	64%	1%	17%	17%	1%	<1%
South Bay	64%	2%	24%	11%	<1%	<1%

Shaded cells indicate mode share above 50% goal
Source: Corey, Canapary & Galanis Research, 2017; Fehr & Peers, 2017

Zone Map



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City charging infrastructure needs to reach 100% electric vehicles: The case of San Francisco

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Keywords: Cities, electric vehicles, charging infrastructure

Introduction

Cities in the United States are increasingly setting ambitious vehicle electrification targets to achieve their air quality and climate change mitigation goals. Although electric vehicle (EV) uptake across U.S. cities in 2019 is still in its early stages, cities aim to greatly accelerate electrification. Several cities have set goals to increase EV uptake. Houston aims for EVs to make up 30% of new vehicles sold in 2030.[1] In Memphis, the city has set a goal of EVs making up 30% of total vehicle travel by 2035.[2] Seattle and Sacramento have set goals of EV's making up 30% of vehicles owned by 2030, and 35% of total vehicles by 2025, respectively.[3] Complete electrification goals include Denver's

1 Evolve Houston, "Electric vehicle roadmap" (2019), https://www.evolvehouston.org/

2 City of Memphis, "Memphis Area Climate Action Plan", (2020), https://shelbycountytn.gov/DocumentCenter/View/37431/Memphis-Area-Climate-Action-Plan-2019-FINAL_4_JANUARY-2020

3 Seattle Office of Sustainability & Environment, "2017 Drive Clean Seattle Implementation Strategy" (2017), https://www.seattle.gov/Documents/Departments/Environment/ClimateChange/Drive_Clean_Seattle_2017_Report.pdf; City of Sacramento, "Electric vehicle strategy" (2017), https://www.cityofsacramento.org/-/media/Corporate/Files/Public-Works/Electric Vehicles/EVStrategy_171206_FINAL_DRAFT_CityOfSacramento.pdf

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and Los Angeles' for 100% zero emission vehicles across the entire vehicle stock by 2050 and San Francisco's for 100% of new vehicles by 2030.[4]

Achieving widespread EV adoption requires increased charging infrastructure deployment to improve EV functionality and convenience for EV drivers. Home charging currently provides the majority of EV charging energy demand. It is usually the least expensive charger type to install and charge from. However, moving beyond early adoption to the broader market means providing more charging options for drivers. For example, drivers without home charger access, such as those in apartments or without designated off-street parking, require more conveniently placed charging elsewhere.

To support continued EV growth, charging infrastructure will have to keep growing and evolving to meet city needs. There is a correlation between the uptake of EVs and public charging infrastructure growth in U.S. cities; the markets with the most EVs tend to have the most comprehensive charging infrastructure.[5] To sustain continued growth in EV adoption, government agencies can proactively plan their infrastructure to match vehicle electrification goals. Although each plan needs to be tailored to the unique local circumstances, there are generally applicable steps. The initial steps include gathering data on EV adoption, baseline infrastructure deployment, and charging behavior to analyze the charging infrastructure required to support their EV plan. The subsequent steps include identifying infrastructure gaps, developing policies to fill the gaps, reevaluating early deployment lessons, and continually examining updated data.[6]

This working paper provides the first such analysis for a U.S. city to quantify its charging needs to support a 100% EV sales goal. The analysis quantifies charging infrastructure needs at the zip code level for San Francisco to meet the city's goal of reaching 100% EV sales by 2030. It estimates the public, workplace, and home charger needs for passenger vehicles from 2020 through 2050 as the fleet continues to turnover to electric after the 100% EV sales phase in. It also considers additional city-level interventions aiming to reduce the personal vehicle travel demand and assesses their impacts on the charging infrastructure needs. In addition, the analysis also estimates, with less granularity, charging infrastructure for growing electric ride-hailing and urban delivery truck fleets.

Analysis

Adapting an approach applied in a previous study,[7] we assess the public Level 2 charger and direct current (DC) fast charger needs based on San Francisco's goals for EV market growth through 2050. The EV stocks, informed by the EV uptake rate and the vehicle stock-turnover model, are used as a primary input to the analysis. Charging behavior in early EV markets and assumptions regarding increasing average charger utilization are

4 City and County of Denver Department of Environmental Health & Southwest Energy Efficiency Project, "Opportunities for vehicle electrification in the Denver Metro area and across Colorado" (2017), https://www.denvergov.org/content/dam/denvergov/Portals/771/documents/EQ/EV/EVFinalReport.pdf; Los Angeles Mayor's Office of Sustainability, "L.A.'s Green New Deal" (2019), https://plan.lamayor.org/sites/default/files/pLAn_2019_final.pdf; San Francisco Mayor's electric vehicle working group, "Proposed electric vehicle roadmap for San Francisco" (2019), https://sfenvironment.org/sites/default/files/fliers/files/sfe_tr_ev-roadmap.pdf

5 Peter Slowik and Nic Lutsey, *The surge of electric vehicles in United States cities*, (ICCT: Washington DC, 2019), https://theicct.org/publications/surge-EVs-US-cities-2019 and Anh Bui, Peter Slowik, & Nic Lutsey, *Update on electric vehicle adoption across U.S. cities*, (ICCT: Washington DC, 2020), https://theicct.org/publications/ev-update-us-cities-aug2020

6 Dale Hall and Nic Lutsey, *Electric vehicle charging guide for cities,* (ICCT: Washington DC, 2019), https://theicct.org/publications/city-EV-charging-guide

7 Michael Nicholas, Dale Hall, and Nic Lutsey, *Quantifying the electric vehicle charging infrastructure gap across U.S. markets*. (ICCT: Washington DC, 2019), https://www.theicct.org/publications/charging-gap-US

primary inputs used to estimate the numbers of home, public, and workplace chargers needed across the city. The following summarizes the key methodological steps, including how city interventions are investigated to quantify their impacts on charging needs.

EV fleet composition

Figure 1 shows the EV adoption trends and EV stock in the city, and the estimated stock by 2050 accounting for fleet turnover and considering the city's goal of 100% EVs sales by 2030. The projected annual vehicle registration data is based on Department of Motor Vehicle data and trends through 2019.[8] The city goal reflects a rapid increase in EV share of new vehicles; resulting in the increase of the city's registered EVs from about 20,000 in 2020, to 180,000 in 2030, to 350,000 in 2040, and to 370,000 in 2050. This trend, based on the underlying vehicle retirement characteristics, results in 39% of the city's light-duty vehicle stock being electric in 2030, 92%, in 2040, and 96% in 2050. The city's new EVs include both battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs), with a shift from new sales being 75% BEV in 2019 to 100% BEVs in the mid 2030s. This city EV path amounts to a substantial acceleration compared to the fastest path publicly discussed by California state regulators.[9] The San Francisco metropolitan area is assumed to lag the city EV trend by several years.

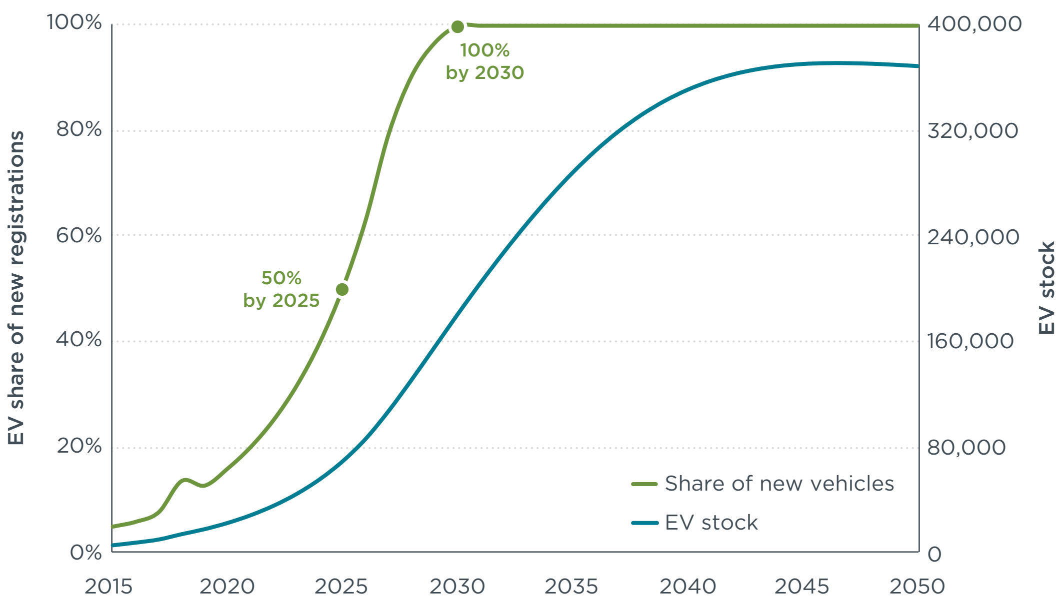


Figure 1. Assumed San Francisco new vehicle EV share and total EV stock from 2015 to 2050.

Several additional assumptions are important in the vehicle stock turnover model, which accounts for new vehicles entering the fleet, and older vehicles retiring. Projections assume a city-wide 1% annual decline in the absolute number of new light-duty vehicle sales, reflecting the recent trend in the data. Although zip code level EV shares differ across San Francisco through 2019, all the zip codes are assumed reach 100% new electric vehicle sales by 2030. Relative differences between vehicle ownership per capita

8 California Department of Motor Vehicles, Vehicle fuel type count by zip code (May 28, 2020), https://data.ca.gov/dataset/vehicle-fuel-type-count-by-zip-code

9 California Air Resources Board, "Advanced Clean Cars II Regulations: Informational Update" (May 28, 2020), https://ww3.arb.ca.gov/board/books/2020/052820/20-5-3pres.pdf

by zip code remain identical to 2018 across all years, reflecting general density, housing, and parking patterns across the city.

Additional local inputs are critical in establishing the baseline charging needs by zip code. Local job and population growth were provided by the city, and housing characteristics, and vehicle ownership are from the American Community Survey.[10] These are integrated in future zip code-level trends. The EVs in each zip code have varying reliance on public chargers as determined by their home charger access. The home charger access is informed by the EV owners' housing characteristics (i.e., detached, attached, and apartments) and we assume EVs are universally adopted by new vehicle buyers across different housing types going forward. In the model, this means by 2040, the percentage of new EV owners by housing type ultimately resembles the percentage of the residents by housing type in each zip code.

Charging energy demand

The total energy demand of each type of charger is calculated as the product of the total number of EVs applicable for the given charger type, charging events per vehicle per day based on a California survey,[11] and the assumed energy consumption per event.[5] Public charger energy demand and home charging demand increase with the growth in EVs registered in each zip code. The workplace charging demand increases with the number of commuter EVs going into each zip code, which includes both intra-city commuters and those commuting into the city from outside of the city.

Several additional factors account for commuter patterns. Based on the California survey, 80% of EV drivers in San Francisco are assumed to be vehicle commuters in 2020. The percentage of EV drivers that commute gradually decreases through 2050 and approaches the percentage of all drivers that commute with their vehicles—including both internal combustion engine and electric vehicles—which was approximately 42% in 2017.[12] Approximately 26% of the city's commuters travel to work somewhere outside of the city.[13] Based on this number and the American Community Survey's data on commute modes, we estimate 5.4%, or approximately 23,000, of the light-duty vehicles in the city commute out of the city for work. From the same sources, 68,000 light-duty vehicles are estimated to commute into San Francisco for work daily. These commuter light-duty vehicles coming into San Francisco represent approximately 15% of the 440,000 vehicles traveling into San Francisco for any purpose daily. Both the intra-city and out-of-city commuters are allocated to the zip codes according to the city's job distribution, including future job projections from the Land Use Allocation data provided by city officials. The intra-city commuter vehicles follow the city EV adoption rate, and the out-of-city commuter EV share lags the city EV share by several years.

Charging events per day varies among drivers with different EV technologies (i.e., plug-in hybrid or full battery electric) and their access to home charging based on their

10 American Community Survey, accessed March, 2020, https://www.census.gov/programs-surveys/acs.

11 Gil Tal, Jae Hyun Lee, & Michael Nicholas, *Observed charging rates in California*. (University of California, Davis, Davis, CA: 2018). https://itspubs.ucdavis.edu/publication_detail.php?id=2993

12 Calculated using commute mode reported in the 2017 American Community Survey data and the vehicle sales data. The change of the percentage of EV owners that commute with EVs year-to-year is related to the EV adoption rate (i.e., percentage of EVs in the overall LDV fleet). It is calculated by assuming that as EV adoption rate reaches 100%, the EV drivers commute with EV reach 45%—the percentage of current vehicle owners that commute with their vehicles. The percentage of EV owners commuting with EVs each year is interpolated based on the initial year's EV adoption rate.

13 San Francisco Municipal Transportation Agency, "2015 Transportation Fact Sheet", (2015), https://www.sfmta.com/reports/2015-transportation-fact-sheet

housing characteristics.[5] Across the years, charging events per day stays constant and the energy consumption per event increases by 9% in 2050 compared to that in 2020, accounting for an incremental increase of electric crossover and sport utility vehicles in the EV stock over time.

Charging infrastructure: Public, home, and workplace chargers

The public charging infrastructure needs, including public Level 2 and DC fast chargers, are projected by dividing the daily energy demand projections by the daily maximum amount of energy supplied by the chargers. The utilization rate in terms of charging hours per day of public Level 2 chargers linearly increases from three hours a day in 2020 to plateauing at eight hours a day in 2025 and thereafter. The utilization rate of DC fast chargers increases from two hours a day in 2020 to also plateauing at eight hours a day in 2025 and thereafter. There is little evidence that chargers currently meet such high average utilization. Eight hours of utilization is based on idealized charger usage in a dense urban EV market—where a maturing charging infrastructure network has co-evolved with vehicles, moving from basic geographic coverage toward capacity-serving. Higher charging utilization can be facilitated by charging coordination among EV drivers and charging providers, pricing, transparency about which chargers are in-use or available, and synergies with regard to the charging patterns and behavior among private EV drivers and ride-hailing drivers. Lower charger utilization than what is assessed here would require greater infrastructure deployment.

The public Level 2 chargers are assumed to have constant 6.6 kilowatt (kW) power across all years. The average charging power of DC fast chargers are assumed to increase linearly from 50 kW in 2020 to 115 kW in 2035, accounting for improved on-vehicle and charging equipment technologies. This is an advanced and rapidly improving network moving toward faster charging, and power capacity in many cases could be 150 kW or more. Greater charging power would require less charging infrastructure deployment, and vice versa.

Home chargers needed by zip code are estimated from the total number of EVs with owners that have access to home chargers, divided by the average number of vehicles in a vehicle owning household to account for EVs in the same household sharing a single charger. Workplace charger projections are calculated based on the total workplace charging events per day required by the intra-city and out-of-city commuters. Ten percent of all commuters with an EV are estimated to have had access to workplace chargers in 2017 and the percentage grows to 14% in 2050. The total workplace chargers needed is based on each workplace charger supporting 1.5 charging events a day.

City-level interventions

In addition to the central analysis presented above, three city-level interventions are investigation to determine their effect on EV charging infrastructure needs. The three interventions are: 1) a sustainable trip goal (i.e., shifting commutes from personal vehicles to transit and pedestrian modes), 2) congestion pricing (i.e., reduced vehicle travel to a portion of the city with a pricing mechanism), and 3) deploying curbside chargers (i.e., equipping city parking with EV chargers). The three interventions reflect how cities are simultaneously seeking to meet their EV goals while also developing roadmaps for other goals related to mode shift, demand shifting, and parking.

We assume San Francisco's goal of 80% sustainable trips by 2030[14] is achieved by all of the zip codes, with each zip code experiencing a constant annual growth rate from its own 2018 sustainable mode share percentage, as calculated using the American Community Survey. As an example, increasing sustainable trips from 60% to 70% leads to a reduction in vehicle trips from 40% to 30% of all trips, resulting in a 25% overall reduction in vehicle trips. That reduction in vehicle trips is assumed to be uniform across the entire vehicle fleet, meaning the EV charging demand is reduced by the same magnitude. The charger projection reduction, as a result of the sustainable trip increase, is calculated as the daily EV charging energy consumption reduction in kilowatt-hours (kWh) divided by the daily maximum energy the chargers can provide in each year. For home chargers, the charging energy demand reduction is also included, but the home charger units are not reduced as EV owners are assumed to still install home chargers when possible, regardless of the reduction in vehicle trips.

For congestion pricing, we assess a hypothetical congestion pricing scheme starting in 2030 that introduces a price on trips entering the downtown core in northeast San Francisco.[15] Although the pricing scheme details are not further specified, it is assumed to reduce the traffic in the congestion-priced zone by 15%, based on the goals and metrics identified in San Francisco County Transportation Authority's Congestion Pricing Study.[16] Like the sustainable trips, congestion pricing also impacts the EV charging demand and subsequently the EV charger projection. For the non-commuter trips originating from each zip code, only the portion of trips going into the congestion-priced zones are reduced by 15%. The portion of the trips going into these zones is determined based on the traffic movement between the zip codes. In lieu of more detailed travel pattern data, traffic movement based on the distribution of the city's jobs in each zip code are used as a proxy. All commuter trips going into the applicable congestion priced zip codes is reduced by 15%.

Curbside chargers are treated as a city intervention because their deployment requires policy and coordination among agencies. The assessment of curbside chargers assumes that 10% of all on-street parking spaces near apartment buildings are fitted with curbside chargers by 2050. By doing this, we consider these curbside chargers as mainly serving residential charging demand. The annual number of parking spaces with curbside chargers installed increases at the same rate as the EV stock share; reaching 1.5%, or 300 chargers, by 2025 and 4.1%, or 800 chargers, by 2030. The number of parking spaces near the apartment buildings is determined based on the parking inventory data,[17] land use data,[18] and American Community Survey data.[19] The daily usage of each curbside charger is assumed to increase from once per day in 2020 to

14 San Francisco Municipal Transportation Agency, "San Francisco Transportation Sector Climate Action Strategy," 2017, https://www.sfmta.com/sites/default/files/reports-and-documents/2017/12/cap_draft_full_doc-accessible-1.01.pdf

15 In the following ZIP codes: 94102, 94103, 94104, 94105, 94107, 94108, 94109, 94111, and 94133, corresponding to the neighborhoods of Civic Center / Hayes, South of Market, Financial District, East Cut / Rincon Hill, South Park / Potrero / Dog Patch, Chinatown / Nob Hill, Polk Gulch / Russian Hill, Embarcadero / Financial District, and North Beach, respectively

16 San Francisco County Transportation Authority, "San Francisco Downtown Congestion Pricing Study Goals and Evaluation Metrics, (2020), https://www.sfcta.org/sites/default/files/2020-05/Downtown-Congestion-Pricing_FINAL-Goals-and-Evaluation-Metrics_2020-05-28.pdf

17 On-street parking based on parking census, updated August 24, 2020, https://data.sfgov.org/Transportation/On-street-Parking-based-on-Parking-Census/9ivs-nf5y

18 Land Use (updated September 6, 2019), https://data.sfgov.org/Housing-and-Buildings/Land-Use/us3s-fp9q

19 The average units in each housing type (i.e., detached, attached, and apartments) are from the land use data, which has the zoning type (e.g., residential, commercial) and residential unit counts by parcel. Using the average units in each housing type, the amount of detached, attached, and apartment buildings in each zip code are estimated from the total residential units. Then parking spaces are allocated to each building type according to the percentages of each type of the building in each zip code.

twice daily in 2050. Curbside charging events provide 13.5 kWh for BEVs and 7 kWh for PHEVs initially and increase incrementally over time. This curbside energy consumption represents a case where the curbside chargers are used like home chargers but shared among drivers without home charger access, leading to a higher energy per event compared to home chargers. Energy demand supplied by curbside chargers is assessed to offset the demand on public chargers.

Ride-hailing and urban delivery trucks

In addition to private passenger vehicle charging, the infrastructure needed to support electric ride-hailing vehicles and the delivery truck fleets in the city is also estimated. Truck and ride-hailing infrastructure needs are adapted from previous ICCT work and briefly summarized here.[20]

For the ride-hailing charging infrastructure analysis, we estimate the BEV ride-hailing fleet and the charging demand for the San Francisco metropolitan area and assess the additional chargers needed. In 2018 there were 600,000 ride-hailing vehicles in California.[21] With an assumed constant annual growth rate of 2%, we estimate 74,000 ride-hailing vehicles in San Francisco metropolitan area in 2020. The percentage of BEVs in the ride-hailing fleet is higher than the San Francisco Metropolitan area BEV stock percentage, representing a more aggressive electrification of the ride-hailing fleet. The energy demand of the fleet is calculated based on the EV miles to be supplied by DC fast chargers as determined by the driver types. These numbers are adapted from ICCT's electric ride-hailing fleet charging infrastructure report,[22] as shown in Table 1, and we assume the BEV efficiency of 3.73 miles per kWh with 0.5% annual efficiency improvement to 2050. We note that the exact composition of the ride-hailing fleet and breakdown of driver types in the future is highly uncertain given emerging labor policies in California in 2020.[23]

Table 1. Ride-hailing driver type distribution and daily miles to be supplied by DC fast charger.

Driver type	Driver breakdown	Average daily miles supplied by DC fast chargers	Percentage of daily miles supplied by DC fast chargers
Part-time with home charging	41%	3	20%
Part-time without home charging	53%	14	100%
Full-time with home charging	3%	32	29%
Full-time without home charging	3%	121	100%

We develop a scenario where the majority of the ride-hailing DC fast charging demand is supplied within the city. As a frequent origin and destination for ride-hailing trips and

20 Michael Nicholas, Peter Slowik, & Nic Lutsey, *Charging infrastructure requirements to support electric ride-hailing in U.S. cities* (ICCT: Washington DC, 2020), https://theicct.org/publications/charging-infrastructure-electric-ride-hailing-us-032020 and Dale Hall & Nic Lutsey, *Estimating the infrastructure needs and costs for the launch of zero-emission trucks,* (ICCT: Washington DC, 2019), https://theicct.org/publications/zero-emission-truck-infrastructure

21 California Air Resources Board, "SB 1014 Clean Miles Standard 2018 Base-year Emissions Inventory Report," (2019), https://ww2.arb.ca.gov/resources/documents/2018-base-year- emissions-inventory-report

22 Michael Nicholas, Peter Slowik, & Nic Lutsey, *Charging infrastructure requirements to support electric ride-hailing in U.S. cities* (ICCT: Washington DC, 2020), https://theicct.org/publications/charging-infrastructure-electric-ride-hailing-us-032020

23 See for example California Assembly Bill AB-5 of 2019, AB-5 worker status: employees and independent contractors, https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201920200AB5, and California General Election November 3, 2020 Proposition 22, Exempts app-based transportation and delivery companies from providing employee benefits to certain drivers, https://voterguide.sos.ca.gov/propositions/22/

a key potential charging hub, 10% of the total energy demand of the ride-hailing BEV fleet is at San Francisco international airport (SFO). Of the remaining charging demand, 70% is assumed to occur in San Francisco city and 30% occurs in the San Francisco metropolitan area. Shifting to relatively greater charging demand outside of San Francisco city would require fewer DC fast chargers within the city, and vice versa. The DC fast chargers projected in the central case for the city's LDV fleet are assumed to support about 45 minutes of ride-hailing BEV charging a day, in addition to the private passenger EVs charging of about eight hours a day in 2025. The additional charging time is converted to energy transferred based on the average charge rate of the given year. The remaining BEV charging demand unfulfilled by the public DC fast chargers already projected for the city is then supplied by additional ride-hailing-dedicated DC fast chargers. We also assume the DC fast chargers at SFO are used by ride-hailing BEVs exclusively.

For the delivery truck fleet, we estimate the growing annual portion of the trucks that are electric and the associated depot and ultra-fast chargers needs using the ratio from ICCT's zero-emission truck charging infrastructure report.[24] In 2016, there were an estimated 3,700 Class 6 trucks in San Francisco.[25] We assume the truck fleet grows 1% a year and the percentage of fully electric trucks in the fleets follows the city's EV stock percentage. Different truck deployment stages have different charger-to-truck ratios. The ratios are based on the findings in ICCT's zero-emission truck charging infrastructure report, as shown in Table 2. We assume the city's electric truck deployment stages with the following timeline: initial deployment from 2016 to 2025, mid-term deployment from 2026 to 2035, and long-term deployment from 2036 to 2050. Finally, we project the delivery truck charging demand based on assumptions regarding the battery capacity, the truck energy efficiency, the route distances, and the charging pattern.[26] All the energy charged overnight at the depot is categorized as depot energy consumption and all the remaining energy need is categorized as ultra-fast charger energy consumption.

Table 2. Charging infrastructure needed for electric truck fleet at different deployment stages.

	Initial deployment	Mid-term deployment	Long-term deployment
Timeframe	Until 2025	2026 - 2035	After 2035
Depot chargers per truck (350 kW)	1	0.67	0.5
Ultra-fast chargers per truck (50kW)	0.14	0.04	0.02

Results

The charging needs analysis results are summarized and presented in several different ways. Charging needs are first summarized on a citywide level to convey the scale of increasing infrastructure needs, followed by zip code-level results to illustrate the variation between zip codes. The charging energy requirements are summarized to show the underlying electricity demand that the city, charging providers, and utilities can

24 Dale Hall & Nic Lutsey. *Estimating the infrastructure needs and costs for the launch of zero-emission trucks,* (ICCT: Washington DC, 2019), https://theicct.org/publications/zero-emission-truck-infrastructure

25 Emissions Inventory (EMFAC), accessed May 4, 2020, https://arb.ca.gov/emfac/emissions-inventory

26 Assumptions used to calculate the delivery truck charging energy demand are 1) 300 kWh of electric truck battery capacity and 80% of that is usable 2) electric truck efficiency was 1.4 kWh per mile with an empty cargo and 1.46 kWh per mile when carrying a full cargo in 2016, 3) truck efficiency increase by 0.5% annually, 4) the truck fleet is divided equally into three groups with one-way route distances of 15, 30, and 50 miles performing 6, 4.4, and 3.7 trips a day (based on a continuous 12 hour workday), respectively, and 5) all electric trucks receive full charge overnight.

expect for a city electrification plan. In each case, the results are shown for the central case as well as the intervention case where additional goals are met that could greatly reduce charging needs.

Charging infrastructure needs

Citywide, the public charging infrastructure needed in the central case is directly related to the amount of EVs in the LDV fleet. Meeting the goal of 100% EV sales shares by 2030 will require a significant deployment of home, workplace, and public charging infrastructure. Table 3 summarizes the overall public and workplace charging infrastructure needs in San Francisco for 2025 and 2030, including comparisons to chargers installed through 2019. By the end of 2019, San Francisco had installed about 41% of the public and workplace charging infrastructure it needs in 2025. To meet its electric vehicle goals, San Francisco public chargers would need to increase from about 800 in 2019, to 2,000 by 2025, and to over 5,100 by 2030. This means 6.1 times more charging is needed by 2030 from what was installed by the end of 2019; or an 18% annual growth rate. For context, the annual growth rate of public chargers in San Francisco was about 20% from 2015 through 2019. The charging needs are greatly reduced in the intervention case. If the city interventions are implemented, chargers needed by 2030 are reduced by 40% and annual public-access charger growth rate is reduced from 18% to 12%.

Table 3. San Francisco public and workplace charging infrastructure deployment needed to reach 100% of new electric vehicles by 2030.

	Year	Central case	Intervention case
Total public access chargers (public, workplace, fast)	2019[a]	834	834
	2025	2,013	1,612
	2030	5,129	2,900
Electric vehicle stock	2019[b]	17,000	17,000
	2025	68,605	68,605
	2030	178,421	178,421
Projected future charging compared to 2019	2025	2.4	1.9
	2030	6.1	3.5
2019 as percentage of future chargers needed	2025	41%	52%
	2030	16%	29%
Annual increase in chargers from 2019 to meet 2025 and 2030 needs	2025	16%	12%
	2030	18%	12%

[a] 2019 Charger data include public and fast chargers, but exclude workplace chargers due to lack of data
[b] 2019 Electric vehicles estimated from California Department of Motor Vehicles data

Charging infrastructure need projections for San Francisco from 2025 to 2050 are shown in Table 4. Home chargers represent the vast majority, approximately 90%, of all charging infrastructure by count in San Francisco. It also is the charger type accounting for the highest total energy demand in the city, as we will discuss in the next section. Home chargers grow from about 32,000 in 2025, to about 80,000 in 2030, and to over 150,000 by 2050. Workplace chargers are the second most abundant charger type. Depending on its development, it has the potential to account for an even larger portion of the total EV charger count and charging demand. In the analysis, we assume only 10% to 14% of the EV commuters have access to workplace chargers.

Table 4. Estimated charging infrastructure needed in San Francisco in 2025 through 2050.

Year	Central case				Intervention case				
	Public Level 2	DC fast[a]	Workplace	Home	Public Level 2	DC fast[a]	Workplace	Home	Curbside
2025	480	147	1,387	31,973	273	84	954	31,973	301
2030	1,412	348	3,369	79,961	435	110	1,557	79,961	798
2040	3,481	680	6,212	147,588	1,099	220	3,239	147,588	1,687
2050	4,104	805	7,107	151,280	1,299	261	3,939	151,280	1,945

[a] Does not include DC fast chargers dedicated for ride-hailing

For public charging, we find that by 2030, approximately 1,400 public Level 2 and 350 DC fast chargers are needed. By 2040, public charging infrastructure needs increase to 3,500 public Level 2 and 680 DC fast chargers and grow to 4,100 public Level 2 and 810 DC fast chargers by 2050. As of 2019, there were about 600 public Level 2 and 28 DC fast chargers in San Francisco. To achieve the projected public charging infrastructure size, the public Level 2 network would need to increase by more than two-fold in 10 years and almost six-fold in 20 years. The number of DC fast chargers, although smaller compared to public Level 2 chargers, requires a more than twelve-fold increase by 2030. As also shown in Table 4 and further assessed below, actions to reduce personal vehicle use in the intervention case greatly reduce the need for charging infrastructure.

Several factors can influence how many future chargers are needed. With all three interventions (i.e., sustainable trips, congestion pricing, and curbside charging), the number of public chargers (Level 2 and DC fast chargers) in the intervention case is reduced by about 70% starting 2030 compared to the central case. Table 5 shows the impact of each intervention on each charger type. We find that, out of the three policies, the sustainable trip goal has the most substantial impact on infrastructure projections. Sustainable trip increases lead to a direct decrease in vehicle trips in all zip codes—an approximately 60% decrease in public charging infrastructure projections and 50% decrease in workplace charger projections in 2030. Congestion pricing leads to a 9% reduction in public chargers and workplace chargers starting 2030. And lastly, installing curbside chargers and shifting public charging demand to the curbside chargers can lead to on average 7% reduction in public chargers.

Table 5. Intervention impacts on charger projections from 2025 to 2050.

	Charger type	2025	2030	2040	2050
Sustainable trips	Public Level 2	-174	-833	-2,050	-2,415
	DC fast	-52	-200	-391	-436
	Workplace	-433	-1,673	-2,707	-5,092
Congestion pricinga	Public Level 2	0	-134	-329	-387
	DC fast	0	-33	-64	-76
	Workplace	0	-320	-586	-668
Curbside chargers	Public Level 2	-33	-89	-198	-231
	DC fast	-11	-24	-42	-49

[a] Congestion pricing intervention impact shown here is independent of the sustainable trip goal. When both the sustainable trip goal and congestion pricing are enacted, the congestion pricing further impacts the sustainable trip reduced vehicle travel demand.

At the zip code level, those with more EVs are generally projected to have more public chargers needed. Figure 2 illustrates the projected EV stock and the numbers of public Level 2 and DC fast chargers in each zip code in 2030. The zip codes in the darker green have higher electric vehicle stocks, and vice versa. Public Level 2 and DC fast chargers are shown respectively by the orange and blue numbers within the circles with varying sizes. The size of the circles represents the relative size of the public charger projection in each zip code. Across the years, the differences in the projections between zip codes are similar in scale.

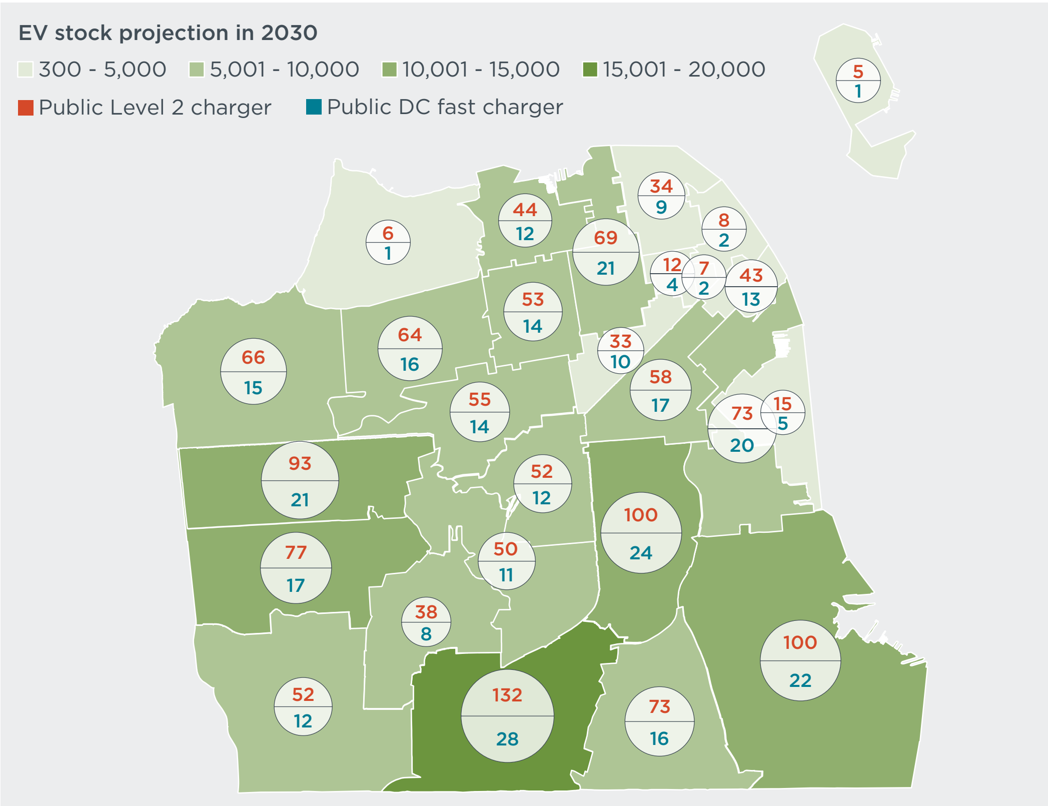


Figure 2. Public Level 2 (orange numbers) and DC fast (blue numbers) chargers needed in 2030.

Since EV stock by zip code is a primary input to the charger projection, the downtown core (northeast San Francisco), with fewer EVs, is projected to need fewer public chargers. Although the result indicates that these zip codes have lower public charging infrastructure needs compared to the zip codes with more EVs in the southern and eastern parts of the city, additional factors are noted. First, the downtown core has the highest workplace charger need, as we will discuss below, and the workplace chargers here are typically located in parking garages. This means these workplace chargers can serve other drivers, especially on weekends and during the nighttime, but this prospect is not investigated further in the analysis. Second, downtown San Francisco's space constraints may make typical public charging stations on lots less feasible. Therefore, commercial curbside chargers and chargers in garages may play an important role here.

Cities need a mix of public Level 2 and DC fast charging infrastructure to satisfy a diverse range of electric vehicle driver travel patterns, charging behavior, and price sensitivities. The ratios of the public Level 2 chargers to DC fast chargers across zip codes in a given year reflect the different charging needs of EV owners based on their unique characteristics, such a as housing type, availability of home charging, and commuting behavior. For example, EV drivers in a zip code with a higher portion of apartment units—leading to less home charging availability—would have a higher reliance on DC fast chargers versus Level 2 chargers compared to EV drivers in a zip code with more home charging available.

The projections of workplace chargers also follow a similar pattern between the zip codes across the different years as they are dependent on the distribution of the city's jobs in the zip codes based on our method. Figure 3 shows the workplace charger projections in 2030, 2040, and 2050 in each zip code. The blue and red points represent workplace charging needs in the central and intervention cases, respectively. The job growth in each zip code is factored in, but since the scale of growth is small, it did not alter the relative differences between the zip codes significantly. Overall, zip codes with higher percentages of the city's jobs are projected to have higher workplace charger needs. The three zip codes in the order of the highest workplace chargers needs in 2030 are 94105 (East Cut-Rincon Hill), 94103 (SoMa), and 94107 (South Park-Potrero Hill).

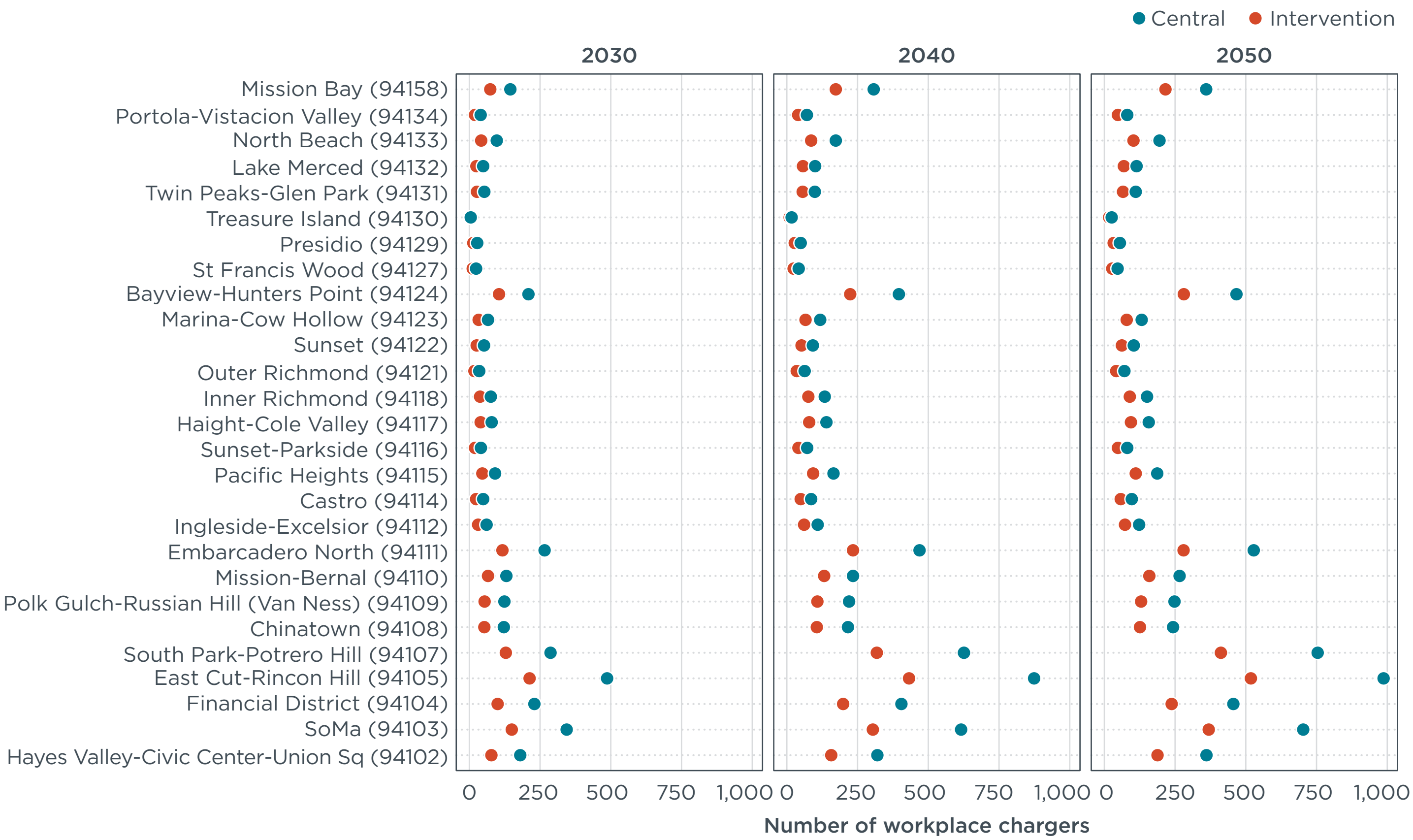


Figure 3. Workplace charger needs in 2030, 2040, and 2050.

EV charging energy demand

The total citywide daily EV charging, as measured in gigawatt-hours (GWh) of energy demand, is significant. We estimate 0.4, 1.1, 2.2, and 2.5 GWh are needed daily by 2025, 2030, 2040, and 2050 for EV charging. For reference, the daily total electricity consumption of San Francisco was around 15.4 GWh in 2018.[27] Table 6 shows the energy consumption by charger types in the central and intervention cases from 2025 to 2050. Home chargers consistently have the highest total energy consumption, followed by DC fast chargers, workplace chargers, and public Level 2 chargers. Home chargers account for more than half of the total EV charging energy demand in both the central and intervention cases. Starting in 2030, we find that the total energy demand under the intervention case (i.e., by achieving sustainable trips and implementing congestion pricing) is less than half of the energy demand in the central case due to the reduced EV travel demand.

Table 6. Projected daily EV charging energy demand (MWh) from 2025 to 2050.

	Year	Public Level 2	DCFC[a]	Workplace	Home	Curbside[b]	Total
Central case	2025	25	84	29	252	0	391
	2030	75	260	75	649	0	1,058
	2040	183	626	147	1,258	0	2,215
	2050	217	741	179	1,369	0	2,506
Intervention case	2025	14	48	21	156	8	247
	2030	23	82	35	223	22	385
	2040	58	202	77	431	49	818
	2050	69	240	100	469	57	936
Percentage Change from central to intervention	2025	-44%	-43%	-28%	-38%	NA	-37%
	2030	-69%	-68%	-53%	-66%	NA	-64%
	2040	-68%	-68%	-48%	-66%	NA	-63%
	2050	-68%	-68%	-44%	-66%	NA	-63%

[a] Does not include DC fast charging demand of the ride-hailing fleet.
[b] NA = not applicable, as curbside charging was not analyzed in the central case

Most zip codes are similar to the citywide result in terms of proportional patterns of the charging demand supplied by each type of chargers. For most zip codes, home charging (both Level 1 and Level 2) accounts for the largest portion, more than half in most cases, of the energy consumption. The colored segments in Figure 4 show the central case charging energy demand of each type of chargers by zip code in 2030, 2040, and 2050. The black dot represents the intervention case total charging energy demand. For zip codes with predominantly apartments, home charging accounts for less than half of the overall charging demand. Figure 4 shows the top three zip codes with the highest percentage of apartments all have very small home charging energy demand: 94104 (Financial District), 94158 (Mission Bay), and 94105 (East Cut and Rincon Hill) with 100%, 98%, and 97% apartments, respectively. Lastly, the top three zip codes with the most projected EVs, 94112 (Ingleside, Excelsior, and Balboa), 94124 (Bay View and Hunters Point), and 94110 (Mission and Bernal), have three largest EV charging demand across all years.

27 California Energy Commission, Electricity Consumption by County, accessed May 4, 2020, https://ecdms.energy.ca.gov/elecbycounty.aspx

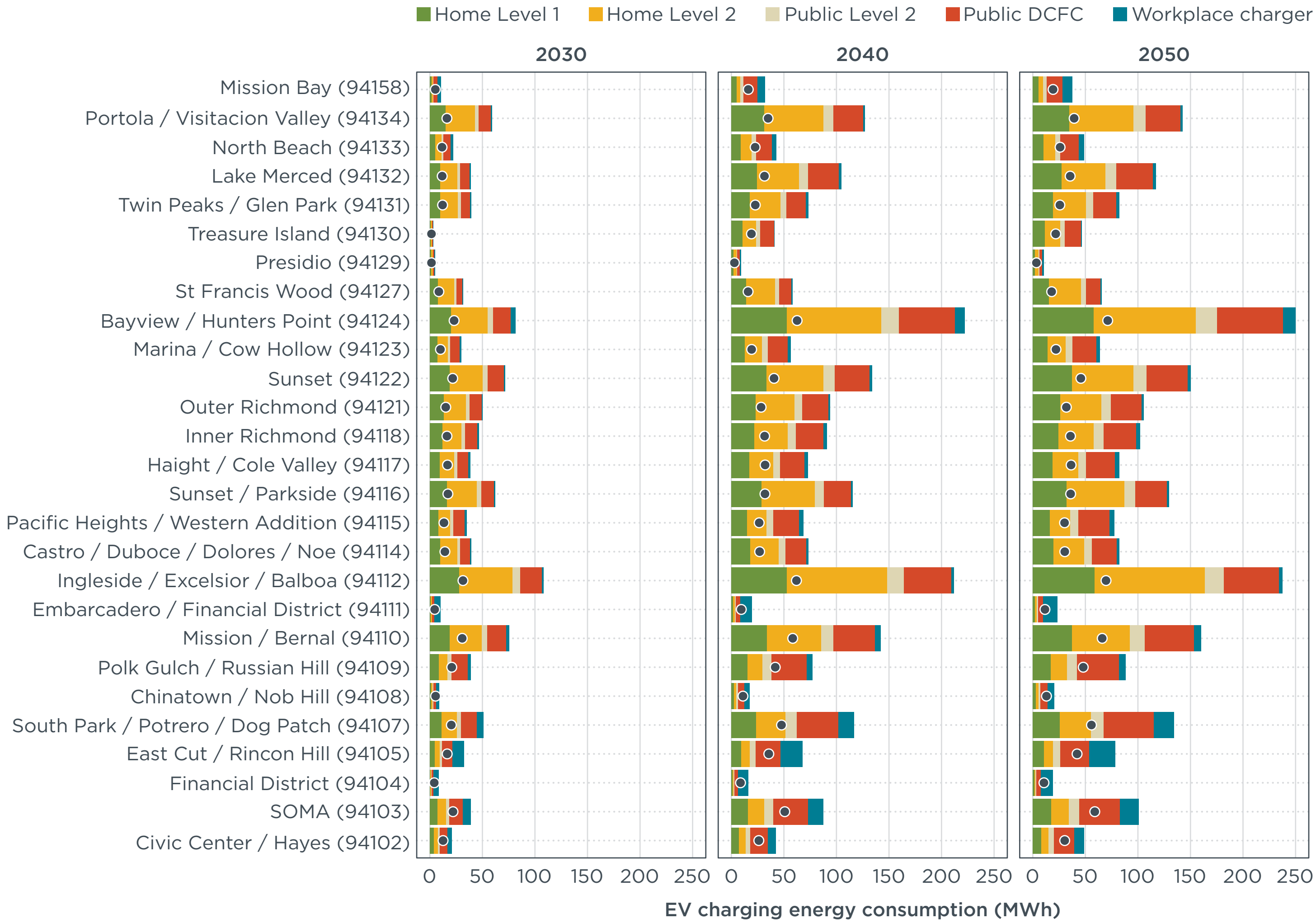


Figure 4. EV charging energy consumption in 2030, 2040, and 2050 for zip codes in San Francisco. The black dots show the reduced total energy consumption in the intervention case.

The proportion of the total charging demand by each charger type largely depends of the inputs regarding energy consumption per event and charging events per day. These inputs are derived from the observed behavior among the early EV adopters across California. In the early market, public charging infrastructure is not yet fully developed. In addition, early EV adopters statewide have on average different housing characteristics and travel behaviors comparing to urban EV drivers, like those in San Francisco. Since early adopters tend to live in single unit detached houses and are operating EVs with a less comprehensive public charging network, we suspect the early adopters' charging behavior can potentially be skewed toward more home charging.[28]

Ride-hailing and medium-duty vehicles

We conduct more limited analyses on the supporting infrastructure needed for ride-hailing fleet and urban delivery electric truck fleet at the city level. Although fleet-level specific operating behavior and operators' decisions can dramatically influence the

28 Clean Vehicle Rebate Project, EV Consumer Survey Dashboard, https://cleanvehiclerebate.org/eng/survey-dashboard/ev

infrastructure layout, we make aggregate estimates for charging needs with assumptions based on two recent ICCT technical analyses.[29]

Ride-hailing charging infrastructure needs are projected based on an aggressive transition where BEVs reaches 80% of the ride-hailing fleet by 2030 and 100% by 2040, and the fleet size grows by 2% annually. Table 7 shows the daily energy demand and the charging infrastructure needed to support the electric ride-hailing fleet from 2030 to 2050. Based on these assumptions, the estimated daily electricity consumption of the ride-hailing BEV fleet in the city and SFO reaches 179 MWh, 265 MWh, and 308 MWh in 2030, 2040, and 2050, respectively. Depending on the year, this is equivalent to approximately 12% to 17% of the light-duty vehicle EV energy demand citywide. The amount of additional *dedicated* DC fast chargers needed in the city and SFO are about 192, 207, and 238 by 2030, 2040, and 2050; equal to around 55%, 30%, and 30% of the projected DC fast chargers for the LDVs in the city in the central case by 2030, 2040, and 2050, respectively.

Table 7. San Francisco metropolitan area ride-hailing BEV charger needs in 2030, 2040, and 2050.

Year	Number of electric ride-hailing vehicles	BEV share of ride-hailing fleet	Daily energy demand (MWh)	Additional dedicated DC fast chargers needed[a]	Dedicated DC fast chargers at SFO
2030	74,500	80%	179	162	30
2040	115,500	100%	265	171	36
2050	141,000	100%	308	196	42

[a] As shown Table 4 above there are 348, 680, and 805 DC fast chargers in the central case by 2030, 2040, and 2050, respectively, before considering electric ride-hailing vehicles

We assumed that there is a minimal capacity for ride-hail drivers to charge on non-dedicated ride-hail chargers of 45 minutes per charger per day. This is because our primary infrastructure analysis above already assumed relatively high utilization of DC fast chargers by the general public of 8 hours per day starting in 2025. Achieving additional capacity would require the coordination between the general public and the ride-hailing fleet, e.g., by having accurate and real-time information on chargers in operation, in use, and queuing.

Many ride-hailing drivers make trips to and from SFO and often wait for trips at the nearby cellphone waiting lot, thus we identified this area as a potential key hub for ride-hailing DC fast charging. Having DC fast chargers at SFO offsets the additional charger needs in the city. This analysis did not evaluate specific areas within the city for dedicated ride-hailing DC fast charger deployment. One option is charging hubs at selected transit stations which could facilitate ride-hailing while complementing transit by providing first and last-mile trips that are electric and shared.

We also assess the charging infrastructure needed to support a fleet of electric delivery trucks in San Francisco. We analyze a total fleet of about 3,800 trucks in 2020 that grows by 1% a year. Table 8 shows the energy demand and the charging infrastructure needed from 2030 to 2050. The electric truck fleet consumes a significant amount of energy—amounting to approximately half of the energy demand of all light duty EVs on the city's road in the central case across all years. The significant energy consumption

29 Peter Slowik, Sandra Wappelhorst, and Nic Lutsey, *How can taxes and fees on ride-hailing fleets steer them to electrify?*, (ICCT: Washington DC, 2019), https://theicct.org/publications/taxes-and-fees-electrify-ridehailing and Dale Hall and Nic Lutsey, *Estimating the infrastructure needs and costs for the launch of zero-emission trucks*, (ICCT: Washington DC, 2019), https://theicct.org/publications/zero-emission-truck-infrastructure

is due to the high energy demand per electric truck. Electric delivery trucks have an energy efficiency about five times lower than passenger BEVs and have longer average daily travel distances. The two factors combined leads to an electric truck daily energy consumption more than 30 times higher compared to a passenger BEV.

Charging infrastructure for the electric truck fleets likely will not be shared by the general public, especially the depot chargers. However, the ultra-fast on-route chargers and the electrical equipment upstream from chargers may be shared with other heavy-duty EVs, including the city's electric buses. The city could investigate the feasibility of developing an ultra-fast charging network in partnership with private fleet owners to share the cost of charging infrastructure.

Table 8. Charging infrastructure needs for electrifying urban delivery trucks.

Year	Total electric trucks	Electric truck share	Energy demand (MWh)	Depot chargers	Ultra-fast chargers
2030	1,650	39%	531	1,101	83
2040	3,853	83%	1,070	1,926	121
2050	4,906	96%	1,240	2,453	121

Conclusions

This working paper demonstrates the steps cities can take to utilize local data to estimate charging infrastructure needs to plan for the transition to electric mobility. The research analyzes questions that are highly relevant across many leading local EV markets in the United States and beyond, namely, quantifying the number, type, and distribution of chargers needed to support rapid uptake in cities. The EV charging analysis presents the case of San Francisco based on data inputs for EV growth, vehicle ownership patterns, commuting and housing patterns, EV charging behavior, and home charging access, among others.

The pace and scale of EV and charging infrastructure growth assessed here for San Francisco would be an unprecedented. Several major cities have surpassed 20% electric share of their passenger vehicle sales.[30] Providing infrastructure for the EV transition presents uncertainties related to charging equipment and reasonable limits on the utilization of chargers to serve drivers and reduce the number of chargers needed. A key principle for infrastructure planning is to opportunistically take advantage where of EVs are parked most often, as done in this idealized analysis of maturing market with co-evolution of EV charging behavior and infrastructure. Improved EV charger coordination, pricing, and transparency are likely necessary to serve drivers and charging providers. The work leads us to the following conclusions and potential policy implications that could be explored further.

City electric vehicle goals require substantial charging infrastructure deployment. For San Francisco, achieving the 100% EV sales goal in 2030 means that more than 170 thousand EVs could be on the city's roads that year. Much more charging infrastructure is needed to support these EVs. Publicly accessible charging (i.e., public Level 2, DC fast, and workplace chargers) in San Francisco would need to increase from approximately 800 in 2019, to 2,000 by 2025, and over 5,000 by 2030. This means six times more charging is needed by 2030 from what was installed by the end of 2019. Cities with

30 Dale Hall, Hongyang Cui, Marie Rajon Bernard, Shuyang Li, Nic Lutsey, *Electric vehicle capitals: Cities aim for all-electric mobility*, (ICCT: Washington, D.C., 2020), https://theicct.org/publications/ev-capitals-of-the-world-2020

similar electric vehicle adoption goals likely require similar expansion in the availability of public charging infrastructure.

Access to home charging remains a key pillar in the infrastructure ecosystem. While public and workplace charging options are needed to support mass market adoption, the vast majority of EV charging will continue to be at home if 2020 charging patterns persist. Widespread access to overnight home charging, including at homes, multi-unit dwellings, residential curbsides, and other near-home locations, are key to minimizing public charging demand. This analysis finds that over 90% of the total chargers needed across San Francisco in 2030 are home chargers, and home chargers supply over half of the total EV charging demand. This is important as home chargers are typically the least expensive charger type to install and charge from, and lower-power overnight charging can reduce overall grid upgrade costs and provide demand management flexibility.

Achieving city electric vehicle goals and the associated charging infrastructure will require supporting policy. San Francisco will need to see the deployment of charging continue to increase at about 18% per year through 2030. This is approximately in line with charging infrastructure growth rates from the past several years. Increasingly stronger city policies like EV-ready building codes, streamlined permitting, prioritized zoning, and preferential EV parking can continue to encourage private infrastructure investment and lay the groundwork for widespread EV adoption and infrastructure deployment.[31] Continued public-private collaboration between city agencies, utilities, and charging providers will be essential. Such collaboration is important to identify and address areas that need charging more quickly, and conversely, areas that are less urgent, depending on EV demand and grid considerations associated with charging behavior, power demand dynamics, and timing for grid upgrades.

Implementing cross-cutting city policies to reduce personal vehicle use can be especially important for cities to reduce charging infrastructure needs. The analysis reveals how public EV charging infrastructure needs by 2030 are reduced by 45%, from approximately 5,100 to 2,900 chargers, and annual 2019-2030 public charger growth rate is reduced from 18% to 12%, if the city interventions are implemented. Shifting mobility from private vehicle trips to sustainable modes of transport like transit, reducing trips into the city core through congestion pricing, and equipping curbside parking with EV charging substantially reduce the need for public and workplace chargers. Doing so would require continued collaboration across city agencies to simultaneously support multiple city goals.

As EV adoption and charger deployment goals are implemented, cities can reexamine and adapt to underlying trends, local factors, and limitations. Deeper investigation into the local energy loads, grid capacity, and site viability could inform utility and charging provider plans. City infrastructure planning would ideally update their charging infrastructure modeling using the latest data, incorporating local community feedback, and identifying additional policy support where warranted. Trends related to EV deployment, transit, and special local policies like San Francisco's Slow Streets program through the pandemic recovery present further uncertainties for cities to track. Beyond incorporating universal EV uptake and increased transit and pedestrian trips as done here, more comprehensive assessment of how cities can simultaneously achieve equity and climate goals in their transportation policies is warranted. San Francisco's in-development plans to accomplish such wide-ranging mobility goals offer an important and exemplary first step.

31 Dale Hall and Nic Lutsey, *Charging infrastructure in cities: Metrics for evaluating future needs*, (ICCT: Washington, D.C., 2020), https://theicct.org/publications/EV_charging_metrics_aug2020

Appendix

Table A1 shows zip code-level charging needs in 2030 based on the analysis above. Home charger projections are identical between central and intervention cases.

Table A1. San Francisco charger needs in 2030 for central and intervention cases

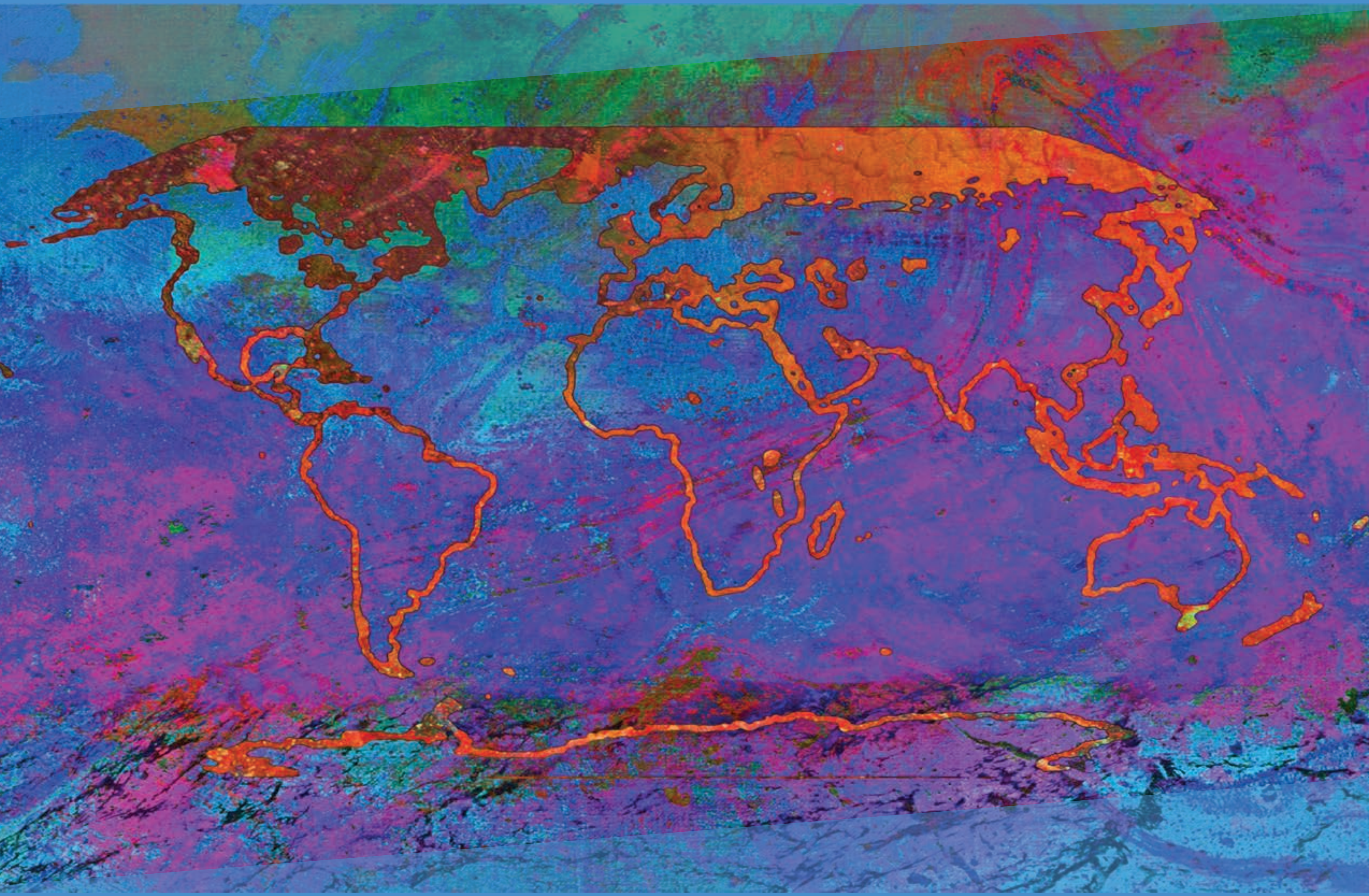
				Central case			Intervention case			
Zip code	Neighborhood name	Home Level 1	Home Level 2	Public Level 2	DCFC	Workplace	Public Level 2	DCFC	Workplace	Curbside
94102	**Civic Center / Hayes Valley**	669	527	33	10	180	16	5	78	55
94103	**SOMA**	1,295	1,135	58	17	344	29	8	150	59
94104	**Financial District**	117	70	7	2	230	4	1	100	1
94105	**East Cut / Rincon Hill**	846	662	43	13	487	23	7	213	7
94107	**South Park / Potrero / Dog Patch**	1,785	1,995	73	20	287	25	7	129	33
94108	**Chinatown / Nob Hill**	244	190	12	4	122	5	2	53	32
94109	**Polk Gulch / Russian Hill**	1,487	1,242	69	21	124	24	7	54	130
94110	**Mission / Bernal**	2,715	3,706	100	24	131	34	8	66	52
94111	**Embarcadero / Financial District**	191	161	8	2	266	3	1	117	5
94112	**Ingleside / Excelsior / Balboa**	3,201	5,011	132	28	61	37	8	31	6
94114	**Castro / Duboce / Dolores / Noe**	1,510	2,070	52	12	49	15	4	24	32
94115	**Pacific Heights / Western Addition**	1,313	1,505	53	14	91	13	3	46	68
94116	**Sunset / Parkside**	1,912	2,911	77	17	41	20	4	20	8
94117	**Haight / Cole Valley**	1,445	1,745	55	14	79	15	4	40	74
94118	**Inner Richmond**	1,723	2,225	64	16	76	17	4	38	40
94121	**Outer Richmond**	1,800	2,487	66	15	35	17	4	18	24
94122	**Sunset**	2,392	3,418	93	21	52	25	6	26	19
94123	**Marina / Cow Hollow**	1,144	1,351	44	12	66	9	2	33	45
94124	**Bayview / Hunters Point**	2,394	3,588	100	22	209	25	6	105	13
94127	**St Francis Wood**	857	1,417	38	8	24	10	2	12	3
94129	**Presidio**	143	176	6	1	28	1	0	14	2
94130	**Treasure Island**	111	117	5	1	5	1	0	3	12
94131	**Twin Peaks / Glen Park**	1,349	1,974	50	11	53	13	3	27	18
94132	**Lake Merced**	1,252	1,795	52	12	49	14	3	25	8
94133	**North Beach**	862	866	34	9	97	13	4	42	42
94134	**Portola / Visitacion Valley**	1,716	2,663	73	16	40	19	4	20	7
94158	**Mission Bay**	296	184	15	5	145	7	2	74	5
Total		**34,772**	**45,190**	**1,412**	**348**	**3,369**	**435**	**110**	**1,557**	**798**

INTERGOVERNMENTAL PANEL ON climate change

Climate Change 2021

The Physical Science Basis

Summary for Policymakers



WGI

Working Group I Contribution to the
Sixth Assessment Report of the
Intergovernmental Panel on Climate Change

WMO UNEP

Climate Change 2021
The Physical Science Basis

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Summary for Policymakers

SPM

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Introduction

This Summary for Policymakers (SPM) presents key findings of the Working Group I (WGI) contribution to the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6)[1] on the physical science basis of climate change. The report builds upon the 2013 Working Group I contribution to the IPCC's Fifth Assessment Report (AR5) and the 2018–2019 IPCC Special Reports[2] of the AR6 cycle and incorporates subsequent new evidence from climate science.[3]

This SPM provides a high-level summary of the understanding of the current state of the climate, including how it is changing and the role of human influence, the state of knowledge about possible climate futures, climate information relevant to regions and sectors, and limiting human-induced climate change.

Based on scientific understanding, key findings can be formulated as statements of fact or associated with an assessed level of confidence indicated using the IPCC calibrated language.[4]

The scientific basis for each key finding is found in chapter sections of the main Report and in the integrated synthesis presented in the Technical Summary (hereafter TS), and is indicated in curly brackets. The AR6 WGI Interactive Atlas facilitates exploration of these key synthesis findings, and supporting climate change information, across the WGI reference regions.[5]

A. The Current State of the Climate

Since AR5, improvements in observationally based estimates and information from paleoclimate archives provide a comprehensive view of each component of the climate system and its changes to date. New climate model simulations, new analyses, and methods combining multiple lines of evidence lead to improved understanding of human influence on a wider range of climate variables, including weather and climate extremes. The time periods considered throughout this section depend upon the availability of observational products, paleoclimate archives and peer-reviewed studies.

A.1 It is unequivocal that human influence has warmed the atmosphere, ocean and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred.
{2.2, 2.3, Cross-Chapter Box 2.3, 3.3, 3.4, 3.5, 3.6, 3.8, 5.2, 5.3, 6.4, 7.3, 8.3, 9.2, 9.3, 9.5, 9.6, Cross-Chapter Box 9.1} (Figure SPM.1, Figure SPM.2)

A.1.1 Observed increases in well-mixed greenhouse gas (GHG) concentrations since around 1750 are unequivocally caused by human activities. Since 2011 (measurements reported in AR5), concentrations have continued to increase in the atmosphere, reaching annual averages of 410 parts per million (ppm) for carbon dioxide (CO_2), 1866 parts per billion (ppb) for methane (CH_4), and 332 ppb for nitrous oxide (N_2O) in 2019.[6] Land and ocean have taken up a near-constant proportion (globally about 56% per year) of CO_2 emissions from human activities over the past six decades, with regional differences (*high confidence*).[7]
{2.2, 5.2, 7.3, TS.2.2, Box TS.5}

1 Decision IPCC/XLVI-2.

2 The three Special Reports are: Global Warming of 1.5°C: An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty (SR1.5); Climate Change and Land: An IPCC Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems (SRCCL); IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC).

3 The assessment covers scientific literature accepted for publication by 31 January 2021.

4 Each finding is grounded in an evaluation of underlying evidence and agreement. A level of confidence is expressed using five qualifiers: very low, low, medium, high and very high, and typeset in italics, for example, *medium confidence*. The following terms have been used to indicate the assessed likelihood of an outcome or result: virtually certain 99–100% probability; very likely 90–100%; likely 66–100%; about as likely as not 33–66%; unlikely 0–33%; very unlikely 0–10%; and exceptionally unlikely 0–1%. Additional terms (extremely likely 95–100%; more likely than not >50–100%; and extremely unlikely 0–5%) are also used when appropriate. Assessed likelihood is typeset in italics, for example, *very likely*. This is consistent with AR5. In this Report, unless stated otherwise, square brackets [x to y] are used to provide the assessed *very likely* range, or 90% interval.

5 The Interactive Atlas is available at https://interactive-atlas.ipcc.ch

6 Other GHG concentrations in 2019 were: perfluorocarbons (PFCs) – 109 parts per trillion (ppt) CF_4 equivalent; sulphur hexafluoride (SF_6) – 10 ppt; nitrogen trifluoride (NF_3) – 2 ppt; hydrofluorocarbons (HFCs) – 237 ppt HFC-134a equivalent; other Montreal Protocol gases (mainly chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs)) – 1032 ppt CFC-12 equivalent). Increases from 2011 are 19 ppm for CO_2, 63 ppb for CH_4 and 8 ppb for N_2O.

7 Land and ocean are not substantial sinks for other GHGs.

A.1.2 Each of the last four decades has been successively warmer than any decade that preceded it since 1850. Global surface temperature[8] in the first two decades of the 21st century (2001–2020) was 0.99 [0.84 to 1.10] °C higher than 1850–1900.[9] Global surface temperature was 1.09 [0.95 to 1.20] °C higher in 2011–2020 than 1850–1900, with larger increases over land (1.59 [1.34 to 1.83] °C) than over the ocean (0.88 [0.68 to 1.01] °C). The estimated increase in global surface temperature since AR5 is principally due to further warming since 2003–2012 (+0.19 [0.16 to 0.22] °C). Additionally, methodological advances and new datasets contributed approximately 0.1°C to the updated estimate of warming in AR6.[10]
{2.3, Cross-Chapter Box 2.3} (Figure SPM.1)

A.1.3 The *likely* range of total human-caused global surface temperature increase from 1850–1900 to 2010–2019[11] is 0.8°C to 1.3°C, with a best estimate of 1.07°C. It is *likely* that well-mixed GHGs contributed a warming of 1.0°C to 2.0°C, other human drivers (principally aerosols) contributed a cooling of 0.0°C to 0.8°C, natural drivers changed global surface temperature by –0.1°C to +0.1°C, and internal variability changed it by –0.2°C to +0.2°C. It is *very likely* that well-mixed GHGs were the main driver[12] of tropospheric warming since 1979 and *extremely likely* that human-caused stratospheric ozone depletion was the main driver of cooling of the lower stratosphere between 1979 and the mid-1990s.
{3.3, 6.4, 7.3, TS.2.3, Cross-Section Box TS.1} (Figure SPM.2)

A.1.4 Globally averaged precipitation over land has *likely* increased since 1950, with a faster rate of increase since the 1980s (*medium confidence*). It is *likely* that human influence contributed to the pattern of observed precipitation changes since the mid-20th century and *extremely likely* that human influence contributed to the pattern of observed changes in near-surface ocean salinity. Mid-latitude storm tracks have *likely* shifted poleward in both hemispheres since the 1980s, with marked seasonality in trends (*medium confidence*). For the Southern Hemisphere, human influence *very likely* contributed to the poleward shift of the closely related extratropical jet in austral summer.
{2.3, 3.3, 8.3, 9.2, TS.2.3, TS.2.4, Box TS.6}

A.1.5 Human influence is *very likely* the main driver of the global retreat of glaciers since the 1990s and the decrease in Arctic sea ice area between 1979–1988 and 2010–2019 (decreases of about 40% in September and about 10% in March). There has been no significant trend in Antarctic sea ice area from 1979 to 2020 due to regionally opposing trends and large internal variability. Human influence *very likely* contributed to the decrease in Northern Hemisphere spring snow cover since 1950. It is *very likely* that human influence has contributed to the observed surface melting of the Greenland Ice Sheet over the past two decades, but there is only *limited evidence*, with *medium agreement*, of human influence on the Antarctic Ice Sheet mass loss.
{2.3, 3.4, 8.3, 9.3, 9.5, TS.2.5}

A.1.6 It is *virtually certain* that the global upper ocean (0–700 m) has warmed since the 1970s and *extremely likely* that human influence is the main driver. It is *virtually certain* that human-caused CO_2 emissions are the main driver of current global acidification of the surface open ocean. There is *high confidence* that oxygen levels have dropped in many upper ocean regions since the mid-20th century and *medium confidence* that human influence contributed to this drop.
{2.3, 3.5, 3.6, 5.3, 9.2, TS.2.4}

A.1.7 Global mean sea level increased by 0.20 [0.15 to 0.25] m between 1901 and 2018. The average rate of sea level rise was 1.3 [0.6 to 2.1] mm yr^{-1} between 1901 and 1971, increasing to 1.9 [0.8 to 2.9] mm yr^{-1} between 1971 and 2006, and further increasing to 3.7 [3.2 to 4.2] mm yr^{-1} between 2006 and 2018 (*high confidence*). Human influence was *very likely* the main driver of these increases since at least 1971.
{2.3, 3.5, 9.6, Cross-Chapter Box 9.1, Box TS.4}

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8 The term 'global surface temperature' is used in reference to both global mean surface temperature and global surface air temperature throughout this SPM. Changes in these quantities are assessed with *high confidence* to differ by at most 10% from one another, but conflicting lines of evidence lead to *low confidence* in the sign (direction) of any difference in long-term trend. {Cross-Section Box TS.1}

9 The period 1850–1900 represents the earliest period of sufficiently globally complete observations to estimate global surface temperature and, consistent with AR5 and SR1.5, is used as an approximation for pre-industrial conditions.

10 Since AR5, methodological advances and new datasets have provided a more complete spatial representation of changes in surface temperature, including in the Arctic. These and other improvements have also increased the estimate of global surface temperature change by approximately 0.1°C, but this increase does not represent additional physical warming since AR5.

11 The period distinction with A.1.2 arises because the attribution studies consider this slightly earlier period. The observed warming to 2010–2019 is 1.06 [0.88 to 1.21] °C.

12 Throughout this SPM, 'main driver' means responsible for more than 50% of the change.

SPM

A.1.8 Changes in the land biosphere since 1970 are consistent with global warming: climate zones have shifted poleward in both hemispheres, and the growing season has on average lengthened by up to two days per decade since the 1950s in the Northern Hemisphere extratropics (*high confidence*).
{2.3, TS.2.6}

Human influence has warmed the climate at a rate that is unprecedented in at least the last 2000 years

Changes in global surface temperature relative to 1850–1900

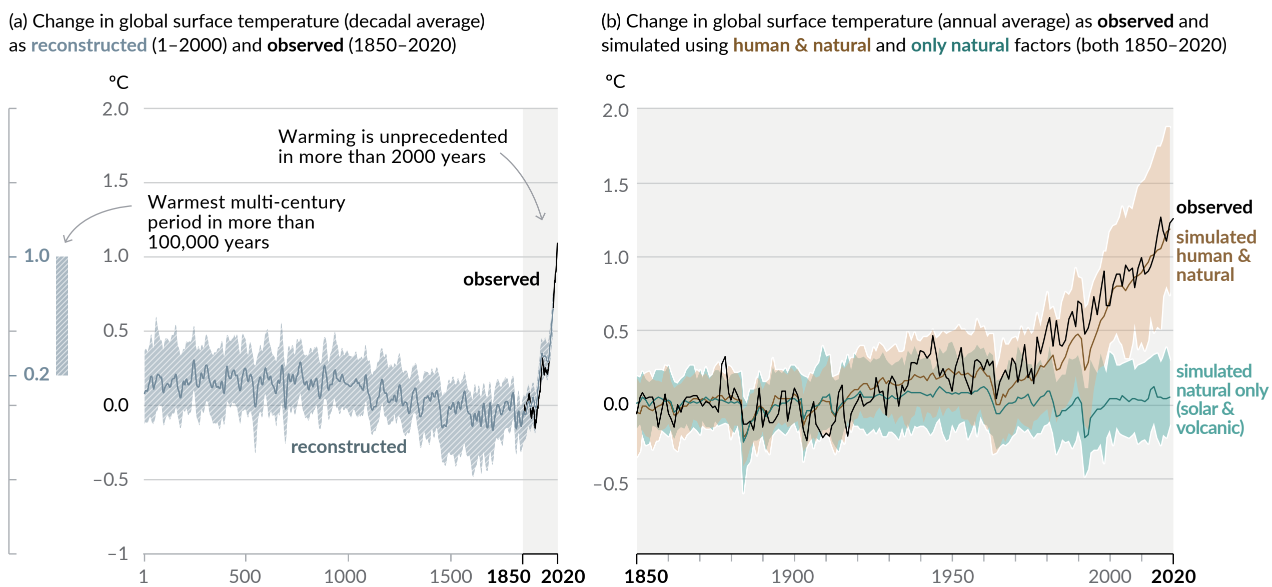

Figure SPM.1 | History of global temperature change and causes of recent warming

Panel (a) Changes in global surface temperature reconstructed from paleoclimate archives (solid grey line, years 1–2000) **and from direct observations** (solid black line, 1850–2020), both relative to 1850–1900 and decadally averaged. The vertical bar on the left shows the estimated temperature (*very likely* range) during the warmest multi-century period in at least the last 100,000 years, which occurred around 6500 years ago during the current interglacial period (Holocene). The Last Interglacial, around 125,000 years ago, is the next most recent candidate for a period of higher temperature. These past warm periods were caused by slow (multi-millennial) orbital variations. The grey shading with white diagonal lines shows the *very likely* ranges for the temperature reconstructions.

Panel (b) Changes in global surface temperature over the past 170 years (black line) relative to 1850–1900 and annually averaged, compared to Coupled Model Intercomparison Project Phase 6 (CMIP6) climate model simulations (see Box SPM.1) of the temperature response to both human and natural drivers (brown) and to only natural drivers (solar and volcanic activity, green). Solid coloured lines show the multi-model average, and coloured shades show the *very likely* range of simulations. (See Figure SPM.2 for the assessed contributions to warming).

{2.3.1; Cross-Chapter Box 2.3; 3.3; TS.2.2; Cross-Section Box TS.1, Figure 1a}

Observed warming is driven by emissions from human activities, with greenhouse gas warming partly masked by aerosol cooling

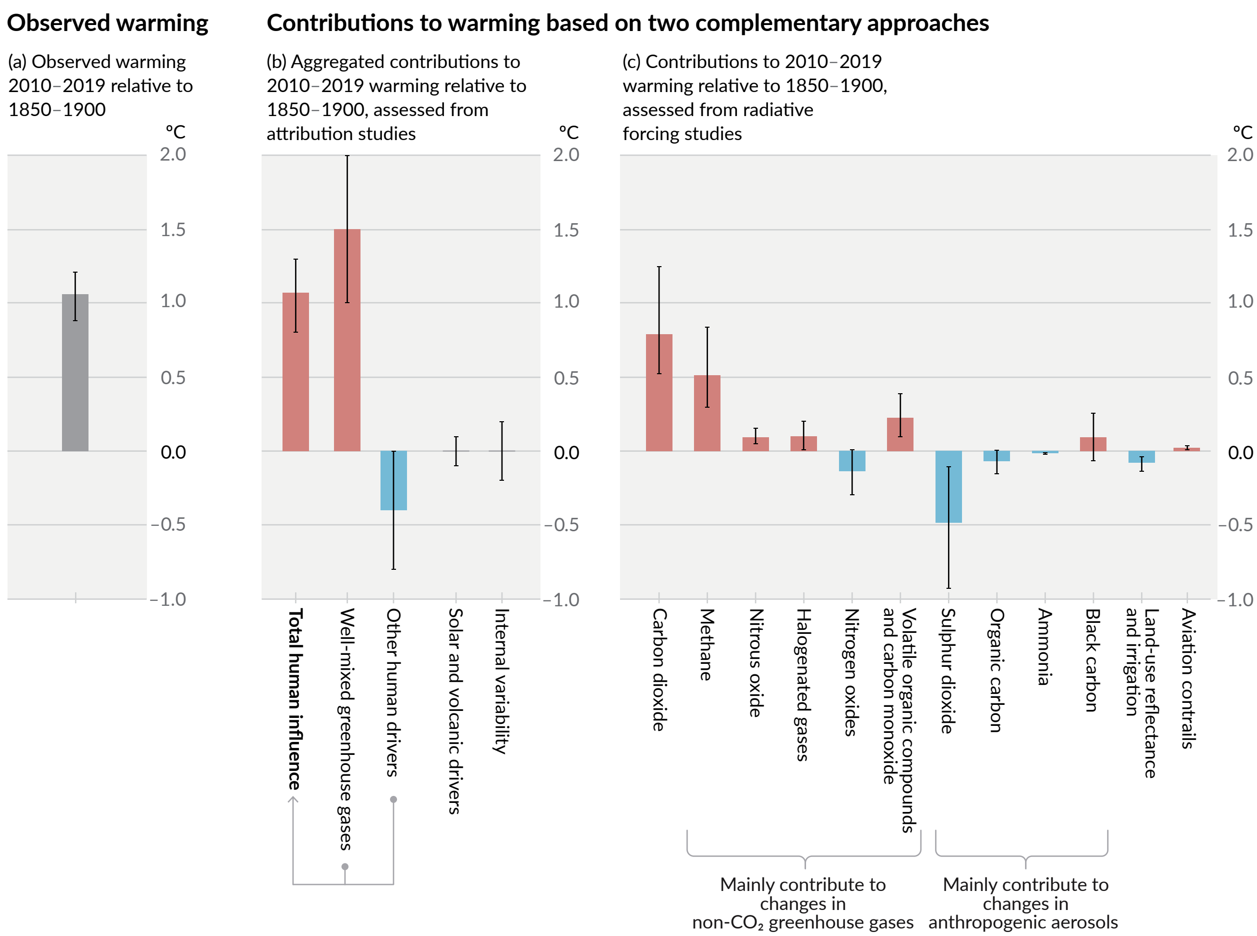

Figure SPM.2 | Assessed contributions to observed warming in 2010–2019 relative to 1850–1900

Panel (a) Observed global warming (increase in global surface temperature). Whiskers show the *very likely* range.

Panel (b) Evidence from attribution studies, which synthesize information from climate models and observations. The panel shows temperature change attributed to: total human influence; changes in well-mixed greenhouse gas concentrations; other human drivers due to aerosols, ozone and land-use change (land-use reflectance); solar and volcanic drivers; and internal climate variability. Whiskers show *likely* ranges.

Panel (c) Evidence from the assessment of radiative forcing and climate sensitivity. The panel shows temperature changes from individual components of human influence: emissions of greenhouse gases, aerosols and their precursors; land-use changes (land-use reflectance and irrigation); and aviation contrails. Whiskers show *very likely* ranges. Estimates account for both direct emissions into the atmosphere and their effect, if any, on other climate drivers. For aerosols, both direct effects (through radiation) and indirect effects (through interactions with clouds) are considered.

{Cross-Chapter Box 2.3, 3.3.1, 6.4.2, 7.3}

A.2 The scale of recent changes across the climate system as a whole – and the present state of many aspects of the climate system – are unprecedented over many centuries to many thousands of years. {2.2, 2.3, Cross-Chapter Box 2.1, 5.1} (Figure SPM.1)

A.2.1 In 2019, atmospheric CO_2 concentrations were higher than at any time in at least 2 million years (*high confidence*), and concentrations of CH_4 and N_2O were higher than at any time in at least 800,000 years (*very high confidence*). Since 1750, increases in CO_2 (47%) and CH_4 (156%) concentrations far exceed – and increases in N_2O (23%) are similar to – the natural multi-millennial changes between glacial and interglacial periods over at least the past 800,000 years (*very high confidence*). {2.2, 5.1, TS.2.2}

A.2.2 Global surface temperature has increased faster since 1970 than in any other 50-year period over at least the last 2000 years (*high confidence*). Temperatures during the most recent decade (2011–2020) exceed those of the most recent multi-century warm period, around 6500 years ago[13] [0.2°C to 1°C relative to 1850–1900] (*medium confidence*). Prior to that, the next most recent warm period was about 125,000 years ago, when the multi-century temperature [0.5°C to 1.5°C relative to 1850–1900] overlaps the observations of the most recent decade (*medium confidence*). {2.3, Cross-Chapter Box 2.1, Cross-Section Box TS.1} (Figure SPM.1)

A.2.3 In 2011–2020, annual average Arctic sea ice area reached its lowest level since at least 1850 (*high confidence*). Late summer Arctic sea ice area was smaller than at any time in at least the past 1000 years (*medium confidence*). The global nature of glacier retreat since the 1950s, with almost all of the world's glaciers retreating synchronously, is unprecedented in at least the last 2000 years (*medium confidence*). {2.3, TS.2.5}

A.2.4 Global mean sea level has risen faster since 1900 than over any preceding century in at least the last 3000 years (*high confidence*). The global ocean has warmed faster over the past century than since the end of the last deglacial transition (around 11,000 years ago) (*medium confidence*). A long-term increase in surface open ocean pH occurred over the past 50 million years (*high confidence*). However, surface open ocean pH as low as recent decades is unusual in the last 2 million years (*medium confidence*). {2.3, TS.2.4, Box TS.4}

A.3 Human-induced climate change is already affecting many weather and climate extremes in every region across the globe. Evidence of observed changes in extremes such as heatwaves, heavy precipitation, droughts, and tropical cyclones, and, in particular, their attribution to human influence, has strengthened since AR5. {2.3, 3.3, 8.2, 8.3, 8.4, 8.5, 8.6, Box 8.1, Box 8.2, Box 9.2, 10.6, 11.2, 11.3, 11.4, 11.6, 11.7, 11.8, 11.9, 12.3} (Figure SPM.3)

A.3.1 It is *virtually certain* that hot extremes (including heatwaves) have become more frequent and more intense across most land regions since the 1950s, while cold extremes (including cold waves) have become less frequent and less severe, with *high confidence* that human-induced climate change is the main driver[14] of these changes. Some recent hot extremes observed over the past decade would have been *extremely unlikely* to occur without human influence on the climate system. Marine heatwaves have approximately doubled in frequency since the 1980s (*high confidence*), and human influence has *very likely* contributed to most of them since at least 2006. {Box 9.2, 11.2, 11.3, 11.9, TS.2.4, TS.2.6, Box TS.10} (Figure SPM.3)

A.3.2 The frequency and intensity of heavy precipitation events have increased since the 1950s over most land area for which observational data are sufficient for trend analysis (*high confidence*), and human-induced climate change is *likely* the main driver. Human-induced climate change has contributed to increases in agricultural and ecological droughts[15] in some regions due to increased land evapotranspiration[16] (*medium confidence*). {8.2, 8.3, 11.4, 11.6, 11.9, TS.2.6, Box TS.10} (Figure SPM.3)

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13 As stated in section B.1, even under the very low emissions scenario SSP1-1.9, temperatures are assessed to remain elevated above those of the most recent decade until at least 2100 and therefore warmer than the century-scale period 6500 years ago.

14 As indicated in footnote 12, throughout this SPM, 'main driver' means responsible for more than 50% of the change.

15 Agricultural and ecological drought (depending on the affected biome): a period with abnormal soil moisture deficit, which results from combined shortage of precipitation and excess evapotranspiration, and during the growing season impinges on crop production or ecosystem function in general (see Annex VII: Glossary). Observed changes in meteorological droughts (precipitation deficits) and hydrological droughts (streamflow deficits) are distinct from those in agricultural and ecological droughts and are addressed in the underlying AR6 material (Chapter 11).

16 The combined processes through which water is transferred to the atmosphere from open water and ice surfaces, bare soils and vegetation that make up the Earth's surface (Glossary).

A.3.3 Decreases in global land monsoon precipitation[17] from the 1950s to the 1980s are partly attributed to human-caused Northern Hemisphere aerosol emissions, but increases since then have resulted from rising GHG concentrations and decadal to multi-decadal internal variability (*medium confidence*). Over South Asia, East Asia and West Africa, increases in monsoon precipitation due to warming from GHG emissions were counteracted by decreases in monsoon precipitation due to cooling from human-caused aerosol emissions over the 20th century (*high confidence*). Increases in West African monsoon precipitation since the 1980s are partly due to the growing influence of GHGs and reductions in the cooling effect of human-caused aerosol emissions over Europe and North America (*medium confidence*).
{2.3, 3.3, 8.2, 8.3, 8.4, 8.5, 8.6, Box 8.1, Box 8.2, 10.6, Box TS.13}

A.3.4 It is *likely* that the global proportion of major (Category 3–5) tropical cyclone occurrence has increased over the last four decades, and it is *very likely* that the latitude where tropical cyclones in the western North Pacific reach their peak intensity has shifted northward; these changes cannot be explained by internal variability alone (*medium confidence*). There is *low confidence* in long-term (multi-decadal to centennial) trends in the frequency of all-category tropical cyclones. Event attribution studies and physical understanding indicate that human-induced climate change increases heavy precipitation associated with tropical cyclones (*high confidence*), but data limitations inhibit clear detection of past trends on the global scale.
{8.2, 11.7, Box TS.10}

A.3.5 Human influence has *likely* increased the chance of compound extreme events[18] since the 1950s. This includes increases in the frequency of concurrent heatwaves and droughts on the global scale (*high confidence*), fire weather in some regions of all inhabited continents (*medium confidence*), and compound flooding in some locations (*medium confidence*).
{11.6, 11.7, 11.8, 12.3, 12.4, TS.2.6, Table TS.5, Box TS.10}

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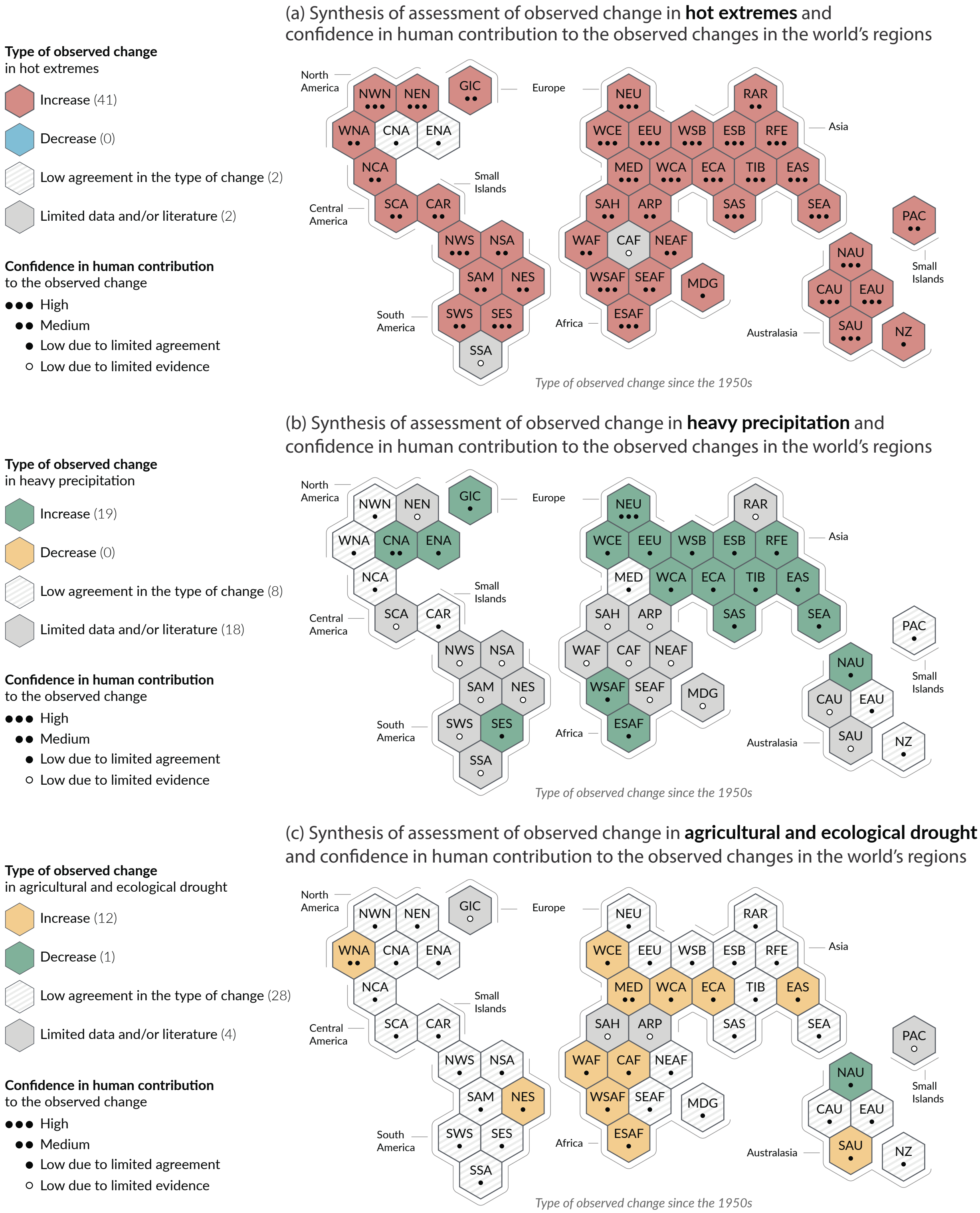
17 The global monsoon is defined as the area in which the annual range (local summer minus local winter) of precipitation is greater than 2.5 mm day^{-1} (Glossary). Global land monsoon precipitation refers to the mean precipitation over land areas within the global monsoon.

18 Compound extreme events are the combination of multiple drivers and/or hazards that contribute to societal or environmental risk (Glossary). Examples are concurrent heatwaves and droughts, compound flooding (e.g., a storm surge in combination with extreme rainfall and/or river flow), compound fire weather conditions (i.e., a combination of hot, dry and windy conditions), or concurrent extremes at different locations.

Climate change is already affecting every inhabited region across the globe, with human influence contributing to many observed changes in weather and climate extremes



Each hexagon corresponds to one of the IPCC AR6 WGI reference regions

NWN *North-Western North America*

IPCC AR6 WGI reference regions: **North America: NWN** *(North-Western North America,* **NEN** *(North-Eastern North America),* **WNA** *(Western North America),* **CNA** *(Central North America),* **ENA** *(Eastern North America),* **Central America: NCA** *(Northern Central America),* **SCA** *(Southern Central America),* **CAR** *(Caribbean),* **South America: NWS** *(North-Western South America),* **NSA** *(Northern South America),* **NES** *(North-Eastern South America),* **SAM** *(South American Monsoon),* **SWS** *(South-Western South America),* **SES** *(South-Eastern South America),* **SSA** *(Southern South America),* **Europe: GIC** *(Greenland/Iceland),* **NEU** *(Northern Europe),* **WCE** *(Western and Central Europe),* **EEU** *(Eastern Europe),* **MED** *(Mediterranean),* **Africa: MED** *(Mediterranean),* **SAH** *(Sahara),* **WAF** *(Western Africa),* **CAF** *(Central Africa),* **NEAF** *(North Eastern Africa),* **SEAF** *(South Eastern Africa),* **WSAF** *(West Southern Africa),* **ESAF** *(East Southern Africa),* **MDG** *(Madagascar),* **Asia: RAR** *(Russian Arctic),* **WSB** *(West Siberia),* **ESB** *(East Siberia),* **RFE** *(Russian Far East),* **WCA** *(West Central Asia),* **ECA** *(East Central Asia),* **TIB** *(Tibetan Plateau),* **EAS** *(East Asia),* **ARP** *(Arabian Peninsula),* **SAS** *(South Asia),* **SEA** *(South East Asia),* **Australasia: NAU** *(Northern Australia),* **CAU** *(Central Australia),* **EAU** *(Eastern Australia),* **SAU** *(Southern Australia),* **NZ** *(New Zealand),* **Small Islands: CAR** *(Caribbean),* **PAC** *(Pacific Small Islands)*

Figure SPM.3 | Synthesis of assessed observed and attributable regional changes

The IPCC AR6 WGI inhabited regions are displayed as **hexagons** with identical size in their approximate geographical location (see legend for regional acronyms). All assessments are made for each region as a whole and for the 1950s to the present. Assessments made on different time scales or more local spatial scales might differ from what is shown in the figure. The **colours** in each panel represent the four outcomes of the assessment on observed changes. Striped hexagons (white and light-grey) are used where there is *low agreement* in the type of change for the region as a whole, and grey hexagons are used when there is limited data and/or literature that prevents an assessment of the region as a whole. Other colours indicate at least *medium confidence* in the observed change. The **confidence level** for the human influence on these observed changes is based on assessing trend detection and attribution and event attribution literature, and it is indicated by the number of dots: three dots for *high confidence*, two dots for *medium confidence* and one dot for *low confidence* (single, filled dot: limited agreement; single, empty dot: limited evidence).

Panel (a) For hot extremes, the evidence is mostly drawn from changes in metrics based on daily maximum temperatures; regional studies using other indices (heatwave duration, frequency and intensity) are used in addition. Red hexagons indicate regions where there is at least *medium confidence* in an observed increase in hot extremes.

Panel (b) For heavy precipitation, the evidence is mostly drawn from changes in indices based on one-day or five-day precipitation amounts using global and regional studies. Green hexagons indicate regions where there is at least *medium confidence* in an observed increase in heavy precipitation.

Panel (c) Agricultural and ecological droughts are assessed based on observed and simulated changes in total column soil moisture, complemented by evidence on changes in surface soil moisture, water balance (precipitation minus evapotranspiration) and indices driven by precipitation and atmospheric evaporative demand. Yellow hexagons indicate regions where there is at least *medium confidence* in an observed increase in this type of drought, and green hexagons indicate regions where there is at least *medium confidence* in an observed decrease in agricultural and ecological drought.

For all regions, Table TS.5 shows a broader range of observed changes besides the ones shown in this figure. Note that Southern South America (SSA) is the only region that does not display observed changes in the metrics shown in this figure, but is affected by observed increases in mean temperature, decreases in frost and increases in marine heatwaves.

{11.9, Atlas 1.3.3, Figure Atlas.2, Table TS.5; Box TS.10, Figure 1}

A.4 Improved knowledge of climate processes, paleoclimate evidence and the response of the climate system to increasing radiative forcing gives a best estimate of equilibrium climate sensitivity of 3°C, with a narrower range compared to AR5.
{2.2, 7.3, 7.4, 7.5, Box 7.2, 9.4, 9.5, 9.6, Cross-Chapter Box 9.1}

A.4.1 Human-caused radiative forcing of 2.72 [1.96 to 3.48] W m^{-2} in 2019 relative to 1750 has warmed the climate system. This warming is mainly due to increased GHG concentrations, partly reduced by cooling due to increased aerosol concentrations. The radiative forcing has increased by 0.43 W m^{-2} (19%) relative to AR5, of which 0.34 W m^{-2} is due to the increase in GHG concentrations since 2011. The remainder is due to improved scientific understanding and changes in the assessment of aerosol forcing, which include decreases in concentration and improvement in its calculation (*high confidence*).
{2.2, 7.3, TS.2.2, TS.3.1}

A.4.2 Human-caused net positive radiative forcing causes an accumulation of additional energy (heating) in the climate system, partly reduced by increased energy loss to space in response to surface warming. The observed average rate of heating of the climate system increased from 0.50 [0.32 to 0.69] W m^{-2} for the period 1971–2006[19] to 0.79 [0.52 to 1.06] W m^{-2} for the period 2006–2018[20] (*high confidence*). Ocean warming accounted for 91% of the heating in the climate system, with land warming, ice loss and atmospheric warming accounting for about 5%, 3% and 1%, respectively (*high confidence*).
{7.2, Box 7.2, TS.3.1}

A.4.3 Heating of the climate system has caused global mean sea level rise through ice loss on land and thermal expansion from ocean warming. Thermal expansion explained 50% of sea level rise during 1971–2018, while ice loss from glaciers contributed 22%, ice sheets 20% and changes in land-water storage 8%. The rate of ice-sheet loss increased by a factor of four between 1992–1999 and 2010–2019. Together, ice-sheet and glacier mass loss were the dominant contributors to global mean sea level rise during 2006–2018 (*high confidence*).
{9.4, 9.5, 9.6, Cross-Chapter Box 9.1}

A.4.4 The equilibrium climate sensitivity is an important quantity used to estimate how the climate responds to radiative forcing. Based on multiple lines of evidence,[21] the *very likely* range of equilibrium climate sensitivity is between 2°C (*high confidence*) and 5°C (*medium confidence*). The AR6 assessed best estimate is 3°C with a *likely* range of 2.5°C to 4°C (*high confidence*), compared to 1.5°C to 4.5°C in AR5, which did not provide a best estimate.
{7.4, 7.5, TS.3.2}

19 Cumulative energy increase of 282 [177 to 387] ZJ over 1971–2006 (1 ZJ = 10^{21} joules).

20 Cumulative energy increase of 152 [100 to 205] ZJ over 2006–2018.

21 Understanding of climate processes, the instrumental record, paleoclimates and model-based emergent constraints (Glossary).

B. Possible Climate Futures

A set of five new illustrative emissions scenarios is considered consistently across this Report to explore the climate response to a broader range of greenhouse gas (GHG), land-use and air pollutant futures than assessed in AR5. This set of scenarios drives climate model projections of changes in the climate system. These projections account for solar activity and background forcing from volcanoes. Results over the 21st century are provided for the near term (2021–2040), mid-term (2041–2060) and long term (2081–2100) relative to 1850–1900, unless otherwise stated.

Box SPM.1 | Scenarios, Climate Models and Projections

Box SPM.1.1: This Report assesses the climate response to five illustrative scenarios that cover the range of possible future development of anthropogenic drivers of climate change found in the literature. They start in 2015, and include scenarios[22] with high and very high GHG emissions (SSP3-7.0 and SSP5-8.5) and CO_2 emissions that roughly double from current levels by 2100 and 2050, respectively, scenarios with intermediate GHG emissions (SSP2-4.5) and CO_2 emissions remaining around current levels until the middle of the century, and scenarios with very low and low GHG emissions and CO_2 emissions declining to net zero around or after 2050, followed by varying levels of net negative CO_2 emissions[23] (SSP1-1.9 and SSP1-2.6), as illustrated in Figure SPM.4. Emissions vary between scenarios depending on socio-economic assumptions, levels of climate change mitigation and, for aerosols and non-methane ozone precursors, air pollution controls. Alternative assumptions may result in similar emissions and climate responses, but the socio-economic assumptions and the feasibility or likelihood of individual scenarios are not part of the assessment.
{1.6, Cross-Chapter Box 1.4, TS.1.3} (Figure SPM.4)

Box SPM.1.2: This Report assesses results from climate models participating in the Coupled Model Intercomparison Project Phase 6 (CMIP6) of the World Climate Research Programme. These models include new and better representations of physical, chemical and biological processes, as well as higher resolution, compared to climate models considered in previous IPCC assessment reports. This has improved the simulation of the recent mean state of most large-scale indicators of climate change and many other aspects across the climate system. Some differences from observations remain, for example in regional precipitation patterns. The CMIP6 historical simulations assessed in this Report have an ensemble mean global surface temperature change within 0.2°C of the observations over most of the historical period, and observed warming is within the *very likely* range of the CMIP6 ensemble. However, some CMIP6 models simulate a warming that is either above or below the assessed *very likely* range of observed warming.
{1.5, Cross-Chapter Box 2.2, 3.3, 3.8, TS.1.2, Cross-Section Box TS.1} (Figure SPM.1b, Figure SPM.2)

Box SPM.1.3: The CMIP6 models considered in this Report have a wider range of climate sensitivity than in CMIP5 models and the AR6 assessed *very likely* range, which is based on multiple lines of evidence. These CMIP6 models also show a higher average climate sensitivity than CMIP5 and the AR6 assessed best estimate. The higher CMIP6 climate sensitivity values compared to CMIP5 can be traced to an amplifying cloud feedback that is larger in CMIP6 by about 20%.
{Box 7.1, 7.3, 7.4, 7.5, TS.3.2}

Box SPM.1.4: For the first time in an IPCC report, assessed future changes in global surface temperature, ocean warming and sea level are constructed by combining multi-model projections with observational constraints based on past simulated warming, as well as the AR6 assessment of climate sensitivity. For other quantities, such robust methods do not yet exist to constrain the projections. Nevertheless, robust projected geographical patterns of many variables can be identified at a given level of global warming, common to all scenarios considered and independent of timing when the global warming level is reached.
{1.6, 4.3, 4.6, Box 4.1, 7.5, 9.2, 9.6, Cross-Chapter Box 11.1, Cross-Section Box TS.1}

22 Throughout this Report, the five illustrative scenarios are referred to as SSPx-y, where 'SSPx' refers to the Shared Socio-economic Pathway or 'SSP' describing the socio-economic trends underlying the scenario, and 'y' refers to the approximate level of radiative forcing (in watts per square metre, or W m^{-2}) resulting from the scenario in the year 2100. A detailed comparison to scenarios used in earlier IPCC reports is provided in Section TS.1.3, and Sections 1.6 and 4.6. The SSPs that underlie the specific forcing scenarios used to drive climate models are not assessed by WGI. Rather, the SSPx-y labelling ensures traceability to the underlying literature in which specific forcing pathways are used as input to the climate models. IPCC is neutral with regard to the assumptions underlying the SSPs, which do not cover all possible scenarios. Alternative scenarios may be considered or developed.

23 Net negative CO_2 emissions are reached when anthropogenic removals of CO_2 exceed anthropogenic emissions (Glossary).

Box SPM.1 (continued)

Future emissions cause future additional warming, with total warming dominated by past and future CO_2 emissions

(a) Future annual emissions of CO_2 (left) and of a subset of key non-CO_2 drivers (right), across five illustrative scenarios

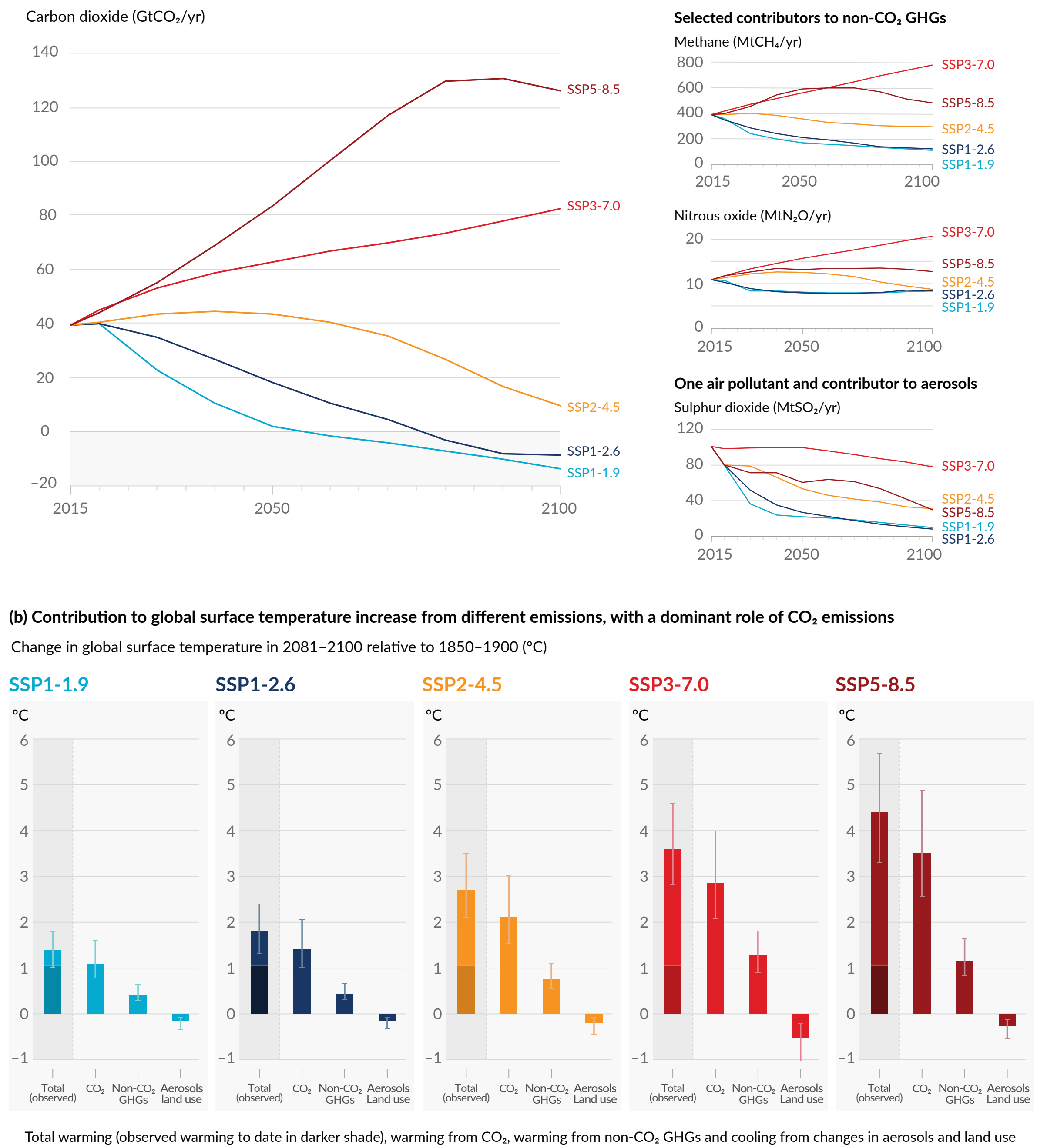


Figure SPM.4 | Future anthropogenic emissions of key drivers of climate change and warming contributions by groups of drivers for the five illustrative scenarios used in this report

The five scenarios are SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5.

Panel (a) Annual anthropogenic (human-caused) emissions over the 2015–2100 period. Shown are emissions trajectories for carbon dioxide (CO_2) from all sectors ($GtCO_2$/yr) (left graph) and for a subset of three key non-CO_2 drivers considered in the scenarios: methane (CH_4, $MtCH_4$/yr, top-right graph); nitrous oxide (N_2O, MtN_2O/yr, middle-right graph); and sulphur dioxide (SO_2, $MtSO_2$/yr, bottom-right graph, contributing to anthropogenic aerosols in panel (b).

Panel (b) Warming contributions by groups of anthropogenic drivers and by scenario are shown as the change in global surface temperature (°C) in 2081–2100 relative to 1850–1900, with indication of the observed warming to date. Bars and whiskers represent median values and the *very likely* range, respectively. Within each scenario bar plot, the bars represent: total global warming (°C; 'total' bar) (see Table SPM.1); warming contributions (°C) from changes in CO_2 ('CO_2' bar) and from non-CO_2 greenhouse gases (GHGs; 'non-CO_2 GHGs' bar: comprising well-mixed greenhouse gases and ozone); and net cooling from other anthropogenic drivers ('aerosols and land use' bar: anthropogenic aerosols, changes in reflectance due to land-use and irrigation changes, and contrails from aviation) (see Figure SPM.2, panel c, for the warming contributions to date for individual drivers). The best estimate for observed warming in 2010–2019 relative to 1850–1900 (see Figure SPM.2, panel a) is indicated in the darker column in the 'total' bar. Warming contributions in panel (b) are calculated as explained in Table SPM.1 for the total bar. For the other bars, the contribution by groups of drivers is calculated with a physical climate emulator of global surface temperature that relies on climate sensitivity and radiative forcing assessments.

{Cross-Chapter Box 1.4; 4.6; Figure 4.35; 6.7; Figures 6.18, 6.22 and 6.24; 7.3; Cross-Chapter Box 7.1; Figure 7.7; Box TS.7; Figures TS.4 and TS.15}

B.1 Global surface temperature will continue to increase until at least mid-century under all emissions scenarios considered. Global warming of 1.5°C and 2°C will be exceeded during the 21st century unless deep reductions in CO_2 and other greenhouse gas emissions occur in the coming decades.
{2.3, Cross-Chapter Box 2.3, Cross-Chapter Box 2.4, 4.3, 4.4, 4.5} (Figure SPM.1, Figure SPM.4, Figure SPM.8, Table SPM.1, Box SPM.1)

B.1.1 Compared to 1850–1900, global surface temperature averaged over 2081–2100 is *very likely* to be higher by 1.0°C to 1.8°C under the very low GHG emissions scenario considered (SSP1-1.9), by 2.1°C to 3.5°C in the intermediate GHG emissions scenario (SSP2-4.5) and by 3.3°C to 5.7°C under the very high GHG emissions scenario (SSP5-8.5).[24] The last time global surface temperature was sustained at or above 2.5°C higher than 1850–1900 was over 3 million years ago (*medium confidence*).
{2.3, Cross-Chapter Box 2.4, 4.3, 4.5, Box TS.2, Box TS.4, Cross-Section Box TS.1} (Table SPM.1)

Table SPM.1 | Changes in global surface temperature, which are assessed based on multiple lines of evidence, for selected 20-year time periods and the five illustrative emissions scenarios considered. Temperature differences relative to the average global surface temperature of the period 1850–1900 are reported in °C. This includes the revised assessment of observed historical warming for the AR5 reference period 1986–2005, which in AR6 is higher by 0.08 [–0.01 to +0.12] °C than in AR5 (see footnote 10). Changes relative to the recent reference period 1995–2014 may be calculated approximately by subtracting 0.85°C, the best estimate of the observed warming from 1850–1900 to 1995–2014.
{Cross-Chapter Box 2.3, 4.3, 4.4, Cross-Section Box TS.1}

	Near term, 2021–2040		Mid-term, 2041–2060		Long term, 2081–2100	
Scenario	Best estimate (°C)	*Very likely* range (°C)	Best estimate (°C)	*Very likely* range (°C)	Best estimate (°C)	*Very likely* range (°C)
SSP1-1.9	1.5	1.2 to 1.7	1.6	1.2 to 2.0	1.4	1.0 to 1.8
SSP1-2.6	1.5	1.2 to 1.8	1.7	1.3 to 2.2	1.8	1.3 to 2.4
SSP2-4.5	1.5	1.2 to 1.8	2.0	1.6 to 2.5	2.7	2.1 to 3.5
SSP3-7.0	1.5	1.2 to 1.8	2.1	1.7 to 2.6	3.6	2.8 to 4.6
SSP5-8.5	1.6	1.3 to 1.9	2.4	1.9 to 3.0	4.4	3.3 to 5.7

B.1.2 Based on the assessment of multiple lines of evidence, global warming of 2°C, relative to 1850–1900, would be exceeded during the 21st century under the high and very high GHG emissions scenarios considered in this report (SSP3-7.0 and SSP5-8.5, respectively). Global warming of 2°C would *extremely likely* be exceeded in the intermediate GHG emissions scenario (SSP2-4.5). Under the very low and low GHG emissions scenarios, global warming of 2°C is *extremely unlikely* to be exceeded (SSP1-1.9) or *unlikely* to be exceeded (SSP1-2.6).[25] Crossing the 2°C global warming level in the mid-term period (2041–2060) is *very likely* to occur under the very high GHG emissions scenario (SSP5-8.5), *likely* to occur under the high GHG emissions scenario (SSP3-7.0), and *more likely than not* to occur in the intermediate GHG emissions scenario (SSP2-4.5).[26]
{4.3, Cross-Section Box TS.1} (Table SPM.1, Figure SPM.4, Box SPM.1)

24 Changes in global surface temperature are reported as running 20-year averages, unless stated otherwise.

25 SSP1-1.9 and SSP1-2.6 are scenarios that start in 2015 and have very low and low GHG emissions, respectively, and CO_2 emissions declining to net zero around or after 2050, followed by varying levels of net negative CO_2 emissions.

26 Crossing is defined here as having the assessed global surface temperature change, averaged over a 20-year period, exceed a particular global warming level.

B.1.3 Global warming of 1.5°C relative to 1850–1900 would be exceeded during the 21st century under the intermediate, high and very high GHG emissions scenarios considered in this report (SSP2-4.5, SSP3-7.0 and SSP5-8.5, respectively). Under the five illustrative scenarios, in the near term (2021–2040), the 1.5°C global warming level is *very likely* to be exceeded under the very high GHG emissions scenario (SSP5-8.5), *likely* to be exceeded under the intermediate and high GHG emissions scenarios (SSP2-4.5 and SSP3-7.0), *more likely than not* to be exceeded under the low GHG emissions scenario (SSP1-2.6) and *more likely than not* to be reached under the very low GHG emissions scenario (SSP1-1.9).[27] Furthermore, for the very low GHG emissions scenario (SSP1-1.9), it is *more likely than not* that global surface temperature would decline back to below 1.5°C toward the end of the 21st century, with a temporary overshoot of no more than 0.1°C above 1.5°C global warming.
{4.3, Cross-Section Box TS.1} (Table SPM.1, Figure SPM.4)

B.1.4 Global surface temperature in any single year can vary above or below the long-term human-induced trend, due to substantial natural variability.[28] The occurrence of individual years with global surface temperature change above a certain level, for example 1.5°C or 2°C, relative to 1850–1900 does not imply that this global warming level has been reached.[29]
{Cross-Chapter Box 2.3, 4.3, 4.4, Box 4.1, Cross-Section Box TS.1} (Table SPM.1, Figure SPM.1, Figure SPM.8)

B.2 Many changes in the climate system become larger in direct relation to increasing global warming. They include increases in the frequency and intensity of hot extremes, marine heatwaves, heavy precipitation, and, in some regions, agricultural and ecological droughts; an increase in the proportion of intense tropical cyclones; and reductions in Arctic sea ice, snow cover and permafrost.
{4.3, 4.5, 4.6, 7.4, 8.2, 8.4, Box 8.2, 9.3, 9.5, Box 9.2, 11.1, 11.2, 11.3, 11.4, 11.6, 11.7, 11.9, Cross-Chapter Box 11.1, 12.4, 12.5, Cross-Chapter Box 12.1, Atlas.4, Atlas.5, Atlas.6, Atlas.7, Atlas.8, Atlas.9, Atlas.10, Atlas.11} (Figure SPM.5, Figure SPM.6, Figure SPM.8)

B.2.1 It is *virtually certain* that the land surface will continue to warm more than the ocean surface (*likely* 1.4 to 1.7 times more). It is *virtually certain* that the Arctic will continue to warm more than global surface temperature, with *high confidence* above two times the rate of global warming.
{2.3, 4.3, 4.5, 4.6, 7.4, 11.1, 11.3, 11.9, 12.4, 12.5, Cross-Chapter Box 12.1, Atlas.4, Atlas.5, Atlas.6, Atlas.7, Atlas.8, Atlas.9, Atlas.10, Atlas.11, Cross-Section Box TS.1, TS.2.6} (Figure SPM.5)

B.2.2 With every additional increment of global warming, changes in extremes continue to become larger. For example, every additional 0.5°C of global warming causes clearly discernible increases in the intensity and frequency of hot extremes, including heatwaves (*very likely*), and heavy precipitation (*high confidence*), as well as agricultural and ecological droughts[30] in some regions (*high confidence*). Discernible changes in intensity and frequency of meteorological droughts, with more regions showing increases than decreases, are seen in some regions for every additional 0.5°C of global warming (*medium confidence*). Increases in frequency and intensity of hydrological droughts become larger with increasing global warming in some regions (*medium confidence*). There will be an increasing occurrence of some extreme events unprecedented in the observational record with additional global warming, even at 1.5°C of global warming. Projected percentage changes in frequency are larger for rarer events (*high confidence*).
{8.2, 11.2, 11.3, 11.4, 11.6, 11.9, Cross-Chapter Box 11.1, Cross-Chapter Box 12.1, TS.2.6} (Figure SPM.5, Figure SPM.6)

B.2.3 Some mid-latitude and semi-arid regions, and the South American Monsoon region, are projected to see the highest increase in the temperature of the hottest days, at about 1.5 to 2 times the rate of global warming (*high confidence*). The Arctic is projected to experience the highest increase in the temperature of the coldest days, at about three times the rate of global warming (*high confidence*). With additional global warming, the frequency of marine heatwaves will continue to increase (*high confidence*), particularly in the tropical ocean and the Arctic (*medium confidence*).
{Box 9.2, 11.1, 11.3, 11.9, Cross-Chapter Box 11.1, Cross-Chapter Box 12.1, 12.4, TS.2.4, TS.2.6} (Figure SPM.6)

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27 The AR6 assessment of when a given global warming level is first exceeded benefits from the consideration of the illustrative scenarios, the multiple lines of evidence entering the assessment of future global surface temperature response to radiative forcing, and the improved estimate of historical warming. The AR6 assessment is thus not directly comparable to the SR1.5 SPM, which reported *likely* reaching 1.5°C global warming between 2030 and 2052, from a simple linear extrapolation of warming rates of the recent past. When considering scenarios similar to SSP1-1.9 instead of linear extrapolation, the SR1.5 estimate of when 1.5°C global warming is first exceeded is close to the best estimate reported here.

28 Natural variability refers to climatic fluctuations that occur without any human influence, that is, internal variability combined with the response to external natural factors such as volcanic eruptions, changes in solar activity and, on longer time scales, orbital effects and plate tectonics (Glossary).

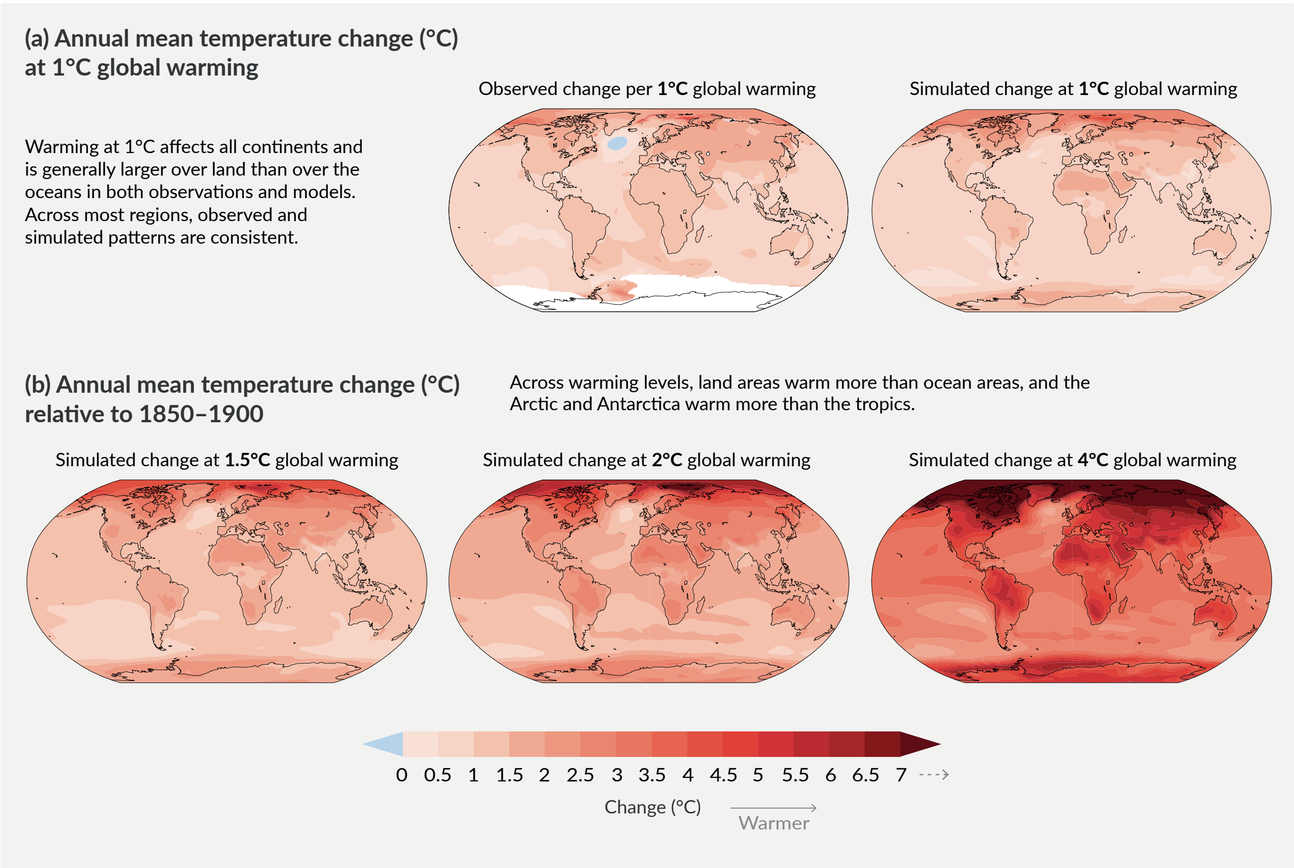
29 The internal variability in any single year is estimated to be about ±0.25°C (5–95% range, *high confidence*).

30 Projected changes in agricultural and ecological droughts are primarily assessed based on total column soil moisture. See footnote 15 for definition and relation to precipitation and evapotranspiration.

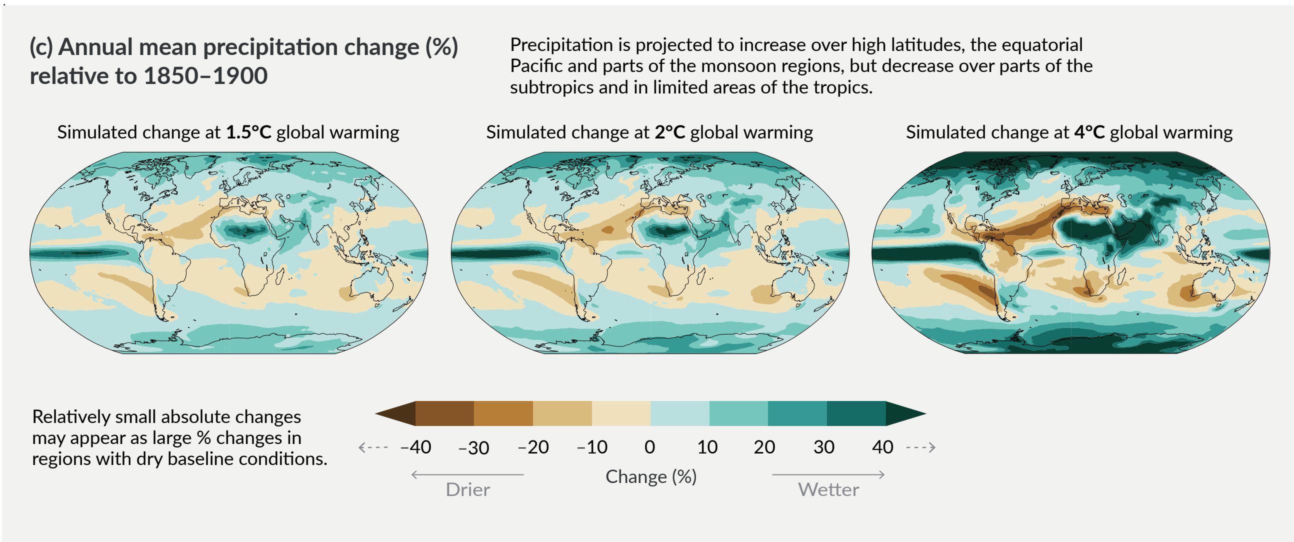
B.2.4 It is *very likely* that heavy precipitation events will intensify and become more frequent in most regions with additional global warming. At the global scale, extreme daily precipitation events are projected to intensify by about 7% for each 1°C of global warming (*high confidence*). The proportion of intense tropical cyclones (Category 4–5) and peak wind speeds of the most intense tropical cyclones are projected to increase at the global scale with increasing global warming (*high confidence*). {8.2, 11.4, 11.7, 11.9, Cross-Chapter Box 11.1, Box TS.6, TS.4.3.1} (Figure SPM.5, Figure SPM.6)

B.2.5 Additional warming is projected to further amplify permafrost thawing and loss of seasonal snow cover, of land ice and of Arctic sea ice (*high confidence*). The Arctic is *likely* to be practically sea ice-free in September[31] at least once before 2050 under the five illustrative scenarios considered in this report, with more frequent occurrences for higher warming levels. There is *low confidence* in the projected decrease of Antarctic sea ice. {4.3, 4.5, 7.4, 8.2, 8.4, Box 8.2, 9.3, 9.5, 12.4, Cross-Chapter Box 12.1, Atlas.5, Atlas.6, Atlas.8, Atlas.9, Atlas.11, TS.2.5} (Figure SPM.8)

With every increment of global warming, changes get larger in regional mean temperature, precipitation and soil moisture



31 Monthly average sea ice area of less than 1 million km², which is about 15% of the average September sea ice area observed in 1979–1988.



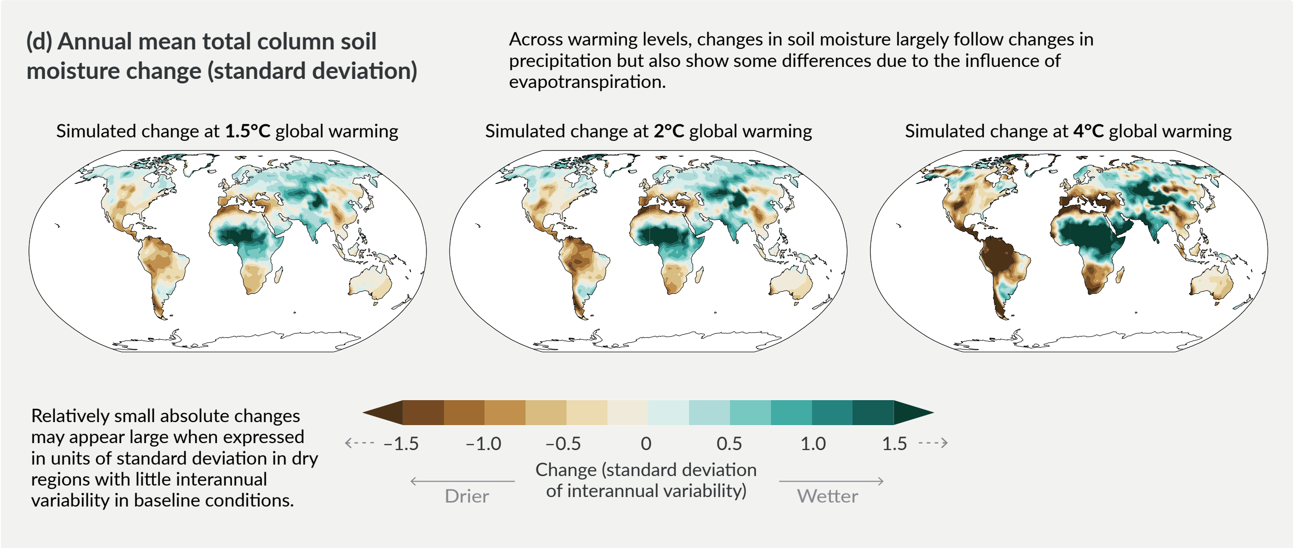


Figure SPM.5 | Changes in annual mean surface temperature, precipitation, and soil moisture

Panel (a) Comparison of observed and simulated annual mean surface temperature change. The **left map** shows the observed changes in annual mean surface temperature in the period 1850–2020 per °C of global warming (°C). The local (i.e., grid point) observed annual mean surface temperature changes are linearly regressed against the global surface temperature in the period 1850–2020. Observed temperature data are from Berkeley Earth, the dataset with the largest coverage and highest horizontal resolution. Linear regression is applied to all years for which data at the corresponding grid point is available. The regression method was used to take into account the complete observational time series and thereby reduce the role of internal variability at the grid point level. White indicates areas where time coverage was 100 years or less and thereby too short to calculate a reliable linear regression. The **right map** is based on model simulations and shows change in annual multi-model mean simulated temperatures at a global warming level of 1°C (20-year mean global surface temperature change relative to 1850–1900). The triangles at each end of the colour bar indicate out-of-bound values, that is, values above or below the given limits.

Panel (b) Simulated annual mean temperature change (°C), panel (c) precipitation change (%), and panel (d) total column soil moisture change (standard deviation of interannual variability) at global warming levels of 1.5°C, 2°C and 4°C (20-year mean global surface temperature change relative to 1850–1900). Simulated changes correspond to Coupled Model Intercomparison Project Phase 6 (CMIP6) multi-model mean change (median change for soil moisture) at the corresponding global warming level, that is, the same method as for the right map in panel (a).

In **panel (c)**, high positive percentage changes in dry regions may correspond to small absolute changes. In **panel (d)**, the unit is the standard deviation of interannual variability in soil moisture during 1850–1900. Standard deviation is a widely used metric in characterizing drought severity. A projected reduction in mean soil moisture by one standard deviation corresponds to soil moisture conditions typical of droughts that occurred about once every six years during 1850–1900. In panel (d), large changes in dry regions with little interannual variability in the baseline conditions can correspond to small absolute change. The triangles at each end of the colour bars indicate out-of-bound values, that is, values above or below the given limits. Results from all models reaching the corresponding warming level in any of the five illustrative scenarios (SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5) are averaged. Maps of annual mean temperature and precipitation changes at a global warming level of 3°C are available in Figure 4.31 and Figure 4.32 in Section 4.6. Corresponding maps of panels (b), (c) and (d), including hatching to indicate the level of model agreement at grid-cell level, are found in Figures 4.31, 4.32 and 11.19, respectively; as highlighted in Cross-Chapter Box Atlas.1, grid-cell level hatching is not informative for larger spatial scales (e.g., over AR6 reference regions) where the aggregated signals are less affected by small-scale variability, leading to an increase in robustness.

{Figure 1.14, 4.6.1, Cross-Chapter Box 11.1, Cross-Chapter Box Atlas.1, TS.1.3.2, Figures TS.3 and TS.5}

Projected changes in extremes are larger in frequency and intensity with every additional increment of global warming

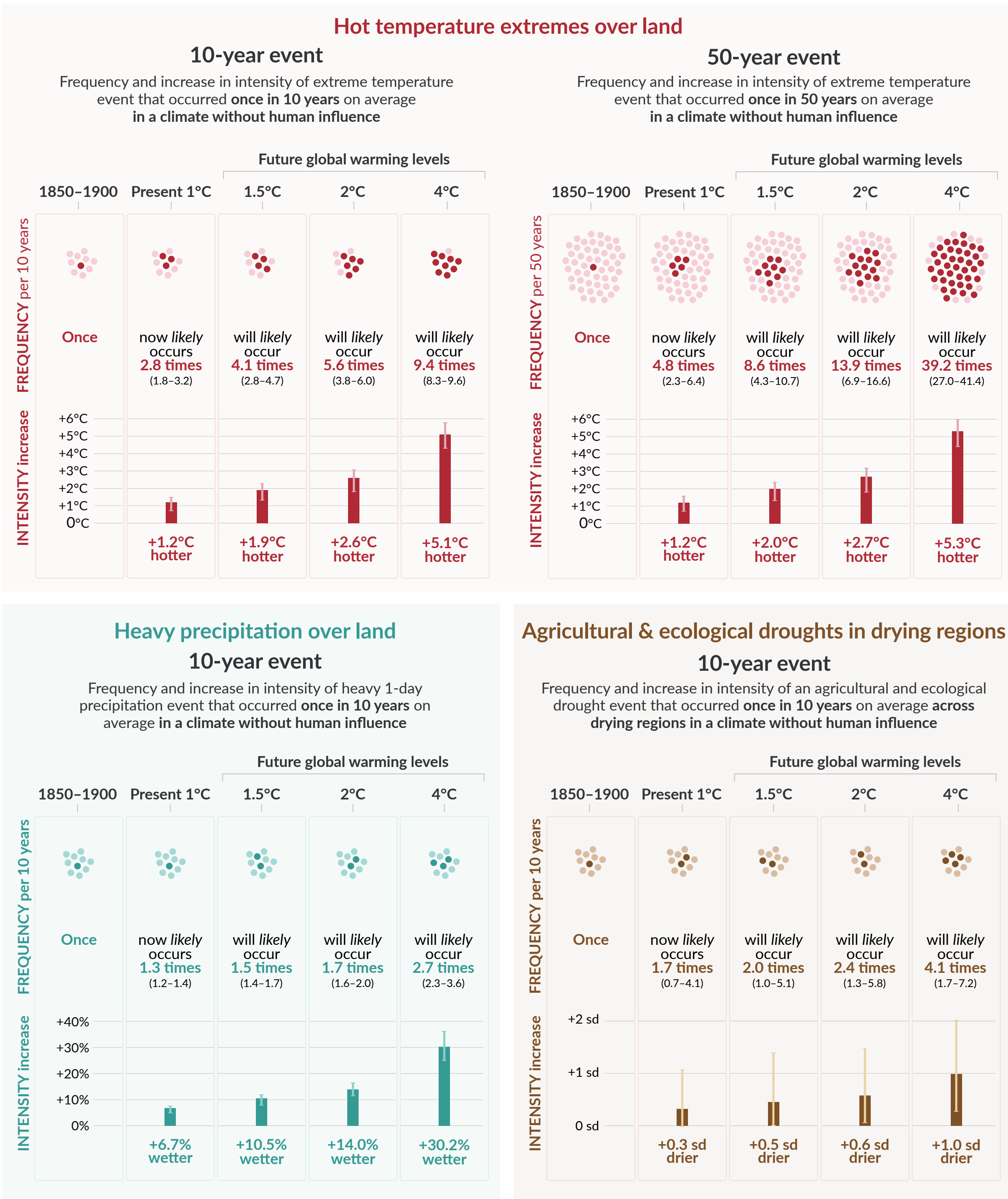


Figure SPM.6 | Projected changes in the intensity and frequency of hot temperature extremes over land, extreme precipitation over land, and agricultural and ecological droughts in drying regions

Projected changes are shown at global warming levels of 1°C, 1.5°C, 2°C, and 4°C and are relative to 1850–1900,[9] representing a climate without human influence. The figure depicts frequencies and increases in intensity of 10- or 50-year extreme events from the base period (1850–1900) under different global warming levels.

Hot temperature extremes are defined as the daily maximum temperatures over land that were exceeded on average once in a decade (10-year event) or once in 50 years (50-year event) during the 1850–1900 reference period. **Extreme precipitation events** are defined as the daily precipitation amount over land that was exceeded on average once in a decade during the 1850–1900 reference period. **Agricultural and ecological drought events** are defined as the annual average of total column soil moisture below the 10th percentile of the 1850–1900 base period. These extremes are defined on model grid box scale. For hot temperature extremes and extreme precipitation, results are shown for the global land. For agricultural and ecological drought, results are shown for drying regions only, which correspond to the AR6 regions in which there is at least *medium confidence* in a projected increase in agricultural and ecological droughts at the 2°C warming level compared to the 1850–1900 base period in the Coupled Model Intercomparison Project Phase 6 (CMIP6). These regions include Western North America, Central North America, Northern Central America, Southern Central America, Caribbean, Northern South America, North-Eastern South America, South American Monsoon, South-Western South America, Southern South America, Western and Central Europe, Mediterranean, West Southern Africa, East Southern Africa, Madagascar, Eastern Australia, and Southern Australia (Caribbean is not included in the calculation of the figure because of the too-small number of full land grid cells). The non-drying regions do not show an overall increase or decrease in drought severity. Projections of changes in agricultural and ecological droughts in the CMIP Phase 5 (CMIP5) multi-model ensemble differ from those in CMIP6 in some regions, including in parts of Africa and Asia. Assessments of projected changes in meteorological and hydrological droughts are provided in Chapter 11.

In the **'frequency' section**, each year is represented by a dot. The dark dots indicate years in which the extreme threshold is exceeded, while light dots are years when the threshold is not exceeded. Values correspond to the medians (in bold) and their respective *likely* ranges based on the 5–95% range of the multi-model ensemble from simulations of CMIP6 under different Shared Socio-economic Pathway scenarios. For consistency, the number of dark dots is based on the rounded-up median. In the **'intensity' section**, medians and their *likely* ranges, also based on the 5–95% range of the multi-model ensemble from simulations of CMIP6, are displayed as dark and light bars, respectively. Changes in the intensity of hot temperature extremes and extreme precipitation are expressed as degree Celsius and percentage. As for agricultural and ecological drought, intensity changes are expressed as fractions of standard deviation of annual soil moisture.

{11.1; 11.3; 11.4; 11.6; 11.9; Figures 11.12, 11.15, 11.6, 11.7, and 11.18}

B.3 Continued global warming is projected to further intensify the global water cycle, including its variability, global monsoon precipitation and the severity of wet and dry events.
{4.3, 4.4, 4.5, 4.6, 8.2, 8.3, 8.4, 8.5, Box 8.2, 11.4, 11.6, 11.9, 12.4, Atlas.3} (Figure SPM.5, Figure SPM.6)

B.3.1 There is strengthened evidence since AR5 that the global water cycle will continue to intensify as global temperatures rise (*high confidence*), with precipitation and surface water flows projected to become more variable over most land regions within seasons (*high confidence*) and from year to year (*medium confidence*). The average annual global land precipitation is projected to increase by 0–5% under the very low GHG emissions scenario (SSP1-1.9), 1.5–8% for the intermediate GHG emissions scenario (SSP2-4.5) and 1–13% under the very high GHG emissions scenario (SSP5-8.5) by 2081–2100 relative to 1995–2014 (*likely* ranges). Precipitation is projected to increase over high latitudes, the equatorial Pacific and parts of the monsoon regions, but decrease over parts of the subtropics and limited areas in the tropics in SSP2-4.5, SSP3-7.0 and SSP5-8.5 (*very likely*). The portion of the global land experiencing detectable increases or decreases in seasonal mean precipitation is projected to increase (*medium confidence*). There is *high confidence* in an earlier onset of spring snowmelt, with higher peak flows at the expense of summer flows in snow-dominated regions globally.
{4.3, 4.5, 4.6, 8.2, 8.4, Atlas.3, TS.2.6, TS.4.3, Box TS.6} (Figure SPM.5)

B.3.2 A warmer climate will intensify very wet and very dry weather and climate events and seasons, with implications for flooding or drought (*high confidence*), but the location and frequency of these events depend on projected changes in regional atmospheric circulation, including monsoons and mid-latitude storm tracks. It is *very likely* that rainfall variability related to the El Niño–Southern Oscillation is projected to be amplified by the second half of the 21st century in the SSP2-4.5, SSP3-7.0 and SSP5-8.5 scenarios.
{4.3, 4.5, 4.6, 8.2, 8.4, 8.5, 11.4, 11.6, 11.9, 12.4, TS.2.6, TS.4.2, Box TS.6} (Figure SPM.5, Figure SPM.6)

B.3.3 Monsoon precipitation is projected to increase in the mid- to long term at the global scale, particularly over South and South East Asia, East Asia and West Africa apart from the far west Sahel (*high confidence*). The monsoon season is projected to have a delayed onset over North and South America and West Africa (*high confidence*) and a delayed retreat over West Africa (*medium confidence*).
{4.4, 4.5, 8.2, 8.3, 8.4, Box 8.2, Box TS.13}

B.3.4 A projected southward shift and intensification of Southern Hemisphere summer mid-latitude storm tracks and associated precipitation is *likely* in the long term under high GHG emissions scenarios (SSP3-7.0, SSP5-8.5), but in the near term the effect of stratospheric ozone recovery counteracts these changes (*high confidence*). There is *medium confidence* in a continued poleward shift of storms and their precipitation in the North Pacific, while there is *low confidence* in projected changes in the North Atlantic storm tracks.
{4.4, 4.5, 8.4, TS.2.3, TS.4.2}

B.4 Under scenarios with increasing CO_2 emissions, the ocean and land carbon sinks are projected to be less effective at slowing the accumulation of CO_2 in the atmosphere.
{4.3, 5.2, 5.4, 5.5, 5.6} (Figure SPM.7)

SPM

B.4.1 While natural land and ocean carbon sinks are projected to take up, in absolute terms, a progressively larger amount of CO_2 under higher compared to lower CO_2 emissions scenarios, they become less effective, that is, the proportion of emissions taken up by land and ocean decrease with increasing cumulative CO_2 emissions. This is projected to result in a higher proportion of emitted CO_2 remaining in the atmosphere (*high confidence*).
{5.2, 5.4, Box TS.5} (Figure SPM.7)

B.4.2 Based on model projections, under the intermediate GHG emissions scenario that stabilizes atmospheric CO_2 concentrations this century (SSP2-4.5), the rates of CO_2 taken up by the land and ocean are projected to decrease in the second half of the 21st century (*high confidence*). Under the very low and low GHG emissions scenarios (SSP1-1.9, SSP1-2.6), where CO_2 concentrations peak and decline during the 21st century, the land and ocean begin to take up less carbon in response to declining atmospheric CO_2 concentrations (*high confidence*) and turn into a weak net source by 2100 under SSP1-1.9 (*medium confidence*). It is *very unlikely* that the combined global land and ocean sink will turn into a source by 2100 under scenarios without net negative emissions (SSP2-4.5, SSP3-7.0, SSP5-8.5).[32]
{4.3, 5.4, 5.5, 5.6, Box TS.5, TS.3.3}

B.4.3 The magnitude of feedbacks between climate change and the carbon cycle becomes larger but also more uncertain in high CO_2 emissions scenarios (*very high confidence*). However, climate model projections show that the uncertainties in atmospheric CO_2 concentrations by 2100 are dominated by the differences between emissions scenarios (*high confidence*). Additional ecosystem responses to warming not yet fully included in climate models, such as CO_2 and CH_4 fluxes from wetlands, permafrost thaw and wildfires, would further increase concentrations of these gases in the atmosphere (*high confidence*).
{5.4, Box TS.5, TS.3.2}

The proportion of CO_2 emissions taken up by land and ocean carbon sinks is smaller in scenarios with higher cumulative CO_2 emissions

Total cumulative CO_2 emissions **taken up by land and ocean** (colours) and remaining in the atmosphere (grey) under the five illustrative scenarios from 1850 to 2100

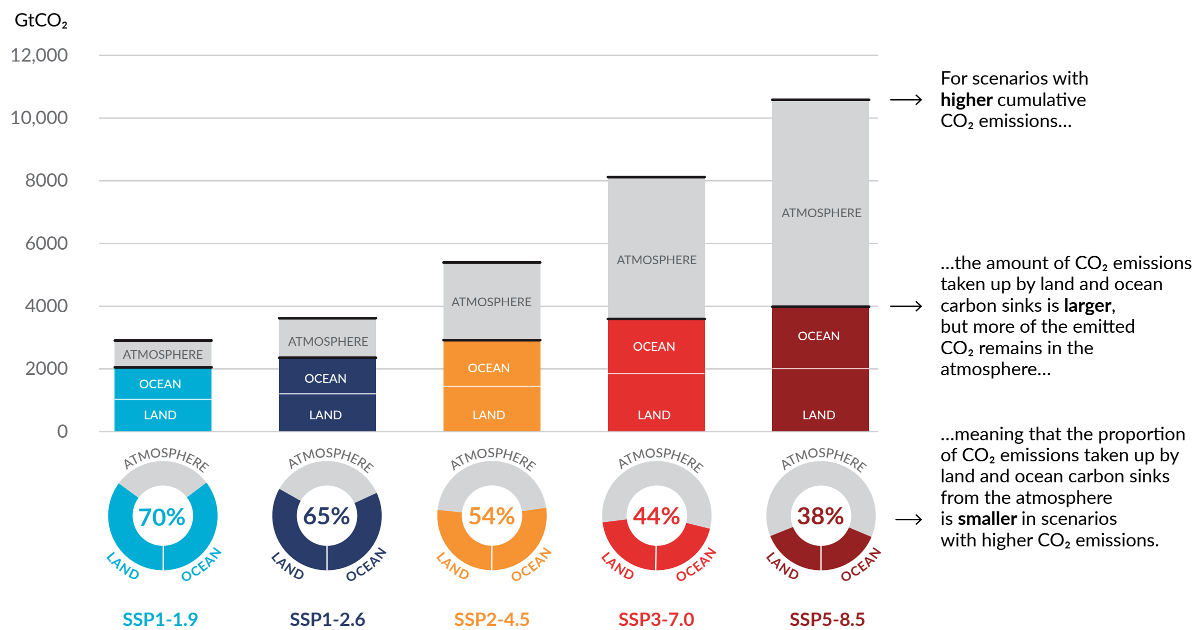


Figure SPM.7 | Cumulative anthropogenic CO_2 emissions taken up by land and ocean sinks by 2100 under the five illustrative scenarios

The cumulative anthropogenic (human-caused) carbon dioxide (CO_2) emissions taken up by the land and ocean sinks under the five illustrative scenarios (SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5) are simulated from 1850 to 2100 by Coupled Model Intercomparison Project Phase 6 (CMIP6) climate models in the concentration-driven simulations. Land and ocean carbon sinks respond to past, current and future emissions; therefore, cumulative sinks from 1850 to 2100 are presented here. During the historical period (1850–2019) the observed land and ocean sink took up 1430 $GtCO_2$ (59% of the emissions).

32 These projected adjustments of carbon sinks to stabilization or decline of atmospheric CO_2 are accounted for in calculations of remaining carbon budgets.

The bar chart illustrates the projected amount of cumulative anthropogenic CO_2 emissions ($GtCO_2$) between 1850 and 2100 remaining in the atmosphere (grey part) and taken up by the land and ocean (coloured part) in the year 2100. **The doughnut chart** illustrates the proportion of the cumulative anthropogenic CO_2 emissions taken up by the land and ocean sinks and remaining in the atmosphere in the year 2100. Values in % indicate the proportion of the cumulative anthropogenic CO_2 emissions taken up by the combined land and ocean sinks in the year 2100. The overall anthropogenic carbon emissions are calculated by adding the net global land-use emissions from the CMIP6 scenario database to the other sectoral emissions calculated from climate model runs with prescribed CO_2 concentrations.[33] Land and ocean CO_2 uptake since 1850 is calculated from the net biome productivity on land, corrected for CO_2 losses due to land-use change by adding the land-use change emissions, and net ocean CO_2 flux.

{5.2.1; Table 5.1; 5.4.5; Figure 5.25; Box TS.5; Box TS.5, Figure 1}

B.5 Many changes due to past and future greenhouse gas emissions are irreversible for centuries to millennia, especially changes in the ocean, ice sheets and global sea level.
{2.3, Cross-Chapter Box 2.4, 4.3, 4.5, 4.7, 5.3, 9.2, 9.4, 9.5, 9.6, Box 9.4} (Figure SPM.8)

B.5.1 Past GHG emissions since 1750 have committed the global ocean to future warming (*high confidence*). Over the rest of the 21st century, *likely* ocean warming ranges from 2–4 (SSP1-2.6) to 4–8 times (SSP5-8.5) the 1971–2018 change. Based on multiple lines of evidence, upper ocean stratification (*virtually certain*), ocean acidification (*virtually certain*) and ocean deoxygenation (*high confidence*) will continue to increase in the 21st century, at rates dependent on future emissions. Changes are irreversible on centennial to millennial time scales in global ocean temperature (*very high confidence*), deep-ocean acidification (*very high confidence*) and deoxygenation (*medium confidence*).
{4.3, 4.5, 4.7, 5.3, 9.2, TS.2.4} (Figure SPM.8)

B.5.2 Mountain and polar glaciers are committed to continue melting for decades or centuries (*very high confidence*). Loss of permafrost carbon following permafrost thaw is irreversible at centennial time scales (*high confidence*). Continued ice loss over the 21st century is *virtually certain* for the Greenland Ice Sheet and *likely* for the Antarctic Ice Sheet. There is *high confidence* that total ice loss from the Greenland Ice Sheet will increase with cumulative emissions. There is *limited evidence* for low-likelihood, high-impact outcomes (resulting from ice-sheet instability processes characterized by deep uncertainty and in some cases involving tipping points) that would strongly increase ice loss from the Antarctic Ice Sheet for centuries under high GHG emissions scenarios.[34]
{4.3, 4.7, 5.4, 9.4, 9.5, Box 9.4, Box TS.1, TS.2.5}

B.5.3 It is *virtually certain* that global mean sea level will continue to rise over the 21st century. Relative to 1995–2014, the *likely* global mean sea level rise by 2100 is 0.28–0.55 m under the very low GHG emissions scenario (SSP1-1.9); 0.32–0.62 m under the low GHG emissions scenario (SSP1-2.6); 0.44–0.76 m under the intermediate GHG emissions scenario (SSP2-4.5); and 0.63–1.01 m under the very high GHG emissions scenario (SSP5-8.5); and by 2150 is 0.37–0.86 m under the very low scenario (SSP1-1.9); 0.46–0.99 m under the low scenario (SSP1-2.6); 0.66–1.33 m under the intermediate scenario (SSP2-4.5); and 0.98–1.88 m under the very high scenario (SSP5-8.5) (*medium confidence*).[35] Global mean sea level rise above the *likely* range – approaching 2 m by 2100 and 5 m by 2150 under a very high GHG emissions scenario (SSP5-8.5) (*low confidence*) – cannot be ruled out due to deep uncertainty in ice-sheet processes.
{4.3, 9.6, Box 9.4, Box TS.4} (Figure SPM.8)

B.5.4 In the longer term, sea level is committed to rise for centuries to millennia due to continuing deep-ocean warming and ice-sheet melt and will remain elevated for thousands of years (*high confidence*). Over the next 2000 years, global mean sea level will rise by about 2 to 3 m if warming is limited to 1.5°C, 2 to 6 m if limited to 2°C and 19 to 22 m with 5°C of warming, and it will continue to rise over subsequent millennia (*low confidence*). Projections of multi-millennial global mean sea level rise are consistent with reconstructed levels during past warm climate periods: *likely* 5–10 m higher than today around 125,000 years ago, when global temperatures were *very likely* 0.5°C–1.5°C higher than 1850–1900; and *very likely* 5–25 m higher roughly 3 million years ago, when global temperatures were 2.5°C–4°C higher (*medium confidence*).
{2.3, Cross-Chapter Box 2.4, 9.6, Box TS.2, Box TS.4, Box TS.9}

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33 The other sectoral emissions are calculated as the residual of the net land and ocean CO_2 uptake and the prescribed atmospheric CO_2 concentration changes in the CMIP6 simulations. These calculated emissions are net emissions and do not separate gross anthropogenic emissions from removals, which are included implicitly.

34 Low-likelihood, high-impact outcomes are those whose probability of occurrence is low or not well known (as in the context of deep uncertainty) but whose potential impacts on society and ecosystems could be high. A tipping point is a critical threshold beyond which a system reorganizes, often abruptly and/or irreversibly. (Glossary) {1.4, Cross-Chapter Box 1.3, 4.7}

35 To compare to the 1986–2005 baseline period used in AR5 and SROCC, add 0.03 m to the global mean sea level rise estimates. To compare to the 1900 baseline period used in Figure SPM.8, add 0.16 m.

Human activities affect all the major climate system components, with some responding over decades and others over centuries

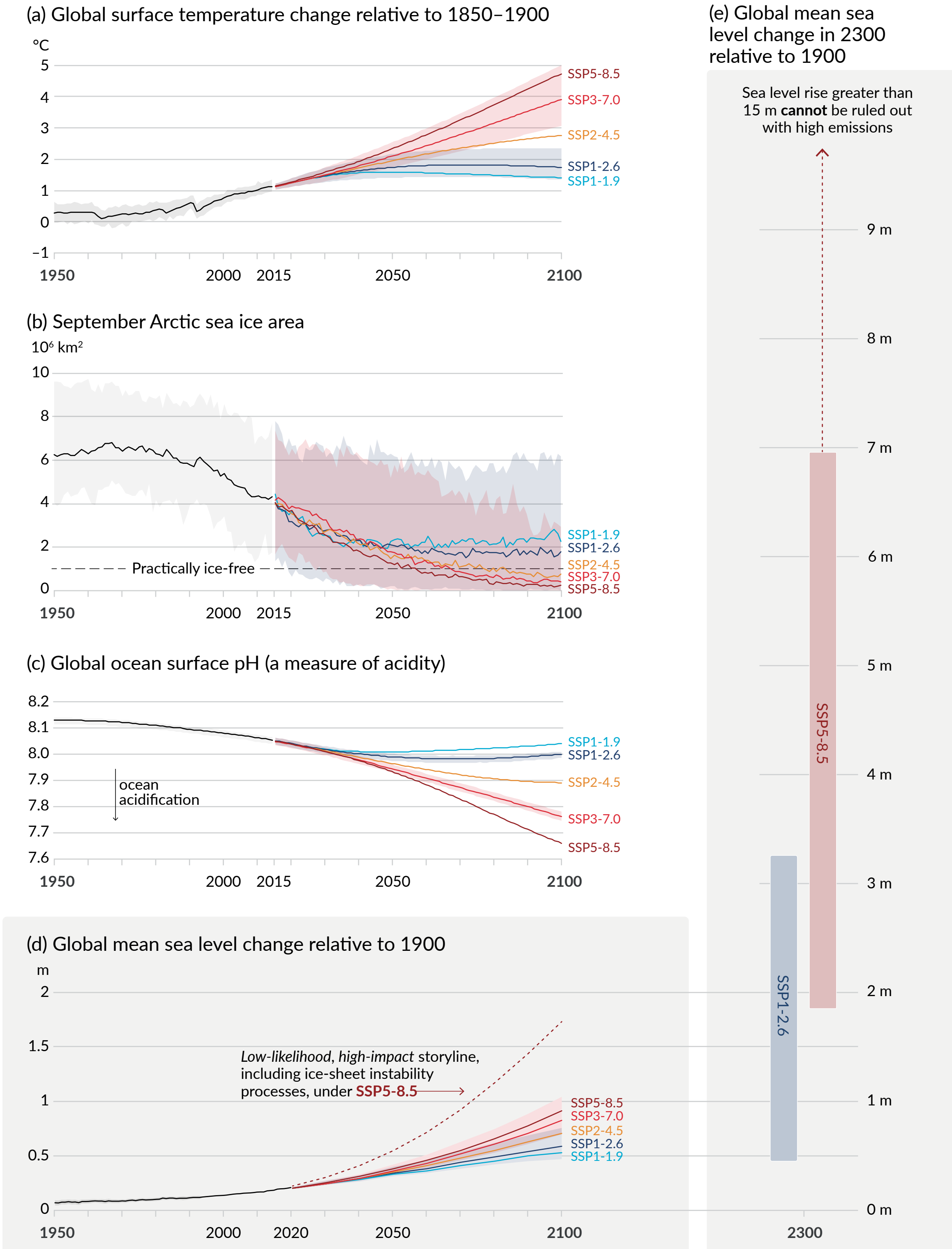

Figure SPM.8 | Selected indicators of global climate change under the five illustrative scenarios used in this Report

The projections for each of the five scenarios are shown in colour. Shades represent uncertainty ranges – more detail is provided for each panel below. The black curves represent the historical simulations (panels a, b, c) or the observations (panel d). Historical values are included in all graphs to provide context for the projected future changes.

Panel (a) Global surface temperature changes in °C relative to 1850–1900. These changes were obtained by combining Coupled Model Intercomparison Project Phase 6 (CMIP6) model simulations with observational constraints based on past simulated warming, as well as an updated assessment of equilibrium climate sensitivity (see Box SPM.1). Changes relative to 1850–1900 based on 20-year averaging periods are calculated by adding 0.85°C (the observed global surface temperature increase from 1850–1900 to 1995–2014) to simulated changes relative to 1995–2014. *Very likely* ranges are shown for SSP1-2.6 and SSP3-7.0.

Panel (b) September Arctic sea ice area in 10^6 km^2 based on CMIP6 model simulations. *Very likely* ranges are shown for SSP1-2.6 and SSP3-7.0. The Arctic is projected to be practically ice-free near mid-century under intermediate and high GHG emissions scenarios.

Panel (c) Global ocean surface pH (a measure of acidity) based on CMIP6 model simulations. *Very likely* ranges are shown for SSP1-2.6 and SSP3-7.0.

Panel (d) Global mean sea level change in metres, relative to 1900. The historical changes are observed (from tide gauges before 1992 and altimeters afterwards), and the future changes are assessed consistently with observational constraints based on emulation of CMIP, ice-sheet, and glacier models. *Likely* ranges are shown for SSP1-2.6 and SSP3-7.0. Only *likely* ranges are assessed for sea level changes due to difficulties in estimating the distribution of deeply uncertain processes. The dashed curve indicates the potential impact of these deeply uncertain processes. It shows the 83rd percentile of SSP5-8.5 projections that include low-likelihood, high-impact ice-sheet processes that cannot be ruled out; because of *low confidence* in projections of these processes, this curve does not constitute part of a *likely* range. Changes relative to 1900 are calculated by adding 0.158 m (observed global mean sea level rise from 1900 to 1995–2014) to simulated and observed changes relative to 1995–2014.

Panel (e) Global mean sea level change at 2300 in metres relative to 1900. Only SSP1-2.6 and SSP5-8.5 are projected at 2300, as simulations that extend beyond 2100 for the other scenarios are too few for robust results. The 17th–83rd percentile ranges are shaded. The dashed arrow illustrates the 83rd percentile of SSP5-8.5 projections that include low-likelihood, high-impact ice-sheet processes that cannot be ruled out.

Panels (b) and (c) are based on single simulations from each model, and so include a component of internal variability. Panels (a), (d) and (e) are based on long-term averages, and hence the contributions from internal variability are small.

{4.3; Figures 4.2, 4.8, and 4.11; 9.6; Figure 9.27; Figures TS.8 and TS.11; Box TS.4, Figure 1}

C. Climate Information for Risk Assessment and Regional Adaptation

Physical climate information addresses how the climate system responds to the interplay between human influence, natural drivers and internal variability. Knowledge of the climate response and the range of possible outcomes, including low-likelihood, high impact outcomes, informs climate services, the assessment of climate-related risks, and adaptation planning. Physical climate information at global, regional and local scales is developed from multiple lines of evidence, including observational products, climate model outputs and tailored diagnostics.

C.1 Natural drivers and internal variability will modulate human-caused changes, especially at regional scales and in the near term, with little effect on centennial global warming. These modulations are important to consider in planning for the full range of possible changes.
{1.4, 2.2, 3.3, Cross-Chapter Box 3.1, 4.4, 4.6, Cross-Chapter Box 4.1, Box 7.2, 8.3, 8.5, 9.2, 10.3, 10.4, 10.6, 11.3, 12.5, Atlas.4, Atlas.5, Atlas.8, Atlas.9, Atlas.10, Atlas.11, Cross-Chapter Box Atlas.2}

C.1.1 The historical global surface temperature record highlights that decadal variability has both enhanced and masked underlying human-caused long-term changes, and this variability will continue into the future (*very high confidence*). For example, internal decadal variability and variations in solar and volcanic drivers partially masked human-caused surface global warming during 1998–2012, with pronounced regional and seasonal signatures (*high confidence*). Nonetheless, the heating of the climate system continued during this period, as reflected in both the continued warming of the global ocean (*very high confidence*) and in the continued rise of hot extremes over land (*medium confidence*).
{1.4, 3.3, Cross-Chapter Box 3.1, 4.4, Box 7.2, 9.2, 11.3, Cross-Section Box TS.1} (Figure SPM.1)

C.1.2 Projected human-caused changes in mean climate and climatic impact-drivers (CIDs),[36] including extremes, will be either amplified or attenuated by internal variability (*high confidence*).[37] Near-term cooling at any particular location with respect to present climate could occur and would be consistent with the global surface temperature increase due to human influence (*high confidence*).
{1.4, 4.4, 4.6, 10.4, 11.3, 12.5, Atlas.5, Atlas.10, Atlas.11, TS.4.2}

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36 Climatic impact-drivers (CIDs) are physical climate system conditions (e.g., means, events, extremes) that affect an element of society or ecosystems. Depending on system tolerance, CIDs and their changes can be detrimental, beneficial, neutral, or a mixture of each across interacting system elements and regions (Glossary). CID types include heat and cold, wet and dry, wind, snow and ice, coastal and open ocean.

37 The main internal variability phenomena include El Niño–Southern Oscillation, Pacific Decadal Variability and Atlantic Multi-decadal Variability through their regional influence.

C.1.3 Internal variability has largely been responsible for the amplification and attenuation of the observed human-caused decadal-to-multi-decadal mean precipitation changes in many land regions (*high confidence*). At global and regional scales, near-term changes in monsoons will be dominated by the effects of internal variability (*medium confidence*). In addition to the influence of internal variability, near-term projected changes in precipitation at global and regional scales are uncertain because of model uncertainty and uncertainty in forcings from natural and anthropogenic aerosols (*medium confidence*).
{1.4, 4.4, 8.3, 8.5, 10.3, 10.4, 10.5, 10.6, Atlas.4, Atlas.8, Atlas.9, Atlas.10, Atlas.11, Cross-Chapter Box Atlas.2, TS.4.2, Box TS.6, Box TS.13}

C.1.4 Based on paleoclimate and historical evidence, it is *likely* that at least one large explosive volcanic eruption would occur during the 21st century.[38] Such an eruption would reduce global surface temperature and precipitation, especially over land, for one to three years, alter the global monsoon circulation, modify extreme precipitation and change many CIDs (*medium confidence*). If such an eruption occurs, this would therefore temporarily and partially mask human-caused climate change.
{2.2, 4.4, Cross-Chapter Box 4.1, 8.5, TS.2.1}

C.2 With further global warming, every region is projected to increasingly experience concurrent and multiple changes in climatic impact-drivers. Changes in several climatic impact-drivers would be more widespread at 2°C compared to 1.5°C global warming and even more widespread and/or pronounced for higher warming levels.
{8.2, 9.3, 9.5, 9.6, Box 10.3, 11.3, 11.4, 11.5, 11.6, 11.7, 11.9, Box 11.3, Box 11.4, Cross-Chapter Box 11.1, 12.2, 12.3, 12.4, 12.5, Cross-Chapter Box 12.1, Atlas.4, Atlas.5, Atlas.6, Atlas.7, Atlas.8, Atlas.9, Atlas.10, Atlas.11} (Table SPM.1, Figure SPM.9)

C.2.1 All regions[39] are projected to experience further increases in hot climatic impact-drivers (CIDs) and decreases in cold CIDs (*high confidence*). Further decreases are projected in permafrost; snow, glaciers and ice sheets; and lake and Arctic sea ice (*medium* to *high confidence*).[40] These changes would be larger at 2°C global warming or above than at 1.5°C (*high confidence*). For example, extreme heat thresholds relevant to agriculture and health are projected to be exceeded more frequently at higher global warming levels (*high confidence*).
{9.3, 9.5, 11.3, 11.9, Cross-Chapter Box 11.1, 12.3, 12.4, 12.5, Cross-Chapter Box 12.1, Atlas.4, Atlas.5, Atlas.6, Atlas.7, Atlas.8, Atlas.9, Atlas.10, Atlas.11, TS.4.3} (Table SPM.1, Figure SPM.9)

C.2.2 At 1.5°C global warming, heavy precipitation and associated flooding are projected to intensify and be more frequent in most regions in Africa and Asia (*high confidence*), North America (*medium* to *high confidence*)[40] and Europe (*medium confidence*). Also, more frequent and/or severe agricultural and ecological droughts are projected in a few regions in all inhabited continents except Asia compared to 1850–1900 (*medium confidence*); increases in meteorological droughts are also projected in a few regions (*medium confidence*). A small number of regions are projected to experience increases or decreases in mean precipitation (*medium confidence*).
{11.4, 11.5, 11.6, 11.9, Atlas.4, Atlas.5, Atlas.7, Atlas.8, Atlas.9, Atlas.10, Atlas.11, TS.4.3} (Table SPM.1)

C.2.3 At 2°C global warming and above, the level of confidence in and the magnitude of the change in droughts and heavy and mean precipitation increase compared to those at 1.5°C. Heavy precipitation and associated flooding events are projected to become more intense and frequent in the Pacific Islands and across many regions of North America and Europe (*medium* to *high confidence*).[40] These changes are also seen in some regions in Australasia and Central and South America (*medium confidence*). Several regions in Africa, South America and Europe are projected to experience an increase in frequency and/or severity of agricultural and ecological droughts with *medium* to *high confidence*;[40] increases are also projected in Australasia, Central and North America, and the Caribbean with *medium confidence*. A small number of regions in Africa, Australasia, Europe and North America are also projected to be affected by increases in hydrological droughts, and several regions are projected to be affected by increases or decreases in meteorological droughts, with more regions displaying an increase (*medium confidence*). Mean precipitation is projected to increase in all polar, northern European and northern North American regions, most Asian regions and two regions of South America (*high confidence*).
{11.4, 11.6, 11.9, Cross-Chapter Box 11.1, 12.4, 12.5, Cross-Chapter Box 12.1, Atlas.5, Atlas.7, Atlas.8, Atlas.9, Atlas.11, TS.4.3} (Table SPM.1, Figure SPM.5, Figure SPM.6, Figure SPM.9)

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38 Based on 2500 year reconstructions, eruptions more negative than $-1\ W\ m^{-2}$ occur on average twice per century.

39 Regions here refer to the AR6 WGI reference regions used in this Report to summarize information in sub-continental and oceanic regions. Changes are compared to averages over the last 20–40 years unless otherwise specified. {1.4, 12.4, Atlas.1}.

40 The specific level of confidence or likelihood depends on the region considered. Details can be found in the Technical Summary and the underlying Report.

C.2.4 More CIDs across more regions are projected to change at 2°C and above compared to 1.5°C global warming (*high confidence*). Region-specific changes include intensification of tropical cyclones and/or extratropical storms (*medium confidence*), increases in river floods (*medium* to *high confidence*),[40] reductions in mean precipitation and increases in aridity (*medium* to *high confidence*),[40] and increases in fire weather (*medium* to *high confidence*).[40] There is *low confidence* in most regions in potential future changes in other CIDs, such as hail, ice storms, severe storms, dust storms, heavy snowfall and landslides.
{11.7, 11.9, Cross-Chapter Box 11.1, 12.4, 12.5, Cross-Chapter Box 12.1, Atlas.4, Atlas.6, Atlas.7, Atlas.8, Atlas.10, TS.4.3.1, TS.4.3.2, TS.5} (Table SPM.1, Figure SPM.9)

C.2.5 It is *very likely* to *virtually certain*[40] that regional mean relative sea level rise will continue throughout the 21st century, except in a few regions with substantial geologic land uplift rates. Approximately two-thirds of the global coastline has a projected regional relative sea level rise within ±20% of the global mean increase (*medium confidence*). Due to relative sea level rise, extreme sea level events that occurred once per century in the recent past are projected to occur at least annually at more than half of all tide gauge locations by 2100 (*high confidence*). Relative sea level rise contributes to increases in the frequency and severity of coastal flooding in low-lying areas and to coastal erosion along most sandy coasts (*high confidence*).
{9.6, 12.4, 12.5, Cross-Chapter Box 12.1, Box TS.4, TS.4.3} (Figure SPM.9)

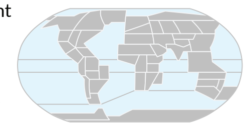
C.2.6 Cities intensify human-induced warming locally, and further urbanization together with more frequent hot extremes will increase the severity of heatwaves (*very high confidence*). Urbanization also increases mean and heavy precipitation over and/or downwind of cities (*medium confidence*) and resulting runoff intensity (*high confidence*). In coastal cities, the combination of more frequent extreme sea level events (due to sea level rise and storm surge) and extreme rainfall/riverflow events will make flooding more probable (*high confidence*).
{8.2, Box 10.3, 11.3, 12.4, Box TS.14}

C.2.7 Many regions are projected to experience an increase in the probability of compound events with higher global warming (*high confidence*). In particular, concurrent heatwaves and droughts are *likely* to become more frequent. Concurrent extremes at multiple locations, including in crop-producing areas, become more frequent at 2°C and above compared to 1.5°C global warming (*high confidence*).
{11.8, Box 11.3, Box 11.4, 12.3, 12.4, Cross-Chapter Box 12.1, TS.4.3} (Table SPM.1)

SPM

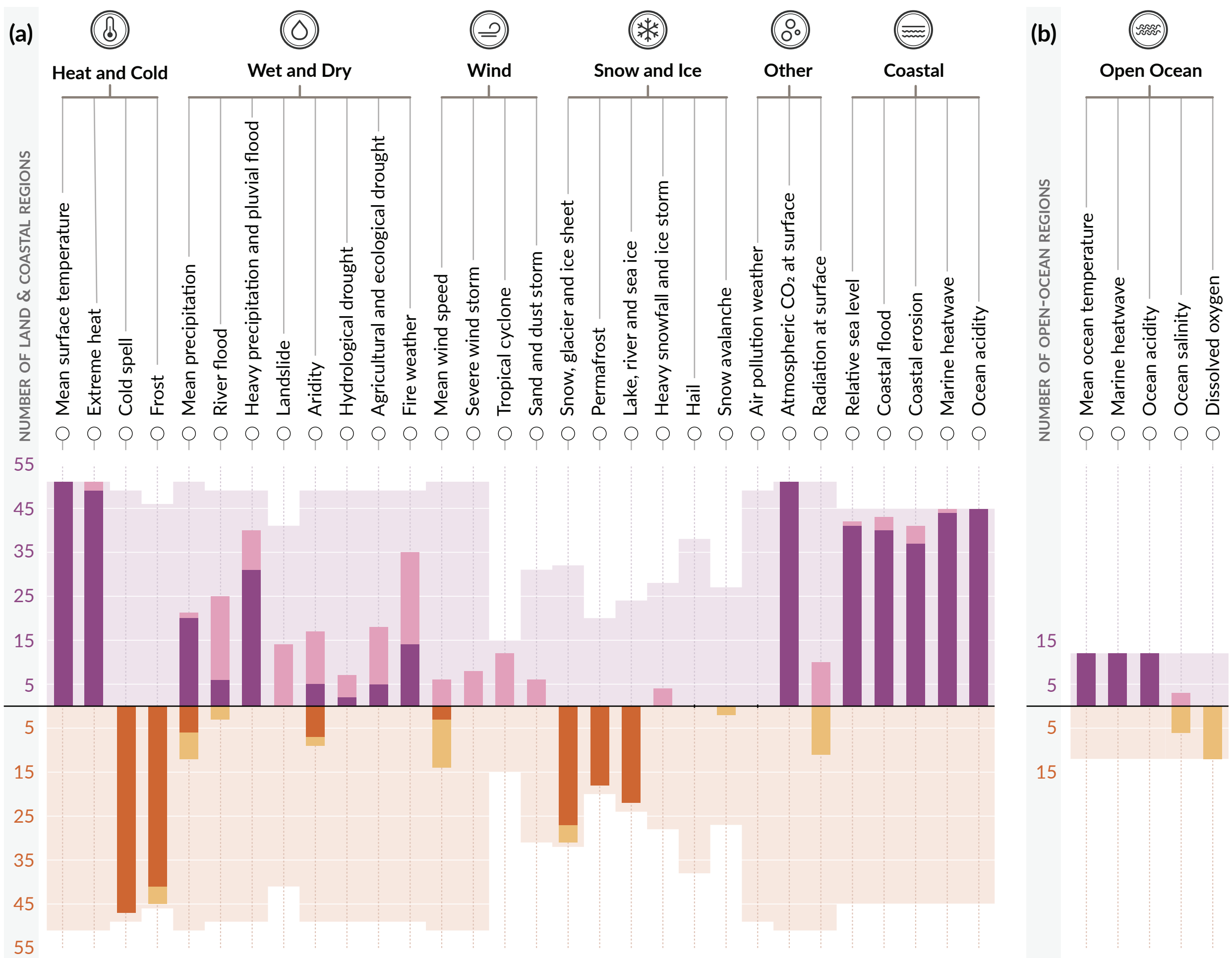
Multiple climatic impact-drivers are projected to change in all regions of the world

Climatic impact-drivers (CIDs) are physical climate system conditions (e.g., means, events, extremes) that affect an element of society or ecosystems. Depending on system tolerance, CIDs and their changes can be detrimental, beneficial, neutral, or a mixture of each across interacting system elements and regions. The CIDs are grouped into seven types, which are summarized under the icons in the figure. All regions are projected to experience changes in at least 5 CIDs. Almost all (96%) are projected to experience changes in at least 10 CIDs and half in at least 15 CIDs. For many CID changes, there is wide geographical variation, and so each region is projected to experience a specific set of CID changes. Each bar in the chart represents a specific geographical set of changes that can be explored in the WGI Interactive Atlas.



interactive-atlas.ipcc.ch

Number of land & coastal regions (a) and **open-ocean regions** (b) where each **climatic impact-driver** (CID) is projected to **increase** or **decrease** with ***high** confidence* (dark shade) or ***medium** confidence* (light shade)



BAR CHART LEGEND

- Regions with ***high** confidence* **increase**
- Regions with ***medium** confidence* **increase**
- Regions with ***high** confidence* **decrease**
- Regions with ***medium** confidence* **decrease**

LIGHTER-SHADED 'ENVELOPE' LEGEND

The height of the lighter shaded 'envelope' behind each bar represents the maximum number of regions for which each CID is relevant. The envelope is symmetrical about the x-axis showing the maximum possible number of relevant regions for CID increase (upper part) or decrease (lower part).

ASSESSED FUTURE CHANGES

Changes refer to a 20–30 year period centred around 2050 and/or consistent with 2°C global warming compared to a similar period within 1960–2014 or 1850–1900.

Figure SPM.9 | Synthesis of the number of AR6 WGI reference regions where climatic impact-drivers are projected to change

A total of 35 climatic impact-drivers (CIDs) grouped into seven types are shown: heat and cold; wet and dry; wind; snow and ice; coastal; open ocean; and other. For each CID, the bar in the graph below displays the number of AR6 WGI reference regions where it is projected to change. The **colours** represent the direction of change and the level of confidence in the change: purple indicates an increase while brown indicates a decrease; darker and lighter shades refer to *high* and *medium confidence*, respectively. Lighter background colours represent the maximum number of regions for which each CID is broadly relevant.

Panel (a) shows the 30 CIDs relevant to the **land and coastal regions**, while **panel (b)** shows the five CIDs relevant to the **open-ocean regions**. Marine heatwaves and ocean acidity are assessed for coastal ocean regions in panel (a) and for open-ocean regions in panel (b). Changes refer to a 20–30-year period centred around 2050 and/or consistent with 2°C global warming compared to a similar period within 1960–2014, except for hydrological drought and agricultural and ecological drought, which is compared to 1850–1900. Definitions of the regions are provided in Sections 12.4 and Atlas.1 and the Interactive Atlas (see https://interactive-atlas.ipcc.ch/).

{11.9, 12.2, 12.4, Atlas.1, Table TS.5, Figures TS.22 and TS.25} (Table SPM.1)

C.3 Low-likelihood outcomes, such as ice-sheet collapse, abrupt ocean circulation changes, some compound extreme events, and warming substantially larger than the assessed *very likely* range of future warming, cannot be ruled out and are part of risk assessment.
{1.4, Cross-Chapter Box 1.3, 4.3, 4.4, 4.8, Cross-Chapter Box 4.1, 8.6, 9.2, Box 9.4, 11.8, Box 11.2, Cross-Chapter Box 12.1} (Table SPM.1)

C.3.1 If global warming exceeds the assessed *very likely* range for a given GHG emissions scenario, including low GHG emissions scenarios, global and regional changes in many aspects of the climate system, such as regional precipitation and other CIDs, would also exceed their assessed *very likely* ranges (*high confidence*). Such low-likelihood, high-warming outcomes are associated with potentially very large impacts, such as through more intense and more frequent heatwaves and heavy precipitation, and high risks for human and ecological systems, particularly for high GHG emissions scenarios.
{Cross-Chapter Box 1.3, 4.3, 4.4, 4.8, Box 9.4, Box 11.2, Cross-Chapter Box 12.1, TS.1.4, Box TS.3, Box TS.4} (Table SPM.1)

C.3.2 Low-likelihood, high-impact outcomes[34] could occur at global and regional scales even for global warming within the *very likely* range for a given GHG emissions scenario. The probability of low-likelihood, high-impact outcomes increases with higher global warming levels (*high confidence*). Abrupt responses and tipping points of the climate system, such as strongly increased Antarctic ice-sheet melt and forest dieback, cannot be ruled out (*high confidence*).
{1.4, 4.3, 4.4, 4.8, 5.4, 8.6, Box 9.4, Cross-Chapter Box 12.1, TS.1.4, TS.2.5, Box TS.3, Box TS.4, Box TS.9} (Table SPM.1)

C.3.3 If global warming increases, some compound extreme events[18] with low likelihood in past and current climate will become more frequent, and there will be a higher likelihood that events with increased intensities, durations and/or spatial extents unprecedented in the observational record will occur (*high confidence*).
{11.8, Box 11.2, Cross-Chapter Box 12.1, Box TS.3, Box TS.9}

C.3.4 The Atlantic Meridional Overturning Circulation is *very likely* to weaken over the 21st century for all emissions scenarios. While there is *high confidence* in the 21st century decline, there is only *low confidence* in the magnitude of the trend. There is *medium confidence* that there will not be an abrupt collapse before 2100. If such a collapse were to occur, it would *very likely* cause abrupt shifts in regional weather patterns and water cycle, such as a southward shift in the tropical rain belt, weakening of the African and Asian monsoons and strengthening of Southern Hemisphere monsoons, and drying in Europe.
{4.3, 8.6, 9.2, TS2.4, Box TS.3}

C.3.5 Unpredictable and rare natural events not related to human influence on climate may lead to low-likelihood, high-impact outcomes. For example, a sequence of large explosive volcanic eruptions within decades has occurred in the past, causing substantial global and regional climate perturbations over several decades. Such events cannot be ruled out in the future, but due to their inherent unpredictability they are not included in the illustrative set of scenarios referred to in this Report
{2.2, Cross-Chapter Box 4.1, Box TS.3} (Box SPM.1)

D. Limiting Future Climate Change

Since AR5, estimates of remaining carbon budgets have been improved by a new methodology first presented in SR1.5, updated evidence, and the integration of results from multiple lines of evidence. A comprehensive range of possible future air pollution controls in scenarios is used to consistently assess the effects of various assumptions on projections of climate and air pollution. A novel development is the ability to ascertain when climate responses to emissions reductions would become discernible above natural climate variability, including internal variability and responses to natural drivers.

D.1 From a physical science perspective, limiting human-induced global warming to a specific level requires limiting cumulative CO_2 emissions, reaching at least net zero CO_2 emissions, along with strong reductions in other greenhouse gas emissions. Strong, rapid and sustained reductions in CH_4 emissions would also limit the warming effect resulting from declining aerosol pollution and would improve air quality.
{3.3, 4.6, 5.1, 5.2, 5.4, 5.5, 5.6, Box 5.2, Cross-Chapter Box 5.1, 6.7, 7.6, 9.6} (Figure SPM.10, Table SPM.2)

D.1.1 This Report reaffirms with *high confidence* the AR5 finding that there is a near-linear relationship between cumulative anthropogenic CO_2 emissions and the global warming they cause. Each 1000 $GtCO_2$ of cumulative CO_2 emissions is assessed to *likely* cause a 0.27°C to 0.63°C increase in global surface temperature with a best estimate of 0.45°C.[41] This is a narrower range compared to AR5 and SR1.5. This quantity is referred to as the transient climate response to cumulative CO_2 emissions (TCRE). This relationship implies that reaching net zero anthropogenic CO_2 emissions[42] is a requirement to stabilize human-induced global temperature increase at any level, but that limiting global temperature increase to a specific level would imply limiting cumulative CO_2 emissions to within a carbon budget.[43] {5.4, 5.5, TS.1.3, TS.3.3, Box TS.5} (Figure SPM.10)

Every tonne of CO_2 emissions adds to global warming

Global surface temperature increase since 1850–1900 (°C) as a function of cumulative CO_2 emissions ($GtCO_2$)

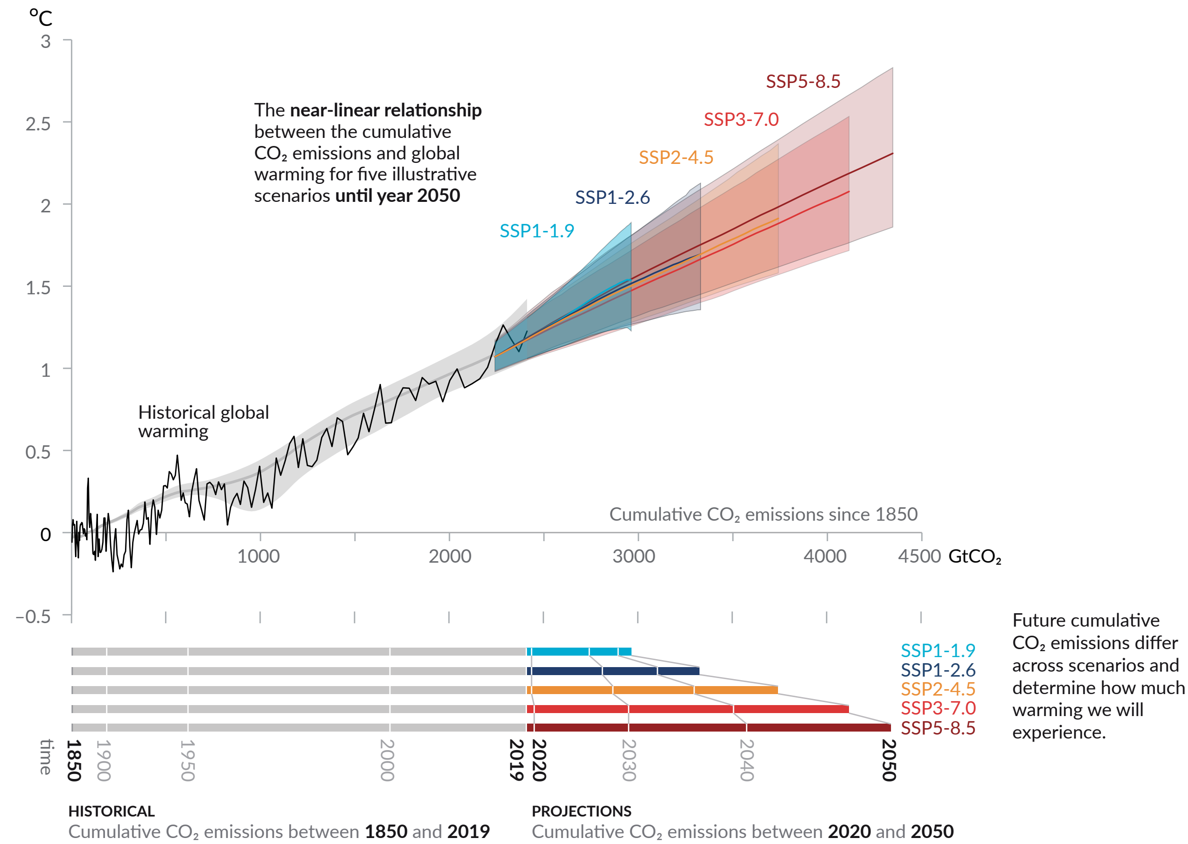


Figure SPM.10 | Near-linear relationship between cumulative CO_2 emissions and the increase in global surface temperature

Top panel: Historical data (thin black line) shows observed global surface temperature increase in °C since 1850–1900 as a function of historical cumulative carbon dioxide (CO_2) emissions in $GtCO_2$ from 1850 to 2019. The grey range with its central line shows a corresponding estimate of the historical human-caused surface warming (see Figure SPM.2). Coloured areas show the assessed *very likely* range of global surface temperature projections, and thick coloured central lines show the median estimate as a function of cumulative CO_2 emissions from 2020 until year 2050 for the set of illustrative scenarios (SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5; see Figure SPM.4). Projections use the cumulative CO_2 emissions of each respective scenario, and the projected global warming includes the contribution from all anthropogenic forcers. The relationship is illustrated over the domain of cumulative CO_2 emissions for which there is *high confidence* that the transient climate response to cumulative CO_2 emissions (TCRE) remains constant, and for the time period from 1850 to 2050 over which global CO_2 emissions remain net positive under all illustrative scenarios, as there is *limited evidence* supporting the quantitative application of TCRE to estimate temperature evolution under net negative CO_2 emissions.

Bottom panel: Historical and projected cumulative CO_2 emissions in $GtCO_2$ for the respective scenarios.

{Section 5.5, Figure 5.31, Figure TS.18}

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41 In the literature, units of °C per 1000 PgC (petagrams of carbon) are used, and the AR6 reports the TCRE ***likely*** range as 1.0°C to 2.3°C per 1000 PgC in the underlying report, with a best estimate of 1.65°C.

42 The condition in which anthropogenic carbon dioxide (CO_2) emissions are balanced by anthropogenic CO_2 removals over a specified period (Glossary).

43 The term 'carbon budget' refers to the maximum amount of cumulative net global anthropogenic CO_2 emissions that would result in limiting global warming to a given level with a given probability, taking into account the effect of other anthropogenic climate forcers. This is referred to as the total carbon budget when expressed starting from the pre-industrial period, and as the remaining carbon budget when expressed from a recent specified date (Glossary). Historical cumulative CO_2 emissions determine to a large degree warming to date, while future emissions cause future additional warming. The remaining carbon budget indicates how much CO_2 could still be emitted while keeping warming below a specific temperature level.

D.1.2 Over the period 1850–2019, a total of 2390 ± 240 (*likely* range) $GtCO_2$ of anthropogenic CO_2 was emitted. Remaining carbon budgets have been estimated for several global temperature limits and various levels of probability, based on the estimated value of TCRE and its uncertainty, estimates of historical warming, variations in projected warming from non-CO_2 emissions, climate system feedbacks such as emissions from thawing permafrost, and the global surface temperature change after global anthropogenic CO_2 emissions reach net zero.
{5.1, 5.5, Box 5.2, TS.3.3} (Table SPM.2)

Table SPM.2 | Estimates of historical carbon dioxide (CO_2) emissions and remaining carbon budgets. Estimated remaining carbon budgets are calculated from the beginning of 2020 and extend until global net zero CO_2 emissions are reached. They refer to CO_2 emissions, while accounting for the global warming effect of non-CO_2 emissions. Global warming in this table refers to human-induced global surface temperature increase, which excludes the impact of natural variability on global temperatures in individual years.
{Table 3.1, 5.5.1, 5.5.2, Box 5.2, Table 5.1, Table 5.7, Table 5.8, Table TS.3}

Global Warming Between 1850–1900 and 2010–2019 (°C)		Historical Cumulative CO_2 Emissions from 1850 to 2019 ($GtCO_2$)					
1.07 (0.8–1.3; likely range)		2390 (± 240; likely range)					
Approximate global warming relative to 1850–1900 until temperature limit (°C)[a]	Additional global warming relative to 2010–2019 until temperature limit (°C)	Estimated remaining carbon budgets from the beginning of 2020 ($GtCO_2$) *Likelihood of limiting global warming to temperature limit*[b]					Variations in reductions in non-CO_2 emissions[c]
		17%	*33%*	*50%*	*67%*	*83%*	
1.5	0.43	900	650	500	400	300	Higher or lower reductions in accompanying non-CO_2 emissions can increase or decrease the values on the left by 220 $GtCO_2$ or more
1.7	0.63	1450	1050	850	700	550	
2.0	0.93	2300	1700	1350	1150	900	

[a] Values at each 0.1°C increment of warming are available in Tables TS.3 and 5.8.

[b] This likelihood is based on the uncertainty in transient climate response to cumulative CO_2 emissions (TCRE) and additional Earth system feedbacks and provides the probability that global warming will not exceed the temperature levels provided in the two left columns. Uncertainties related to historical warming (±550 $GtCO_2$) and non-CO_2 forcing and response (±220 $GtCO_2$) are partially addressed by the assessed uncertainty in TCRE, but uncertainties in recent emissions since 2015 (±20 $GtCO_2$) and the climate response after net zero CO_2 emissions are reached (±420 $GtCO_2$) are separate.

[c] Remaining carbon budget estimates consider the warming from non-CO_2 drivers as implied by the scenarios assessed in SR1.5. The Working Group III Contribution to AR6 will assess mitigation of non-CO_2 emissions.

D.1.3 Several factors that determine estimates of the remaining carbon budget have been re-assessed, and updates to these factors since SR1.5 are small. When adjusted for emissions since previous reports, estimates of remaining carbon budgets are therefore of similar magnitude compared to SR1.5 but larger compared to AR5 due to methodological improvements.[44]
{5.5, Box 5.2, TS.3.3} (Table SPM.2)

D.1.4 Anthropogenic CO_2 removal (CDR) has the potential to remove CO_2 from the atmosphere and durably store it in reservoirs (*high confidence*). CDR aims to compensate for residual emissions to reach net zero CO_2 or net zero GHG emissions or, if implemented at a scale where anthropogenic removals exceed anthropogenic emissions, to lower surface temperature. CDR methods can have potentially wide-ranging effects on biogeochemical cycles and climate, which can either weaken or strengthen the potential of these methods to remove CO_2 and reduce warming, and can also influence water availability and quality, food production and biodiversity[45] (*high confidence*).
{5.6, Cross-Chapter Box 5.1, TS.3.3}

D.1.5 Anthropogenic CO_2 removal (CDR) leading to global net negative emissions would lower the atmospheric CO_2 concentration and reverse surface ocean acidification (*high confidence*). Anthropogenic CO_2 removals and emissions are partially

44 Compared to AR5, and when taking into account emissions since AR5, estimates in AR6 are about 300–350 $GtCO_2$ larger for the remaining carbon budget consistent with limiting warming to 1.5°C; for 2°C, the difference is about 400–500 $GtCO_2$.

45 Potential negative and positive effects of CDR for biodiversity, water and food production are methods-specific and are often highly dependent on local context, management, prior land use, and scale. IPCC Working Groups II and III assess the CDR potential and ecological and socio-economic effects of CDR methods in their AR6 contributions.

compensated by CO_2 release and uptake respectively, from or to land and ocean carbon pools (*very high confidence*). CDR would lower atmospheric CO_2 by an amount approximately equal to the increase from an anthropogenic emission of the same magnitude (*high confidence*). The atmospheric CO_2 decrease from anthropogenic CO_2 removals could be up to 10% less than the atmospheric CO_2 increase from an equal amount of CO_2 emissions, depending on the total amount of CDR (*medium confidence*).
{5.3, 5.6, TS.3.3}

D.1.6 If global net negative CO_2 emissions were to be achieved and be sustained, the global CO_2-induced surface temperature increase would be gradually reversed but other climate changes would continue in their current direction for decades to millennia (*high confidence*). For instance, it would take several centuries to millennia for global mean sea level to reverse course even under large net negative CO_2 emissions (*high confidence*).
{4.6, 9.6, TS.3.3}

D.1.7 In the five illustrative scenarios, simultaneous changes in CH_4, aerosol and ozone precursor emissions, which also contribute to air pollution, lead to a net global surface warming in the near and long term (*high confidence*). In the long term, this net warming is lower in scenarios assuming air pollution controls combined with strong and sustained CH_4 emissions reductions (*high confidence*). In the low and very low GHG emissions scenarios, assumed reductions in anthropogenic aerosol emissions lead to a net warming, while reductions in CH_4 and other ozone precursor emissions lead to a net cooling. Because of the short lifetime of both CH_4 and aerosols, these climate effects partially counterbalance each other, and reductions in CH_4 emissions also contribute to improved air quality by reducing global surface ozone (*high confidence*).
{6.7, Box TS.7} (Figure SPM.2, Box SPM.1)

D.1.8 Achieving global net zero CO_2 emissions, with anthropogenic CO_2 emissions balanced by anthropogenic removals of CO_2, is a requirement for stabilizing CO_2-induced global surface temperature increase. This is different from achieving net zero GHG emissions, where metric-weighted anthropogenic GHG emissions equal metric-weighted anthropogenic GHG removals. For a given GHG emissions pathway, the pathways of individual GHGs determine the resulting climate response,[46] whereas the choice of emissions metric[47] used to calculate aggregated emissions and removals of different GHGs affects what point in time the aggregated GHGs are calculated to be net zero. Emissions pathways that reach and sustain net zero GHG emissions defined by the 100-year global warming potential are projected to result in a decline in surface temperature after an earlier peak (*high confidence*).
{4.6, 7.6, Box 7.3, TS.3.3}

D.2 Scenarios with very low or low GHG emissions (SSP1-1.9 and SSP1-2.6) lead within years to discernible effects on greenhouse gas and aerosol concentrations and air quality, relative to high and very high GHG emissions scenarios (SSP3-7.0 or SSP5-8.5). Under these contrasting scenarios, discernible differences in trends of global surface temperature would begin to emerge from natural variability within around 20 years, and over longer time periods for many other climatic impact-drivers (*high confidence*).
{4.6, 6.6, 6.7, Cross-Chapter Box 6.1, 9.6, 11.2, 11.4, 11.5, 11.6, Cross-Chapter Box 11.1, 12.4, 12.5} (Figure SPM.8, Figure SPM.10)

D.2.1 Emissions reductions in 2020 associated with measures to reduce the spread of COVID-19 led to temporary but detectable effects on air pollution (*high confidence*) and an associated small, temporary increase in total radiative forcing, primarily due to reductions in cooling caused by aerosols arising from human activities (*medium confidence*). Global and regional climate responses to this temporary forcing are, however, undetectable above natural variability (*high confidence*). Atmospheric CO_2 concentrations continued to rise in 2020, with no detectable decrease in the observed CO_2 growth rate (*medium confidence*).[48]
{Cross-Chapter Box 6.1, TS.3.3}

D.2.2 Reductions in GHG emissions also lead to air quality improvements. However, in the near term,[49] even in scenarios with strong reduction of GHGs, as in the low and very low GHG emissions scenarios (SSP1-2.6 and SSP1-1.9), these improvements

46 A general term for how the climate system responds to a radiative forcing (Glossary).

47 The choice of emissions metric depends on the purposes for which gases or forcing agents are being compared. This Report contains updated emissions metric values and assesses new approaches to aggregating gases.

48 For other GHGs, there was insufficient literature available at the time of the assessment to assess detectable changes in their atmospheric growth rate during 2020.

49 Near term: 2021–2040.

are not sufficient in many polluted regions to achieve air quality guidelines specified by the World Health Organization (*high confidence*). Scenarios with targeted reductions of air pollutant emissions lead to more rapid improvements in air quality within years compared to reductions in GHG emissions only, but from 2040, further improvements are projected in scenarios that combine efforts to reduce air pollutants as well as GHG emissions, with the magnitude of the benefit varying between regions (*high confidence*).
{6.6, 6.7, Box TS.7}.

D.2.3 Scenarios with very low or low GHG emissions (SSP1-1.9 and SSP1-2.6) would have rapid and sustained effects to limit human-caused climate change, compared with scenarios with high or very high GHG emissions (SSP3-7.0 or SSP5-8.5), but early responses of the climate system can be masked by natural variability. For global surface temperature, differences in 20-year trends would *likely* emerge during the near term under a very low GHG emissions scenario (SSP1-1.9), relative to a high or very high GHG emissions scenario (SSP3-7.0 or SSP5-8.5). The response of many other climate variables would emerge from natural variability at different times later in the 21st century (*high confidence*).
{4.6, Cross-Section Box TS.1} (Figure SPM.8, Figure SPM.10)

D.2.4 Scenarios with very low and low GHG emissions (SSP1-1.9 and SSP1-2.6) would lead to substantially smaller changes in a range of CIDs[36] beyond 2040 than under high and very high GHG emissions scenarios (SSP3-7.0 and SSP5-8.5). By the end of the century, scenarios with very low and low GHG emissions would strongly limit the change of several CIDs, such as the increases in the frequency of extreme sea level events, heavy precipitation and pluvial flooding, and exceedance of dangerous heat thresholds, while limiting the number of regions where such exceedances occur, relative to higher GHG emissions scenarios (*high confidence*). Changes would also be smaller in very low compared to low GHG emissions scenarios, as well as for intermediate (SSP2-4.5) compared to high or very high GHG emissions scenarios (*high confidence*).
{9.6, 11.2, 11.3, 11.4, 11.5, 11.6, 11.9, Cross-Chapter Box 11.1, 12.4, 12.5, TS.4.3}

2019 SAN FRANCISCO SECTOR-BASED GREENHOUSE GAS EMISSIONS INVENTORY AT A GLANCE

By San Francisco Department of Environment, Climate Program

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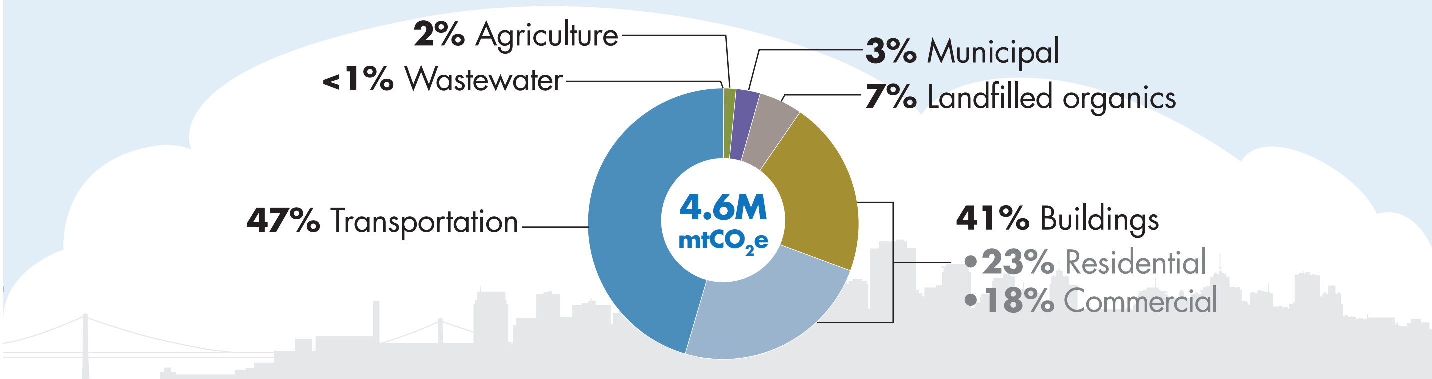
TABLE OF CONTENTS

1990-2019 San Francisco trends

Emissions	GDP	Population
-41%	**199%**	**22%**
2019 total **4.6 million mtCO2e**	2019 total **$179 billion**	2019 total **881,549 people**
≈ weight of **12** Golden Gate Bridges	≈ stack of $100 bills the height of **752** Transamerica Buildings	≈ the population of **Fiji**

2019 San Francisco emissions by sector



Reductions from 1990 levels:

Transportation	Municipal	Landfilled Organics	Buildings
-16%	**-32%**	**-35%**	**-58%**

San Francisco per capita emissions

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EMISSIONS OVERVIEW

EMISSIONS TRENDS

In 2019, San Francisco's community-wide greenhouse gas (GHG) emissions totaled 4.6 million $mtCO_2e$ (Fig. 1). This total is 41% below emissions levels in 1990. These reductions came despite a 22% increase in population and a near-tripling of economic output from $59.7 billion in 1990 to $178.5 billion in 2019. As a result, San Francisco's emissions per capita was 5.21 $mtCO_2e$/person in 2019, about half of the 11 mtCO2e/person seen in in 1990.

2019 emissions were 420,000 $mtCO_2e$ (8%) lower than in 2018. Building emissions fell 285,000 $mtCO_2e$ (13%) between 2018 and 2019, driven by lower emissions from San Francisco's grid-supplied electricity. This was the largest contributor to the community-wide drop in emissions. The Transportation sector saw a 116,000 $mtCO_2e$ (5%) drop in emissions, led by reductions in emissions from cars and trucks on the road.

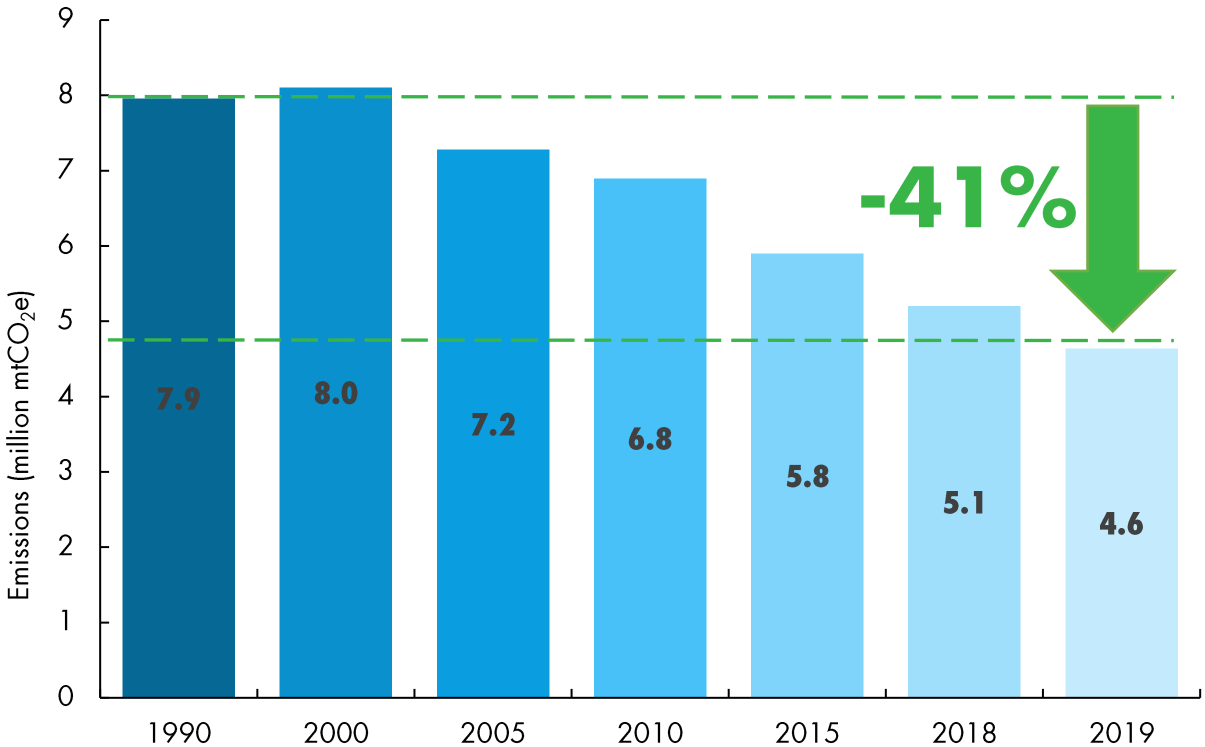

Figure 1. San Francisco's GHG Emissions from Inventory Year 1990 to 2019.

Emissions are categorized into seven sectors in the 2019 inventory (Fig. 2):

- The **Residential Buildings** sector accounts for 23% of the city's emissions. Within the sector, 96% of emissions come from natural gas, 2% from electricity, and 2% from other fuels.
- The **Commercial Buildings** sector accounts for 18% of the city's emissions. Within the sector, 85% of emissions come from natural gas, 8% from steam, and 7% from electricity.
- The **Transportation** sector accounts for 47% of the city's emissions. Within the sector, 72% of emissions come from passenger vehicles, 19% from Maritime Ships and Boats[1] (non-ferry), 6% from off-road equipment, and 3% from public transportation[2].
- The **Landfilled Organics** sector accounts for 7% of the city's emissions[3].
- The **Municipal** sector accounts for 3% of the city's emissions. This includes facilities and fleet, and nearly all emissions come from natural gas and vehicle fuel use.
- The **Agriculture** sector accounts for 2% of the city's emissions. [4]
- The **Wastewater** sector accounts for <1% of the city's emissions.[5]

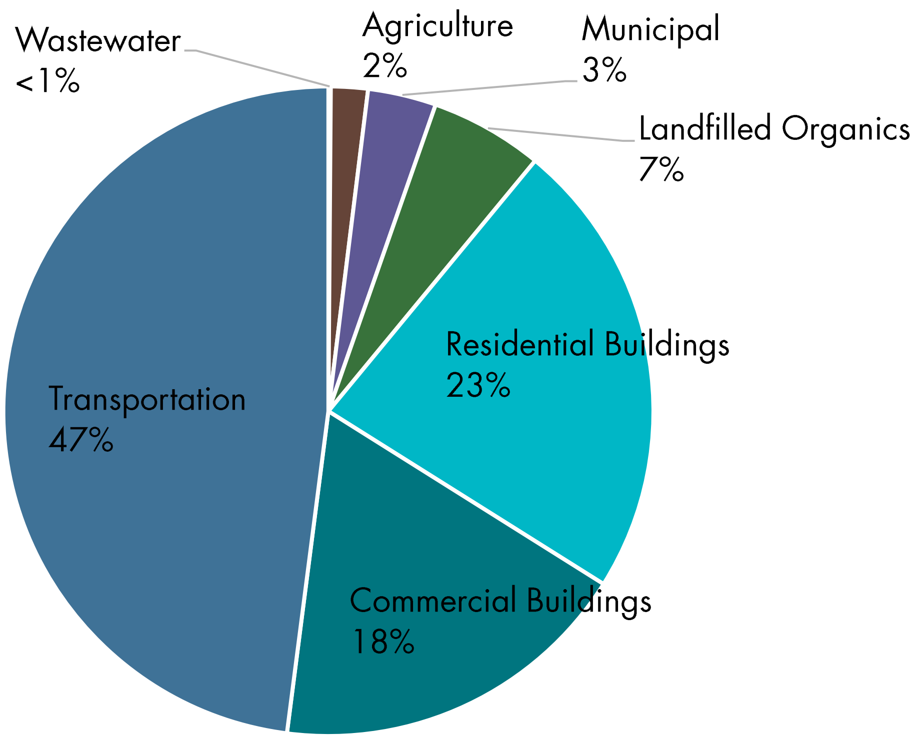

Figure 2. San Francisco 2019 emissions by sector

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[1] Maritime ships and boats consist of ships and boats within 24 nautical miles.

[2] Public transportation consists of Muni, BART, Caltrain (rail and buses), commuter ferries, and other buses (including Golden Gate Transit).

[3] Emissions from Landfilled Organics, previously known as the Waste sector, occur when disposed organics break down (decompose) in a landfill and produce methane.

[4] Agriculture sector is a relatively new sector tracked starting in inventory year 2016. These emissions are allocated to the city proportionally from BAAQMD's regional inventory.

[5] Wastewater sector is a relatively new sector tracked starting in inventory year 2016.

In 2019, San Francisco successfully reduced emissions to 41% below 1990 levels from 7.9 million[6] mtCO_2e to 4.6 million mtCO_2e (Fig. 1). Emissions fell in the top five of the seven sectors tracked:

Sector	2019 Emissions compared to 1990 levels
Residential Buildings	47% decline
Commercial Buildings	67% decline
Transportation	16% decline
Landfilled Organics	35% decline
Municipal	32% decline
Agriculture	9% increase
Wastewater	26% increase

Since 1990, San Francisco's GHG inventories have been calculated and reported in accordance with the ICLEI U.S. Community Protocol (USCP) for Accounting and Reporting of Greenhouse Gas Emissions. The methodology and sectors tracked were third-party verified in inventory year 2012. All subsequent inventories were completed according to the guidance of the verifiers. In 2015, the City began reporting its emissions to C40 to comply with a newer protocol to report emissions referred to as the Global Protocol for Community-Scale Greenhouse Gas Emissions Inventories (GPC). GPC incorporated new emission categories to track. Furthermore, while ICLEI protocols are used to calculate GHG emissions, GPC serves as a framework to unify San Francisco's inventory protocols with other cities and publicly disclose emissions to the global community.

EMISSIONS REDUCTION DRIVERS

Reductions in emissions can be attributed to a variety of factors, such as the implementation of innovative technologies, policies, and programs. Annual emissions may also vary with changes in the weather. The main drivers of the emission reductions observed between 1990 and 2019 are illustrated below. This 2021 report reflects inventory year 2019; it does not reflect inventory year 2020, which will likely be impacted by the COVID-19 pandemic.

- A cleaner electric grid for all of San Francisco. City-owned buildings have been powered by 100% GHG-free electricity since 2012, and the power mix available to other customers has become significantly cleaner since 1990. CleanPowerSF, San Francisco's Community Choice Aggregation program, has expanded its clean energy portfolio and customer base while reinvesting ratepayer funds in local renewable energy resources. By the end of 2019, the program more than tripled the number of customers served compared to 2018, serving 380,000 customers by the end of the year. CleanPowerSF served 47% of the City's electricity load in 2019. Of the electricity served by CleanPowerSF and PG&E (San Francisco's investor-owned utility), 83% came from renewable resources in 2019.[7]

- A scale-up in energy efficiency programs that helped curtail demand for electricity and natural gas. In 2019, San Francisco's Energy Watch program saved San Francisco commercial and multifamily properties a total of 680,000 kWh across 31 projects and an average of $4,400 in bill savings each. This translates to a GHG emissions reduction of 162 $mtCO_2e$, or the equivalent of removing 35 passenger vehicles from the road for a year.

- Progressive green building codes which ensure new construction is built to the highest standards for energy, water, and other key environmental performance metrics. Local green building code requirements contributed 149 million square feet in commercial buildings becoming LEED certified by the end of 2019. This includes 67 city-owned buildings and interiors that were LEED certified between 2004 and 2018, totaling 9.37 million square feet.

Impact of Weather on Emissions

It is important to differentiate between long-term emissions reductions driven by new technologies, policies, and programs and short-term reductions due to changes in factors such as the weather. Weather can affect usage patterns. For example, warmer temperatures compared to a previous year can drive down the use of natural gas. Understanding how weather impacts emission levels is important because there are likely to be short-term, year-to-year variations in emissions as San Francisco continues to make progress towards longer-term reduction targets.

[7] California's cleaner grid is driven at the state level through the Renewable Portfolio Standards (RPS), which sets a goal of 33% renewable energy by 2020 and 50% by 2030.

- Cleaner fuels which helped decouple transportation emissions from growth. Between 1990 and 2019 commuting into and out of the city increased alongside the City's growing economy. Even with an additional 340 million vehicle miles added to San Francisco roads between 1990 and 2019, vehicle emissions declined 22%, due to State and local efforts to reduce the carbon intensity[8] of vehicle fuels.

- A switch to renewable diesel by which the City reduced emissions from SF MUNI buses and municipal fleet vehicles. Diesel consumption across the city fleet has been halved since 2015 when this transition began. Commuter ferries also began the switch to renewable diesel in 2017, further reducing carbon emissions in the Transportation sector. Renewable diesel is an interim fuel that will be phased out as transportation modes shift toward electrification. Renewable diesel consumption currently makes up less than 1% of transportation emissions.

[8] Carbon intensity is the amount of carbon emitted per unit of energy used.

SECTOR SUMMARY

Below is an in-depth analysis of San Francisco's emissions trends since 1990 in the Residential Buildings, Commercial Buildings, Transportation, Landfilled Organics, Municipal, Agriculture, and Wastewater sectors.

RESIDENTIAL BUILDINGS

In 2019, emissions from the Residential sector totaled 1.05 million mtCO_2e, accounting for 23% of San Francisco's GHG emissions (Fig. 3). Emissions from the Residential sector have declined 47% since 1990 (Fig. 4). This was driven primarily by a cleaner electrical grid, improved energy codes, and city-wide energy efficiency programs. Residential sector emissions are generated from fossil fuels used to heat household spaces, provide hot water, dry clothes, and cook. Emissions from the Residential sector result primarily from natural gas use (96%), followed by electricity use (2%) and other fuel consumption (2%) (Fig. 5). Emissions from electricity are much lower than those from natural gas because of San Francisco's push to increase its renewable energy portfolio.

Between inventory years 2018 and 2019, Residential Buildings sector emissions fell by 8%. This came as San Francisco customers saw an increased supply of low-carbon electricity, resulting in a 50% decrease in Residential Building electricity emissions year-over-year. Many residential customers received electricity from CleanPowerSF in 2019: CleanPowerSF served more than 66% of residential customer load in 2019, compared to less than 20% in 2018. Residential sector emissions should continue to trend downward over time.

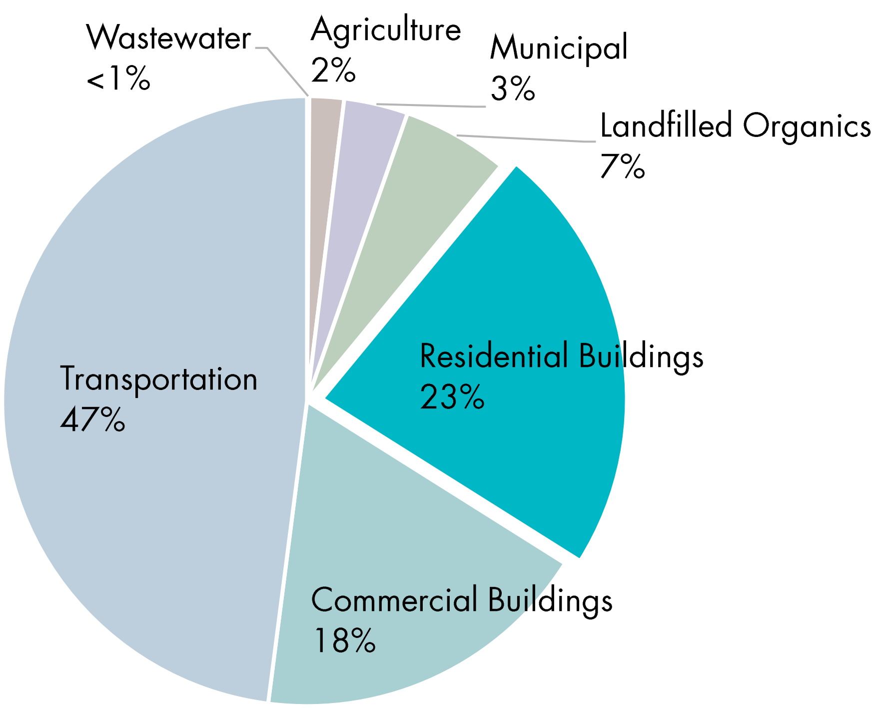

Figure 3. 2019 Residential sector emissions.

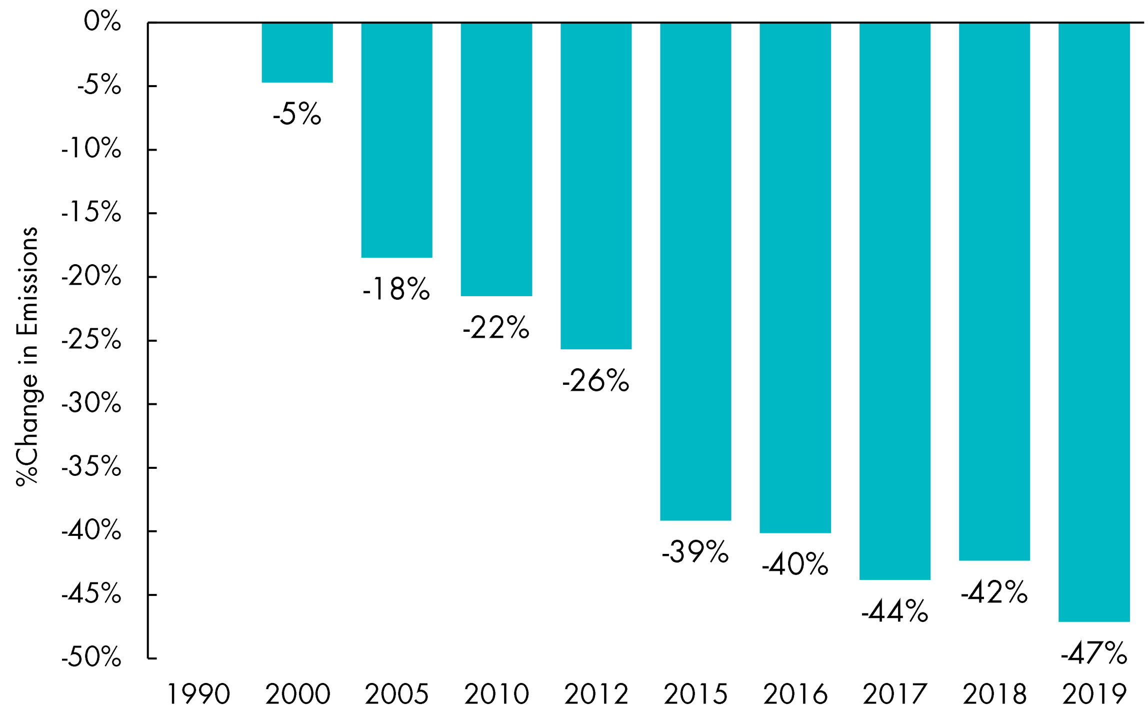

Figure 4. 2019 Residential sector emissions compared to 1990.

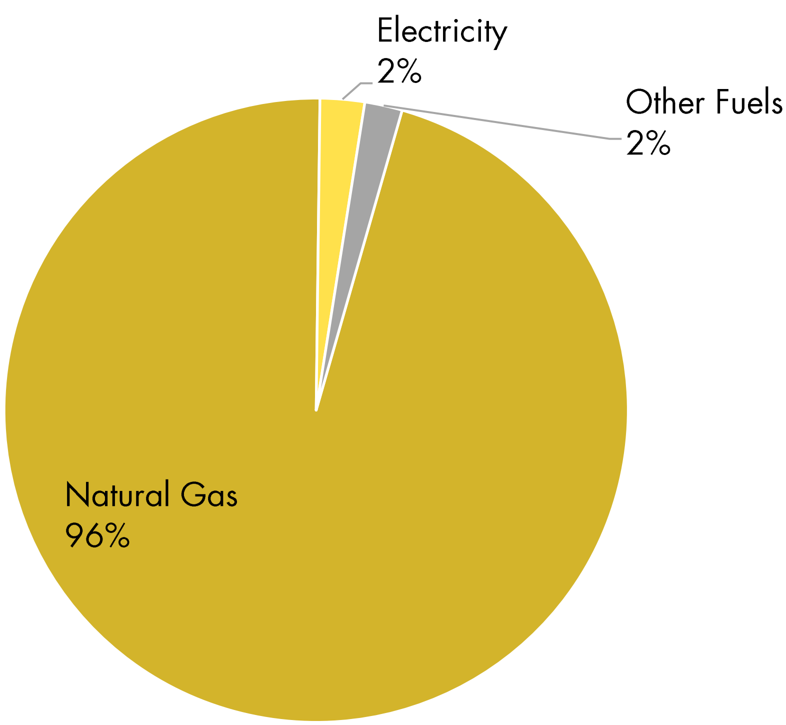

Figure 5. 2019 Residential sector emissions by commodity.

COMMERCIAL BUILDINGS

In 2019, emissions from the Commercial[9] sector totaled 831,000 mtCO_2e, accounting for 18% of San Francisco's GHG emissions (Fig. 6). This includes commercial and industrial, direct access, district, and steam loop customers.[10] Emissions from the Commercial sector have declined 67% since 1990 (Figure 7). As in the Residential sector, this decrease in emissions was mainly due to a combination of a cleaner electrical grid, improved energy codes, and city-wide energy efficiency programs. Generating and distributing steam in a centralized manner through the downtown district steam loop is more efficient than generating steam in individual buildings. While this efficiency has helped reduce emissions, the steam loop is a historic system that may be replaced as the City transitions to a carbon-free solution. Commercial natural gas use was responsible for the largest share of emissions (85%), followed by steam (8%) and electricity (7%) (Fig. 8). As in the residential sector, emissions from electricity usage make up a relatively small portion of sector emissions due to San Francisco's increasingly renewable and low- and zero-carbon electricity generation mix.

Between inventory years 2018 and 2019, Commercial Buildings sector emissions dropped by 19% from over 1 million mtCO_2e to 831,000 mtCO_2e, due largely to a drop in electricity emissions. This was driven by an increased supply of low-carbon electricity to San Francisco's Commercial customers from PG&E and CleanPowerSF, the two largest electricity load-serving entities for Commercial Buildings.

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[9] The commercial sector includes the Industrial sector because of California's Data Privacy Aggregation rules, which causes the two sectors to be combined. The Industrial sector is reported as part of the Commercial sector as there are more commercial buildings than industrial buildings in San Francisco.

[10] Direct Access is electricity usage for customers for whom PG&E provides transmission and distribution services, but not electricity generation (Commercial, Industrial, as well as Residential). District electricity includes accounts such as BART, School Districts, Hospital Districts, Water or Sewer Districts, Fire Districts, Junior College Districts, District Fairs, Public Utility Districts, Community Service Districts, Cemetery Districts, Mosquito Abatement Districts, and/or Park Districts. The steam loop is powered by natural gas use and serves only commercial and municipal customers in the downtown core.

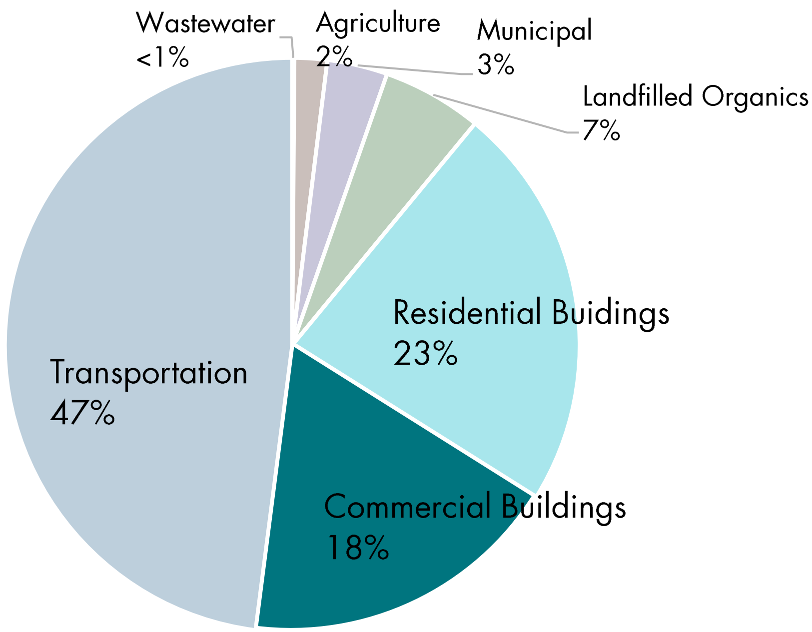

Figure 6. 2019 Commercial sector emissions.

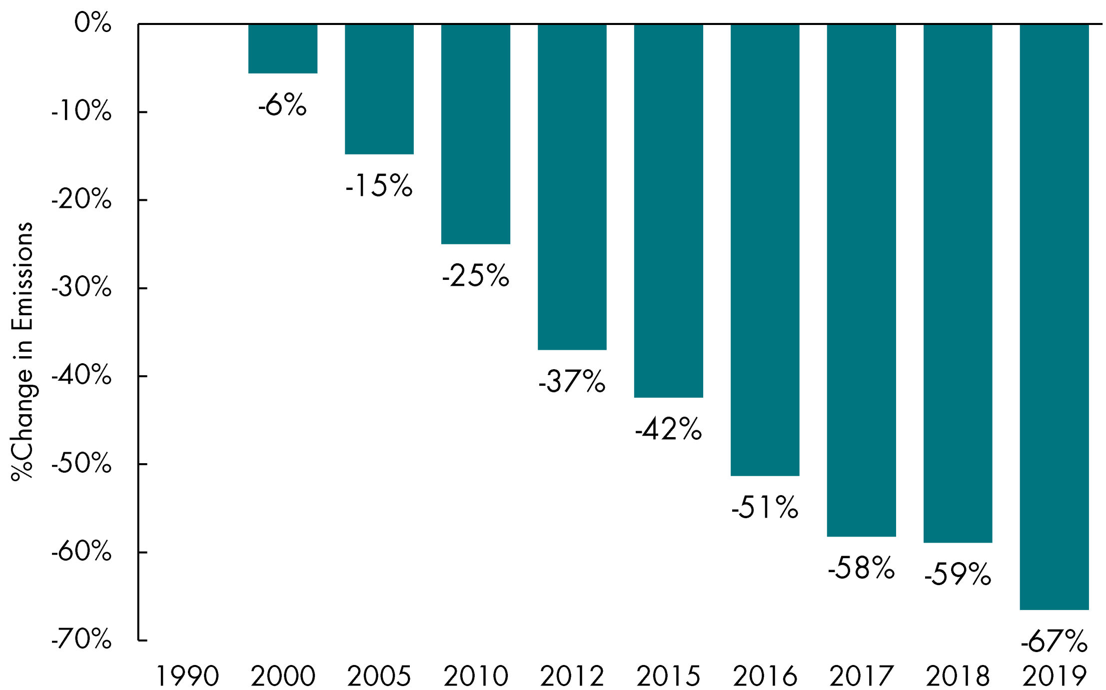

Figure 7. Commercial sector emissions changes compared to 1990 levels.

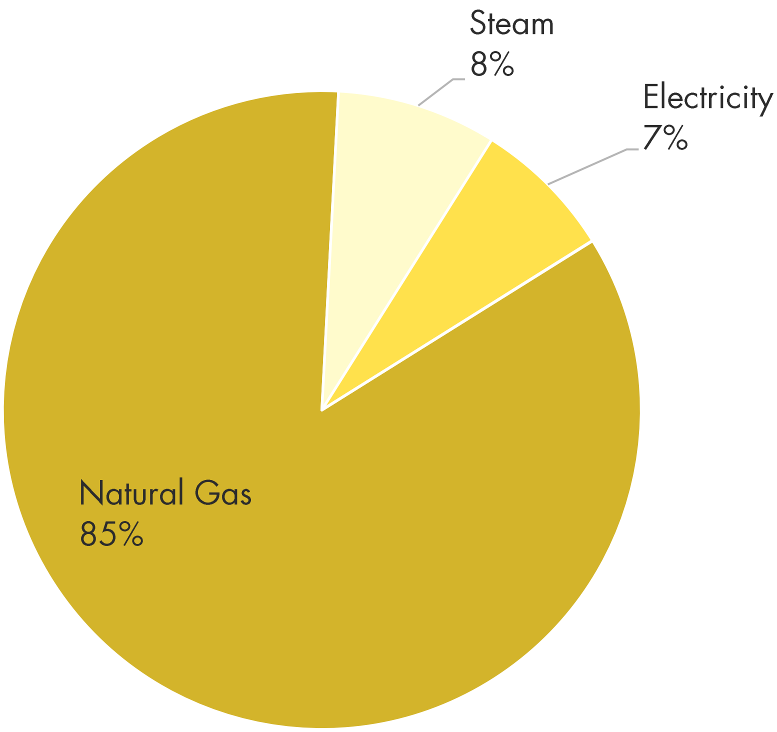

Figure 8. 2019 Commercial sector emissions by commodity.

TRANSPORTATION

In 2019, emissions in the Transportation sector totaled 2.20 million mtCO_2e, accounting for 47% of San Francisco's GHG emissions (Fig. 9). Emissions from the Transportation sector have declined 16% below 1990 levels mainly due to higher fuel efficiency standards and cleaner vehicle fuels mandated by the State of California (Fig. 10). Emissions from public transportation (e.g. MUNI, Commuter Ferries) have fallen as diesel consumption has been replaced by renewable diesel since 2016. Gasoline used by the Transportation sector was responsible for the largest share of emissions (72%), followed by diesel (21%), other fuels (6%), electricity (1%), and renewable diesel (<1%)[11] (Fig. 11). Broken down by vehicle type, privately-owned passenger vehicles[12] were responsible for 72% of emissions at 1.59 million mtCO_2e (Fig. 12)[13]. Maritime Ships and Boats accounted for 19% of emissions, and Off-Road Equipment accounted for 6% of emissions. Public Transportation accounted for the remaining 3% of emissions.

Transportation sector emissions decreased from 2.32 million to 2.20 million mtCO_2e (2% decrease) between inventory years 2018 and 2019. Car and truck VMTs – primarily generated by driving to work, school, etc. – is the largest contributor to emissions for the sector and declined 4%. Emissions from diesel for ships and boats also fell 2% with a drop in usage. Emissions from MUNI buses remained

[11] Includes trace amount of emissions from the CH_4 and N_2O portion of renewable diesel.

[12] Consists of private vehicles such as cars and light duty trucks.

[13] Gasoline consumed makes up all of passenger vehicle emissions.

low as the fleet used no conventional diesel for the second year in a row, replaced by renewable diesel[14] consumption.

Transportation Network Companies (TNCs), also referred to as ride-sharing companies, represent a growing source and share of transportation emissions in San Francisco with its specific impacts unknown due to a lack of data. The California Air Resources Board's 2018 emissions profile[15] concluded that TNC vehicles produce nearly 50% more emissions per passenger mile than other automobiles. The San Francisco County Transportation Authority's analysis of TNCs in 2017 found that TNCs represent roughly 15%[16] of all vehicle trips within the City. San Francisco recognizes that TNCs play a role in our transportation emissions and the City is working to incorporate their impacts into future emissions inventories.

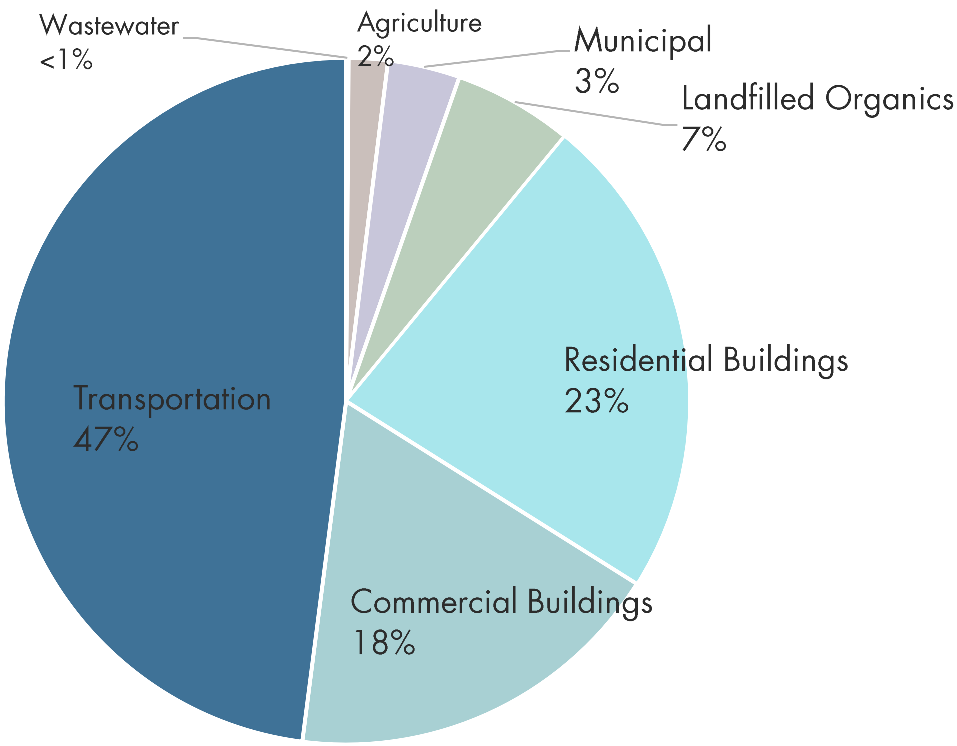

Figure 9. 2019 Transportation sector emissions.

[14] Renewable diesel used in San Francisco comes from renewable resources such as tallow, used cooking oils, and ethanol byproducts.

[15] California Air Resourced Board, "2018 base year Emissions Inventory Report", December 2019, https://ww2.arb.ca.gov/sites/default/files/2019-

[16] San Francisco County Transportation Authority, "TNCs Today", June 2017, https://www.sfcta.org/projects/tncs-today

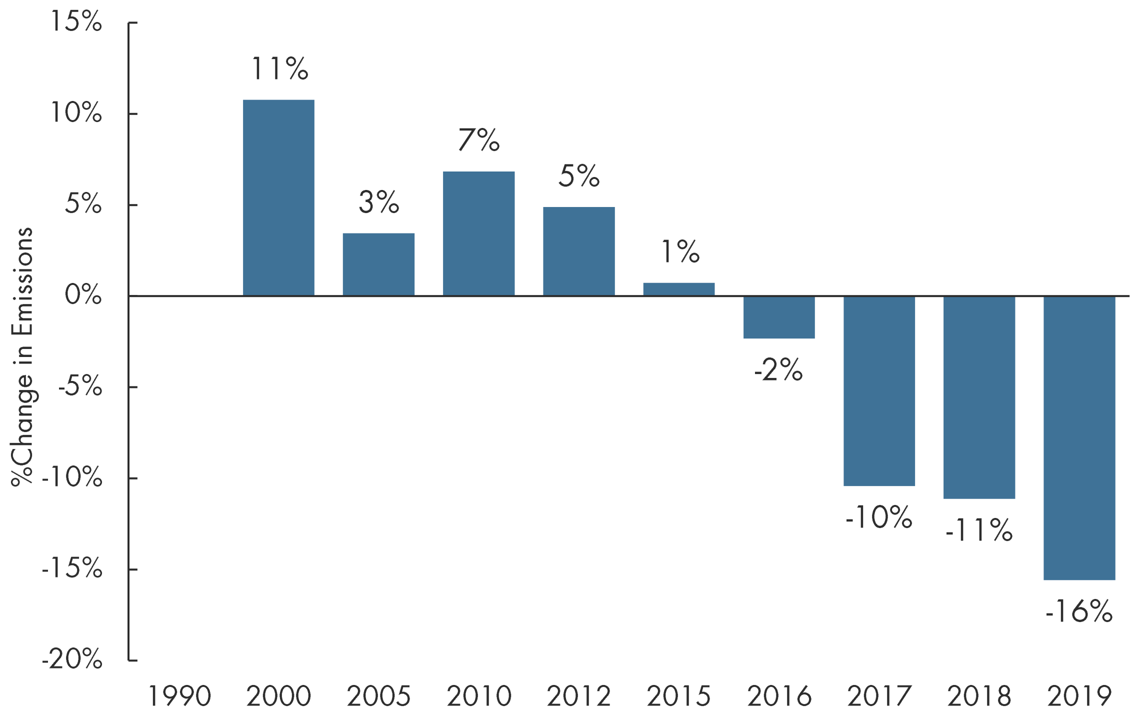

Figure 10. 2019 Transportation sector emissions changes compared to 1990 levels.

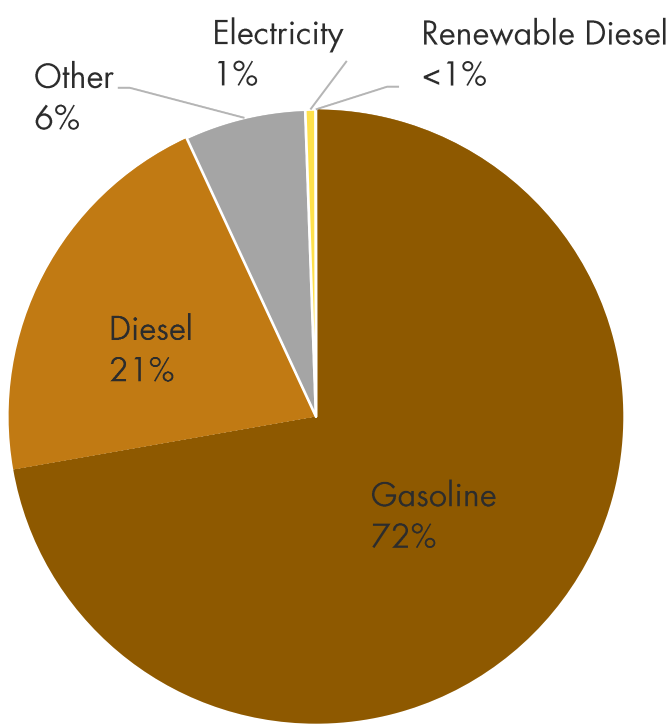

Figure 11. 2019 Transportation sector emissions by commodity.

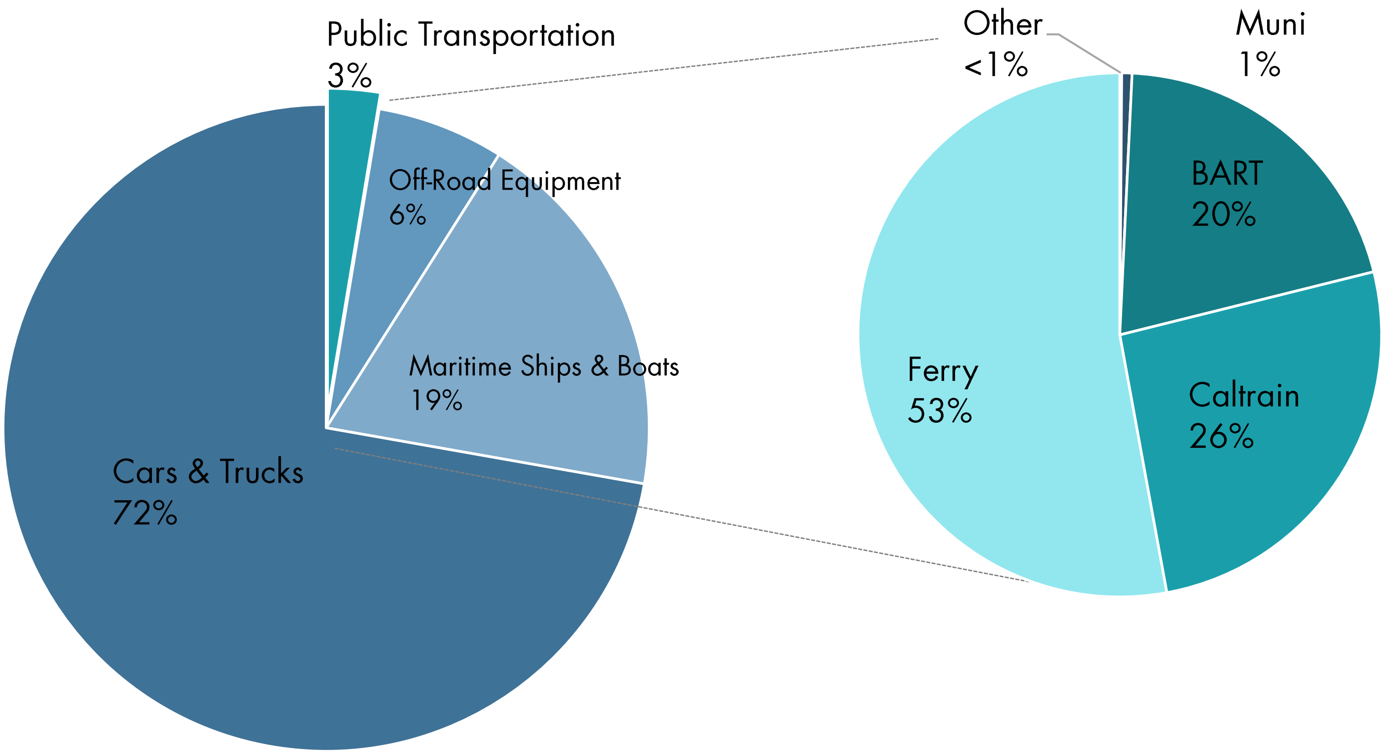

Figure 12. 2019 Transportation emissions by sub-sector.

LANDFILLED ORGANICS

In 2019, emissions from landfilled organics[17] totaled 308,000 $mtCO_2e$, accounting for 7% of San Francisco's GHG emissions (Fig. 13). Organic materials sent to landfill decompose and release methane emissions to the atmosphere. Emissions from Landfilled Organics have declined 45% below 1990 levels due to improved resource recovery in the City (Fig. 14).

Emissions from Landfilled Organics fell 6% between inventory years 2018 and 2019. This change was due to a corresponding decline in the tonnage of organics sent to the landfill. This was a reversal of a rising emissions trend that began in 2012. Over the last decade, the city's economic and population growth had resulted in higher rates of organics disposed to landfill and driven a construction and demolition[18] boom, resulting in an increase in discarded organic and inorganic material sent to landfill. Emissions from landfilled organics disposal per capita have decreased 46% from 1990 levels, from 65 to 29 $mtCO_2e$ per person in 2019.

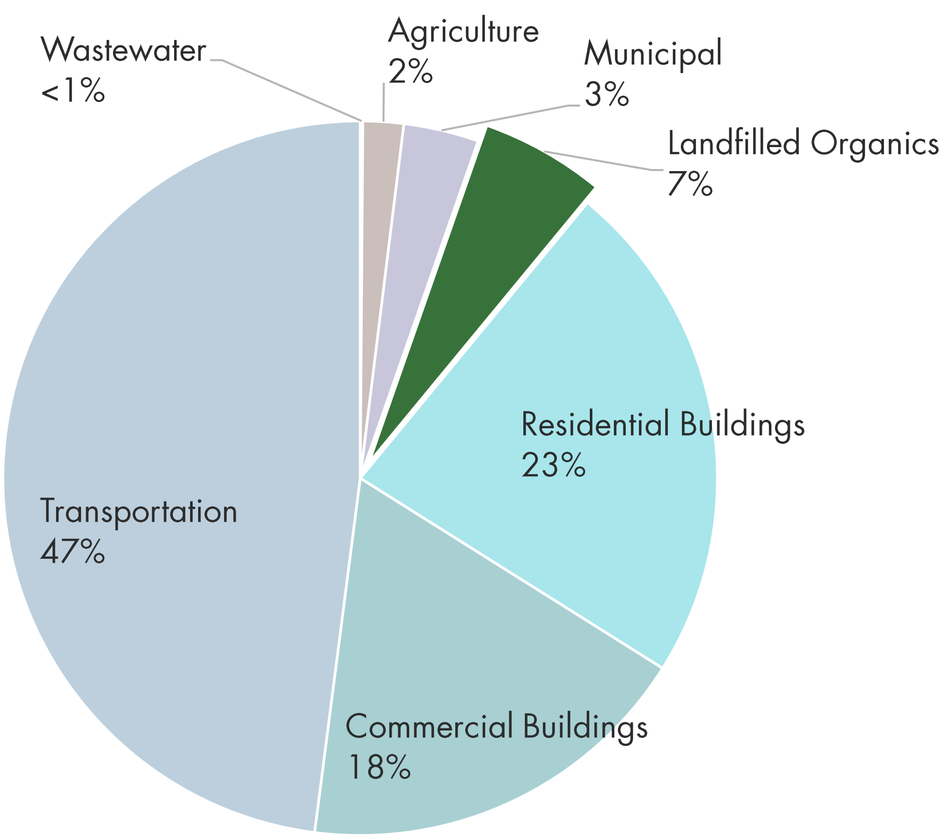

Figure 13. 2019 Landfilled Organics emissions.

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[17] Referred to as the Waste sector in previous inventory years.

[18] Construction and Demolition is a mixture of inorganic materials such as concrete, metals and glass as well as organic materials such as wood and cardboard. Organic materials decompose in landfills and release methane.

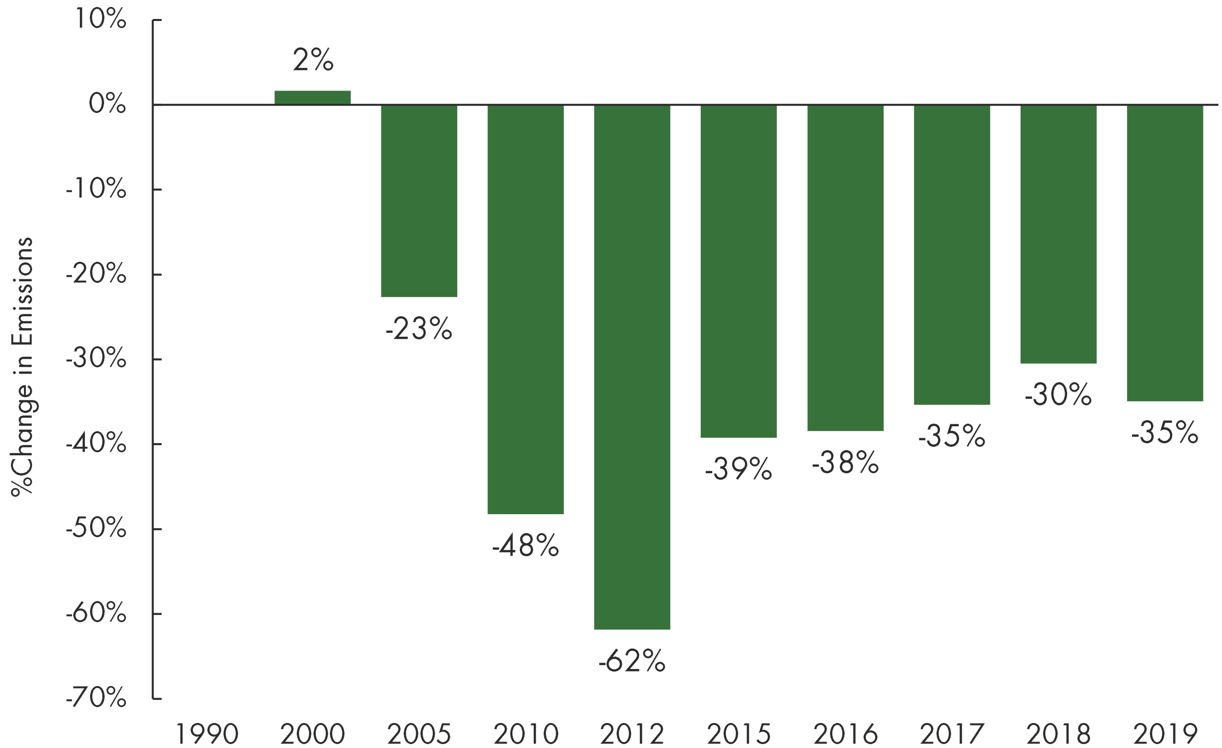

Figure 14. Landfilled Organics emissions changes compared to 1990 levels.

MUNICIPAL

In 2019, emissions from the Municipal sector totaled 156,000 mtCO_2e, accounting for 3% of San Francisco's total emissions (Fig. 15). Emissions in the Municipal sector[19] were generated from city-owned buildings (86%) and the City's fleet of non-revenue vehicles[20] (14%). Municipal sector emissions declined 31% below 1990 levels. The steepest decline occurred between 2010 and 2012 when all city-owned buildings began to fully source 100% GHG-free electricity[21] generated from San Francisco Public Utilities Commission's Hetch-Hetchy hydroelectric dam (Fig. 16). As a result, natural gas consumption makes up nearly 100% of the emissions in Municipal buildings (Fig. 17).

Municipal building emissions are driven by natural gas use. Municipal building emissions rose by 0.5% from 133,000 mtCO_2e to 134,000 between inventory years 2018 and 2019 but have fallen by 31% since 1990. Municipal energy efficiency projects, programs, and energy code improvements helped reduce emissions. The City continues to improve its efforts to make municipal buildings more efficient with 67 LEED buildings, totaling 9.37 million square feet, certified from 2004 to 2018.

Municipal fleet emissions fell by 7% between inventory years 2018 and 2019. This was driven by a drop in gasoline consumption, which made up 91% of total non-revenue fleet emissions (Fig. 18). Emissions from diesel use have continued to decline with the rollout of renewable diesel which began in fiscal year 2016. Specifically, diesel consumption in 2019 was a tenth of what it was in 1990, contributing to a 36% drop in fleet emissions compared to 1990 levels. Moving forward, the City will push further city fleet emissions reductions with continued efforts to transition diesel vehicles to renewable diesel, the City Fleet Zero Emissions Vehicles Ordinance, and the EV Readiness Ordinance to target emissions from gasoline consumption. A more detailed analysis of Municipal emissions can be found in the latest SF Municipal Progress Report on Climate and Sustainability[22].

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[19] The majority of energy data for the municipal sector is obtained directly from PG&E.

[20] Since 2009, city-owned fleet emissions were categorized and tracked within the Municipal sector. Non-revenue vehicles are all operations vehicles that do not generate revenue, specifically, all vehicles excluding MUNI bus and light rail vehicles that collect fares from riders.

[21] City-owned buildings have been sourcing hydropower since the 1970's with very little generation coming from carbon-intense sources. Starting in fiscal year 2011, the SFPUC began providing power content labels to the CPUC in which all hydropower since has been verified 100% GHG-free electric power.

[22] https://sfenvironment.org/sites/default/files/fliers/files/sfe_municipal_progress_report_19.pdf

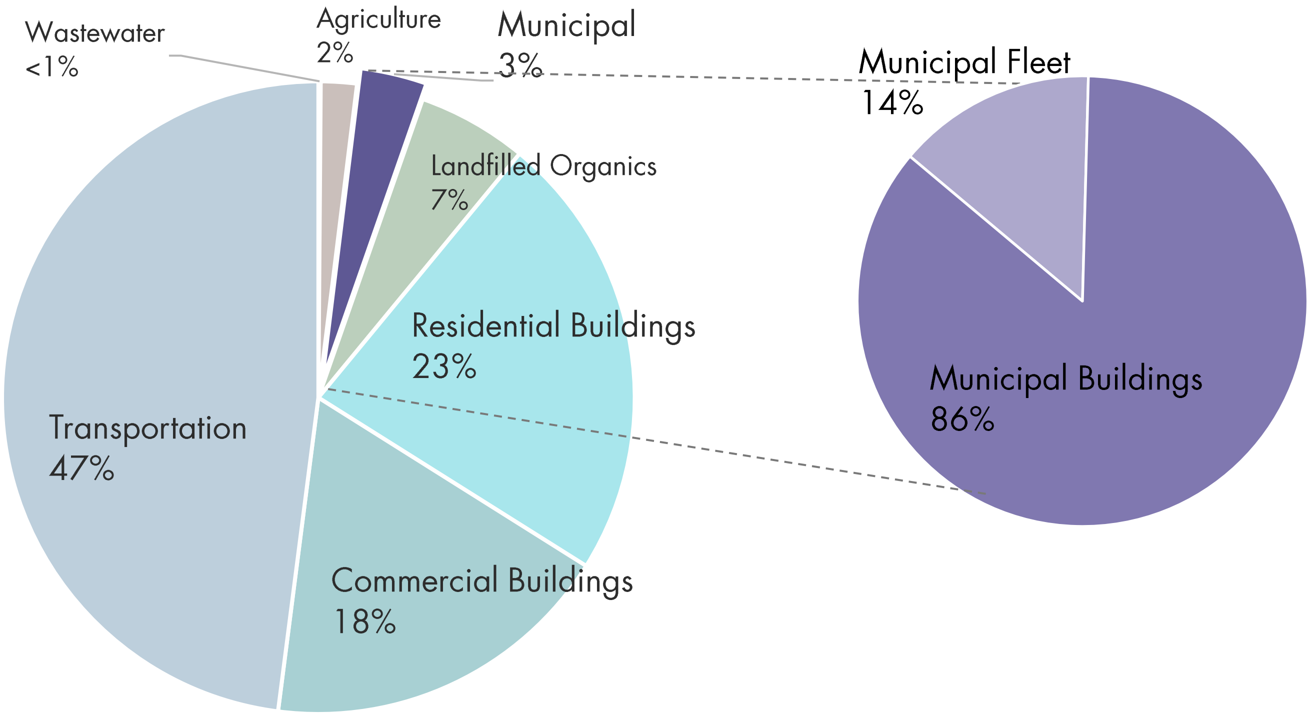

Figure 15. 2019 Municipal sector emissions.

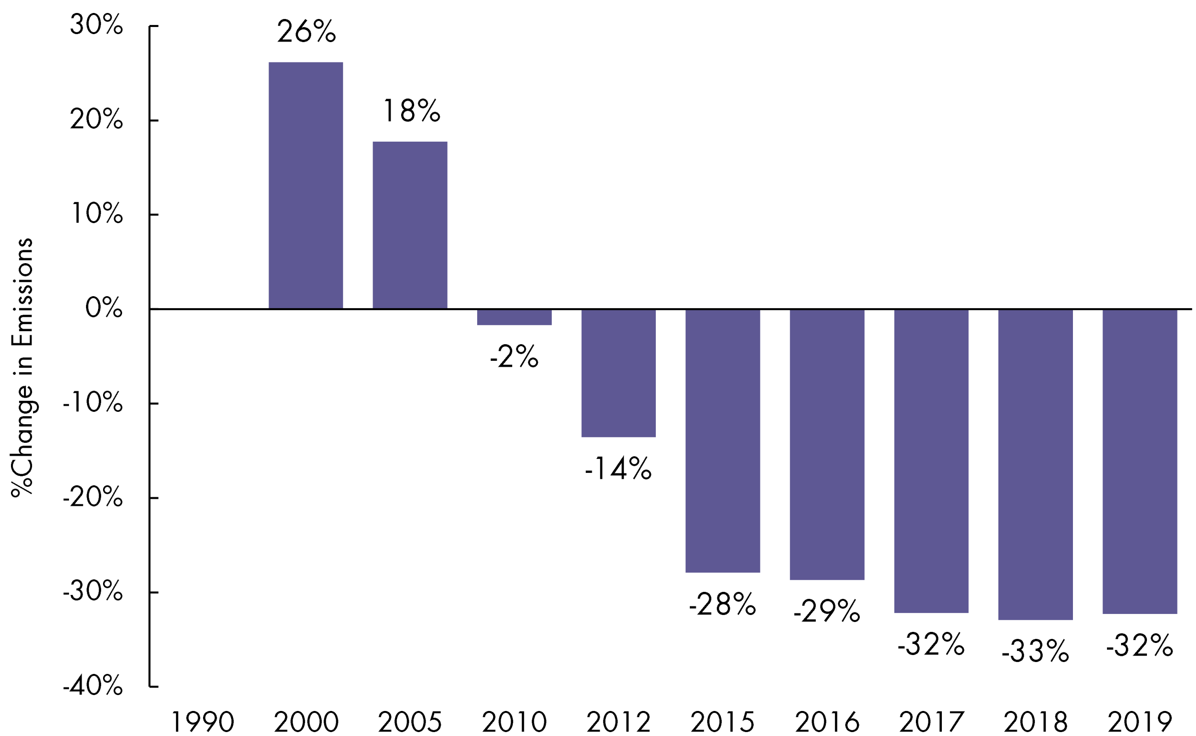

Figure 16. Municipal sector emissions changes compared to 1990 levels.

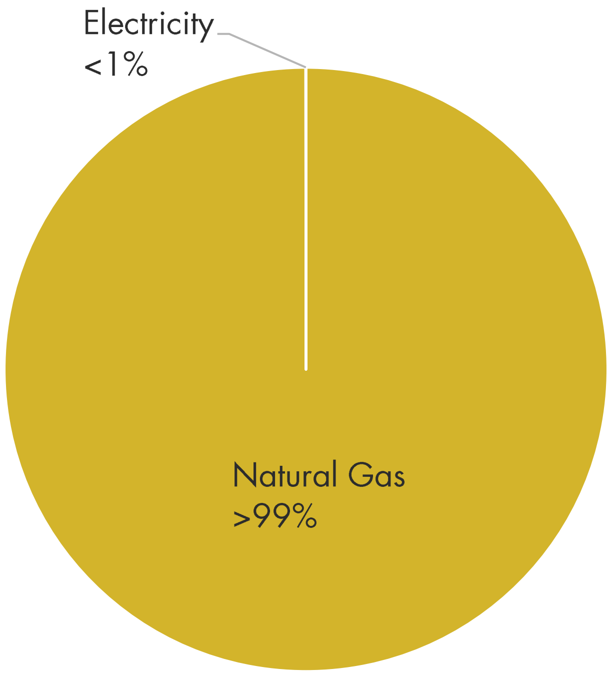

Figure 17. 2019 Municipal buildings emissions share by commodity.

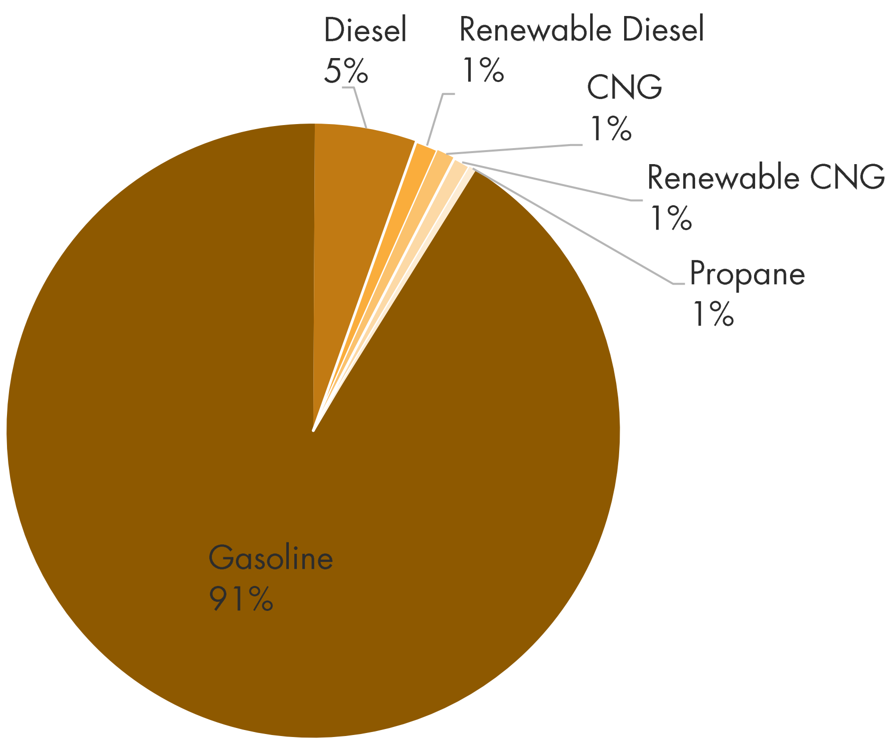

Figure 18. 2019 Municipal non-revenue fleet emissions share by commodity.

AGRICULTURE

In 2019, emissions in the Agriculture sector totaled 84,000 $mtCO_2e$, accounting for 2% of San Francisco's GHG emissions (Fig. 19). Emissions from the Agriculture sector have increased 9% from 1990 levels (Fig. 20) and are generated mostly from animal waste with the remaining share from managing urban soils.[23]

Emissions from the Agriculture sector were little changed between inventory years 2018 and 2019, rising 350 $mtCO_2e$ (<1%) year-over-year. This sector represents a small fraction of San Francisco's emissions and is not a major driver of emissions trends. As such, no further analysis was conducted on the trends impacting this sector at this time.

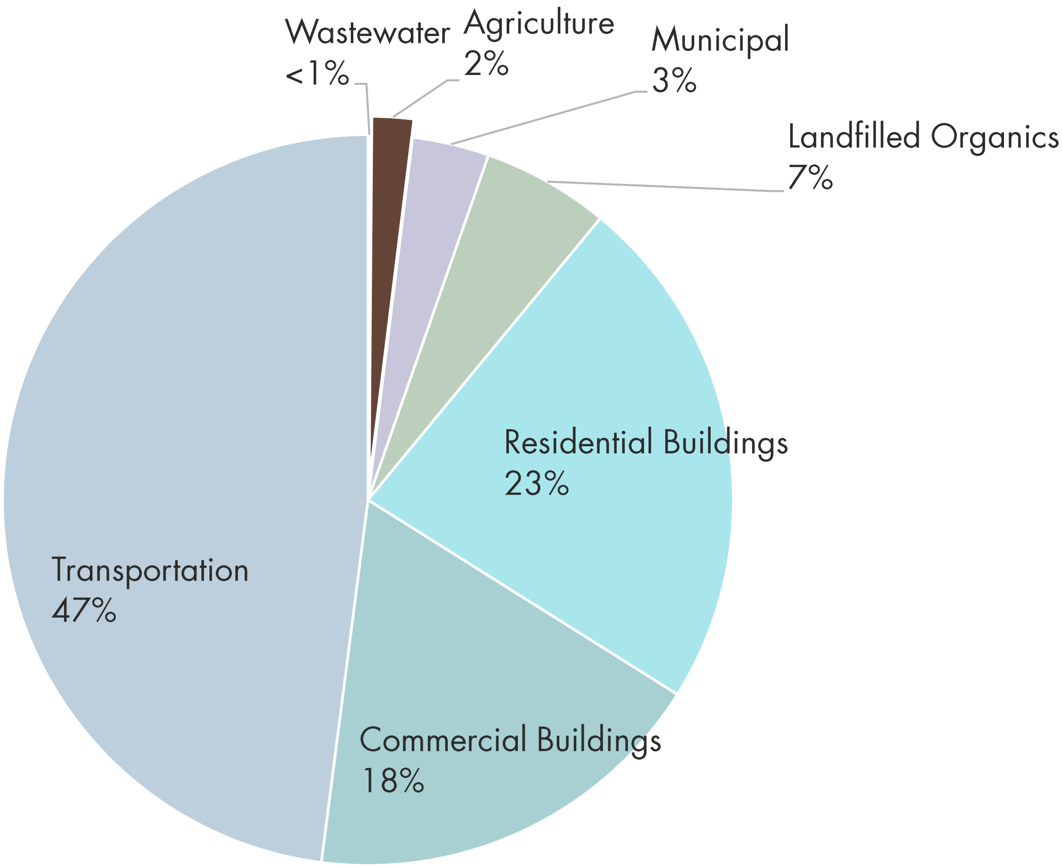

Figure 19. 2019 Agriculture sector emissions.

[23] Emissions in the agricultural sector are allocated to the city proportionally from BAAQMD's regional inventory.

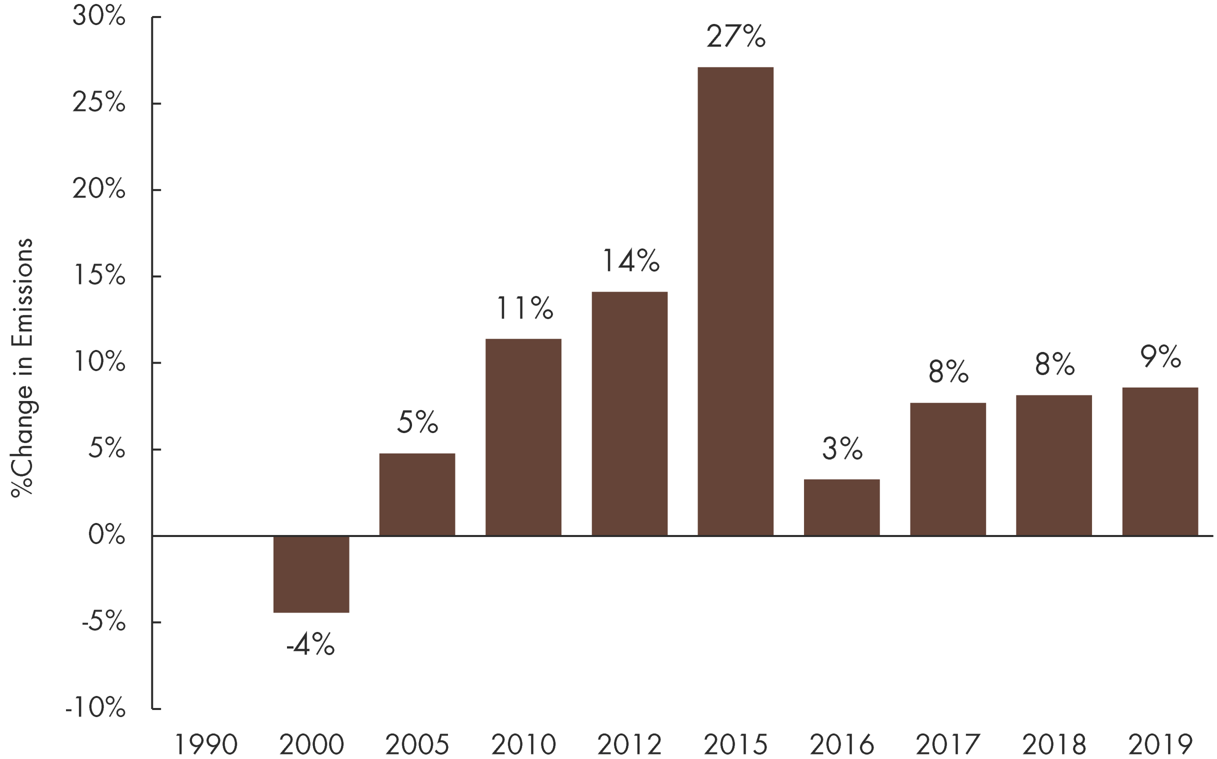

Figure 20. 2019 Agriculture sector emissions changes compared to 1990 levels.

WASTEWATER

In 2019, emissions in the Wastewater sector totaled 5,400 $mtCO_2e$, accounting for just one tenth of a percent of San Francisco's GHG emissions (Fig. 21). Emissions from the Wastewater sector have increased 26% from 1990 levels mainly due to a 22% increase in population, which increases the volume of wastewater treated at the City's water pollution control plants (Fig. 22).

Wastewater sector emissions occur mainly from fugitive emissions, or emissions that are released as effluent is discharged to a body of water. The remaining emissions occur from the energy used in treating wastewater, other processes associated with the treatment, and gases released during the digestion stage. Fugitive nitrogen emissions were responsible for the largest share of wastewater emissions (81%) followed by process nitrogen emissions (17%) and reuse of captured digester gas to power the treatment plant (2%).

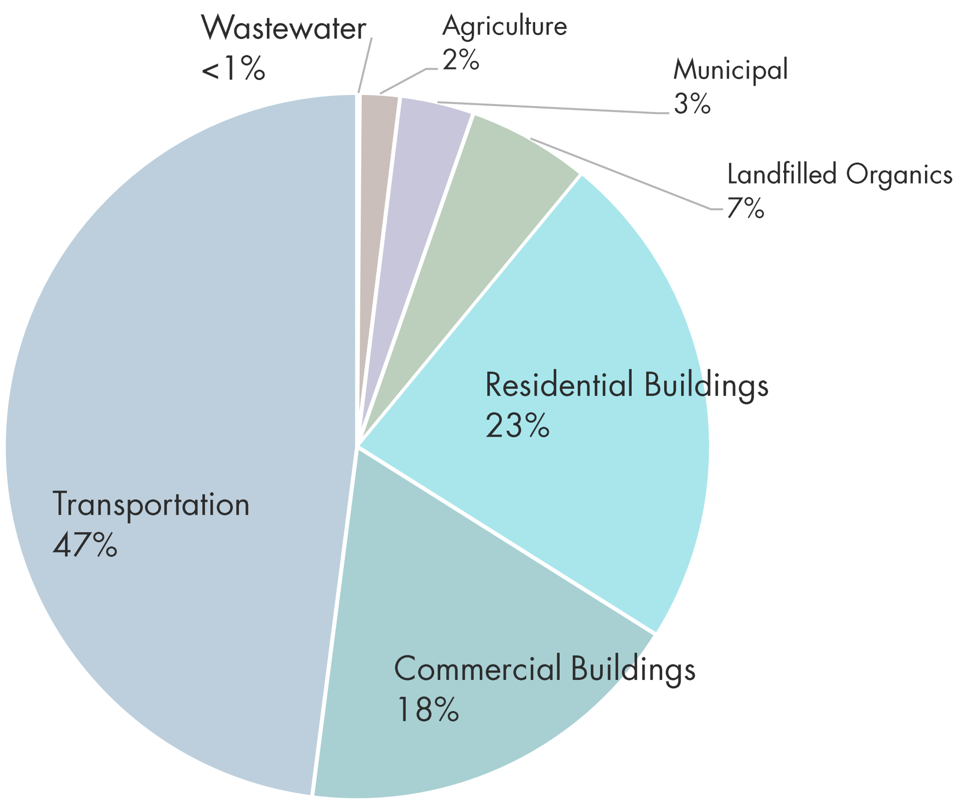

Figure 21. 2018 Wastewater sector emissions.

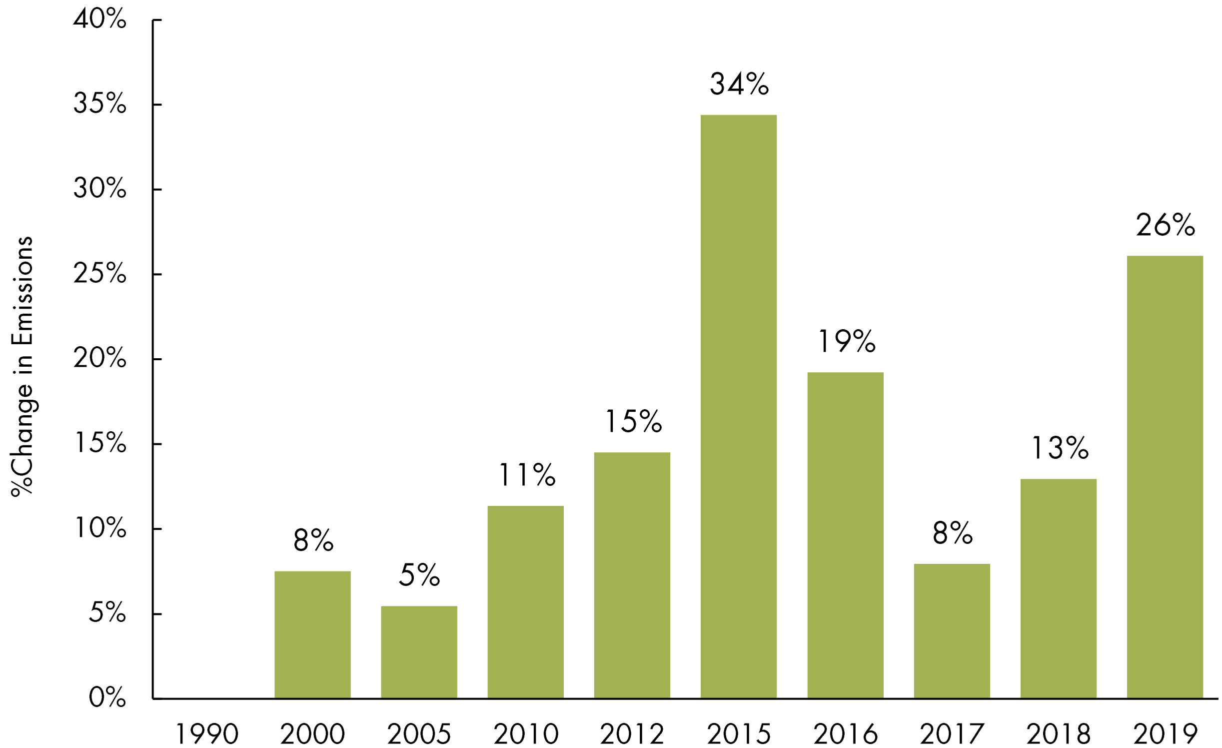

Figure 22. Wastewater sector emissions changes compared to 1990 levels.

STATE OF CALIFORNIA GAVIN NEWSOM, *Governor*

PUBLIC UTILITIES COMMISSION

505 VAN NESS AVENUE
SAN FRANCISCO, CA 94102-3298

FILED
06/01/21
03:06 PM

June 1, 2021

Agenda ID #19555
Quasi-Legislative

TO PARTIES OF RECORD IN RULEMAKING 18-12-006:

This is the proposed decision of Commissioner Clifford Rechtschaffen. Until and unless the Commission hears the item and votes to approve it, the proposed decision has no legal effect. This item may be heard, at the earliest, at the Commission's July 15, 2021 Business Meeting. To confirm when the item will be heard, please see the Business Meeting agenda, which is posted on the Commission's website 10 days before each Business Meeting.

Parties of record may file comments on the proposed decision as provided in Rule 14.3 of the Commission's Rules of Practice and Procedure.

/s/ ANNE E. SIMON__________

Anne E. Simon
Chief Administrative Law Judge

AES:avs

Attachment

Decision **PROPOSED DECISION OF COMMISSIONER RECHTSCHAFFEN**
(Mailed 6/1/2021)

BEFORE THE PUBLIC UTILITIES COMMISSION OF THE STATE OF CALIFORNIA

Order Instituting Rulemaking to Continue the Development of Rates and Infrastructure for Vehicle Electrification.	Rulemaking 18-12-006

DECISION SETTING NEAR-TERM PRIORITIES FOR TRANSPORTATION ELECTRIFICATION INVESTMENTS BY THE ELECTRICAL CORPORATIONS

TABLE OF CONTENTS

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DECISION SETTING NEAR-TERM PRIORITIES FOR TRANSPORTATION ELECTRIFICATION INVESTMENTS BY THE ELECTRICAL CORPORATIONS

Summary

This decision adopts guidance and a streamlined advice letter process for the Electrical Corporations, Pacific Gas Electric Company, Southern California Edison Company, San Diego Gas & Electric Company, Liberty Utilities LLC, Bear Valley Electric Service, and PacifiCorp, regarding near-term priority transportation electrification investments and addresses issues of equity as they relate to transportation electrification. Party comment is invited on whether equity considerations are appropriately addressed. This decision also provides guidance to the Electrical Corporations in the event that they choose to submit proposals for transportation electrification investments prior to the time Transportation Electrification Plans are filed, to avoid gaps in existing program offerings to support meeting state goals for electric vehicle charging facilities for the year 2025.

This proceeding remains open.

1. Background

The Commission opened this rulemaking to, among other things, provide a forum for the development and implementation of policies to guide the Commission's review of investments proposed by the Electrical Corporations[1] in pursuit of transportation electrification (TE). The Assigned Commissioner's Scoping Memo and Ruling (scoping memo) stated that the Commission's Energy Division staff would draft a Transportation Electrification Framework (TEF) to

[1] For the purpose of this proceeding, "Electrical Corporations" refer to the investor-owned utilities Pacific Gas and Electric Company (PG&E), Southern California Edison Company (SCE), San Diego Gas & Electric Company (SDG&E), Liberty Utilities (CalPeco Electric) LLC, Bear Valley Electric Service, and PacifiCorp d/b/a Pacific Power – are considered investor-owned utilities.

allow for such review, aligned with the goals of Senate Bill (SB) 350 (Ch. 547, Stats. 2015) (SB 350).[2] The scoping memo stated that the draft TEF would address a multitude of issues related to investments in TE, including establishing targets specific to certain state policy goals, cost-effectiveness metrics, marketing, education, and outreach efforts, and rate design principles.[3]

A proposed TEF was circulated to parties for their review and comment on February 3, 2020. Comments were received on certain sections of the proposed TEF at different times. On March 6, 2020, several parties filed opening comments on Sections 2, 3.1, 3.2, 3.3, 4, and 5 of the proposed TEF: Vehicle-Grid Integration Council (VGIC), PacifiCorp, Southern California Edison Company (SCE), the Public Advocates Office at the California Public Utilities Commission (Cal Advocates), California Energy Storage Alliance (CESA), Tesla, Inc. (Tesla), Environmental Defense Fund (EDF), Pacific Gas and Electric Company (PG&E), San Diego Gas & Electric Company (SDG&E), Liberty Utilities (CalPeco Electric) LLC (Liberty), BNSF Railway, California Independent System Operator (CAISO), jointly by Community Environmental Council and Green Power Institute (CEC/GPI), Energy Producers and Users Coalition (EPUC), City of Long Beach (Long Beach), Small Business Utility Advocates (SBUA), San Diego Association of Governments (SANDAG), California Large Energy Consumers Association (CLECA), Connect California LLC, Envoy Technologies, Inc. (Envoy), Electrify America LLC (Electrify America), jointly by Center for Biological Diversity, East Yard Communities for Environmental Justice, Sierra Club, Union of Concerned Scientists, Center for Community Action and Environmental Justice (Joint

[2] Scoping memo at 2.

[3] Scoping memo at 2-5.

Commenters), California Transit Association, EVgo Services LLC (EVgo), ChargePoint, Inc. (ChargePoint), Enel X North America, Inc. (Enel X), the Utility Reform Network (TURN), Utility Consumers' Action Network (UCAN), jointly by Greenlots and Siemens eMobility (Greenlots), jointly by Natural Resources Defense Council, the Coalition of California Utility Employees, Enel X, Greenlots, EVBox Inc., and Siemens (NRDC), Advanced Energy Economy, Alliance for Transportation Electrification (ATE), and jointly by General Motors, LLC, Kia Motors Corporation, Ford Motor Company, Alliance for Automotive Innovation, and Hyundai Motor Company (Joint Automakers).

Concurrently on March 6, 2020, a *Joint Motion to Stay the Draft Transportation Electrification Framework to Revise the Procedural Schedule and Provide for Alternative Proposals* (Joint Motion) was served on behalf of NRDC, Coalition of California Utility Employees, Sierra Club, EDF, Center for Community Action and Environmental Justice, East Yard Communities for Environmental Justice, Union of Concerned Scientists, Center for Biological Diversity, Alliance for Automotive Innovation, Honda Motor Co. Inc, San Diego Airport Parking Company, Cruise LLC, CALSTART, Advanced Energy Economy, ATE, Enel X, VGIC, Siemens, Greenlots, Nuvve Corporation, ChargePoint, SCE, and SDG&E (collectively, the Joint Movants).

The Joint Motion requested that the Commission stay the schedule for considering the proposed TEF and revise the procedural schedule to provide for the development and consideration of alternatives to the TEF. The Joint Motion was denied on March 24, 2020 by email ruling. The ruling of March 24, 2020 clarified that alternatives to the proposed TEF were welcome within party comment on the proposed TEF itself. The ruling of March 24, 2020 also extended the deadline for reply comments on Sections 2, 3.1, 3.2, 3.3, 4, and 5 of the proposed TEF to April 27, 2020.

Reply comments were filed by the following parties on April 27, 2020: TURN, SDG&E, PG&E, EVgo, SCE, Silicon Valley Leadership Group, EDF, SBUA, California Hydrogen Business Council, ChargePoint, jointly by National Diversity Coalition and National Asian American Coalition (NDC), Alliance for Automotive Innovation, Plug In America, VGIC, Cal Advocates, jointly by City of San Jose, California Choice Energy Authority, Sonoma Clean Power Authority, Marin Clean Energy, Silicon Valley Clean Energy Authority, Redwood Coast Energy Authority, Monterey Bay Community Power, East Bay Community Energy (Joint CCAs), Tesla, Center for Sustainable Energy (CSE), Siemens, ATE, CALSTART, Peninsula Clean Energy, Sacramento Municipal Utility District (SMUD), BNSF Railway, Enel X, UCAN, CEC/GPI, Joint Commenters, Electrify America, Greenlots, NRDC, the Greenlining Institute (Greenlining),[4] and Ecology Action.[5]

Comments on sections of the proposed TEF other than Sections 2, 3.1. 3.2, 3.3, 4, and 5 were received later in 2020. This decision does not consider those later-filed comments, and instead relies on the party comments filed on March 6 and April 27, 2020 for its findings, conclusions, and orders related to Section 5 of the proposed TEF related to near-term priorities for TE investments. Guidance related to other sections of the proposed TEF will be issued by the Commission

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[4] The reply comments of Ecology Action were filed on May 6, 2020; but deemed filed on April 27, 2020.

[5] The reply comments of Ecology Action were filed on May 8, 2020; but deemed filed on April 27, 2020.

at a later date. The comments on the proposed TEF filed after April 27, 2020 may be considered in subsequent Commission decisions in this proceeding.

2. Issues Before the Commission

As noted by the scoping memo, the issue before the Commission in this decision is whether to adopt a TEF for the Electrical Corporations.[6] As this decision considers whether to adopt elements of Section 5 of the proposed TEF, this decision specifically considers guidance regarding near-term priorities for TE investments by the Electrical Corporations.

Some issues contemplated by the scoping memo that are related to the implementation this decision, such as ensuring equitable TE investments, are also considered. However, a comprehensive revised draft TEF will not be issued at this time. Rather, the proposals set forth in Section 5, only, will be finalized here.

3. Context for Decision on Near-Term Priorities in Light of State Policy Goals

The proposed TEF recommended that the Commission adopt a TEF for the Electrical Corporations. The TEF was intended to be "a common comprehensive framework for review of proposed investments by the [Electrical Corporations] to stimulate [TE], aligned with the goals of [SB 350]."[7] More specifically, the proposed TEF provided a framework for Electrical Corporations to plan TE investments and activities through 2030, including emerging trends, and included more detailed guidance for action the Electrical Corporations should take through 2025.

[6] Scoping memo at 2-5.

[7] Proposed TEF at 13.

The Commission is still considering party comment on the proposed TEF's requirements for Transportation Electrification Plans (TEPs) to be filed by each of the Electrical Corporations. While party comments support the Commission requiring Electrical Corporations to submit TEPs and we intend to require the Electrical Corporations to develop and submit TEPs, the details of the contents and timing of the TEPs will be addressed in a future Commission decision. As proposed, the TEPs would allow for more streamlined approval of Electrical Corporation investments in TE infrastructure, after the completion of a planning process by the Electrical Corporations to determine the appropriate scope and scale of those investments. As noted by several parties in their comments, the timeline for future TE investments by the Electrical Corporations depends largely on when the TEPs and program applications are approved. At this time, although the Commission aims to consider TEPs and Electrical Corporation proposals based on those TEPs as soon as possible, it is prudent to provide guidance on possible interim investments for Electrical Corporations and expedited processes for reviewing certain proposals to help ensure that the important state zero-emission vehicle (ZEV) policy goals are met in a timely fashion.

California has established several critical TE policy goals to accelerate the adoption of ZEVs and increase access to charging stations. In March 2012, former Governor Jerry Brown issued Executive Order B-16-12, establishing a target of reaching one million ZEVs on the road by 2025. The passage of SB 350 (de Leon, 2015) directed the CPUC to work with the California Energy Commission (CEC) and the California Air Resources Board (CARB) to require the Electrical Corporations to develop proposals to accelerate widespread TE. Former Governor Brown later increased the state's ZEV deployment goal via

Executive Order B-48-18 which sets a goal of five million ZEVs by 2030, and 250,000 light-duty or passenger ZEV chargers (hereinafter "light-duty chargers" or "light-duty EVSE"[8]), including 10,000 direct current fast chargers (DCFCs), in place in California by 2025.

More recently in September 2020, Governor Newsom issued Executive Order N-79-20, which sets multiple additional ZEV goals: 1) 100 percent of in-state sales of new passenger cars and trucks be ZEVs by 2035; 2) 100 percent of medium- and heavy-duty (MD/HD) vehicles in the state be ZEVs by 2045, for all operations where feasible and by 2035 for drayage trucks; and 3) 100 percent of zero-emission off-road vehicles and equipment be ZEVs by 2035, where feasible.

According to the CEC's Assembly Bill (AB) 2127 Electric Vehicle Charging Infrastructure Assessment staff report (AB 2127 staff report), California has nearly 67,000 public and shared light-duty EV chargers installed, including over 5,000 DCFCs, as of September 30, 2020. The AB 2127 staff report found that an approximately 121,000 additional chargers are currently planned or under development. This leaves a gap of approximately 60,000 light-duty chargers—59,000 Level 2[9] and 500 DCFC--needed between now and 2025.[10] Although the AB 2127 staff report identifies additional needed light-duty chargers to meet the 2030 goal of five million ZEVs, and a preliminary projection of the light-duty chargers required to support Executive Order N-79-20's goal of all new

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[8] EVSE stands for Electric Vehicle Service Equipment.

[9] Level 2 chargers are EV chargers that use between 208 and 240 volts of alternating current (AC) electricity to charge EVs at a rate of up to 19.2 kilowatts (kW).

[10] AB 2127 staff report at 12. Pursuant to Rule 13.9, this decision takes notice of the findings of the AB 2127 staff report that are referred to in this decision, and relies upon them for the findings, conclusions, and orders of this decision. Parties that dispute the accuracy of the findings of the AB 2127 staff report that are relied upon by this decision should make that known in their comments on the proposed version of this decision.

passenger vehicles being ZEVs by 2030, this decision focuses on the report's 2025 projections of light-duty charger needs as this decision specifically considers near-term investments.

The AB 2127 staff report also provides early analysis on projected MD/HD charging infrastructure needs to support Executive Order N-79-20. Through the CEC's HEVI-LOAD[11] model, the CEC staff report estimates that 157,000 chargers will be needed in 2030. This includes a total of approximately 157,000 DCFCs—141,000 of which would be 50 kilowatts (kW) and 16,000 would be 350kW. These modeling results are based on early CARB analysis that estimates that 180,000 MD/HD ZEVs will be needed in 2030 to meet Executive Order N-79-20. Although these MD/HD targets are focused on 2030, in the absence of earlier quantified targets for this sector, these are the most relevant for this decision focused on near-term TE investments. It is important to note that some of these numbers, as well as the light-duty numbers, may shift as the CEC finalizes the data in the final CEC report and subsequent updates.

As described above, CEC staff have quantified a numerical target for light-duty EV charger deployment across the state to achieve the Executive Order B-48-18 infrastructure targets, a numerical target for light-duty EV charging to achieve the additional required infrastructure necessary to support Executive Order B-48-18's target of five million ZEVs by 2030, and numerical targets for both light-duty and MD/HD EV charger deployment to put the State on the trajectory to achieve the 2035 and 2045 goals set forth in Executive Order N-79-20. CEC staff have further found that additional TE investments by the Electrical Corporations and other public sources are necessary to meet the target,

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[11] HEVI-LOAD refers to Medium- and Heavy-Duty Electric Vehicle Infrastructure Load, Operations and Deployment.

but note that private investment will be critical as ratepayers and the public cannot bear all of the costs associated with needed charging throughout the state. While an absence of Electrical Corporation investments would not prevent the installation of some new chargers between now and 2025 – due to state-funded incentive programs, publicly-owned utility programs, and private investments – the AB 2127 staff report is clear that some measure of Electrical Corporation investment is needed. According to CEC staff, "[w]hile companies have demonstrated success in deploying charging solutions requiring little or no ratepayer or public funding support, at present, many charging service providers have not found a self-sustaining business model operable at the scale for California to achieve widespread electrification."[12] However, the AB 2127 staff report identifies necessary structural changes so that the market could operate more independently such as an continued coordinated government and regulatory approach towards making investments aimed at solving EV charging industrywide constraints to minimize startup costs and barriers and encourage investments beyond first-movers.

While the AB 2127 staff report models the charger deployment targets for the whole state, it is the role of the Commission to determine the level of support ratepayers should provide to help the state to ensure that an additional 59,000 Level 2 chargers and 500 DCFCs are operational by 2025. State-funded programs, publicly owned utility investment, private investments, and other sources of funding will lead to the deployment of some additional chargers by 2025. However, this decision finds that some level of Electrical Corporation

[12] AB 2127 staff report at 75.

investments in TE infrastructure beyond that already approved by the Commission will be required for the state to meet its 2025 charger goals.

The Commission expects that a subsequent decision on the TEF will make a determination on how the Electrical Corporations will play a role in meeting these state targets in the long run. If Electrical Corporations submit proposals for near-term investments they should provide rationale for how the programs will help California meet these targets without placing the full burden on ratepayers.

For context, the Commission has authorized the Electrical Corporations to spend more than $720 million[13] on light-duty charging alone to build approximately 52,000 chargers – $44 million for SCE's Charge Ready Pilot and Bridge, $45 million for SDG&E's Power Your Drive, $130 million for PG&E's EV Charge Network, $22.4 million for PG&E's DCFC make-ready program, $436 million for SCE's Charge Ready 2, and $43 million for SDG&E's Power Your Drive 2. The Commission has authorized a total spending of $1.5 billion in TE expenditures when the medium- and heavy-duty sector is accounted for.

This decision does not establish a particular quantity of chargers that should be incented through customer-side TE investments by the Electrical Corporations. However, based on the discussion above, this decision does find that some incremental investments by the Electrical Corporations beyond what has already been authorized over the next four years for light-duty EV charging and medium- and heavy-duty EV charging will be necessary to meet the State's policy goals, and this decision aims to give the Electrical Corporations reasonable guidance for helping the state to achieve those goals. This decision also incorporates by reference holdings from Decision (D.) 20-09-025, where the

[13] This does not include some of the smaller pilots authorized as Priority Review Programs.

Commission concluded that it is the Legislature's intent that the Commission establish policy and authorize reasonable utility investment that attracts private investment in EV charging services, makes charging infrastructure more available to Californians, and increases adoption and usage of EVs across all classes and weights, including light-, medium-, and heavy-duty electric vehicles, and off-road electric vehicles or off-road electric equipment.[14]

Because of the time needed to plan, permit, construct, and operate EVSE installations, any proposals that the Electrical Corporations submit to address the near-term investments should be filed with the Commission soon to ensure that they are supporting the state in meeting its 2025 policy goals. To that end, this decision provides guidance for proposals from the Electrical Corporations to incent deployment of charging solutions in the near-term priority areas identified by this decision and to allow for extensions of existing programs for efficiency and to avoid gaps in program offerings that would inhibit the state from meeting these targets.

An advice letter process for these proposals is discussed further in this decision, based on the near-term priorities section (Section 5) of the proposed TEF and party comments on the same. However, if choosing not to use the advice letter process, Electrical Corporations are not restricted to proposals that meet the near-term priority areas identified by this decision, and may file applications for TE infrastructure beyond those proposals up to the time that their TEPs are approved.

[14] D.20-09-025 at 16-17.

3.1. AB 841 Provisions

On September 30, 2020, the Governor signed AB 841 (stats. 2020, Ch. 372), which, among other things, amended Pub. Util. Code § 740.12 (effective January 1, 2021) to require that at least 35 percent of TE investments made by the large Electrical Corporations be made in "underserved communities." This legislation was passed and chaptered subsequent to party comment on the draft TEF.

AB 841 defines an underserved community as a community that meets one of the following criteria:

1. A community with a median household income less than 80 percent of the statewide average.[15]
2. Census tracts with median household incomes at or below 80 percent of the statewide median income or with median household incomes at or below the threshold designated as low income by the Department of Housing and Community Development's list of state income limits adopted pursuant to Health and Safety Code § 50093.[16]
3. Is within an area identified as among the most disadvantaged 25 percent of the state according the California Environmental Protection Agency and based on the most recent California Communities Environmental Health Screening Tool, also known as CalEnviroScreen.[17]
4. A community in which at least 75 percent of public school students in the project area are eligible to receive free or

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[15] Pub. Util. Code § 1601(e)(1), citing Pub. Resources Code § 75005(g). As noted by comments to the proposed decision, there appears to be a misapplication of the concept of median income when compared with average income and ambiguity in the use of the term "community;" but this language is directly from statute and cannot be modified by this decision. The electrical corporations should use good faith efforts to reasonably apply this definition.

[16] Pub. Util. Code § 1601(e)(2), citing Health & Saf. Code § 39713(d)(2).

[17] Pub. Util. Code § 1601(e)(3).

reduced-price meals under the National School Lunch Program.[18]

5. A community located on lands belonging to a federal recognized California Indian tribe.[19]

AB 841 also requires that the Electrical Corporations seek Commission approval of "a new tariff or rule that authorizes each Electrical corporation to design and deploy all Electrical distribution infrastructure on the utility side of the customer's meter for all customers installing separately metered infrastructure to support charging stations…"[20] As of the time of this decision, Energy Division staff are reviewing the advice letter filings that each Electrical corporation submitted to establish this new policy. However, it is important to note that since AB 841 and the establishment of these new tariffs or rules covers all of the costs on the utility-side of the meter for infrastructure related to the deployment of EV charging, any proposal for near-term investment pursuant to this decision should only be for customer-side infrastructure.

AB 841 further provides additional directives on the Electric Vehicle Infrastructure Training Program (EVITP) applicable to this decision. Pub. Util. Code § 740.20(a)(1) requires that EV charging infrastructure and equipment located on the customer-side of the Electrical meter that is funded or authorized, in whole, or in part, by the Commission shall be installed by a contractor with the appropriate license classification, as determined by the Contractors' State

[18] Pub. Util. Code § 1601(e)(4). There is some ambiguity in the use of the term "community;" but this language is directly from statute and cannot be modified by this decision. The electrical corporations should use good faith efforts to reasonably apply this definition.

[19] Pub. Util. Code § 1601(e)(5). There is some ambiguity in the use of the term "community;" but this language is directly from statute and cannot be modified by this decision. The electrical corporations should use good faith efforts to reasonably apply this definition.

[20] Pub. Util. Code § 740.19(c).

License Board, and at least one electrician on each crew, at any given time, who holds an EVITP certification. Pub. Util. Code § 740.20(a)(2) requires that projects installing charging ports supplying 25 kilowatts (kWh) or more to a vehicle have at least 25 percent of the total electricians working on the crew for the project, at any given time, hold EVITP certification. These provisions apply to all Commission authorized programs adopted after January 1, 2021 and all work performed on or after January 1, 2022.

Pub. Util. Code § 740.20(b)(1) clarifies that § 740.12(a) does not apply to EV charging infrastructure installed by employees of an Electrical Corporation or local publicly owned electric utility.

4. Near-Term Priority Investments

The proposed TEF stated that Electrical Corporations should provide clear justification for ratepayer investment in any applications filed prior to the adoption of their TEPs and outlined several priority areas for TE investments for the Electrical Corporations between the present and the time their TEPs are approved by the Commission, if the Electrical Corporations choose to request funding. The proposed TEF referred to these as "near-term priorities" and this decision adopts the use of that term. The proposed TEF also recommended the Commission adopt a streamlined advice letter process for review of smaller TE investments "to effectively address key barriers to widespread TE."[21] Electrical Corporations may choose to propose investments in the near-term priority areas via advice letter, as described below, and can submit applications for extensions of existing programs in order to avoid any gaps in program offerings. They also

[21] Proposed TEF at 24.

have the option to submit programs that do not fit the parameters above via traditional applications, pursuant to SB 350.

The proposed TEF reasoned that the near-term priorities were justified by the "current state of the market, state regulatory deadlines, and other TE barriers that could be addressed through 'no-regrets' investments."[22]

The proposed TEF recognized that, with potentially two years between issuing of the TEF and approval of the Electrical Corporations' TEPs and program proposals, there may be barriers and priorities that require electric corporation investment in the near-term. The proposed TEF suggested that the Electrical Corporations could consider filing applications before approval of their TEPs that address the following near-term priorities:

- Resiliency;[23]
- Customers without access to home charging;[24]
- Medium and heavy-duty EV adoption;[25] and
- New building construction.[26]

The proposed TEF recommended that the following conditions apply to any near-term priority proposal:

- Completed within two years of the initial application.

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[22] Proposed TEF at 42.

[23] Consisting of programs that support the installation of EV charging at evacuation/emergency response centers; and/or piloting technologies and programs that use EVs as backup power resources to enhance resiliency in communities that may face power shut-offs due to weather, wildfire risk or other emergencies.

[24] Consisting of programs that address the cost of fueling disparity through non-infrastructure approaches; and/or create charging options for customers that lack access to home EV charging.

[25] Consisting of programs that support regulatory mandates to electrify transit under CARB's Innovative Clean Transit regulation, and/or implement strategies to electrify high-emitting medium- and heavy-duty fleets.

[26] Consisting of programs that support lower-cost EVSE installation in new buildings.

- Should inform and be incorporated into the Electrical Corporation's longer-term TE planning.
- Minimize long-term commitments that may be inconsistent with the Electrical Corporation's TEP.[27]
- Address equity.
- Adhere to a total budget of $20 million for each Electrical Corporation for all near-term priority projects.
- Clear justification for ratepayer investment (*i.e.*, near-term priority proposal should not propose new investment in areas where the market shows signs of private sector engagement).

The proposed TEF recommended the Electrical Corporations address the following barriers and issues for near-term priority applications or advice letters for projects seeking to address TE resiliency:[28]

- Propose the inclusion of language in Public Safety Power Shutoff (PSPS) notifications suggesting customers fully charge their EV as soon as possible.
- Propose a process to identify and implement strategies to reduce customer's rates for electricity consumed as a transportation fuel between the announcement and enactment of a PSPS.
- Demonstrate proactive coordination with emergency services organizations, community-based organizations, local communities, planning agencies, and auto manufacturers to identify the infrastructure investments, utility IT system upgrades, and other technology

[27] For example, by avoiding irrevocable hardware commitments or market interventions that the Commission has not already authorized in a prior TE-related decision, and/or by including criteria for hardware and software that can be supported and implemented by multiple entities.

[28] Staff's discussion on resiliency focused on activities to prepare for, withstand, and recover from disturbances. While both the range of activities and the types of disturbances that are included in discussions about resilience can vary widely depending on the context, staff uses resilience to mean the ability and availability of EVs to provide and receive energy services during a grid outage.

developments necessary to enable vehicle-to-building functions to support resiliency efforts.

- Demonstrate alignment with the policy priorities of the microgrid proceeding Rulemaking (R.) 19-09-009 by designing appropriate pilots that test the use of EVs as backup power resources.
- Propose the deployment of off-grid EV charging solutions, placed in strategic locations such as Electrical Corporation Community Resource Centers with a demonstration of coordination with community organizations and representatives when choosing where to locate this charging.
- For TE assets that may be damaged by wildfire or other disaster, propose employing the Catastrophic Events Memorandum Account (CEMA) through which they are authorized to seek cost recovery of damaged investments in a declared emergency.
- In areas that have or will potentially suffer damage from a wildfire or other natural disaster, demonstrate partnership with local resources to ensure that new construction is compatible with the expected growth in EV adoption.
- Include forecasted distribution and transmission capacity upgrades necessary to support projected EV adoption in areas that have or will potentially suffer damage from a wildfire or other natural disaster, along with other needed EV infrastructure in new buildings.

The proposed TEF recommended that Electrical Corporations address the following barriers and issues for near-term priority advice letters or applications for projects seeking to address the needs of customers without access to home charging:

- Leverage lessons learned from existing Electrical corporation TE programs.
- Demonstrate an innovative approach to meeting the infrastructure needs of this segment, or a non-

infrastructure approach to address cost of fueling disparity.

- Seek community and stakeholder feedback in advance of submission to the Commission.
- Include a component to address environmental and social justice communities.
- Seek to share costs with non-ratepayer sources.
- Consider whether incentives could be designed to help offset the cost of public charging for customers that lack home charging options.

Since the release of the proposed TEF, the Commission issued a decision concerning the Low Carbon Fuel Standard (LCFS) holdback credit revenue.[29] This decision directed some of the funds not spent on equity projects to be spent on TE resiliency programs. This decision defined resiliency projects as:

1. Those that lead to the installation of EV charging facilities at evacuation/emergency response centers, or at other critical facilities and critical infrastructure, like those defined under the Self-Generation Incentive Program. This could include deployment of charging infrastructure at these locations, storage-supported charging, off-grid charging, or other innovative ways to support charging infrastructure and resiliency by providing EV owners with the ability to charge their vehicles in the event that grid outages prevent them from fueling their EVs where they would normally charge them; and/or
2. Those that pilot technologies that allow EV owners to use their EV to power electric equipment at their homes or businesses in the event of grid outages due to weather, wildfire risk, or other emergencies.

The proposed TEF recommended that Electrical Corporations address the following barriers and issues for near-term priority advice letters or applications

[29] D.20-12-027.

for projects seeking to bridge gaps between Commission authorized electric corporation medium- and heavy-duty programs and time-sensitive infrastructure needs:

- Describe how specific recently adopted State regulations require the immediate support of ratepayers prior to applications submitted based on approved TEPs.
- Describe how the Electrical Corporation coordinated with State agency(s) to identify unaddressed, time sensitive needs and how the near-term priority program addresses these needs.
- Explain why previously approved program funding levels will not be sufficient to meet these needs, or why previously approved programs will end before these needs are met.

The proposed TEF recommended the Electrical Corporations address the following barriers and issues for near-term priority advice letters or applications for projects seeking to support EV charging infrastructure in new construction:

- Leverage best practices from and coordinate outreach with existing Electrical Corporation energy efficiency programs while also addressing any specific unique needs for TE host sites.
- Coordinate with environmental and social justice communities, including affordable housing developers if not already included in outreach, during program development to ensure participation by a broad range of communities.
- Include outreach strategies for smaller building/facility types.
- Ensure that the program only applies to developments that exceed the minimum existing code in their local jurisdictions, including any local codes that exceed the existing CALGreen requirements.

- Ensure some level of developer buy-in and cost sharing, and be simple to understand and implement.

4.2. General Comments on Near-Term Priority Approach

Several parties broadly criticized the near-term priorities proposal, and the proposed $20 million budget cap in particular, arguing that it would delay the process for approving critical TE investments, constrain the funding necessary to meet the state's TE policy goals, and arbitrarily limit the scope of many TE infrastructure proposals.[30] Among these parties, NRDC predicted that the near-term priorities approach would result in "diminutive-scale pilots that are too small to provide any meaningful support for the identified 'near-term priorities.'"[31] SCE believed that the near-term priority categories were "arbitrarily prescribed" and did not "adequately address the numerous substantial barriers faced across EV sectors and segments."[32] SDG&E opposed the proposed near-term priorities process, claiming that it would unjustifiably circumscribe the scope and scale of applications to support state policy goals and would be contrary to legislative direction in SB 350.[33] The Alliance for Automotive Innovation made similar arguments with respect to near-term

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30 *See, e.g.*, VGIC opening comments at 3-4; EDF opening comments at 3 (characterizing the near-term priorities as "too narrowly defined and too small in scope to enable meaningful progress"); SMUD reply comments at 3 ("[t]he TEF limitations on the size, scope, and duration of [TE] applications and the overly prescriptive nature of the process proposed in the TEF for adoption of future TE programs detracts from achieving the necessary first step of defining the scope of transportation electrification over the next ten to twenty years, and will hinder the State's efforts to meet the its ambitious EV goals and, ultimately, [greenhouse gas] goals").

31 NRDC opening comments at 4.

32 SCE opening comments at 5.

33 SDG&E opening comments, *passim*.

priority projects, and recommended simply accepting and reviewing any applications for TE investments in the near-term by applying SB 350.[34]

While noting that the list of near-term priorities had merit, PG&E argued that the overall approach "lacks the urgency necessary to support immediate TE needs."[35] PG&E sought flexibility for near-term TE investments with "sufficient justification and evidence to warrant consideration."[36] They proposed additional pathways for an Electrical Corporation to seek approval of near-term priority TE investments, including that the Commission "allow for streamlined, Commission approval via advice letter of proposals to extend any existing [Electrical Corporation] program already approved by the [Commission] subject to reasonable cost caps and implementation of lessons learned from the existing programs."[37] PG&E also sought clarification that workplace charging was not specifically excluded from near-term priority proposals.[38]

Greenlots and Siemens also opposed the near-term priorities approach on the basis that it artificially constrains the ability of the Electrical Corporations to propose TE investments, and therefore "impermissibly re-writes the roles that the legislature defined, while defining the scope and scale of utility programs in a manner that is fundamentally inconsistent with these roles."[39] ATE made a similar argument.[40]

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[34] Alliance for Automotive Innovation reply comments at 2.

[35] PG&E opening comments at 18.

[36] PG&E opening comments at 19.

[37] PG&E opening comments at 5.

[38] PG&E reply comments at 6.

[39] Greenlots and Siemens opening comments at 14.

[40] ATE reply comments at 10-11.

SCE proposed an alternative approach to selecting and funding applications for near-term priority projects. SCE recommended replacing the process proposed in the TEF with a more urgent process where 1) Electrical Corporation programs and activities are selected that are critical to meet the state policy goals related to TE, 2) avoid disruptions to those programs and activities, 3) accelerate the Commission's approval process, and 4) ensure funding is sufficient to support the state's TE policy goals.[41] ATE and Greenlots each supported SCE's proposal.[42]

CESA noted their support for the list of near-term priorities in general but did not believe they should be used to constrain applications by Electrical Corporations for TE investments before their TEPs are finalized. Instead, CESA argued that Commission should simply use the existing SB 350 framework to review proposals for TE investments before TEPs are approved, while perhaps using the near-term priorities list as potential grounds for an "expedited review" of a project proposal.[43] AEE, Liberty, Joint Automakers, Tesla, and ChargePoint urged the Commission to not limit pre-TEP applications to the near-term priority issues identified in the proposed TEF.[44] SBUA raised similar concerns,[45] and wished to see small business included in the near-term investments proposed by the Electrical Corporations.[46]

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[41] SCE opening comments at 7.

[42] ATE reply comments at 11; Greenlots reply comments at 11.

[43] CESA opening comments at 8.

[44] AEE opening comments at 15; Liberty opening comments at 4; Joint Automakers opening comments at 7; Tesla opening comments at 2; ChargePoint opening comments at 19.

[45] SBUA opening comments at 7.

[46] SBUA reply comments at 10-11.

Other parties supported the proposed near-term priorities approach. California Transit Association believed it was a useful way of focusing Electrical Corporation investments, so long as it did not halt progress toward widespread TE.[47] SANDAG also supported the list of near-term priorities.[48] Electrify America supported the near-term priorities list, and further supported the proposed TEF's recommendation that the Electrical Corporations avoid investments in areas where the private sector can make an investment in TE infrastructure.[49]

TURN agreed with the near-term priorities as proposed, and believed that proposals in the MD/HD sector should be reviewed to ensure they are not duplicative of existing MD/HD investments by the Electrical Corporations.[50]

Cal Advocates agreed with the proposed list of near-term priorities, and believed that pre-TEP applications should be limited to those priorities with the exception of extensions of existing programs.[51] Cal Advocates qualified their support by saying that a piloting phase should be conducted in each of the near-term priority areas before "full-scale" programs in these areas are proposed.[52]

4.3. Commission Guidance for Near-Term Priority Program Proposals

In light of the overwhelming interest of the parties in maintaining flexibility for Electrical Corporation TE investment proposals before the approval of a TEP, and the urgent need to meet the state's TE policy goals by 2025, this

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[47] California Transit Association opening comments at 5.

[48] SANDAG opening comments at 3.

[49] Electrify America opening comments at 8.

[50] TURN opening comments at 16.

[51] Cal Advocates opening comments at 14.

[52] Cal Advocates opening comments at 21.

decision clarifies that Electrical Corporations may file three forms of near-term requests for TE investments:

1) Advice Letter Process: Proposals for TE investments in the near-term priority categories identified by the proposed TEF and discussed within this decision, and which are capped at $20 million per program and $80 million for each Electrical Corporation should be submitted in the form of a Tier 3 advice letter. The Commission's Energy Division staff will develop a template for these advice letters and serve the template on the service list for this proceeding, in addition to posting it to the Commission's TE webpage. Energy Division staff may periodically update the template and will review Electrical Corporation proposals based on the template. These programs should address areas of investment that are new or nearly new to the Electrical Corporations.

2) Application Process for Extensions of Existing Programs:[53] If the Electrical Corporations are to support the AB 2127 incremental infrastructure targets in the near-term, they will need to keep investing in charging infrastructure in all the sectors they are currently investing. As such, one of the goals of this decision is to avoid any gaps in program offerings that would inhibit the state from meeting these targets. The Electric Corporations must work with the CEC to provide any requested data to the CEC to inform the needs assessment in the AB 2127 report, and to identify the charging infrastructure needs on a service territory and/or local level. Given that proposals for extensions may be large and given the potential need for discovery for which an advice letter process will not allow, the Electrical Corporations should submit these proposals via application. However, due to party support to expedite this review process, this decision outlines some parameters

[53] This decision defines existing TE programs as the electrical corporations' large scale infrastructure programs: PG&E's EV Charge Network, SDG&E's Power Your Drive, SCE's Charge Ready and Charge Ready 2, PG&E's EV Fast Charge, PG&E's EV Fleet, SCE's Charge Ready Transport, and SDG&E's Power Your Drive for Fleets.

for inclusion in applications, which could lead to an expedited proceeding similar to the SB 350 process for the Priority Review Programs.[54]

3) Other Applications: Electrical Corporations may propose programs outside of the near-term priority areas, above the advice letter budget cap, and/or outside of the existing program extensions in the form of a formal application. This would be reviewed by the Commission in accordance with the requirements of SB 350, AB 841, the Commission's Rules of Practice and Procedure (Rules), and other applicable law.

Specific requirements for proposals in the form of a Tier 3 advice letter are detailed below for each of the near-term priority sectors. Any proposal for TE infrastructure investments, whether via advice letter or application, must meet certain universal requirements concerning equity and environmental justice. The Commission prefers utilities use the advice letter process, wherever possible. Once the Commission considers and approves an Electrical Corporation's TEP, these processes and requirements will likely be modified and post-TEP applications must be made in accordance with the approved TEP.

In response to party comment seeking clarity on the status of existing pilots, the Electrical Corporations may request an extension of existing pilots, per the application pathway described above. Any application for an extension to a pilot should demonstrate that 1) there is outstanding demand to participate in the expiring or soon expiring program, 2) the extension makes modifications to align with the Vehicle-Grid Integration (VGI) Working Group's load management guidance, 3) the Electrical Corporation clearly incorporates lessons learned from the pilot to maximize ratepayer benefits and reduce per port costs

[54] *See* A.17-01-020, et al. Scoping Ruling at 11.

relative to the existing program, 4) that any proposed per port costs remain below the average per port cost threshold the Commission has adopted in recent TE decisions, to the extent applicable, 5) the extension aligns with the equity and environmental justice requirements detailed in this decision, 6) the Electrical Corporation provides rationale for how the proposal will help California meet the state charging targets without ratepayers taking on the full burden, taking into account any updates to the CEC's AB 2127 report, 7) the Electrical Corporation proposes to own no more than 50 percent of the behind-the-meter infrastructure, 8) the Electrical Corporation proposes to limit utility ownership of the EVSE to sites located in an underserved community, 9) that proposals include competitive options for customer ownership of the behind-the-meter make-ready, and 10) the Electrical Corporation provides sufficient data to allow for the Commission and parties to evaluate the proposed costs of the program, the planned deployment of infrastructure, the number of sites and ports planned, the planned number of vehicles electrified (for MD/HD only), the planned data collection, and the specific marketing, education, and outreach (ME&O) actions and associated goals planned.

4.3.1. Equity and Environmental Justice Requirements for Near-Term Priority Program Proposals

This decision holds that as a matter of law, transportation electrification in California must be equitable.[55] Parties also recognized the critical importance of ensuring that Electrical Corporation investments in TE infrastructure are equitable and that they respect environmental justice concerns. No party

[55] *See* Pub. Util. Code § 740.12(b).

disputed that such considerations should be included as a condition of TE investments and integrated into program design from the start.

Numerous parties noted the need for greater equity in public charging. EVgo stated that "public charging infrastructure is especially crucial to reaching new demographics of EV drivers who many not have access to charging at home or the workplace."[56] Envoy "agree[d] with [the] TEF Staff Proposal that [the Electrical Corporations] have a role to play in expanding access to diverse clean transportation technologies across Environmental and Social Justice (ESJ) communities."[57] The Joint Commentators noted that "two large IOUs—[PG&E] and SDG&E—have not yet proposed large-scale programs to support the passenger vehicles of Californians without access to home charging."[58] Similarly, Greenlining "agree[d] with staff that there should be a greater expansion of strategies to ensure customers without access to home charging are able to receive it,"[59] recommending that staff "continue to highlight and center [equity] efforts to ensure a commitment to equitable access to clean transportation rather than having it be an afterthought."[60] Identifying access as one of its three bedrock objectives, Electrify America highlighted "ACCESS: First, there must be public vehicle charging options that are available ubiquitously to all drivers, especially for the significant population that will not have access to workplace or residential chargers."[61] Tesla stated "[o]ne strategy that continues to be

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[56] EVgo opening comments at 11.

[57] Envoy opening comments at 5.

[58] Joint Commenters opening comments at 4.

[59] Greenlining reply comments at 22.

[60] Greenlining reply comments at 16.

[61] Electrify America opening comments at 2-3.

important to ensure there is equity in the cost of fueling is to provide greater access to charging where you park, which includes installing charging infrastructure at multi-unit dwellings (MUDs), workplaces (including beyond the traditional sense such as at retail stores) and around town. The utilities can and should continue to play a role in providing access to charging for these sites."[62] Additionally, CSE emphasized that "[w]hile multiple agencies have already prioritized Disadvantaged Communities (DACs) as preferred locations for siting EV infrastructure, additional efforts are necessary to ensure that the residents of these communities are aware of these resources and derive direct economic benefits from them."[63]

Parties recognized several barriers to accessible public charging, such as awareness, public education and proximity, and offered suggestions. GPI observed that "[many consumers] don't fully understand ZEV benefits such as . . . accessible public charging."[64] According to Siemens, "'Market maturity'" should be defined from a consumer perspective, reflecting availability of and access to charging services in ways that are attractive to consumers, including those in Disadvantaged Communities, and should be capable of being readily verified and quantified."[65] GPI/CEC suggested that "IOUs could survey their customers and install EVSE at publicly accessible workplace locations such as schools or government offices, and then do targeted outreach (such as mailers with information about the new chargers being accessible, and marketing

[62] Tesla opening comments at 11.

[63] CSE reply comments at 2.

[64] GPI opening comments at 9.

[65] Siemens reply comments at 1.

collateral on utility rebate programs and the benefits of EVs) to MDU complexes within a few blocks of the location."[66]

Greenlining recommended that the Commission operationalize equity to the maximum extent possible, including building off of existing equity efforts.[67] Referencing the SB 350 Barriers Study, Greenlining proposed building equity into the TE process through authentic and meaningful community engagement informed by community needs assessments, cultural considerations, and other efforts led by entities including community based organizations (CBOs).[68] CEC/GPI also stated that marketing, education and outreach (ME&O) for low-income and disadvantaged communities is important for increasing mid- and long-term EV adoption, as "low-income Californians could save thousands of dollars on gas each year if they knew about the affordability of 100+ mpge EVs. Lower income 'supercommuters' who live in outlying regions with more affordable housing, with 50+ mile commutes, have the most to save, and should be among the targets of deep ME&O efforts."[69] The Joint Commenters stated that "equity demands that all Californians have access to passenger vehicle chargers by the time electric vehicles are cheaper to purchase than combustion vehicles."[70]

This decision therefore holds that it is reasonable to integrate the following equity and environmental justice requirements for any proposals for TE infrastructure received prior to the Commission's approval of an Electrical

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[66] GPI/CEC reply comments at 7; *see* GPI/CEC opening comments at 10.

[67] Greenlining reply comments at 16.

[68] Greenlining reply comments at 17-19.

[69] CEC/GPI reply comments at 5.

[70] Joint Commenters opening comments at 5.

Corporation's TEP. The requirements are further guided by the Commission's Environmental and Social Justice Action Plan (ESJ Action Plan) goals, including consistent integration of equity and access considerations throughout Commission proceedings; increased investment in clean energy resources to benefit environmental and social justice (ESJ) communities, especially to improve local air quality and public health; and the promotion of economic and workforce development opportunities for residents living in an ESJ community.[71] Recommendations for prioritizing and investing in community outreach and engagement from the Disadvantaged Communities Advisory Group 2019-2020 Annual Report[72] also informed the requirements below. Both documents were also referenced by Greenlining in their comments.[73] Accordingly, the Electrical Corporations should strive to integrate the following equity and environmental justice requirements for any proposals for TE infrastructure:

- Utilize a program specific infrastructure or expenditure target of at least 50 percent for customers living in underserved communities.[74]

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[71] *See* the Commission's Environmental and Social Justice Action Plan webpage at https://www.cpuc.ca.gov/esjactionplan, and the final ESJ Action Plan as of May 2020 at http://www.cpuc.ca.gov/uploadedFiles/CPUCWebsite/Content/UtilitiesIndustries/Energy/EnergyPrograms/Infrastructure/DC/Env%20and%20Social%20Justice%20ActionPlan_%202019-02-21.docx.pdf.

[72] *See* Disadvantaged Communities Advisory Group 2019-2020 Annual Report at p 8-12, available at https://www.cpuc.ca.gov/uploadedFiles/CPUCWebsite/Content/UtilitiesIndustries/Energy/EnergyPrograms/Infrastructure/DC/2019-2020%20DACAG%20Annual%20Report.pdf.

[73] Greenlining reply comments at 15.

[74] The term underserved communities is defined in D.20-12-027 at 11-16, and the electrical corporations should use that definition. This requirement would ensure compliance with AB 841's requirement that at least 35 percent of TE investments are in underserved communities. (Pub. Util. Code § 740.12(b).)

- If a proposal utilizes customer incentives or rebates, utilize larger incentives or rebates for customers located in underserved communities.
- Ensure program incentives reach customers in counties with high poverty rates or underserved community rates. Programs may include proposals to offset costs of upgrading residential service behind the customer's meter for a L2 EVSE installation.[75]
- Demonstrate that the Electrical Corporation coordinated with more than one CBO during the development of the proposal and has the support of local/regional/tribal governments and CBOs during program implementation.
- As a part of coordination with CBOs, Electrical Corporations must ensure that EV charging infrastructure deployed in underserved communities is accessible and tailored to community residents, addressing community specific needs such as language and Americans with Disabilities Act (ADA) accessibility, visibility, public education on EV compatibility, and cultural considerations of local history, and safety.[76] This is intended to increase awareness of available EV charging infrastructure for community members who may not have access to home or workplace EV charging facilities, and to ensure the infrastructure feels safe to access throughout hours of operation. In conjunction with filing proposals, the Electrical Corporations should submit a plan of how they are working to increase accessibility at any publicly accessible EV charging location, for sites located in an underserved community and non-underserved community sites, as safety and accessibility are not issues reserved to underserved communities. The plans should also discuss how the Electrical Corporations are working with CBOs to

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[75] This proposal can assist "supercommuters" that have daily commutes that exceed the capability of L1 charging.

[76] *See* Greenlining reply comments at 17 ("Include Cultural Considerations such as language and local history").

develop these plans. The Electrical Corporations should ensure accessibility and safety are factored into all sites where EV charging infrastructure is installed.

- Coordinate ME&O to promote participating in an infrastructure program with CBOs and regional/local/tribal governments to encourage more equitable outreach and participation, and ensure that at least some portion of any proposed TE infrastructure budget is dedicated to ME&O and is primarily dedicated to CBOs to execute outreach to community residents.
- Include detail on how the proposal will address the barriers to equity identified in the Commission's Environmental and Social Justice Action Plan (ESJ Action Plan)[77] and Tribal Consultation Policy,[78] and/or Part B of CARB's Low-Income Barriers Study.[79]
- Further the principles of economic equity and promote access to high quality jobs for residents of underserved communities. The IOUs should articulate how each project incorporates any of the following priority provisions:
  - Job quality measures, such as wage and benefit standards and responsible contractor standards;
  - Job access measures, such as targeted hire requirements as well as specified targets for residents of underserved communities;
  - Comprehensive project agreements that address both job quality and job access, such as application of the

[77] Available at: https://www.cpuc.ca.gov/uploadedFiles/CPUCWebsite/Content/UtilitiesIndustries/Energy/EnergyPrograms/Infrastructure/DC/Env%20and%20Social%20Justice%20ActionPlan_%202019-02-21.docx.pdf.

[78] Available at: https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M212/K861/212861685.PDF.

[79] Available at: https://ww2.arb.ca.gov/sites/default/files/2018-08/sb350_final_guidance_document_022118.pdf.

Skilled & Trained Workforce requirement[80], and use of Community Workforce Agreements for large-scale TE projects;

- Funding directed to training partnerships that are guided in their programming to ensure that investments in training are connected to and result in placement in high-quality jobs.

4.3.2. CARB Mandates for the MD/HD Sector

CARB is currently implementing and promulgating a variety of regulations to promote the electrification of the MD/HD sector. This includes CARB's Mobile Source Strategy (MSS) and other rulemakings that seek to implement state policy goals related to TE.

In order to efficiently align state efforts in this sector, any Electrical Corporation proposal for near-term priority TE investments in the MD/HD sector, whether through the advice letter process or in an application, shall ensure that the investments proposed align with the CARB electrification mandates for the sector. For example, CARB has set or identified potential electrification goals for several vehicle segments for the next several years. If any gaps are identified in current programs, Electrical Corporations could consider whether to propose funding additional EV charging infrastructure as a near-term priority. Some examples include, but are not necessarily limited to:

- Large transit agencies must transition to 100% zero emission buses, starting with 25% for large transit in 2023.[81]

[80] Frequently Asked Questions on Skilled & Trained Workforce ("STW") Requirements, available at https://www.dir.ca.gov/Public-Works/ADA-Compliant-STW-FAQ.pdf.

[81] Innovative Clean Transit (ICT) Regulation Fact Sheet, May 16, 2019 at ww2.arb.ca.gov/resources/fact-sheets/innovative-clean-transit-ict-regulation-fact-sheet

- Transport Refrigeration Units must begin transitioning to full electrification beginning in 2024.[82]
- Delivery and drayage fleets are assumed to have 100 percent ZEV sales starting with model year 2024.[83]

4.3.3. Ratepayer Protections in the Advice Letter Process

The advice letter process for seeking approval of near-term priority program proposals for TE investments by the Electrical Corporations is intended to provide a streamlined mechanism to more quickly authorize expenditures to support the state's near-term EV policy goals. Nevertheless, SB 350 made clear the Legislature's intent that TE investment proposals from the Electrical Corporations "include performance accountability measures, and are in the interests of ratepayers."[84] As a result, this decision finds that it would be appropriate for the advice letter process to include structural protections for ratepayer interests so that the speed of the advice letter process, including the lack of evidentiary hearing and cross-examination, does not prejudice the interests of ratepayers in the proposed investments.

Energy Division staff will develop an advice letter template based on the one drafted within the proposed TEF and serve it to the DRIVE OIR service list once completed as well as post it on the Commission's TE webpage.[85] Near-term priority program proposals filed via advice letter must comply with this template. Additionally, the following must be addressed by an Electrical

[82] November 2020 draft Mobile Source Strategy, ww2.arb.ca.gov/sites/default/files/2020-11/Draft_2020_Mobile_Source_Strategy.pdf, Table 3 - at 33

[83] November 2020 draft Mobile Source Strategy, ww2.arb.ca.gov/sites/default/files/2020-11/Draft_2020_Mobile_Source_Strategy.pdf, at p89

[84] Pub. Util. Code § 740.12(b).

[85] www.cpuc.ca.gov/zev.

Corporation in proposals for near-term priority TE investments filed using the advice letter process:

- An estimate of the total site-level funding that will be paid by ratepayers and amount paid by the site host (percentages or dollar amount). To encourage development of EV charging at a lower cost to ratepayers, programs should be designed to ensure non-ratepayer funding sources are leveraged. An Electrical Corporation should track and update the expected ratepayer funding level needed to install EV charging infrastructure throughout the proposal's implementation.
- A clear justification for why additional ratepayer investment prior to TEP approval is necessary for a given proposal.
- A description of the specific barriers to TE that the proposal seeks to overcome and why immediate ratepayer funding is needed to address these barriers.
- A proposal implementation duration of no longer than three years from Commission approval of the proposal.
- Electrical Corporations must also include a provision within any customer agreements and within its agreement with qualified participating vendors, including EV Service Providers, regarding giving the electric corporation and any contracted evaluator data needed for program evaluation.
- Each near-term priority program proposal using the advice letter process must have a budget that does not exceed $20 million.
    - The Electrical Corporations must establish a new one-way Near-Term Priority (NTP) TE balancing account using the advice letter process. Each NTP TE balancing account will have a cap of $80M.
    - Within the NTP TE balancing account, the Electrical Corporations must establish subaccounts for each near-

term priority program. Each program will be limited to $20 million.

  - Each near-term priority program must recover authorized program funding through distribution rates allocated to customer classes on an equal cents per kWh basis.

- Each Electrical Corporation's aggregated budget for near-term priority program proposals using the advice letter process shall not exceed $80 million.
- To qualify for the advice letter process, utility proposals must not include utility ownership of any customer-side infrastructure (EVSE and/or make-ready) except for sites located in underserved communities. Electrical Corporations are limited to owning no more than 50 percent of the customer-side infrastructure per program proposal.
- Any expedited applications for extensions of existing programs submitted pursuant to this PD must not include utility ownership of any customer-side infrastructure (EVSE and/or make-ready) except for sites located in underserved communities. Electrical Corporations are limited to owning no more than 50 percent of the customer-side infrastructure per program proposal.

Energy Division staff shall review the advice letters based on the following reasonableness criteria:

- Is the proposed program within a near-term priority sector as defined by this Decision?
- Is the proposed program within the budget limit as defined by this Decision?
- Does the proposed program demonstrate the electric corporation incorporated lessons learned from previous programs or, if a "first of its kind" program, reflects input from stakeholders with expertise in the targeted sector?

- Are the costs of the proposed program reasonable when compared to the program benefits and costs of similar programs?
- Do the proposed per port costs remain below the average per port cost threshold the Commission has adopted in recent TE decisions, to the extent applicable?
- Does the proposed program demonstrate efforts to develop a private TE charging market and lead to a reduction in market dependence on ratepayer funding?
- Does the program comply with the advice letter template?

This decision authorizes the Commission's Energy Division staff to summarily reject any advice letter submitted under this mechanism that fails to comply with any of the above. No resolution is required for such rejection; a non-standard disposition letter per General Order (GO) 96-B shall suffice.

4.3.4. Budgetary Cap of $20 Million for Advice Letter Proposals

With respect to the budgetary cap on advice letter proposals of $20 million, and $80 million in the aggregate for each Electrical Corporation, this decision reviews party comment on this issue as proposed by staff and describes its reasoning for adopting the cap for advice letter proposals.

Cal Advocates supported the proposed cap of $20 million, noting that the cap was similar to mechanisms already used by the Commission to limit spending on certain expedited applications for TE investments.[86] TURN also supported the proposed cap, arguing that the Electrical Corporations already received authorization to spend several hundred million dollars on TE infrastructure. Their reasoning is that the Electrical Corporations do not require authorization for substantial TE investments at this time given that their

[86] Cal Advocates opening comments at 14.

previously authorized budgets will continue to be spent over the next several years.[87]

CESA opposed any attempt to limit the budget of pre-TEP applications by the Electrical Corporations, while noting that a budget cap for certain expedited pilot proposals may be warranted.[88] ATE agreed that the $20 million cap should not be imposed.[89] EDF also opposed the $20 million cap.[90] Joint Automakers opposed the cap as "insufficient" to meet state policy goals.[91]

With respect to the MD/HD sector, BNSF asserted that the $20 million cap would be inadequate to fund near-term projects in that sector. They cited an experience of installing four pieces of electrified equipment across three of their sites at a total cost of $3.5 million, demonstrating the need for a higher sector-wide budget for MD/HD investments.[92]

Joint Commenters argued that the proposed $20 million cap was unreasonable. They reasoned that the time until TEPs are approved is unknown, and it may take several years. As a result, imposing a cap would constrain TE investments for potentially several years. They further noted that the Commission has no basis for determining if the $20 million cap is appropriate in the first instance when the investment needs of the near-term priority sectors are uncertain.[93] CALSTART made similar arguments, noting that the infrastructure

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[87] TURN opening comments at 17.

[88] CESA opening comments at 10.

[89] ATE opening comments at 4.

[90] EDF opening comments at 16.

[91] Joint Automakers opening comments at 6. (*See also* SCE opening comments at 6.)

[92] BNSF reply comments at 5.

[93] Joint Commenters opening comments at 20-21.

needs for the MD/HD sector were so uncertain that the $20 million cap was unreasonably restrictive for that near-term priority.[94]

VGIC opposed the proposed $20 million cap,[95] reasoning that the large increase in TE investments required to meet state policy goals would be constrained by the proposed $20 million cap.[96] PG&E made similar arguments, noting figures showing that a $20 million budget would only support the addition of only 1,000 to 1,300 Level 2 EVSE.[97] ChargePoint expressed concerns about the proposed $20 million cap given uncertainties in the needed investments through 2024.[98]

GPI/CEC also opposed a cap on near-term priority projects and recommended a cap on the order of $80 million if a cap was to be imposed.[99] SBUA did not think a fixed $20 million cap was appropriate and recommended adopting a "soft cap" that could increase if circumstances warranted.[100]

As noted previously, this decision only imposes the proposed budgetary cap of $20 million on individual proposals submitted via the advice letter process, with an aggregate cap for each Electrical Corporation of $80 million for all near-term priority program proposals submitted via the advice letter process.

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[94] CALSTART opening comments at 6 ('$20 million would likely be a drop in the bucket of [MD/HD sector] make-ready needs, if this situation arises").

[95] VGIC opening comments at 3.

[96] VGIC opening comments at 12, noting that at current levels the $20 million cap would only fund the equivalent of five pilot programs.

[97] PG&E opening comments at 19.

[98] ChargePoint opening comments at 20, reply comments at 7.

[99] GPI/CEC opening comments at 15-16, reply comments at 10.

[100] SBUA opening comments at 8.

This decision imposes these budgetary caps in order to safeguard the interests of ratepayers, as required by SB 350 and as argued by Cal Advocates and TURN.

However, in light of overwhelming party interest in maintaining flexibility for Electrical Corporation proposals for TE investments, and the urgency of meeting the state's policy goals related to TE, this decision holds that there should not be an *ex ante* budgetary cap imposed on near-term priority program proposals outside of the advice letter process and filed with the Commission as a formal application. For clarity, this holding in no way diminishes the authority of the Commission to ensure that the approved budgets of near-term priority program proposals submitted via formal applications are reasonable and in the interests of ratepayers. Additionally, staff should review the budgets and per port costs within Electrical Corporation proposals filed by advice letter to ensure the costs are reasonable for the programs proposed, considering cost limitations the Commission has previously approved for TE programs. While this decision does not establish a specific dollar amount cost containment measure for proposals filed through an advice letter, the Electrical Corporations must demonstrate effort toward keeping per port costs low and reasonable. Staff will have discretion in reviewing the advice letters to evaluate whether the Electrical Corporation's proposal sufficiently demonstrates this effort towards lowering per port costs and/or reduce total, site-level ratepayer expenditures to install TE infrastructure.

4.4. Potential Additions to the List of Near-Term Priorities

Many parties recommended additions to the proposed list of four near-term priority areas. BNSF argued for more general categories of "EV infrastructure to support all State agency TE-related regulations," "transportation refrigeration units," and "cargo-handling equipment."[101] CALSTART recommended that "corridor charging" be included as a near-term priority to incentivize fast-charging in rural areas along statewide transit networks.[102] EVgo posited that the Electrical Corporations should look to improve their internal processes supporting TE infrastructure investments as a near-term priority.[103] ChargePoint believed that charging for light-duty fleets, such as rideshare services, could be considered as a near-term priority.[104]

GPI/CEC recommended including a separate near-term priority area for ME&O,[105] and included descriptions for several potential "deep ME&O" projects to be considered for near-term priority consideration.[106] EDF also proposed a separate track for ME&O proposals, as well as fleet engagement and load management guidance.[107] UCAN recommended that "grid stewardship," or planning for TE infrastructure build-out, qualify as a near-term priority.[108] SBUA recommended including small businesses and shared parking facilities as particular near-term priorities.[109]

CSE proposed including equity as a formal near-term priority.[110] NDC similarly argued that near-term priority investments should target substantive

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[101] BNSF opening comments at 7.

[102] CALSTART opening comments at 7-8.

[103] EVgo opening comments at 9.

[104] ChargePoint opening comments at 19.

[105] GPI/CEC opening comments at 12.

[106] GPI/CEC reply comments at 6-8.

[107] EDF opening comments at 21.

[108] UCAN opening comments at 19.

[109] SBUA opening comments at 7.

[110] CSE reply comments at 2.

near-term investments (*e.g.*, 50 percent of total investments) toward underserved communities.[111]

VGIC generally argued for more flexibility and a removal of limitations on pre-TEP applications by the Electrical Corporations.[112] They cited various VGI policy initiatives as potential additions to a near-term priorities list.[113] SANDAG argued that funding for emerging technologies should be included in the near-term priority applications.[114]

Joint CCAs proposed the following additions to the list of near-term priorities: fast charging programs, programs for MUDs, programs for new low-income housing developments, resiliency projects, and ME&O.[115] PCE also supported the addition of fast charging, Level 1 charging,[116] and advanced load management solutions to the list of near-term priorities.[117]

Plug In America believed that all existing TE investment areas approved by the Commission should be included as near-term priorities eligible for pre-TEP approval. This would include workplaces, MUDs, disadvantaged communities, DCFC stations, and single-family residences.[118] SVLG also recommended including DCFC, workplace charging, and fleet electrification as near-term priorities.[119]

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[111] NDC reply comments at 9-10.

[112] VGIC opening comments at 10.

[113] VGIC opening comments at 11.

[114] SANDAG opening comments at 3-4.

[115] Joint CCAs reply comments at 2.

[116] Generally, charging that utilizes a standard NEMA 5-15 outlet at 120 volts.

[117] PCE reply comments at 18-24.

[118] Plug In America reply comments at 5.

[119] SVLG reply comments at 5.

PG&E sought the inclusion of a broad near-term priority that would allow for any proposals to consider the "adoption of mechanisms… that would offer broad support to entities adopting TE." Specifically, PG&E proposed that these mechanisms could include supplemental allowances to help customers offset the cost of make-ready infrastructure, alternative financing mechanisms, inclusion of utility-side make-ready as part of standard utility business, and other tools and initiatives to support both utility-side and customer-side TE infrastructure at reasonable cost.[120] SCE wished to ensure that Level 1 and Level 2 charging for workplaces could be included in near-term priority proposals.[121] SDG&E recommended that the near-term priority applications allow for any public, MD/HD, MUD, and/or workplace program applications without program size limitations.[122]

As noted previously, the Electrical Corporations may submit applications to the Commission for TE investment proposals that do not qualify under one of the near-term priority categories. Specifically, the Electrical Corporations are encouraged to minimize any gaps in their current program offerings. However, applications outside of this would be formal applications and would not qualify for the advice letter process. Parties should also note that some of the proposed additions to near-term priorities, such as ME&O, may be proposed for inclusion in projects serving one of the near-term priorities (*e.g.*, ME&O may support a program to encourage away-from-home charging).

[120] PG&E reply comments at 7-8.

[121] SCE reply comments at 2.

[122] SDG&E reply comments at 7.

4.5. Proposed Resiliency Near-Term Priority

Several parties generally supported the inclusion of resiliency as a near-term priority, including Joint Commenters,[123] CALSTART,[124] Connect California,[125] EVgo,[126] EDF,[127] and VGIC.[128] While supporting a focus on resiliency in general, Tesla sought flexibility in how to approach resiliency noting that the proposed TEF did not appear to allow for proposals to make existing infrastructure more resilient.[129]

SCE supported the execution of pilots to test the ability of EVs to provide grid power, as well as technology to ensure EV charging in areas affected by emergencies. SCE argued that these pilots should be revised on an annual basis.[130]

VGIC recommended prioritizing projects that test and validate resiliency strategies that utilize EVs as grid resources.[131] EDF supports validating and offering services which would enable EVs to operate as a grid resource for both normal and critical grid operations.[132]

TURN supported well-targeted pilots in this area and urged the Commission to focus on areas subject to very high or extreme fire threat. TURN

[123] Joint Commenters opening comments at 21.

[124] CALSTART opening comments at 7.

[125] Connect California opening comments at 5.

[126] EVgo opening comments at 9-10.

[127] EDF opening comments at 17.

[128] VGIC opening comments at 13.

[129] Tesla opening comments at 7-8.

[130] SCE opening comments at 17.

[131] VGIC opening comments at 13.

[132] EDF opening comments at 17.

also argued that the Commission should focus on a wide variety of forms of resiliency, including mobile charging solutions.[133]

PG&E opposed a focus on resiliency in this proceeding, noting that the issue of Electrical system resiliency is currently under review in a number of other Commission proceedings.[134] Cal Advocates did not oppose the inclusion of resiliency as a near-term priority, but recommended coordination with other Commission proceedings on this issue to avoid duplication.[135]

UCAN supported a modified version of resiliency for a near-term priority. They did not believe that EVs should be used as backup sources of grid power; but did recommend "quick wins" for EV drivers finding themselves in emergencies, including PSPS notifications, emergency rate discounts, and distributed backup charging facilities.[136] SBUA concurred that a focus of resiliency should be on ensuring that charging is available during emergencies.[137]

BNSF did not support using railyard electric off-road equipment, such as hostlers, cranes, and side picks, as grid resources for resiliency projects.[138] California Transit Association also had concerns about this proposed category, stating that transit buses should not be regarded as a resiliency resource. They claimed that if buses were used as a resource, then transit agencies "would be unable to carry out their disaster response function, possibly causing unnecessary loss of life." Instead of focusing on emphasizing the use of an EV

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133 TURN opening comments at 17-18.

134 PG&E opening comments at 20.

135 Cal Advocates opening comments at 15.

136 UCAN opening comments at 20.

137 SBUA opening comments at 8.

138 BNSF opening comments at 7.

for providing energy services, they argued that this near-term priority category should, with respect to transit agencies, focus on resources to allow for the charging of transit vehicles during emergencies.[139]

Since parties provided comments on the proposed TEF, the Commission has adopted a number of decisions to address the barriers or further explore issues related to TE resiliency identified by staff in the draft TEF.[140] In light of the Commission taking these steps, this decision finds it reasonable to include resiliency as a near-term priority for Electrical Corporation TE investments. Electrical Corporations must show that any programs they propose avoid duplication of resiliency efforts ordered in D.20-05-051, D.20-06-017, D.20-12-029, D.20-12-029, and D.21-01-018.

In D.20-05-051, the Commission adopted electric investor-owned utilities' (IOUs) de-energization guidelines that expanded upon those adopted in Resolution ESRB-8 and D.19-05-042.[141] The decision directs IOUs to work with the appropriate governing authorities to identify critical transportation, water, and communications infrastructure.[142]

In D.20-06-017, the Commission adopted short-term actions relating to the acceleration of microgrid deployment and related resiliency strategies pursuant to SB 1339 (Stern, 2018).[143] The decision adopted solutions to accelerate interconnection of resiliency projects, modernize tariffs to maximize social

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[139] California Transit Association opening comments at 6-7; (*see also* CALSTART opening comments at 7).

[140] *See* D.20-05-051, D.20-06-017, D.20-12-029, and D.21-01-018

[141] D.20-05-051 at 2.

[142] D.20-05-051 at 54.

[143] D.20-06-017 at 2.

resiliency benefits, promote collaborative engagement between large IOUs and local and tribal governments, and several PG&E and SDG&E resiliency proposals.[144]

In D.20-12-027, the Commission adopted guidance relating to the use of the utilities' Low Carbon Fuel Standard holdback proceeds. The decision directed the large IOUs to use up to 20 percent of the annual LCFS holdback proceeds not spent on equity towards resiliency programs, as discussed earlier in this decision.

In D.20-12-029, the Commission adopted strategies and metrics to further the integration of EVs as electrical grid resources, fulfilling the Commission's obligations under SB 676 (Ch. 484, Stats. 2019)[145] and advancing the use of Vehicle Grid Integration (VGI) for resiliency purposes.[146]

In D.21-01-018, the Commission adopted microgrid rates, tariffs and rules for large IOUs that facilitate the commercialization of microgrids pursuant to SB 1339.[147] The decision also created a Resiliency and Microgrids Working Group.[148]

To keep with the Commission's core mission to ensure the state has safe and reliable electricity, and to identify TE resiliency efforts already underway by the Electrical Corporation to comply with the five decisions listed above, within 120 days of approval of this decision, each Electrical Corporations must conduct a review of existing EV charging infrastructure funded through Commission

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144 D.20-06-017 at 2-3.

145 D.20-12-029 at 2.

146 *See* D.20-12-029 at 21.

147 D.21-01-018 at 2.

148 D.21-01-018 at 2.

approved TE programs and serve a stocktake of the findings to the DRIVE OIR service list. The stocktake should provide a comprehensive overview of the Electrical Corporations' TE resiliency efforts and, at a minimum, seek to determine (1) whether there are any potential hazard(s) that pose a risk to the accessibility, safety, and/or functionality of the charging infrastructure, (2) whether the EV charging infrastructure is installed in a manner that complies with and furthers the Commission's safety and resiliency goals (3) what, if any, investments are needed to reinforce the installed infrastructure's ability to be resilient to a power disruption, and (4) if and how the Electrical Corporation will address these gaps in resiliency through near-term priority program proposals.

After submission of their stocktake to the DRIVE OIR service list, each Electrical Corporation may choose to propose near-term priority programs for TE resiliency that address the gaps identified within the stocktake. In addition to complying with the requirements for advice letter proposals that this decision adopts, the Electrical Corporations' proposals for TE resiliency projects filed via Tier 3 advice letter shall also comply with the following requirements:

- Any filing seeking approval of a TE resiliency proposal should specifically address topics including but not limited to: 1) loads, assets, facilities, and populations the proposed TE resiliency project is intended to benefit; 2) the types, locations, and probabilities of the hazard(s) that place the intended beneficiaries at risk and what the TE resiliency project is intended to mitigate; 3) the mechanism by which the project is expected to mitigate the identified risks; 4) the expected quantitative impact of the proposed project on the identified risks; 5) the expected impacts of the proposed project on equity and affordability; and 6) the cost of the proposal.
- Any TE resiliency proposal seeking to install battery storage backup through the Tier 3 advice letter pathway

for off-grid EV charging should prioritize sourcing the power for charging the EVSE battery from renewable energy resources or low-emitting sources.

- Any resiliency proposal shall demonstrate efforts to work with county/local and tribal governments, state emergency agencies, CCAs, local planning/transportation agencies, CBOs, and ESJ organizations to develop resiliency-focused programs. Due to relevant stakeholder presence and a core focus on resiliency planning, we encourage the utilities to use the semi-annual workshops as required by Ordering Paragraph 7 of D.20-06-017 to present their project plans to the above stakeholders and gather feedback. The proposal should specifically state in which of the semi-annual resiliency planning meetings described in Ordering Paragraph 7 of D.20-06-017 the Electrical Corporation discussed it, or provide a reasonable justification if the proposal was not discussed in any of those meetings. The proposal should demonstrate how the Electrical Corporation plans to continue working with these stakeholders throughout the implementation process.
- The Electrical Corporations shall record costs for ratepayer supported TE infrastructure deemed damaged during a state emergency within each Electrical corporation's Catastrophic Event Memorandum Account.

4.6. Proposed Near-Term Priority Programs to Address Customers Without Access to Home Charging

EVgo supported the proposal for a near-term priority focused on the needs of drivers without access to home charging, particularly for communities with a high density of MUDs.[149] EDF recommended thinking beyond public charging to consider incentives for MUD landlords to install EVSE, as well as potential incentives to lower the energy prices faced by EV drivers at public charging

[149] EVgo opening comments at 11.

locations.[150] PG&E cautioned against the use of vouchers to lower charging fees for non-home charging as a potentially unnecessary ratepayer subsidy given that there are a variety of pricing schemes for non-home charging, including some free charging.[151]

Greenlining expressed support for this near-term priority, but sought clarity on the customers being targeted by the investments and whether customers with certain income levels would be prioritized.[152]

ChargePoint expressed the view that workplace charging remained an important way for EV drivers to charge away from home, and recommended a focus on cost-effective solutions in that area for non-home charging programs.[153]

Several parties, including SBUA, asserted that the inequities in costs for those that charge at home as opposed to away from home results from rate design. As a result, they suggested the Commission review commercial EV rate designs to address the issue of charging cost equity.[154]

GPI/CEC recommended piloting dual workplace/MUD charging options to increase utilization of Level 2 EVSE at workplaces, with MUD tenants encouraged to use workplace charging infrastructure during non-business hours. TURN supported this proposal.[155]

In light of party comments on the proposed TEF, this decision finds it reasonable to establish as a near-term priority investment to support customers

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150 EDF opening comments at 19.

151 PG&E opening comments at 21.

152 Greenlining reply comments at 22.

153 ChargePoint opening comments at 22.

154 *See, e.g.*, SBUA opening comments at 9.

155 TURN reply comments at 15.

without access to home charging. In response to party comment, this decision does not preclude workplace charging from being included within this category either, if such workplace programs pilot new use-cases and/or technologies (*e.g.*, VGI, mobile charging solutions, etc.). Since this decision lays out a pathway for expedited review of applications to extend existing programs, this category of near-term priority advice letter proposals should be reserved for approaches to addressing this customer segment that are outside of the Electrical Corporations' existing approaches. This decision also adopts the following requirements for any Electrical Corporation proposal for programs to address customers without access to home charging submitted as a Tier 3 advice letter:

- The proposal should demonstrate that the Electrical corporation leveraged lessons learned from any relevant existing and completed TE programs that targeted customers without access to home charging to either propose an innovative pilot approach to EV charging infrastructure deployment, or a non-infrastructure approach to address the costs of fueling disparity.
- The proposal shall clearly state how the proposed program fills a gap not currently addressed by an existing program.

4.7. Proposed Medium- and Heavy-Duty Near-Term Priority

Joint Commenters strongly supported the inclusion of MD/HD as a near-term priority, and believed that the current TE investments proposed in this area are inadequate.[156] Cal Advocates echoed this argument, citing the release of CARB's Innovative Clean Transit (ICT) regulation after the approval of most TE

[156] Joint Commenters opening comments at 23.

infrastructure plans as creating a need for near-term investments in this area before TEP approval.[157]

SCE noted the substantial state regulations driving TE adoption in the MD/HD sector and urged the Commission to increase the funding available for pre-TEP projects in this area. They argued that the substantial TE infrastructure needs in the MD/HD sector, as required by regulation, cannot be met with a $20 million cap on investments as proposed.[158]

UCAN supported projects that support transit fleet electrification, but expressed concern around ratepayer funds being used to support TE infrastructure for private sector fleet electrification.[159]

TURN did not object to the inclusion of the MD/HD sector as a near-term priority, but noted that there were several Electrical Corporation pilots related to the MD/HD sector already under development. TURN urged the Commission to wait until the results of the existing pilots are known to decide if further investments in the MD/HD sector were necessary.[160]

BNSF believed that the MD/HD category should be broadened to include "all mobile source strategy elements, including off-road electrification projects such as electric or hybrid electric cranes, electric top picks/side loaders, and electric hostlers."[161] Joint Commenters made a similar argument, urging the inclusion in the MD/HD definition of "off-road equipment, including other mobile sources of pollution for which CARB has proposed zero-emission

[157] Cal Advocates opening comments at 17-18.

[158] SCE opening comments at 19.

[159] UCAN opening comments at 21.

[160] TURN opening comments at 18-19.

[161] BNSF opening comments at 9.

regulations" that includes, for example, cargo handling equipment, forklifts, idling transportation refrigeration units and locomotives, and vessels at berth.[162] CALSTART sought clarification that the MD/HD category included "[z]ero-emission off-road equipment… such as forklifts, yard tractors, cargo handling equipment, etc."[163] Cal Advocates supported the inclusion of maritime and trainyard in the definition of MD/HD equipment covered by this near-term priority.[164]

BNSF argued for full funding for MD/HD near-term priority projects, even if the Electrical Corporation was not granted ownership of the make-ready TE infrastructure. BNSF asserted that many MD/HD entities may not allow the Electrical Corporation to own make-ready TE infrastructure.[165] BNSF also recommended that MD/HD near-term priority projects allow for only one EV to qualify for the project if the single EV utilizes a large battery (*e.g.*, 1 MWh or more).[166]

CALSTART recommended that the Commission adopt several specific goals for near-term applications from the Electrical Corporations in the MD/HD sector, including: educational guidance for fleet operators; preparing fleet operators and helping them understand the integration of TE infrastructure; flexibility in timelines for TE infrastructure ownership; and hydrogen ZEV deployment.[167] Liberty also believed that fleet operators should be incented to

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[162] Joint Commenters opening comments at 19.

[163] CALSTART opening comments at 7.

[164] Cal Advocates reply comments at 11.

[165] BNSF opening comments at 7.

[166] BNSF opening comments at 7-8.

[167] CALSTART opening comments at 8-9.

electrify their fleets by, for example, allowing an Electrical Corporation to pay for installation costs and own the EVSE used by the customer.[168]

At the outset, this decision clarifies that the definition of the MD/HD sector includes all of the forms of transportation electrification that are required to meet the state's policy goals, as explained and defined by D.20-09-025. Therefore, the MD/HD sector as referred to in this decision includes medium-duty EVs, heavy-duty EVs,[169] off-road EVs, or off-road electric equipment.[170]

In light of party comments on the proposed TEF, this decision finds that it is reasonable to establish the MD/HD sector as a near-term priority for Electrical Corporation investments in TE infrastructure. Given the stated desire to avoid gaps in program offerings and the need to support the state goals to electrify the MD/HD sector, extensions of existing MD/HD programs should go through the expedited application process discussed above. For MD/HD sector programs addressing an area not currently addressed by the Electrical Corporations' existing MD/HD programs (*e.g.,* train electrification), proposals should go through the advice letter process. This decision adopts the following requirements for any Electrical Corporation proposal for investments to support the electrification of the MD/HD sector submitted as a Tier 3 advice letter:

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[168] Liberty opening comments at 5.

[169] Per 17 Cal. Code Regs. § 95481, a medium-duty EV is an EV that is rated between 8,501 and 14,000 pounds gross vehicle weight rating, and a heavy-duty EV is an EV that is rated at or greater than 14,001 pounds gross vehicle weight rating. *See* D.20-09-025 at 9-10.

[170] Off-road EVs or off-road electric equipment means "with the exception of trains or locomotives, any non-stationary device, powered by an electric motor or using an energy storage system, used primarily off the highways to propel, move, or draw persons or property, and used in, but not limited to, any of the following applications: Marine Vessels, Cargo Handling Equipment, Construction or Agricultural Equipment, Small Off-Road Engines, and Off-Highway Recreational Vehicles." (D.20-09-025 at 24.)

- The proposal must identify which State regulation(s) require the support of ratepayers prior to Commission approval of the Electrical Corporation's TEP.
- The Electrical Corporation must describe why previously approved MD/HD sector program(s) are not sufficient to meet the charging needs to comply with a State regulation(s) or gap(s) in their existing MD/HD program.
- The Electrical Corporation should describe how its proposed program addresses any barriers that have arisen within CPUC-approved programs (*e.g.,* vehicle electrification requirement, power level limitations, etc.).
- The proposal should describe how the Electrical Corporation coordinated with State (agencies), local and tribal governments, and/or regional organizations to develop the proposal and how coordination will continue throughout the implementation of the proposal.

4.7.1. Electrical Corporation Coordinator for the MD/HD Sector

BNSF supported the proposal for a single Electrical Corporation to coordinate statewide MD/HD TE infrastructure development.[171] CALSTART believed such a coordinator could be useful.[172] Liberty supported the use of a coordinator, and believed that the Electrical Corporations should propose a coordinator.[173] Cal Advocates believed a coordinator would be appropriate and recommended that the Electrical Corporations work with the Commission's Energy Division staff to select a coordinator. They note this process was used to select an administrator for the state's Clean Fuel Reward program.[174] SBUA

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[171] BNSF opening comments at 8.

[172] CALSTART opening comments at 9.

[173] Liberty opening comments at 5.

[174] Cal Advocates opening comments at 18.

supported an Electrical Corporation coordinator role.[175] Greenlining argued that equity should be considered in the selection of a statewide coordinator.[176]

Joint Commenters did not support a statewide coordinator for MD/HD programs.[177] EDF also opposed appointing a single Electrical Corporation to coordinate the MD/HD sector, although they supported the Commission providing high-level coordination on MD/HD issues.[178] SCE also opposed a single statewide coordinator, and instead proposed that the Electrical Corporations generally coordinate their activities.[179]

In light of party comments on this issue, this decision finds that the Electrical Corporations should coordinate their MD/HD efforts to most effectively support CARB electrification mandates for the sector, and create consistency in program design where feasible. This decision does not designate a single Electrical corporation to act as the lead coordinator at this time.

4.8. Proposed New Building Near-Term Priority

Envoy supported the proposal for the inclusion of new buildings as a near-term priority for TE investments.[180] ChargePoint did not object to the near-term priority designation, but noted that building owners and developers may not know the use case of their future tenants. ChargePoint therefore recommended a focus on make-ready for these buildings rather than EVSE.[181] SBUA also

[175] SBUA opening comments at 10.

[176] Greenlining reply comments at 22.

[177] Joint Commenters opening comments at 23.

[178] EDF opening comments at 22.

[179] SCE reply comments at 2.

[180] Envoy opening comments at 8-9.

[181] ChargePoint opening comments at 23.

supported make-ready investments in new buildings, while allowing building owners to select their EVSE.[182]

UCAN did not support the identification of new buildings as a near-term priority, reasoning that TE infrastructure costs could increase the cost of new residential construction and therefore be controversial.[183]

BNSF recommended that the Commission adopt a "fixed voucher" for TE infrastructure design costs and a separate incentive for the actual construction costs.[184] Joint Commenters believed that the new building programs should be focused on make-ready upgrades for public housing and housing in disadvantaged or low-to-moderate income communities.[185] They also recommended that for affordable housing developments, "incentives may need to do more to fully ameliorate added costs and cover potentially 100 percent of added costs to being EV-ready."[186]

SCE believed that a fixed dollar-per-port incentive would be an efficient way to design programs related to new buildings. SCE proposed setting the incentive amount so that it would cover incremental costs beyond code requirements.[187] EVgo believed this approach had merit given its elegance, and proposed further evaluation.[188]

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[182] SBUA opening comments at 10.

[183] UCAN opening comments at 23.

[184] BNSF opening comments at 8.

[185] Joint Commenters opening comments at 23-24.

[186] Joint Commenters opening comments at 24.

[187] SCE opening comments at 22.

[188] EVgo reply comments at 5.

Liberty also supported this near-term priority, and proposed that Electrical Corporations be allowed to develop and own EVSE to prioritize TE infrastructure in underserved communities.[189] Cal Advocates did not object to this near-term priority, but recommended a pilot approach be pursued initially before finalizing rebate and incentive levels.[190] Like Joint Commenters, Cal Advocates believed that a focus on ESJ communities was appropriate and supported higher incentive levels for new construction in those areas.[191]

Since stakeholders submitted comments on this section of the proposed TEF, the Commission has adopted a decision authorizing SCE to implement its Charge Ready 2 program.[192] One component of the Charge Ready 2 program is an authorized $54 million on the New Construction Rebate Program, which will provide up to $3,500 per port as a rebate for new construction multi-unit dwellings that exceed the state or local building codes for EV charging and "EV ready" installations.

In light of party comments on this issue, this decision finds that it is reasonable to establish the new building sector as a near-term priority for Electrical Corporation investments in TE infrastructure. This decision also adopts the following requirements for any Electrical Corporation proposal for investments to support the electrification of new buildings filed as a Tier 3 advice letter:

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[189] Liberty opening comments at 5.

[190] Cal Advocates opening comments at 19.

[191] Cal Advocates opening comments at 21.

[192] D.20-08-045

- Proposals must exclusively support infrastructure that exceeds existing state and local EV infrastructure building code requirements.
- Proposals should demonstrate that the Electrical Corporation consulted with local jurisdictions to determine how much participating builders should exceed the local codes to be eligible for rebates.
- Proposals must demonstrate that they are filling a gap not addressed through another program, code, or agency.
- Proposals should include a mechanism for the Electrical Corporation to report to the Commission's Energy Division on any code updates that impact new construction programs, along with a procedural pathway to modify or halt the program if necessary.
- Proposals should include robust data collection requirements and be consistent with those adopted for the Charge Ready 2 program in D.20-08-045.
- Proposals for new construction programs shall limit expenditure to rebates for customer-owned infrastructure only, and the rebates for new construction infrastructure should be expensed (*i.e.,* not capitalized by the Electrical Corporation but recovered as an operations and maintenance cost).
- Rebates for sites located in an underserved community should cover 100 percent of the infrastructure and installation costs. Rebates for non-underserved community sites should cover no more than 50 percent of the infrastructure costs of building over the code minimum, with a cap of $2,000 per port over code plus an adder for publicly accessible parking areas that would require the installation of one or more accessible EVSE parking space.

4.9. Proposed Level 2 EVSE and Panel Upgrade for Low-Income Customers in Underserved Communities Near-Term Priority

As discussed above, additional TE investments in underserved communities and equity considerations are a top priority for this decision. While the Commission believes the four near-term priority categories (TE resiliency, customers without access to home charging, medium and heavy-duty, and new building construction) and the equity guidance for these investments encompass a wide range of areas for the Electrical Corporations to propose TE investments, we are convinced by party comments in favor of additional near-term priority categories, especially in light of the need for an additional 59,000 Level 2 EVSE in California, to meet the 2025 goals. Accordingly, this decision approves a fifth near-term priority category focused on providing single-family residential panel upgrades to support L2 charging to those in underserved communities.

Access to home charging for low-and moderate-income ratepayers may be functionally limited due to installation cost barriers, resulting in equity issues among residents in single-family homes. NDC noted that "in places such as the Inland Empire area, low-income residents are 50% more likely to reside in a single-family home than similar earners in the San Francisco and Los Angeles Areas," and recommended "robust deployment goals that specifically target underserved communities based on equity concerns."[193] ChargePoint recognized that "there may still be barriers to be addressed, including equity in home charging," and recommended a more flexible approach generally for near-term proposals.[194] Referencing the National Research Council report, "Overcoming

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[193] NDC reply comments at 8.

[194] ChargePoint opening comments at 19, quoted in PG&E reply comments at 4-5.

Barriers to Deployment of Plug-in Electric Vehicles,"[195] GPI/CEC noted that a barrier to EV adoption included "complexities of installing home charging."[196] VGIC, SDG&E, and AAI strongly disagreed with excluding support for single-family home residential charging stations.[197] According to AAI, "there may still be compelling reasons for utility programs to accelerate infrastructure deployment and vehicle-grid integration in . . . residential settings, and other locations despite signs of private sector investment."[198]

Accordingly, as a fifth near-term priority category, the Electrical Corporations may propose a program focused on providing rebates to offset the cost of Level 2 installations (both the EVSE and necessary panel upgrades) for low-income customers in underserved communities. The Electrical Corporations may propose to offer rebates for the ordinary cost of upgrading residential service behind the customer's meter and installation of Level 2 EVSE if such rebates are not already being offered for services through an existing program.[199] The Electrical Corporations may propose such programs through the advice letter process outlined for the near-term priority areas. This proposal not only ensures the equitable distribution of charging infrastructure, but removes the financial barrier to Level 2 EVSE installation that many homeowners and renters of single family homes face in underserved communities. Moreover, this

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[195] Available at https://www.nap.edu/catalog/21725/overcoming-barriers-to-deployment-of-plug-in-electric-vehicles.

[196] GPI/CEC opening comments, attachment at 10.

[197] VGIC opening comments at 10, VGIC reply comments at 11, SDG&E opening comments at 7, and AAI reply comments at 5.

[198] AAI reply comments at 3-4.

[199] Existing rebate programs in this instance may include programs of the electrical corporations, local jurisdictions, original equipment manufacturers, or other sources of funds available to customers for the purposes outlined here.

proposal can assist "supercommuters" that have daily commutes that exceed the capability of Level 1 charging.[200]

We encourage parties to provide remarks on this new near-term priority in their opening and reply comments to the proposed decision.

5. Interaction Between the Proposed TEF and SB 350

Several parties raised concerns that the Commission process for review of Electrical Corporation applications for TE investments, as proposed by the TEF, would inherently modify the requirements placed on the Commission by SB 350.[201] That law codified Section 740.12 of the Public Utilities Code, which states in pertinent part:

> The commission, in consultation with the State Air Resources Board and the Energy Commission, shall direct Electrical Corporations to file applications for programs and investments to accelerate widespread transportation electrification…. The commission shall approve, or modify and approve, programs and investments in transportation electrification, including those that deploy charging infrastructure, via a reasonable cost recovery mechanism, if they are consistent with this section, do not unfairly compete with nonutility enterprises as required under Section 740.3, include performance accountability measures, and are in the interests of ratepayers as defined in Section 740.8.

The premise of the argument provided by some parties is that the proposed TEF impermissibly modifies the requirement that the Commission "approve, or modify and approve" TE investment proposals by the Electrical Corporations by creating several new requirements for such proposals, including: cost caps for near-term applications, defined investment areas for

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200 *See* CEC/GPI reply comments at 5, Joint Commenters opening comments at 5.

201 *See, e.g.*, SDG&E reply comments, *passim*.

near-term applications, defining market barriers for the Electrical Corporations to address in their future applications.

This decision finds that the language of SB 350 justifies the Commission's imposition of certain processes to regulate the *applications* by the Electrical Corporations for TE investments. Indeed, SB 350 is clear that it is the Commission's responsibility to "direct" those applications, and this decision holds that part of the duty to direct an application for TE investments may include setting parameters for the same. The proposed TEF is a form of Commission direction for TE investment applications – a power granted to the Commission by SB 350.

Furthermore, Public Utilities Code Section 701 allows the Commission to "do all things, whether specifically designated in this part or in addition thereto, which are necessary and convenient in the exercise of such power and jurisdiction" to "supervise and regulate every public utility." This decision finds that the authority of Section 701 extends to directing Electrical Corporations on the parameters of TE investment applications to be filed with the Commission, regardless of the merits of the arguments related to SB 350.

Finally, the parameters for Electrical corporation applications established by this decision are directly related to the Legislature's command that the Commission ensure that applications for TE investments do not unfairly compete with nonutility enterprises, include performance accountability measures, and are in the interests of ratepayers. Greenlots argued that the proposed TEF would be contrary to SB 350 if it expanded the Commission's role beyond simply evaluating TE infrastructure applications "based on the standards of review codified by SB 350."[202] However, the TEF itself is an effective means of implementing SB 350 and ensuring the policy goals therein are achieved. It would be illogical to find that the Commission has the duty to apply certain standards of review to an application but not the authority to scope those standards into the applications themselves. It is not contrary to SB 350 for the Commission to adopt certain parameters for applications by the Electrical Corporations for TE investments that seek to enforce the Legislature's view of what constitutes an acceptable application for TE investments.

6. Comments on Proposed Decision

The proposed decision of Commissioner Clifford Rechtschaffen in this matter was mailed to the parties in accordance with Section 311 of the Public Utilities Code and comments were allowed under Rule 14.3 of the Commission's Rules of Practice and Procedure. Comments were filed on __________, and reply comments were filed on _____________ by ________________.

In particular, the Commission seeks party comment on how the proposed decision may be further revised to adequately incorporate equity as an explicit commitment in Electrical Corporation proposals for TE infrastructure.

7. Assignment of Proceeding

Clifford Rechtschaffen is the assigned Commissioner and Patrick Doherty and Sasha Goldberg are the assigned Administrative Law Judges in this proceeding.

Findings of Fact

1. An additional 121,000 light-duty EV chargers are currently planned or under development, leaving a gap of 60,000 chargers to be planned, built, and electrified between now and 2025.

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[202] Greenlots reply comments at 3.

2. Additional TE investments by the Electrical Corporations are necessary in order to meet the targets for EV chargers established by state policy.

3. Some level of Electrical Corporation investments in TE infrastructure beyond that already approved by the Commission will be necessary to support the state to meet its 2025 charger goals.

4. The Electrical Corporations cannot be responsible for the full burden of meeting the state's EV charger deployment goals.

5. Any proposals for additional TE infrastructure expenditures that the Electrical Corporations elect to propose should be filed in a timely manner with the Commission to ensure that the state's policy goals are met by 2025.

6. It is critically important to ensure that Electrical Corporation investments in TE infrastructure are equitable and that they address environmental justice concerns.

7. The Electrical Corporations should avoid gaps in their existing program offerings.

8. CARB is currently implementing and promulgating a variety of regulations to promote the electrification of the MD/HD sector.

9. The definition of MD/HD sector includes all of the forms of transportation electrification that are required to meet the state's policy goals, as explained and defined by D.20-09-025. Therefore, the MD/HD sector as referred to in this decision includes medium-duty EVs, heavy-duty EVs, off-road EVs, and off-road electric equipment.

10. The parameters for Electrical Corporation applications established by this decision are directly related to the Legislature's command that the Commission ensure that applications for TE investments do not unfairly compete with

nonutility enterprises, include performance accountability measures, and are in the interests of ratepayers.

Conclusions of Law

1. It is the Legislature's intent that the Commission establish policy and authorize reasonable utility investment that attracts private investment in EV charging services, makes charging infrastructure more available to Californians, and increases adoption and usage of EVs across all classes and weights, including light-, medium-, and heavy-duty electric vehicles, and off-road electric vehicles or off-road electric equipment.

2. Given the urgent need to meet the state's EV policy goals by 2025, it is reasonable to authorize proposals for TE investments in the near-term priority categories identified by this decision in the form of a Tier 3 advice letter to be reviewed by the Commission's Energy Division staff and disposed of via Commission resolution pursuant to General Order 96-B.

3. Given the urgent need to meet the state's EV policy goals by 2025, it is reasonable to allow expedited application proposals for TE investments to extend existing programs and avoid gaps in existing program offerings.

4. Electrical Corporations should be allowed to file near-term priority program applications for TE investments outside of the near-term priority categories adopted by this decision, or as a supplement to the Tier 3 advice letter proposals for TE investments to support the near-term priorities, in the form of a formal application, which will be reviewed by the Commission in accordance with the requirements of SB 350, the Commission's Rules, other applicable law, and in light of AB 841.

5. Transportation electrification in California should be equitable.

6. It is reasonable to apply equity and environmental justice requirements to near-term priority program proposals for TE infrastructure.

7. It is reasonable to efficiently align state efforts in the MD/HD sector.

8. It is the Legislature's intent that TE investment proposals from the Electrical Corporations include performance accountability measures, and are in the interests of ratepayers.

9. The Commission should adopt an advice letter process for proposals for TE investments to support near-term priorities. That process should include structural protections for ratepayer interests so that the speed of the advice letter process, including the lack of evidentiary hearing and cross-examination, does not prejudice the interests of ratepayers in the proposed investments.

10. Budgetary caps should be imposed on proposals filed via the advice letter process in order to safeguard the interests of ratepayers.

11. There should not be an ex ante budgetary cap imposed on near-term priority program proposals outside of the advice letter process and filed with the Commission as a formal application.

12. It is reasonable to establish resiliency as a near-term priority for Electrical Corporation TE investments.

13. It is reasonable to establish as a near-term priority programs to address customers without access to home charging.

14. It is reasonable to establish the MD/HD sector as a near-term priority for Electrical Corporation investments in TE infrastructure.

15. The Electrical Corporations should coordinate their MD/HD sector efforts, and create consistency in program design where feasible.

16. It is reasonable to establish the new building sector as a near-term priority for Electrical corporation investments in TE infrastructure.

17. It is reasonable to establish Level 2 installations for low-income customers in underserved communities as a near-term priority for Electrical Corporation investments in TE infrastructure.

18. SB 350 justifies the Commission's imposition of certain processes to regulate the applications by the Electrical Corporations for TE investments.

19. SB 350 is clear that it is the Commission's responsibility to "direct" applications by the Electrical Corporations for TE investments, and this decision holds that part of that duty to direct an application for TE investments may include setting parameters for the same.

20. The TEF is an effective means of implementing SB 350 and ensuring the policy goals therein are achieved.

21. The authority granted to the Commission by Section 701 extends to directing Electrical Corporations on the parameters of TE investment applications to be filed with the Commission.

22. It is not contrary to SB 350 for the Commission to adopt certain parameters for applications by the Electrical Corporations for TE investments that seek to enforce the Legislature's view of what constitutes an acceptable application for TE investments.

O R D E R

IT IS ORDERED that:

1. Any proposal for transportation electrification (TE) investments by any of Southern California Edison Company, San Diego Gas & Electric Company, Liberty Utilities (CalPeco Electric) LLC, PacifiCorp d/b/a Pacific Power, Bear Valley Electric Service, and Pacific Gas and Electric Company shall comply with the following requirements, regardless of whether the proposal is filed as a Tier 3 advice letter to be considered under General Order 96-B or is filed as a

stand-alone application to be considered under the Commission's Rules of Practice and Procedure:

- Utilize a program specific infrastructure or expenditure target of at least 50 percent for customers located in underserved communities.
- If a proposal utilizes customer incentives or rebates, utilize larger incentives or rebates for customers located in underserved communities.
- Ensure program incentives reach customers in counties with high poverty rates or underserved community rates. Programs may include proposals to offset costs of upgrading residential service behind the customer's meter for a L2 EVSE installation.
- Demonstrate that the Electrical Corporation coordinated with more than one community based organization (CBO) during the development of the proposal and has the support of local/regional/tribal governments and CBOs during program implementation.
- As a part of coordination with community based organizations (CBOs), Electrical Corporations must ensure that EV charging infrastructure deployed in underserved communities is accessible and tailored to community residents, addressing community specific needs such as language and Americans with Disabilities Act (ADA) accessibility, visibility, public education on EV compatibility, and cultural considerations of local history, and safety. This is intended to ensure the infrastructure feels safe to access throughout hours of operation, and to increase awareness of available EV charging infrastructure for community members who may not have access to home or workplace EV charging facilities. In conjunction with filing proposals, the Electrical Corporations should submit a plan of how they are working to increase accessibility at any publicly accessible EV charging location, for sites located in an underserved community and non-underserved community sites, as safety and accessibility

are not issues reserved to underserved communities. The plans should also discuss how the Electrical Corporations are working with CBOs to develop these plans. The Electrical Corporations should ensure accessibility and safety are factored into all sites where EV charging infrastructure is installed.

- Coordinate Marketing Education & Outreach (ME&O) to promote participating in an infrastructure program with CBOs and regional/local/tribal governments to encourage more equitable outreach and participation, and ensure that at least some portion of any proposed TE infrastructure budget is dedicated to ME&O and is primarily dedicated to CBOs to execute outreach to community residents.
- Include detail on how the proposal will address the barriers to equity identified in the Commission's Environmental and Social Justice Action Plan (ESJ Action Plan)[203] and Tribal Consultation Policy,[204] and/or Part B of CARB's Low-Income Barriers Study.
- Articulate how each project incorporates any of the following priority provisions:
    - i. Job quality measures, such as wage and benefit standards and responsible contractor standards;
    - ii. Job access measures, such as targeted hire requirements as well as specified targets for residents of underserved communities;
    - iii. Comprehensive project agreements that address both job quality and job access, such as application of the Skilled & Trained Workforce

[203] Available at: https://www.cpuc.ca.gov/uploadedFiles/CPUCWebsite/Content/UtilitiesIndustries/Energy/EnergyPrograms/Infrastructure/DC/Env%20and%20Social%20Justice%20ActionPlan_%202019-02-21.docx.pdf.

[204] Available at: https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M212/K861/212861685.PDF.

requirement[205], and use of Community Workforce Agreements for large-scale TE projects;

- Funding directed to training partnerships that are guided in their programming to ensure that investments in training are connected to and result in placement in high-quality jobs.

2. Any proposal for transportation electrification (TE) investments in a near-term priority area by any of Southern California Edison Company, San Diego Gas & Electric Company, Liberty Utilities (CalPeco Electric) LLC, PacifiCorp d/b/a Pacific Power, Bear Valley Electric Service, and Pacific Gas and Electric Company filed as a Tier 3 advice letter, shall comply with the following requirements:

- Information on funding avenues that are not sourced from ratepayers should be included in the proposal and be tracked/updated throughout the proposal's implementation.
- A clear justification for why additional ratepayer investment prior to Transportation Electrification Plan (TEP) approval is necessary for a given proposal.
- Clear demonstration of what barriers to widespread TE the proposal will address.
- A proposal implementation duration of no longer than three years after Commission authorization.
- Each near-term priority program proposal using the Tier 3 advice letter process must have an estimated budget that does not exceed $20 million.
  - The Electrical Corporations must establish a new one-way Near-Term Priority (NTP) TE balancing account

[205] Frequently Asked Questions on Skilled & Trained Workforce ("STW") Requirements, available at https://www.dir.ca.gov/Public-Works/ADA-Compliant-STW-FAQ.pdf.

using the advice letter process. Each NTP TE balancing account will have a cap of $80M.

- Within the NTP TE balancing account, the Electrical Corporations must establish subaccounts for each near-term priority program. Each program will be limited to $20 million.
- Each near-term priority program must recover authorized program funding through distribution rates allocated to customer classes on an equal cents per kWh basis.
- Each Electrical Corporation's aggregate estimated budget for near-term priority program proposals using the Tier 3 advice letter process shall not exceed $80 million.

- To qualify for the advice letter process, proposals must not include utility ownership of any customer-side infrastructure (Electric Vehicle Service Equipment and/or make-ready) except for sites located in underserved communities. Electrical Corporations are limited to owning no more than 50 percent of the customer-side infrastructure per program proposal.
- Any expedited applications for extensions of existing programs submitted pursuant to this PD must not include utility ownership of any customer-side infrastructure (Electric Vehicle Service Equipment and/or make-ready) except for sites located in underserved communities. Electrical Corporations are limited to owning no more than 50 percent of the customer-side infrastructure per program proposal.
- Any Electrical Corporation proposal for near-term priority TE investments in the medium-duty and heavy-duty sector, whether through the advice letter process or in an application, shall ensure that the investments proposed align with the CARB electrification mandates for the sector.
- The proposal must identify which State regulation(s) require the support of ratepayers prior to Commission

approval of the Electrical Corporation's Transportation Electrification Plan.

3. Any proposal for transportation electrification (TE) investments to support the near-term priority of programs to address transportation electrification resiliency by any of Southern California Edison Company, San Diego Gas & Electric Company, Liberty Utilities (CalPeco Electric) LLC, PacifiCorp d/b/a Pacific Power, Bear Valley Electric Service, and Pacific Gas and Electric Company, and filed as a Tier 3 advice letter, shall comply with the following requirements:

- Within 120 days of approval of this decision, each electric corporation should conduct an assessment of existing EV charging infrastructure funded through Commission approved programs and serve a stocktake to the DRIVE OIR service list identifying (1) what potential hazard(s) pose a risk to the accessibility and/or functionality of the charging infrastructure, (2) how the infrastructure is installed in a manner that furthers the Commission's resiliency directives ordered through recent resiliency decisions, (3) what, if any, investments are needed to re-enforce the installed infrastructures ability to be resilient to a natural event caused power disruption, and (4) how the electric corporation will address these gaps in resiliency through near-term priority programs.
- Specifically address topics including but not limited to: 1) loads, assets, facilities, and populations the proposed TE resiliency project is intended to benefit; 2) the types, locations, and probabilities of the hazard(s) that place the intended beneficiaries at risk and what the TE resiliency project is intended to mitigate; 3) the mechanism by which the project is expected to mitigate the identified risks; 4) the expected quantitative impact of the proposed project on the identified risks; 5) the expected impacts of the proposed project on equity and affordability; and 6) the cost of the proposal.

- Any TE resiliency proposal seeking to install battery storage backup for off-grid EV charging should prioritize sourcing the power for charging the EVSE battery from renewable energy resources or low-emitting sources.
- Any resiliency proposal shall demonstrate efforts to work with county/local and tribal governments, state emergency agencies, CCAs, local planning/transportation agencies, CBOs, and ESJ organizations to develop resiliency-focused programs. Due to relevant stakeholder presence and a core focus on resiliency planning, we encourage the utilities to use the semi-annual workshops as required by Ordering Paragraph 7 of Decision (D.)20-06-017 to present their project plans to the above stakeholders and gather feedback. The proposal should specifically state in which of the semi-annual resiliency planning meetings described in Ordering Paragraph 7 of D.20-06-017 it was discussed, or provide a reasonable justification if was not discussed in any of those meetings. The proposal should demonstrate how the Electrical Corporation plans to continue working with these stakeholders throughout the implementation process.
- The Electrical Corporations shall record costs for ratepayer supported TE infrastructure deemed damaged during a state emergency within each Electrical Corporation's Catastrophic Event Memorandum Account.

4. Any proposal for transportation electrification (TE) investments to support the near-term priority of programs to address customers without access to home charging by any of Southern California Edison Company, San Diego Gas & Electric Company, Liberty Utilities (CalPeco Electric) LLC, PacifiCorp d/b/a Pacific Power, Bear Valley Electric Service, and Pacific Gas and Electric Company, and filed as a Tier 3 advice letter, shall comply with the following requirements:

- The proposal should demonstrate that the Electrical Corporation considered and incorporated lessons learned from existing and completed TE programs that targeted customers without access to home charging to either propose innovative pilot approaches to electric vehicle charging infrastructure deployment, or a non-infrastructure approach to address the costs of fueling disparity.

- The proposal shall clearly state how the proposed program fills a gap not currently addressed by an existing program.

5. Any proposal for transportation electrification (TE) investments to support the near-term priority of support for the medium-duty and heavy-duty sector (MD/HD sector) by any of Southern California Edison Company, San Diego Gas & Electric Company, Liberty Utilities (CalPeco Electric) LLC, PacifiCorp d/b/a Pacific Power, Bear Valley Electric Service, and Pacific Gas and Electric Company, and filed as a Tier 3 advice letter, shall comply with the following requirements:

- The Electrical Corporation must describe why previously approved MD/HD sector programs are not sufficient to meet the charging needs to comply with State regulations or why there are gaps in their existing MD/HD program.
- The Electrical Corporation should describe how its proposed program addresses any barriers that have arisen within the Commission-approved programs (*e.g.*, vehicle electrification requirement, power level limitations, etc.).
- The proposal should describe how the Electrical Corporation coordinated with State agencies, local and tribal governments, and/or regional organizations to develop the proposal and how coordination will continue throughout the implementation of the proposal.

6. Any proposal for transportation electrification (TE) investments to support the near-term priority of new buildings by any of Southern California Edison Company, San Diego Gas & Electric Company, Liberty Utilities (CalPeco Electric) LLC, PacifiCorp d/b/a Pacific Power, Bear Valley Electric Service, and Pacific

Gas and Electric Company, and filed as a Tier 3 advice letter, shall comply with the following requirements:

- Any proposal must exclusively support infrastructure that exceeds existing state and local electric vehicle (EV) infrastructure code requirements.
- Any proposal should evidence that the Electrical Corporation consulted with local jurisdictions to determine how much participating builders should exceed the local codes to be eligible for rebates.
- Proposals must demonstrate that they are filling a gap not addressed through another program, code, or agency.
- Any proposal should include a mechanism for the Electrical Corporation to report to the Commission's Energy Division on any code updates that impact new construction, along with a procedural pathway to modify or halt the program if necessary.
- Any proposal should include robust data collection requirements and be consistent with those adopted for the Charge Ready 2 program in Decision 20-08-045.
- Any proposal for new construction programs shall limit expenditure to rebates for customer-owned infrastructure only.
- All incentives for new construction infrastructure should be rebates and therefore be expensed (*i.e.,* not capitalized by the Electrical Corporation but recovered as an operations and maintenance cost).
- Rebates for sites located in an underserved community should cover 100 percent of the infrastructure and installation costs. Rebates for non-underserved community sites should cover no more than 50 percent of the infrastructure costs of building over the code minimum, with a cap of $2,000 per port over code plus an adder for publicly accessible parking areas that would require the installation of one or more accessible Electric Vehicle Supply Equipment parking space.

7. Any proposal for transportation electrification programs to support Level 2 installations for low-income customers in underserved communities, by any of Southern California Edison Company, San Diego Gas & Electric Company, Liberty Utilities (CalPeco Electric) LLC, PacifiCorp d/b/a Pacific Power, Bear Valley Electric Service, and Pacific Gas and Electric Company, and filed as a Tier 3 advice letter shall comply with the advice letter requirements outlined in Ordering Paragraph 2. Additionally, the advice letter shall comply with the following:

- The proposal shall clearly state how the proposed program fills a gap not currently addressed by an existing program.
- The proposal should demonstrate that it avoids duplication with Level 2 funding available from Electrical Corporation programs, local jurisdictions, original equipment manufacturers or other sources of funding.

8. Rulemaking 18-12-006 remains open.

This order is effective today.

Dated ____________________________, at San Francisco, California

WHITE PAPER

OCTOBER 2017

EMERGING BEST PRACTICES FOR ELECTRIC VEHICLE CHARGING INFRASTRUCTURE

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

Electric vehicles offer great potential to dramatically reduce local air pollution, greenhouse gas emissions and resulting climate change impacts, and oil use from the transport sector. With electric vehicle costs steadily falling, the transition continues to become more feasible. This potential is enabled and made compelling by the ubiquity of electricity and the growing availability of low-carbon, renewable energy sources. Yet there are unanswered questions about the deployment of electric vehicle charging infrastructure and the associated policy that will need to be addressed to help pave the way for electrification.

This report provides a global assessment of charging infrastructure deployment practices, challenges, and emerging best practices in major electric vehicle markets, with an emphasis on public charging facilities. Although most early adopters charge their vehicles at home, public charging is an important part of the electric vehicle ecosystem. We analyze public charging infrastructure in the top electric vehicle markets globally, including a statistical analysis of the relationship between public charging and electric vehicle uptake. Our analysis is at the metropolitan-area level to better discern local infrastructure variation, practices, and circumstances.

Figure ES-1 depicts electric vehicle uptake and public charging infrastructure development in the top electric vehicle markets by share of new vehicles in 2016. Norway and the Netherlands, which have seen electric vehicle shares higher than 5% of new sales, have public charging infrastructure per capita that is several times that of other leading markets. China, the world's largest electric vehicle market by volume, has the highest number of charging stations, with more than 100,000 Level 2 and 38,000 direct current (DC) fast charge points. Other countries with an electric vehicle share of new sales greater than 1% have varying amounts of public charging infrastructure and different fractions of DC fast charging, reflecting different roles of public charging infrastructure that vary according to demographics and policy priorities.

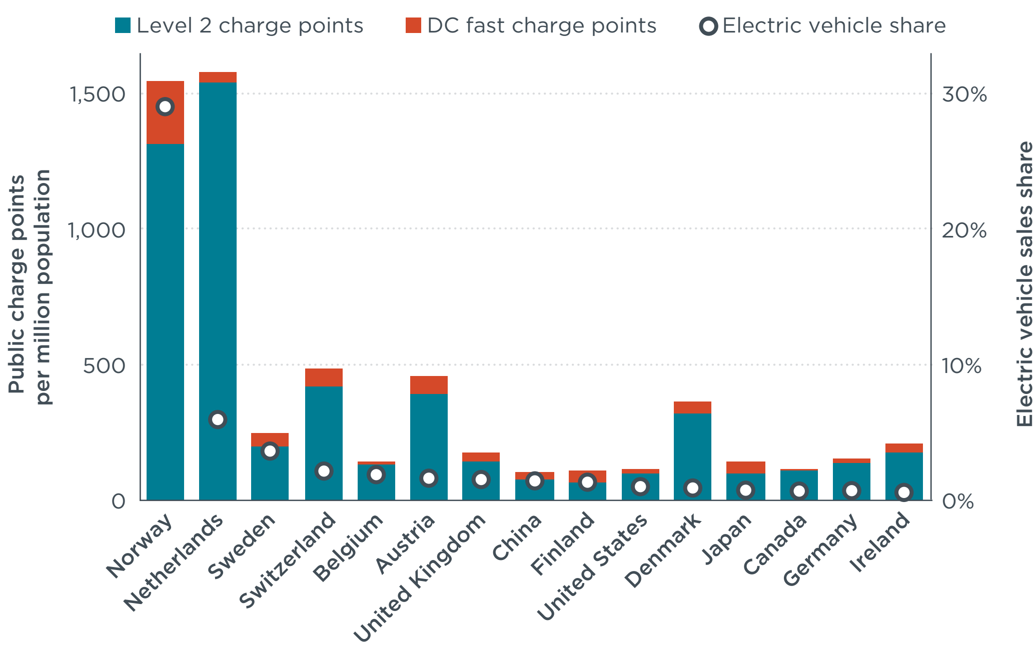

Figure ES-1. 2016 electric vehicle sales share and public charge points per million population in major national markets.

We find that charging infrastructure availability varies greatly at a local level. We offer four high-level conclusions on the fast-developing charging infrastructure around the world.

Public charging infrastructure is a key to growing the electric vehicle market. Using a multivariable regression of 350 metropolitan areas, we find that both Level 2 and DC fast charging infrastructure are linked with electric vehicle uptake, as are consumer purchase incentives. We therefore corroborate other research on the importance of developing charging infrastructure in unison with electric vehicle deployment. The leading electric vehicle markets of Norway and the Netherlands have more than 10 times as many public charge points per capita as average markets, and leading markets in California and China had three to five times the average. Yet the significant charging variability across the hundreds of cities analyzed in this study points to major differences across the electric vehicle markets regarding the role of public charging. As the global electric vehicle market grows—likely by at least a factor of 10 by 2025—so too will the need for much more public charging infrastructure.

There is no universal benchmark for the number of electric vehicles per public charge point. Electric vehicle owners in California more frequently have access to home and workplace charging, and one public charger per 25 to 30 electric vehicles is typical. In the Netherlands, private parking and charging are relatively rare, and one public charger per 2 to 7 electric vehicles is typical. This ratio ranges from 3 to 6 in major markets in China, and these cities typically had the highest percentages of rapid charging. Given the wide variation of public charging availability across markets with higher electric vehicle uptake, and their differing housing and population density characteristics, it seems clear that there is no ideal global ratio for the number of electric vehicles per public charge point. Comparisons of similar markets still offer an instructive way to understand where and how charging is insufficient. Lagging electric markets can strive toward the leading benchmarks of comparable cities, while top markets continue to set new benchmarks as the market and its charging infrastructure coevolve.

Multifaceted and collaborative approaches have been most successful in promoting early charging infrastructure buildout. Governments at the local, regional, and national levels around the world have used varied strategies to promote public and private charging infrastructure. Successful programs have transparently engaged many stakeholders through integration of driver feedback on charger deployment, implementation of smart charging systems, distribution of funding to local governments, creation of public-private partnerships, and consultation with electric utilities. To address changing needs in this growing market, governments create and fund programs that target difficult market segments, such as curbside charging stations, multi-unit dwellings, and intercity fast charging.

Barriers to the deployment of the ideal electric vehicle charging network remain. Despite all the electric vehicle improvements entering the market, charging infrastructure still suffers from fragmentation, inconsistent data availability, and a lack of consistent standards in most markets. Open standards for vehicle–charge point communication and payment may mitigate some of these issues by enabling interoperability between charging networks, increasing innovation and competition, and reducing costs to drivers. As demonstrated by successful efforts in the Netherlands, governments may wish to require data collection and the use of open standards for publicly funded projects to help market development.

I. INTRODUCTION

Electric vehicles offer the potential to dramatically reduce local air pollution, climate change impacts, and oil use from the transport sector. Petroleum-fueled combustion vehicles have dominated the past century, but the recent growth of electric vehicles presents an opportunity to transform the transportation sector. With increased production volumes and battery cost reductions over the next 10 years, electric vehicles are projected to approach cost-competitiveness with conventional vehicles (Slowik & Lutsey, 2017; UBS, 2017). In just the past 6 years, electric vehicles have gone from a fringe technology with no mass production to a fast-growing part of the vehicle market. In early 2017, the two-millionth electric vehicle was sold, and electric vehicles have surpassed 10% of new vehicle sales in multiple local markets.

The potential benefits of electric vehicles are enabled, and made much more compelling, by the attributes of electricity. Electricity is ubiquitous and available for electric charging nearly everywhere, including in and near many homes. The cost of electricity can be lower per effective energy unit than petroleum fuels, and is typically made much lower than petroleum by the greater efficiency of electric motors relative to internal combustion engines. Whereas renewable and lower-carbon liquid fuels have been relatively elusive, electricity is generated from many renewable and low-carbon energy sources, which represent an ever-growing fraction of global electricity generation.

Yet a lack of charging infrastructure still presents a barrier to growth in the electric vehicle market. Although electricity itself is ubiquitous, its transmission, distribution, and retail charging options for electric vehicles are not. The fueling infrastructure to support combustion-powered vehicles is already in place, with a robust network of gasoline and diesel fueling stations around the world. Taking the U.S. situation as an example: Through 2016, there were more than 150,000 filling stations for gasoline and diesel fuel in the United States, most of which have many pumps (API, 2017). This network of stations has evolved in number and location to be able to fuel the approximately 250 million gasoline and diesel vehicles in the United States (Davis et al., 2016). Compare this with the electricity availability for electric vehicles. Beyond the electricity that is widely available at most households, there were about 15,000 publicly accessible charging stations at the end of 2016 (U.S. DOE, 2017a). If publicly accessible charging infrastructure for electric vehicles remains limited, this would restrict drivers' ability to take longer trips and would practically limit the utility and attractiveness of electric vehicles for any household without a private garage to charge the vehicle.

As a result, the development of a robust charging infrastructure network is widely considered a key requirement for a large-scale transition to electromobility. Such infrastructure would not only provide more charging options for drivers, but would also promote awareness and range confidence for prospective electric vehicle owners. Several automakers have begun to directly build out their own charging infrastructure networks, while others have engaged in partnerships with other automakers and charging providers. Many governments have created programs to encourage the construction of charging infrastructure through incentives, regulations, and partnerships. Nonetheless, there is relatively little consensus about the optimal concentration and distribution of charging infrastructure or the relationship between charging infrastructure and electric vehicle uptake. Even getting access to the number and location of available charging points can be difficult.

At this stage, governments, auto industry experts, and researchers around the world have many questions about electric vehicle charging infrastructure. How much charging infrastructure is required for a mature market, and what types are likely to be needed in the future as electric vehicle technology continues to evolve? What policy frameworks and funding mechanisms can help to ensure that the necessary charging infrastructure is in place for electric vehicles? Finally, are there strong global examples of policies and initiatives that demonstrate how best to overcome prevailing barriers and deploy charging infrastructure for electric vehicles?

This paper seeks to address these questions with a comprehensive review of the current status of charging infrastructure in major electric vehicle markets in North America, Europe, and Asia. Although the majority of charging in most regions occurs at home, this analysis focuses primarily on public charging infrastructure to help inform topical government policy and funding questions. We assess the relationship between charging infrastructure and electric vehicle uptake at the metropolitan-area level. Through this analysis, we quantify emerging benchmarks for charging infrastructure deployment and best practices for charging infrastructure promotion, construction, and operation. Additionally, we compare major government programs to increase charging infrastructure and discuss some of the barriers and exemplary programs that are helping to overcome these barriers.

II. BACKGROUND ON ELECTRIC VEHICLE CHARGING INFRASTRUCTURE

ELECTRIC VEHICLE CHARGING TECHNOLOGY

As electric vehicle charging technology continues to advance, several standards and guidelines have become widely accepted across the industry. To provide a technical background for the following analysis and policy discussion, this section gives a brief overview of charging infrastructure technology, standards, and terminology.

Charging speeds. Charging power, which determines the time required to charge a vehicle, can vary by orders of magnitude across charge points, as shown in Table 1. A small household outlet may charge as slowly as 1.2 kW, while the most advanced rapid charging stations can charge at up to 350 kW. Charging infrastructure is broadly broken into three categories based on speed: Level 1, Level 2, and direct current (DC) fast charging (sometimes referred to as Level 3).

Table 1. Characteristics of Level 1, Level 2, and DC fast charging.

Charging level	Voltage (V)	Typical power (kW)	Setting
Level 1	120 V AC	1.2–1.8 kW	Primarily residential in North America
Level 2	200–240 V AC	3.6–22 kW	Home, workplace, and public
DC fast	400 V DC	50 kW or more	Public, primarily intercity

V = volt; AC = alternating current; DC = direct current; kW = kilowatt

Many electric vehicles are limited in the maximum charging power they can accept, because of restrictions in their ability to convert AC power from the grid to DC power that charges the batteries. For example, the Chevrolet Volt, a plug-in hybrid vehicle (PHEV), is limited to 3.6 kW, and the Nissan Leaf, a battery electric vehicle (BEV), is limited to 6.6 kW. Furthermore, some electric vehicle models, including most PHEVs, are not capable of DC fast charging.

Charging infrastructure can also be categorized by "mode," which specifies the type of electric and communications connection between the vehicle and the charging infrastructure (Bräunl, 2012). Mode 1 consists of 120 or 240 V charging up to 16 amperes (A) on a shared circuit without safety protocols. Mode 2 consists of 120 or 240 V charging up to 32 A from a standard outlet, on a shared or dedicated circuit, with safety protocols including grounding detection, overcurrent protection, temperature limits, and a pilot data line. Mode 3 allows 240 V charging at any amperage on a wired-in charging station on a dedicated circuit, with the same safety protocols as Mode 2 and an active communication line with the vehicle. This enables smart charging—the coordination of charging according to utility needs, fleet schedules, or renewable energy availability. Finally, Mode 4 is defined as DC fast charging on a 400 V, wired-in connection, and requires more advanced safety and communications protocols.

Charging connector standards. Depending on region and speed of charging, the type of plug and socket used for charging electric vehicles may vary. The most common plug types are illustrated in Table 2 and Table 3. Although these plug types are generally well-defined and each works well for its specific application, the variety of standards may lead to confusion among drivers and hesitation from industry.

In North America and Japan, most electric vehicles use the SAE J1772 connector, which contains five pins and a mechanical lock. In Europe, Level 2 charging uses the Type 2 or Mennekes connector, which has seven pins and takes advantage of the three-phase alternating current grid. China also requires (as of 2017) a variant of the Type 2 plug (under the standard GB/T 20234.2-2015), although legacy vehicles and charging stations have not yet been converted (NDRC, 2015). The exception to this regional breakdown is Tesla, which uses a proprietary connector for its vehicles sold in North America, although adapters to SAE J1772 are available. In Europe and Asia, Tesla vehicles have a Type 2 plug.

Table 2. Comparison of the most popular AC charging connector types.

SAE J1772	Type 2 (Mennekes)	Tesla (US)
		
North America and Japan	Europe and China	Tesla vehicles in North America

Photo credit (left to right): National Alternative Fuels Training Center, Mennekes AG, Silverstone Green Energy

For DC fast charging, connector types vary by automaker in addition to region, with the most common connectors shown in Table 3. Nissan and Mitsubishi created and promoted the CHAdeMO (short for Charge de Move) fast charging standard beginning in 2011 (Mitsubishi Motors Corporation, 2014). This type is still used on electric vehicles produced by Nissan, Mitsubishi, Kia, Citroën, and Peugeot. In contrast, several automakers from the United States and Europe have advocated for the Combined Charging System (CCS), which uses the SAE J1172 or Mennekes AC plugs along with two additional DC pins for fast charging. This standard has now been adopted by BMW, Daimler, Ford, Fiat Chrysler, General Motors, Honda, Hyundai, and Volkswagen. Whereas CCS (sometimes referred to as SAE Combo or Combo2 in North America and Europe, respectively) uses the same receptacle on the car as a Level 2 charger, CHAdeMO requires a separate port. As in the case of Level 2 charging, Tesla uses its proprietary plug for its DC Supercharger stations in the United States, although the company also makes Tesla-to-CHAdeMO adapters. China has recently mandated the use of a new standard (GB/T 20234.3-2015) for all new vehicles and fast charging infrastructure; Tesla vehicles sold in China will also use this standard (Lambert, 2016; NDRC, 2015).

Table 3. Comparison of the most popular DC fast charging connector types in general use by major automobile manufacturers.

CHAdeMO	CCS (North America)	CCS (Europe)
		
Nissan, Mitsubishi, Kia, Citroën, Peugeot	BMW, Daimler, Ford, Fiat Chrysler, General Motors, Honda, Hyundai, Volkswagen	

Photo credit (left to right): National Alternative Fuels Training Center, SAE, Hadhuey via Wikimedia Commons

CHARGING DATA AVAILABILITY

In the rapidly evolving charging infrastructure industry, availability and access to accurate, up-to-date data can be limited in various markets. This situation can be problematic for drivers, who may have a more difficult time finding a place to charge; for charge point operators, who may see lower use at their stations; for governments, unable to direct investment efficiently; and for auto dealers, who need to assure customers of charging availability. There are several kinds of data regarding charging infrastructure that can be recorded, including location, type, operational status, and usage.

In many markets, there are numerous services attempting to advertise station information to drivers, although some of this information is likely to be incomplete or outdated at any given moment. Many different stakeholders offer these services, including governments (the Alternative Fuels Data Center in the United States), nonprofits (Open Charge Map or LEMnet in Europe), for-profit companies (ChargeHub in Canada, Zap-Map in the United Kingdom), automakers (the Nippon Charge Service consortium in Japan), and charge networks (ChargePoint in the United States, State Grid Corporation in China). Although most of these services offer maps (and in some cases mobile apps) for drivers, few offer open access to data.

A lack of information about maintenance and operational status can present an issue for charging stations, leading to higher downtime and frustration for drivers. Many newer charging stations are connected to the internet and can provide live information about their status and any problems, which can be incorporated into online charging station locating services. For stations without such capabilities, or on services that cannot access privately held data, allowing users to easily report a station’s status or successful charge (such as the “Check In” feature on PlugShare) can be useful in providing frequently updated status information. In turn, sharing such data can help charging station managers quickly repair the infrastructure.

Finally, more advanced networked stations frequently collect usage data from charging stations; these data can provide helpful lessons for governments and researchers, and may eventually lead to more efficient charging station construction and management practices (i.e., OLEV, 2013; Winn, 2016). Some governments choose to make usage data reporting a precondition for funding—for example, in British Columbia and the United Kingdom (evCloud, 2017; OLEV, 2016a).

LITERATURE REGARDING CHARGING AND ELECTRIC VEHICLE UPTAKE

Many governments consider transportation electrification an important step toward climate, air quality, and energy independence goals. To help achieve these goals, governments have invested substantial funding to promote electric vehicles and the associated charging infrastructure. Although charging infrastructure is a major priority for governments seeking to accelerate electric vehicle adoption, specific relationships between charging infrastructure availability and increased electric vehicle sales have been elusive. Likewise, there are no universally accepted goals or standards for charging infrastructure density, either on a per-capita or per-vehicle basis. Nonetheless, several studies in the past few years have provided helpful insights into this question.

Sierzchula et al. (2014) assessed factors influencing electric vehicle adoption across 30 countries in 2012 at a national level, focusing primarily on financial incentives. In their analysis, charging infrastructure was included as an explanatory variable, measured as charging stations per 100,000 residents in each country. A regression of several variables, with electric vehicle market share as the dependent variable, showed that charging infrastructure is the best predictor of national electric vehicle market share. Nonetheless, there are exceptions to this trend, such as Israel and Ireland, with relatively extensive charging infrastructure and low electric vehicle sales shares.

Harrison and Thiel (2017) modeled the impact of several factors, including charging infrastructure, on electric vehicle market share in Europe. This model calculated the utility and respective market share of different powertrain types, using feedback loops to capture realistic decision-making patterns by drivers, manufacturers, charging infrastructure providers, and policymakers. The model also assessed the profitability of charging stations under various scenarios and considered subsidies and government targets for charging infrastructure. The authors found that the private market can profitably support 95% of public charging stations, up to a ratio of 25 electric vehicles per charge point. They also found that electric vehicle market share increases as the electric vehicle/charge point ratio decreases from 25 to 5 electric vehicles per charge point. Charging infrastructure availability also appears to have the strongest impact on uptake once electric vehicle stock share exceeds 5%, which is currently the case only in Norway.

Slowik and Lutsey (2017) followed an approach similar to that of Sierzchula et al. (2014), but for the United States. Unlike other analyses, however, they focused their analysis on the 50 largest metropolitan areas in the United States, breaking down charging infrastructure at a regional level. Overall, the study found a significant relationship between public charging (measured in charge points per capita) and electric vehicle uptake, and identified 275 charge points per million residents as a benchmark for leading U.S. markets. The number of fast charging points per capita was also found to correlate with electric vehicle sales share, as was workplace charging. However, the authors more broadly concluded that a robust electric vehicle market requires multiple types of supporting policy, including charging infrastructure, consumer incentives, and local promotion actions that address consumer awareness barriers.

In general, there is broad agreement that public charging infrastructure is important to the growth of the electric vehicle market, among other factors related to electric vehicle cost and awareness. However, there has been limited research into how much charging infrastructure is needed for a given market and how strongly charging infrastructure encourages electric vehicle sales, even within one market. This may be partially due to the data availability problems described above. It may also be due to the quickly evolving state of electric vehicle technology, where electric vehicles and charging infrastructure will grow and coevolve together with patterns that still remain largely unclear.

Although this paper cannot comprehensively and definitively answer these questions, we seek to provide greater clarity about the existing relationship between charging infrastructure and electric vehicle sales in major electric vehicle markets around the world as of 2016. The next sections describe the policy context and offer an analysis of public charging deployment around the world.

III. GOVERNMENT PROGRAMS FOR PUBLIC CHARGING INFRASTRUCTURE

Since the introduction of modern electric vehicles, many governments at the local and national level have promoted electric vehicle charging infrastructure in recognition of the necessity of charging stations for a mature market. However, these plans vary widely in scope and focus, reflecting the uncertainty and pace of change in this industry. Here, we summarize major government programs promoting charging infrastructure in selected markets and highlight some emerging best practices. We focus on programs to increase the stock of public charging infrastructure through subsidies, grants, and public-private partnerships.

ASIA

China. Many stakeholders in China, including the central government, local governments, and utilities, have been active in quickly building a charging infrastructure network in that country. The charging network will serve China's ambitions to greatly increase its electric vehicle market in the years ahead. The market, with more than 300,000 electric car sales and 1% of new sales in 2016, is set to meet increasing New Energy Vehicle quotas that are under development to at least triple electric sales in the 2020 time frame. The central government has announced the goal of having electric vehicles reach 20% of national vehicle production, or about 7 million electric vehicles per year, by 2025 (MIIT, NDRC, & MOST, 2017).

The number of charge points has expanded dramatically in China in the past few years, especially in the 88 designated pilot cities funded by the central government, led by Shanghai, Beijing, and Shenzhen. As part of the program, these cities are required to provide one charge point for every 8 electric vehicles, and charging stations should be no farther than 1 km from any point within the center area of the city (NDRC, 2015). The municipal governments in these cities have sometimes funded many of the local stations (typically called "charging piles"), often in collaboration with the national utility State Grid (Research in China, 2017). The State Grid is also working to construct fast charging plazas within cities and along major intercity corridors as part of a plan to build 120,000 fast charging stations and 500,000 total public stations by 2020 (NDRC, 2015; Xin, 2017). Furthermore, some automakers in China have constructed charging stations in the regions where they are headquartered to benefit drivers of their vehicles, although there still remain some issues with interoperability of stations between automaker brands (Yuan, 2016). China represents almost half of the global supply of electric vehicle charging infrastructure—a proportion likely to increase in the coming years, given the strong government support at many levels and high electric vehicle volume there.

Japan. Since the introduction of modern electric vehicles in Japan in 2011, the government and the country's major automakers have supported charging infrastructure, viewing it as a key requirement for increased electric vehicle sales. In 2013, the government created the massive Next Generation Vehicle Charging Infrastructure Deployment Promotion Project to fund charging stations around cities and highway rest stations in 2013 and 2014 (CHAdeMO Association, 2016). The Development Bank of Japan partnered with Nissan, Toyota, Honda, Mitsubishi, and power company TEPCO to construct the Nippon Charge Service (NCS), a nationwide network of charging stations (including many fast charging stations) now operated as a private joint venture. Almost 7,500 stations are now part of this network, with continued funding at least through 2018.

EUROPE

Charging infrastructure in Europe has been constructed by a combination of private charge point providers, power companies, automakers, and governments, primarily at the national and city levels. Many countries within the European Union have created funding schemes or public-private partnerships to increase charging infrastructure, sometimes targeting specific regions in order to create leading electric vehicle markets. Some countries, such as Norway and the Netherlands, have provided incentives for charging infrastructure for several years; others, like Germany, have recently launched major new charging infrastructure programs, indicating growing recognition of the benefits of charging station investments.

The European Union has indicated that electric vehicles and charging infrastructure are a major transportation priority, and is considering extending its vehicle CO_2 regulations to 2025 or 2030 to promote electric vehicles, among other policy approaches (Lutsey, 2017). The European Union has also directed all member states to "ensure that recharging points accessible to the public are built up with adequate coverage, in order to enable electric vehicles to circulate at least in urban/suburban agglomerations and other densely populated areas" (European Parliament, 2014). In addition, the European Commission has supported more than a dozen electric vehicle infrastructure projects through the TEN-T/CEF-T program, with a focus on trans-European corridors and linking the projects operated by member states (TEN-T, 2016). The European Union has also taken an active role to promote interoperability, open standards, and smart charging, as demonstrated in the Green eMotion and PlanGridEV research projects conducted with industry partners (Green eMotion, 2015; RWE Deutschland, 2016).

France. Building on earlier goals to accelerate the shift to electric vehicles, the French government in 2017 has stated a goal of shifting all vehicle sales to electric by 2040. Promotional programs for charging infrastructure have been in place for several years in France. The primary program, operated by the French Environment and Energy Management Agency, distributes funding to municipalities and regional governments, helping to fund more than 12,000 charge points (Environment and Energy Management Agency, 2016). Recipients must commit to building at least 20 charge points and offer free parking for charging vehicles. Currently, most charging stations are eligible for a 30% subsidy. The state-owned utility EDF has also taken a lead role in charging infrastructure, constructing the Corri-Door fast charging network with more than 200 locations across the country (Lefevre, 2016). The federal government's strong role is evident in the large numbers of charging stations in France.

Germany. Germany has sought to ramp up its charging infrastructure to match its electric mobility ambitions. Sales of electric vehicles had reached 100,000 by early 2017, and the German federal government has goals to reach 1 million by 2020 and 5 million by 2030. Despite these stated goals, the government did not widely support public charging infrastructure until recently. Beginning in 2009, the government supported more than 200 projects in eight "model regions" with €130 million, boosting charging infrastructure in areas such as Hamburg and Saxony (BMVBS, 2011). A few cities created their own programs to provide incentives for charging infrastructure; for example, Munich provided a 20% subsidy for private, public, and workplace charging stations (Mobility House, 2017). Most other early charging stations were built by power companies and various private companies.

In early 2017, the government announced a major new nationwide program to promote electric vehicles, including €300 million earmarked for public charging infrastructure through 2020. Of this, €200 million is intended for the construction of 5,000 DC fast charging stations and the remaining €100 million for 10,000 Level 2 stations, with stations distributed across the country (BMVI, 2017). Businesses may apply for funding to cover 60% of the hardware and network connection costs of the stations, and grant recipients must conform to the Open Charge Point Protocol (see below). The scale of this project indicates a substantial commitment to electromobility in Germany, and its results may hold lessons for other governments attempting to support charging infrastructure.

The Netherlands. As a global leader in electromobility, the Netherlands has been on the forefront of charging infrastructure for several years, and many of its cities already have a dense network of charging stations in place. The Netherlands has ambitions to have electric vehicles reach 10% of new vehicles by 2020 and 50% by 2025, and to deploy a nationwide network of charging points to ensure they remain a frontrunner in electric mobility. Much of the early construction of charging infrastructure was initiated by ElaadNL, a foundation created by six power network operators in the country; this group continues to maintain and upgrade about 3,000 stations around the country (ElaadNL, 2016). The federal government also provided €16 million in incentives for charging infrastructure through their 2011 "Electric Mobility Gets Up to Speed" program (Netherlands Enterprise Agency, 2011). More recently, the federal government consolidated various programs and began to promote charging stations through its "Green Deal," including forming partnerships with businesses (Green Deal, 2016).

Regional and local governments in the Netherlands have shown similar ambition in promoting electric vehicle charging infrastructure. The province of Noord-Brabant began a smart charging trial project in 2014 with the installation of public smart charging stations in major cities, and has announced tenders for the installation of 2,000 new smart charging stations beginning in 2017 (Nederland Elektrisch, 2016). The city-operated Amsterdam Elektrisch program, in partnership with utility Nuon, will install curbside chargers on demand, ensuring that all residents have a place to charge an electric vehicle. A similar model has also been adopted by other cities such as Utrecht and The Hague (Gemeente Amsterdam, 2017). Several other provinces and municipalities offer incentives or trial programs for electric vehicle charging infrastructure, leading to the high number of charge points in the Netherlands today. Moreover, the Netherlands has become a leader in charging standardization and interoperability, as discussed below.

Norway. Norway is the global leader in national electric vehicle sales share, with approximately 30% in 2016, and it seeks to shift to 100% electric vehicle sales by 2025. The country has a number of unique challenges relating to charging infrastructure, related to both its high density of electric vehicles and its cold climate. The government has been a key driver of charging infrastructure through the early stages of the electric vehicle market and will continue to invest in this area. The 2016 National Transport Plan states that "Power charging facilities or fuel supply for zero-emission vehicles should be so easily available that long distance driving is possible and unacceptable waiting times are avoided both in the city and for long-haul operations" (Norwegian National Rail Administration et al., 2016).

The key sponsor of Norway's charging infrastructure has been Enova (formerly known as Transnova), an agency funded through petroleum and natural gas sales that promotes greenhouse gas emissions reductions and energy efficiency improvements. Transnova first began construction of charging infrastructure with an investment of €6 million in 2009 and has since steadily continued funding (Nobil, 2012). In 2015 and 2016, the agency issued four calls for proposals, and most recently it has focused on the installation of fast charging stations on remote highways in northern Norway. In addition to this federal investment, many Norwegian cities and towns also have a long record of investing in charging stations; for example, Oslo budgeted €2 million for initial buildout of charging stations through 2011 (Nobil, 2012).

United Kingdom. The government of the United Kingdom, through the Office of Low Emission Vehicles (OLEV), operates a diverse set of programs to encourage the buildout of charging infrastructure in that country. In addition to support for domestic and workplace charge points, OLEV operates the On-street Residential Chargepoint Scheme, which provides funding to local authorities to install public Level 2 charging stations in residential areas for residents without private off-street parking (OLEV, 2016a). This program, designed to cover 75% of hardware costs for these stations, is also notable for its clear guidance for reducing costs and maximizing convenience for installers, drivers, and cities. At the same time, Highways England has plans to install charging infrastructure every 20 miles along the major road network as part of its Road Investment Strategy (Jones, 2015). With EU funding support, the electricity provider Ecotricity has installed at least one rapid charger in each of the United Kingdom's Motorway Service Areas.

Local governments have also been involved in construction of charging infrastructure. Like Germany, specific cities and regions received special funding for trial projects in the Plugged-In Places program through 2014, which included matching funds to businesses that installed charging stations. This has resulted in eight popular regional charging networks with a total of more than 6,400 charge points installed, including Plugged-in Midlands, with almost 1,000 charge points covering East and West Midlands. This was followed by various national schemes that concentrated funding on DC fast charging.

In 2016, the U.K. government announced the Go Ultra Low Cities scheme, which awarded £40 million to a number of cities to roll out pioneering initiatives to assist them in becoming internationally outstanding examples for the promotion of ultralow-emission vehicles. Charging infrastructure is a key part of the initiatives, with funding made available for rapid charging hubs, residential and car club charge points, and trials of various on-street charging initiatives. The program is expected to fund 750 stations in total (Go Ultra Low, 2016). Additionally, under the leadership of Transport for London and various private-sector partners, London has created the Source London network and plans to add 4,500 charge points by 2018 (Source London, 2016). Plans have also been announced to take forward legislative measures to ensure that sufficient charging infrastructure is available at Motorway Service Areas and can be required to be installed at large fuel retailers.

NORTH AMERICA

Canada. Canada's electric vehicle market, driven by early growth in Québec and British Columbia, reached cumulative sales of more than 30,000 electric vehicles in early 2017. The Canadian government is undergoing a broad zero-emission vehicle strategy to set new goals for electrification and its associated policy and charging infrastructure.

Charging infrastructure in Canada has primarily been deployed through a number of provincial and local programs, and the federal government is becoming increasingly involved in the sector. The government is working to write a national zero-emission vehicle strategy and has already committed $182.5 million for electric vehicle charging and hydrogen fueling infrastructure through 2017 (Transport Canada, 2017). Québec, which has about half of the country's electric vehicle stock, has been especially active: The Electric Circuit network, operated by public utility Hydro Québec, includes almost 1,000 stations as of July 2017, and it has expanded into Ontario (Electric Circuit, 2017). Three other charging networks are also active in the province, bringing the number of public charging stations available around 1,600. The province also provides support for charging at private homes, workplaces, and multi-unit dwellings, and is working with neighboring U.S. states to create cross-border fast charging corridors. Ontario and British Columbia have also invested substantially in public charging infrastructure, Ontario through its Ministry of Transport and British Columbia through its utility BC Hydro.

United States. The U.S. electric vehicle market continues to grow, helped by a combination of federal and state consumer incentives and investment, zero-emission vehicle regulatory policy, and a series of state and local city promotion activities (Slowik & Lutsey, 2017). The California zero-emission vehicle policy, adopted by states representing nearly one-third of the U.S. vehicle market, is expected to increase electric vehicles in the market from more than 600,000 in early 2017 to several million by 2025. To serve the early growth, much of the initial investment in charging infrastructure in the United States came from the American Recovery and Reinvestment Act of 2009, which provided federal funding through the EV Project and the U.S. Department of Transportation's Transportation Investment Generating Economic Recovery program, among many infrastructure projects in the United States from 2010 to 2013. By the end of 2014, there were about 18,000 public Level 2 and DC fast electric charge points in the United States (U.S. DOE, 2017a). Since then, charging infrastructure has been deployed with funding and authority from many different federal, state, and local agencies and has increased to more than 27,000 charge points by the end of 2015, and to 36,000 charge points at the end of 2016 (U.S. DOE, 2017a). Almost all of these government-funded stations are operated by private networks.

As of 2016, one of the most promising developments for sustained investment in charging infrastructure consists of electric power utilities providing mutual benefits to all ratepayers through their investments in charging infrastructure. This new movement has been led by major utility actions in California (see CPUC, 2017; Edison International, 2016; SDG&E, 2016). A number of utilities and public utility commissions in other states are following California's lead, while in other states, utility commissions and stakeholder groups are considering the costs and long-term benefits of rate-based utility investment in charging infrastructure and other transportation electrification programs. As input to help guide charging deployment, California developed the EVI-Pro model, a tool that projects the number of home, workplace, and public charge points needed by 2025 in each county to correspond to the expected growth in the electric vehicle fleet (CEC & NREL, 2017).

As part of the settlement of the Volkswagen diesel scandal, VW will invest approximately $2 billion in charging infrastructure and other programs to support clean transportation across the United States for a 10-year period commencing in 2017, 40% of which will be invested in projects in California. The first phase will result in several thousand charge points at more than 900 sites across the country, including local community charging and intercity fast charging corridors, with some stations capable of providing 350 kW DC charging (Electrify America, 2017). The settlement also establishes an Environmental Mitigation Trust that allocates funds to the states and allows them to use up to 15% of their allocation for zero-emission vehicle fueling infrastructure.

SUMMARY AND LESSONS

As the electric vehicle market evolves, governments are increasingly working to promote charging infrastructure. Table 4 summarizes some of the major national-level charging infrastructure programs in leading electric vehicle markets, illustrating that there are multiple ways for governments to promote this part of the market. Additionally, in markets such as the United States and the Netherlands, local governments have played a strong role in building charging infrastructure.

Table 4. Summary of major national-level charging infrastructure programs in selected markets, including budget and form of award.

Country	Program	Budget	Mechanisms of support
China	• State Grid national fast charging corridors • Regional investments by automakers • City government-funded construction in pilot cities		• State-owned utility programs • Public-private partnership • Grants to local governments
France	• Funding given 3,000 cities for 12,000 charge points • EDF power company building nationwide DC fast charging network		• Local governments apply for grants
Germany	• €300 million for 10,000 Level 2 and 5,000 DC fast charging stations	€300 million ($285 million)	• Subsidies for 60% of costs for all eligible businesses
Japan	• Next Generation Vehicle Charging Infrastructure Deployment Promotion Project • Nippon Charge Service government-automaker partnership	Up to ¥100 billion ($1 billion)	• Grants to local governments and highway operators • Public-private partnership
Netherlands	• "Green Deal" (curbside chargers on request)	€33 million ($31 million)	• Contracts tendered to businesses on project-by-project basis
Norway	• Enova grant scheme from 2009 onward		• Quarterly calls for proposals for targeted projects
United Kingdom	• Curbside stations for residential areas • Highways England building DC fast charging stations along major roads in England	£2.5 million ($2 million) £15 million ($12 million)	• Municipalities apply for grants; installers reimbursed • Grants and tenders administered by public body
United States	• Grants for funding public charging stations through American Recovery and Reinvestment Act	$15 million	• Matching grants for local governments

Although there is no conclusively superior design for a charging infrastructure program, several lessons can be gleaned from these government programs. In particular, there is evident value in targeting specific charging needs, making the charging program information clear and easily accessible, and promoting competition. Naturally, all recommendations must be tailored to fit local political, geographic, and demographic contexts for each market.

» It is important to target specific, known charging needs. The problem of charging infrastructure availability is complex and large, and constructing a comprehensive charging network would be prohibitively expensive. Furthermore, because the industry is evolving quickly, current assumptions about technology and driver preferences may not hold in the future. Therefore, it is usually preferable for a government program to focus on one form of charging infrastructure where there is a clear need (e.g., intercity DC fast charging or curbside residential charging). This can also help to encourage broader geographic coverage and will lead to a more accurate assessment of the costs of a given program.

» Clear, accessible information on charging programs helps all stakeholders. For programs offering subsidies or accepting applications, it is important to make information and guidance about the program easily accessible and simple to understand. This includes posting basic information online, requiring only one or two clicks from the primary electric vehicle informational website. Ideally, the most important provisions of the rule for different actors (such as drivers, local governments, and businesses) would be identified. If a government offers multiple programs, these would ideally be displayed together, along with links to other similar programs at a local level (or at a national level for local governments). A strong example of this is OLEV's programs in the United Kingdom: Three schemes are laid out on one webpage with clear guidance for all parties, accessible in only one click from the main OLEV page.

» Competition among charging providers will facilitate growth of the early infrastructure and will also help to identify the leading business models over time. It is generally accepted that the charging infrastructure industry will eventually shift to the private sector as electric vehicle sales increase the demand for charge points and the profitability of their operation. In the near term, although incentives are needed, regulators can set the stage for robust private-sector leadership by promoting competition and innovation through government programs. This could include holding frequent bids for projects (as in the Netherlands), adding bonuses to subsidies for specific advanced features, or capping the reimbursable price of stations while mandating a particular functionality.

IV. ANALYSIS OF PUBLIC CHARGING INFRASTRUCTURE

Governments and private companies have been constructing public charging infrastructure for several years, resulting in more than 200,000 stations of various types around the world. The status of charging infrastructure varies greatly from country to country as well as from city to city, and comparison of these local markets can help to elucidate broader trends within the electric vehicle market. This section presents and analyzes data on charging infrastructure in major electric vehicle markets. For each market, we use the most complete publicly available data on charge point counts for the end of 2016, unless otherwise noted. We include both BEVs and PHEVs in our counts of electric vehicles, and we define a charge point as a single outlet or plug; a charging station may have one or more charge points. We also break down the public charging data into Level 2 or DC fast charging to identify differences across the major electric vehicle markets. Further information on data sources is given in the Annex.

To help inform topical questions around the world about public electric vehicle charging, we present data according to several different metrics that are each relevant in different contexts. We present charging infrastructure data in terms of charge points per 1 million residents in each area, which allows comparison of the extent of charging with an adjustment for different jurisdiction sizes. This metric is key in comparing markets of different sizes, and also provides a measure that is independent of the number of electric vehicles. Having a metric that is separate from the size of the city and the electric vehicle population is necessary to analyze the statistical link between electric vehicle uptake and charging deployment. We also assess and compare charging infrastructure on a per–electric vehicle basis. Such a charger/vehicle ratio (or the inverse) offers additional input to help approximate the number of charging stations for a given electric vehicle market. Some jurisdictions find such ratios more useful in projecting the necessary charging infrastructure to match electric vehicle growth. Both of these metrics can clarify differences across global electric vehicle markets, as illustrated below.

At a national level, the availability of charging infrastructure varies widely, as shown in Figure 1. The global leaders in electric vehicle uptake, Norway and the Netherlands, are also leaders in charge point availability, with far more total charge points per million residents than other countries. While the Netherlands has the most Level 2 charge points per population, Norway has the highest concentration of DC fast charge points per capita. Before adjusting for population, China is the clear leader by charge point volume, with more than 100,000 Level 2 charge points and 38,000 DC fast charge points, followed by the United States (36,000 total charge points), the Netherlands (27,000), Japan (18,000), Germany (12,000), and the United Kingdom (11,000). As shown, there are major differences across the markets in terms of the percentage of charging that is DC fast. In Belgium, the Netherlands, and Germany, DC fast chargers constitute less than 10% of the charging points. In most countries, DC fast chargers represent 10% to 20% of charger deployment. China, Japan, and Finland have the highest share of rapid charge points, 25% to 45%.

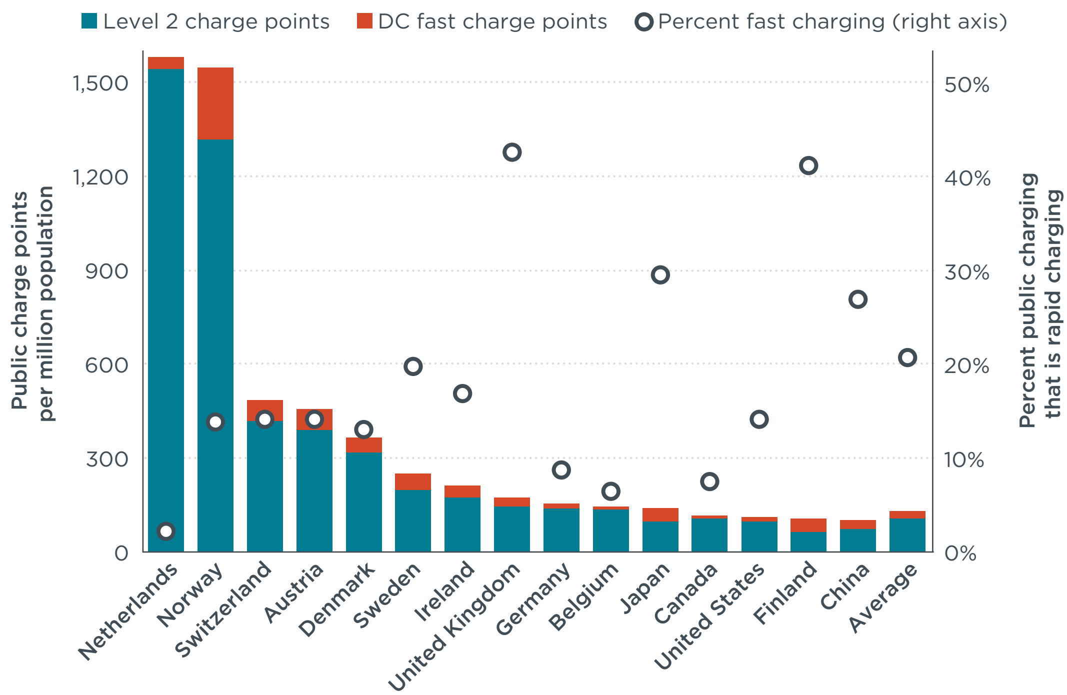

Figure 1. Comparison of electric vehicle charging infrastructure per million population in selected national markets around the world.

PUBLIC CHARGING INFRASTRUCTURE BY METROPOLITAN AREA

A national-level outlook is useful for considering broad electric vehicle readiness and the impact of national charging infrastructure programs, but it does little to clarify the relationship between charging infrastructure and electric vehicle uptake. Within countries (especially large markets such as China and the United States), there is significant variability among cities with regard to electric vehicle uptake and charging infrastructure density. Furthermore, charging infrastructure is part of a regional ecosystem, where drivers can make use of charging stations in a wide area as they commute and take additional local trips. For these reasons, our primary analysis is focused at a metropolitan-area level (see Table A-2 for definitions).

For the following analysis, we include metropolitan area–level data from 14 countries: Austria, Belgium, Canada, China, Denmark, Finland, Germany, Japan, the Netherlands, Norway, Sweden, Switzerland, the United States, and the United Kingdom. These markets were targeted primarily because they have the highest electric vehicle uptake, and also because data in these markets were available for both local-level electric vehicle uptake and public charging infrastructure. We estimate that these national markets effectively include about 90% of global electric vehicle sales. The only substantial national market for which we could not find comparable electric vehicle and charging data is France, which is therefore excluded. We note that in the relationships depicted in Figure 2, Figure 3, and the statistical data, we include only metropolitan areas with resident populations of at least 200,000. This excludes many smaller markets with few electric vehicle sales that could have otherwise skewed the results. The data are for 2016, with the exception of China markets, where some of the most recent available local-level data are for 2015.

Figure 2 illustrates charging infrastructure deployment and electric vehicle uptake in major metropolitan areas around the world. Cumulative electric vehicle sales (including both BEVs and PHEVs) per million population are plotted on the vertical axis; public charge points (both Level 2 and DC fast) per million population are plotted on the horizontal axis. The bubble size indicates the number of electric vehicles sold in 2016 in a given market. Data points are colored according to country; selected markets with high electric vehicle uptake are labeled.

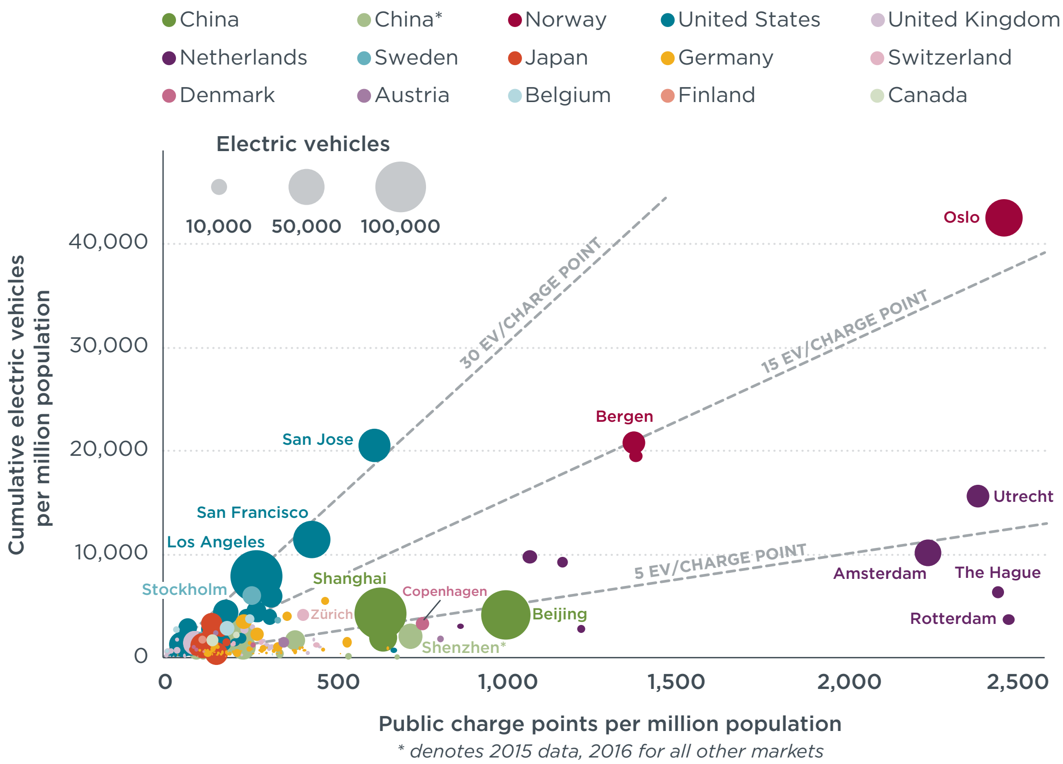

Figure 2. Public charging infrastructure and electric vehicle registrations per million population by metropolitan area, with size of circles indicating total electric vehicles.

Several conclusions can be drawn from Figure 2. As with the national-level data in Figure 1, the data demonstrate that there are some rough apparent patterns between electric vehicle uptake and charging infrastructure availability. There is also substantial variability across the markets. If the electric vehicle–public charger relationship were a clear universal one, the data would line up more diagonally. We overlay three diagonal trend lines within the figure, indicating ratios of 30, 15, and 5 electric vehicles per charge point, to highlight how the cities compare. The cluster of data points at the lower left is a clear testament to the early state of electric vehicle market development at present. In most of the markets below 5,000 electric vehicles per million population and fewer than 400 charge points per million electric vehicles, fewer than 1% of new vehicle sales are plug-in electric.

Electric vehicle charging and uptake data from the various metropolitan areas within each country show approximate patterns. Oslo and Bergen, the two major metropolitan areas in Norway, are labeled. These two, with about one-third of all new vehicle sales being plug-in electric vehicles, have the highest uptake, and they each show a relationship of about 14 to 17 electric vehicles per public charger. The markets in the Netherlands tend to have a lower ratio of electric vehicles per charge point, at 3 to 6 electric vehicles per charger for the three largest electric vehicle markets, Amsterdam, Utrecht, and The Hague. This could be due to the relatively low rate of private garage ownership in these markets (see below). In contrast, the large California markets tend to lie above the other cities with a higher vehicle/charge point ratio, approximately 25 to 30 electric vehicles per charge point. This could be due to greater access to private home charging, as well as workplace charging in northern California. The major China markets had a range of 3 to 11 electric vehicles per charge point.

Over all markets considered in this study, we find an average of approximately 7 electric cars per public charge point. Given the wide variation observed across the markets, including the successful high-uptake markets, it seems clear that this average ratio does not represent a consistent or universal metric for assessing the maturity of local electric vehicle markets. We further examine this ratio of electric vehicles per charge point, along with factors such as city housing type and population density, below.

RAPID VERSUS NORMAL PUBLIC CHARGING INFRASTRUCTURE

As charging infrastructure continues to expand, a key issue is in establishing the correct balance between convenient-yet-expensive DC fast charging and inexpensive-but-slower Level 2 charging. Along with the variation in overall amount of charging infrastructure shown above, the various electric vehicle markets also vary greatly by their different numbers of Level 2 (normal) and DC fast (rapid) charging infrastructure. Figure 3 illustrates these differences, plotting Level 2 charge points (horizontal axis) and DC fast charge points (vertical axis) per million population for the major metropolitan areas with substantial electric vehicle uptake. Data points to the lower right have less, and points to the upper left have more, DC fast charging. Again, we note that some of the regional data for China are through 2015 rather than 2016. Selected major markets are labeled. We also overlay three diagonal trend lines to illustrate how the cities compare with respect to 40%, 15%, and 5% of their public charging infrastructure being rapid charging.

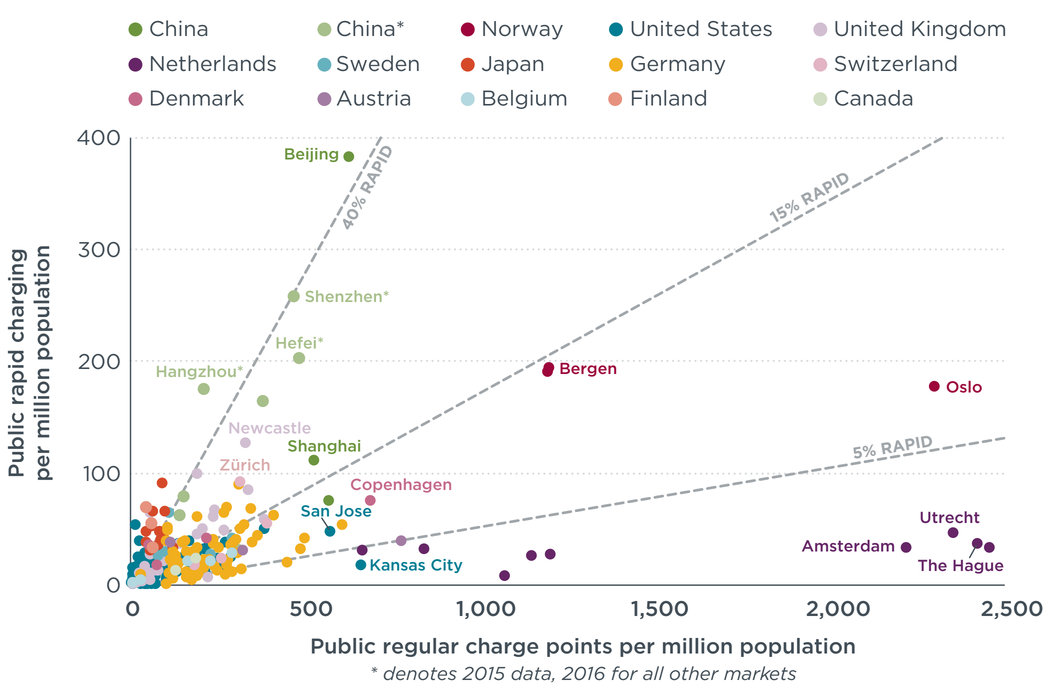

Figure 3. Relative numbers of public regular Level 2 and DC fast charge points per million population in selected major metropolitan areas.

A consistent ratio of Level 2 charge points to DC fast charge points would show more of a clear diagonal line; however, there is no such universal trend in these data. Some approximate patterns do emerge, revealing that local conditions diverge greatly from the global average of about 20% fast charging. The cities in China, to the upper left, tend to have the highest proportion of fast charge points—about 30 to 40% of all public charging facilities—at least in part because of installations by their major utilities. Cities in the Netherlands generally have the most charging overall but the lowest percentage of rapid charge points, about 1.5 to 2%. The low percentage of fast charge points may reflect the large numbers of curbside charging stations intended for overnight use and the large numbers of PHEVs lacking fast-charging capability. The highest electric vehicle uptake markets in Norway had high amounts of both regular Level 2 and DC fast charging, and had 6% (Oslo) and 13% (Bergen) of the charging as DC fast charging. The three largest U.S. markets, Los Angeles, San Francisco, and San Jose, had 7 to 11% of their charging as DC fast charging. However, there can also be substantial variation within each country. For example, although the Kansas City area leads the United States with 664 charge points per million population, it has less than half as many fast charging points, adjusted for population, relative to the San Francisco or San Jose areas.

STATISTICAL LINK BETWEEN PUBLIC CHARGE POINTS AND ELECTRIC VEHICLE UPTAKE

As previously noted, public charging infrastructure has often been found to be linked with greater electric vehicle uptake. With the detailed local-level data from most major global electric vehicle markets, we sought to test this relationship with a stepwise multiple linear regression to find the best fit among the factors analyzed. In addition to analyzing the link between charging availability and electric vehicle uptake, we sought other data that also might help to partially explain the variation in Figures 2 and 3 above.

On the basis of the research literature, we sought to include housing and demographic data to help control for known major differences across global cities. We were able to collect data on the percent of households that are multi-unit dwellings, which could serve as a rough proxy for the number of households that are less likely to have their own private parking or garage. In addition, we included a population density (number of residents per land area within the metropolitan area) in the analysis to account for significant land use and travel pattern differences across the areas. In addition, we included consumer financial incentives in the analysis, applying the methodology from Yang et al. (2016). We felt it necessary to include the major differences in available consumer incentives among the electric vehicle markets, considering the strength of the relationship with uptake in previous analyses (as mentioned above).

The results of this regression are summarized in Table 5. The statistical test is for the dependent variable of electric vehicle share of new 2016 vehicle sales, with several different charging, incentive, housing, and land use variables as independent variables in different combinations. For the analysis below, we conducted a multivariate linear regression using StatPlus software (AnalystSoft, 2017a, 2017b). As above, we included only metropolitan areas with populations of at least 200,000. For this statistical analysis, we included only a smaller subset of cities for data availability and data quality considerations: metropolitan areas from the United States, Norway, the United Kingdom, the Netherlands, Germany, Denmark, Austria, Finland, Belgium, and Japan. The remaining four countries were excluded because we could not find comparable data on housing attributes or electric vehicle incentive policies. The resulting regressions are based on 350 metropolitan areas with populations more than 200,000.

We used separate variables for regular Level 2 charging and DC fast charging to discern whether they were both significant. For the consumer incentives, we included electric vehicle purchase incentives (tax credits, rebates) as well as tax incentives (e.g., exemptions from vehicle taxation). As shown in Table 5, we conducted separate electric vehicle regressions for BEVs and PHEVs based on separate data for each type's incentives and uptake.

In Table 5, the variables marked X had the strongest statistical fit (*P* values less than 0.05) and were part of the statistical regression for electric vehicle uptake. For the consumer incentives, we included a weighted incentive between BEVs and PHEVs for the general electric vehicle regression. As summarized in Table 5, we found a significant statistical link between electric vehicle uptake and charging infrastructure, incentives, housing characteristics, and population density (R^2 = 0.78). Table A-3 shows the statistical regression outputs related to Table 5.

Table 5. Summary of statistical regression for electric vehicle uptake with charging infrastructure, incentives, population density, and housing type.

	Electric vehicle share	BEV share	PHEV share
Level 2 charge points per million population	X	X	X
DC fast charge points per million population	X	X	X
Consumer electric vehicle incentive (weighted BEV/PHEV) value	X		
Consumer BEV incentive		X	
Consumer PHEV incentive			X
Percent of households that are in multi-unit dwellings	X	X	
Population density	X		X
Adjusted R^2 value	0.78	0.65	0.78

Variables with X are statistically significant ($P < 0.05$)
BEV = battery electric vehicle; PHEV = plug-in hybrid electric vehicle

When isolating BEVs and PHEVs, the statistical fits were similar, with charging and incentives still significant in each case, but for BEVs the population density was not significant, and for PHEVs population density was significant. In each of these regressions, both Level 2 and DC fast charging are shown to be statistically significant, which suggests that they both play a role for electric vehicle drivers. Although fast charging is predominantly used for BEVs, we note that PHEV models such as the Mitsubishi Outlander and BMW i3 Rex version include fast charging capability. The R^2 values of 0.65 to 0.78 indicate that unexplained variation remains in the relationships. This could include the many different national, state, and local policies that affect electric vehicles; model availability; automaker marketing and dealer activities (e.g., see Slowik & Lutsey, 2017); and other factors that are not analyzed here.

Although it is widely recognized that charging infrastructure will be required to expand the electric vehicle market, there is considerable uncertainty about the precise amount of public charging infrastructure needed to reach a given market size. As suggested by the successful early electric markets described above, there is no single global answer to this question. It is unlikely that any market has achieved the perfect balance of electric vehicles and charge points, and it would be difficult to know when this is the case. The electric vehicle market and the associated charging infrastructure will grow and coevolve. The rapid development of the technology means that the situation may be quite different in a few years. Furthermore, local conditions, the availability of private and workplace charging, and the mix of electric vehicle types could also strongly influence the appropriate level of public charging infrastructure deployment in various markets.

RATIO BETWEEN ELECTRIC VEHICLES AND PUBLIC CHARGE POINTS

The idea of a ratio between electric vehicles and public charge points is attractive to policymakers, as this ratio could inform targets for infrastructure buildout to support an electric vehicle market of a given size. Although our analysis shows the difficulties in developing international benchmarks or quantitative guidelines for charging infrastructure, several organizations have sought to do so, as shown in Table 6. These ratios help to reveal broad international trends, but it is not yet clear whether these ratios represent the correct benchmarks for future market development or how useful they might be for national or local decision-makers planning their charging infrastructure to match electric vehicle deployment. The estimates from the Electric Power Research Institute (EPRI) and the National Renewable Energy Laboratory (NREL) are based on detailed models of the evolution of the U.S. electric vehicle market. The International Energy Agency (IEA) Electric Vehicle Initiative's ratios are based on global averages in 2015 and 2016. The numbers from the California Energy Commission (CEC) and NREL are the California average values for a more detailed tool that estimates the future public charging on the basis of projected future electric vehicle deployment and several local factors.

Table 6. Indicated average electric vehicle/public charge point ratios.

Organization	Region	Electric vehicle/public charge point ratio	Source
European Council	European Union	10	European Parliament (2014)
NDRC	China	8 (pilot cities), 15 (other cities)	NDRC (2015)
IEA Electric Vehicle Initiative	Worldwide	8 (2015), 15 (2016)	EVI (2016, 2017)
EPRI	United States	7-14	Cooper & Schefter (2017); EPRI, 2014
NREL	United States	24	Wood et al. (2017)
CEC/NREL	California	27	CEC & NREL (2017)

On the basis of the data presented above, we provide an additional summary chart to explore what the local-level data reveal for public charging deployment trends. Figure 4 shows the distribution of electric vehicle sales among major metropolitan areas within the countries analyzed here (again, only for areas with at least 200,000 residents) according to their electric vehicle/charge point ratio. This distribution shows that within each country, there tend to be some groupings related to the relationship between electric vehicle sales and number of charge points. For example, the ratio in the Netherlands and China ranges from 0 to 10, whereas in the United Kingdom it generally ranges from 15 to 25. As shown above, this ratio can vary by a factor of 20—for example, from 1.5 (Rotterdam, Netherlands) to 33 (San Jose, United States). We also examined how this ratio has changed from 2014 to 2016 in select markets in the United States, Norway, Sweden, and Germany; in general, the same national relationships shown in Figure 2 and Figure 4 were consistent over this period. With the limited sample of multi-year data, we find no clear trend that would indicate that electric vehicle stock or public charging infrastructure tends to grow at a faster rate or that the ratios are shifting in any clear way.

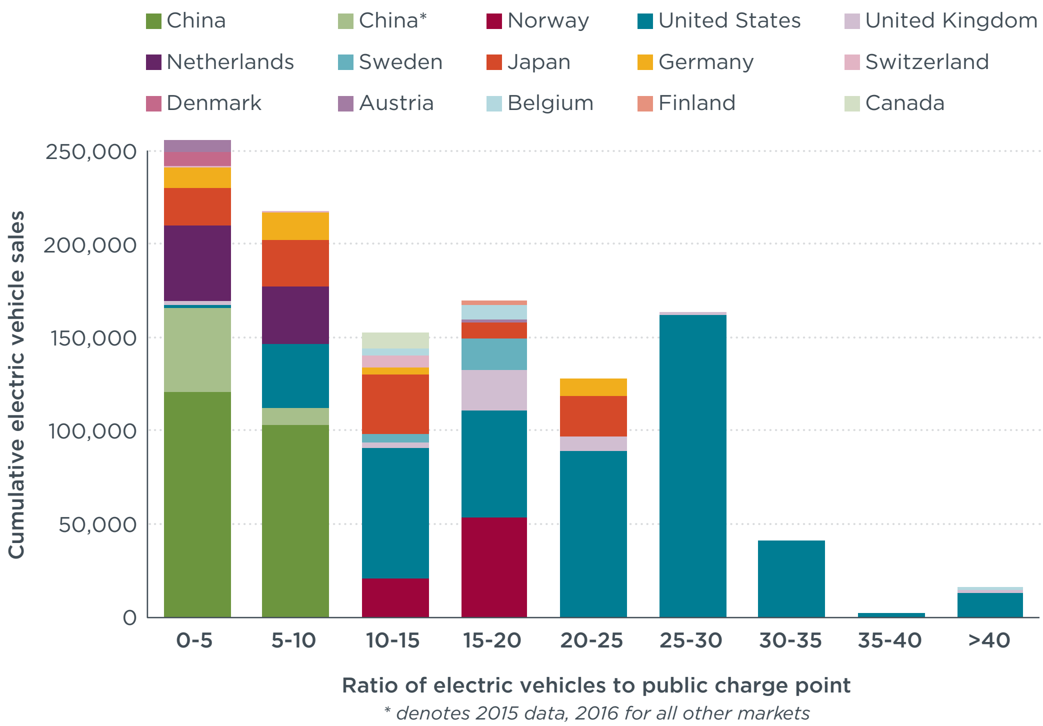

Figure 4. Distribution of cities by electric vehicle/public charge point ratio.

We note that this global comparison and the above statistical analysis of public charging infrastructure availability at the local level constitute a novel contribution to the research literature, and that there are a number of additions that could strengthen this type of research. First, our study only covers select countries with high electric vehicle uptake. Second, some of the data may be incomplete for particular local markets. Integration of privately held charging point data with the data compiled here might result in more accurate estimates and relationships. Third, we do not include workplace charging in this analysis, which may play a similar role in some circumstances. In most markets, there are very few data revealing the share of workplace charging. Finally, many additional factors influence electric vehicle uptake, such as model availability, income, fuel and electricity costs, and residential and workplace charging availability. Accounting for these variables in a statistical regression may lead to a more accurate estimate of the relationship between charge points and uptake. Certainly, this is a rich area for further research as the market evolves and more data become available.

V. ADDITIONAL TOPICS IN PUBLIC INFRASTRUCTURE PLANNING

STANDARDIZATION AND INTEROPERABILITY

Much of the early electric vehicle charging infrastructure was not systematically planned or optimally placed. Rather, in many cases it was developed in a relatively fragmented way, with different government and private-sector players deploying numerous types of infrastructure without necessarily holding a shared vision. Although standards for the physical plugs have been generally accepted (as described above), the back-end communications, payment, and power supply standards are less developed. In many markets, this means that an electric vehicle driver needs a variety of memberships, accounts, and cards to access all of the nominally publicly available infrastructure. This was not a problem for most early adopters of this technology, when almost all charging was done at home and many charging stations were free; however, it is likely to become an increasingly difficult issue as the market grows.

There have been several major efforts toward improving the user experience of charging infrastructure by promoting interoperability, both for drivers and for charging network operators. For electric vehicle drivers, interoperability, or “e-roaming,” means that drivers can charge at any station with a single identification or payment method, and that all charging stations can communicate equally with vehicles. For this to work seamlessly, common standards for charging network operators must also be established so that usage data and payment information can be consolidated and directed to the correct accounts. Of particular interest is the experience of the Netherlands, a leading electric vehicle market with the highest number of charging stations per capita. Through careful planning and regulation, every public charging station (and many private stations) in the country can now be operated and paid for using a single radio-frequency identification card or key fob. This has made traveling with an electric vehicle in the Netherlands much easier and more affordable while also promoting competition in the electric vehicle charging industry.

Driver roaming is accomplished through the widespread adoption of open standards, including the Open Charge Point Protocol (OCPP) and Open Clearing House Protocol (OCHP), which allow for efficient communication between charging stations, the grid, and back-end offices to ensure interoperability in operation and payment. These protocols are now enforced through all public tenders in the Netherlands. ELaadNL, a consortium of grid operators formerly known as the ELaad Foundation, was largely responsible for the early development of these standards; the organization is also currently working on the Open Smart Charging Protocol (OSCP), which would allow coordinated smart charging across many stations.

While the Netherlands has led in this area, numerous projects in other countries are also trying to promote interoperability. Ladenetz, a government-sponsored collaboration among municipal utilities, universities, and private electric vehicle service equipment (EVSE) operators in Germany and the Netherlands, seeks to create a Europe-wide network of interoperable and user-friendly charging stations. Hubject, a company founded by BMW, Bosch, Siemens, and EnBW, has launched a service known as “intercharge” that incorporates e-roaming into more than 40,000 stations.

In the United States—where interoperability in the charging infrastructure sector is perhaps least developed—BMW, Nissan, ChargePoint, and EVgo founded the ROEV (Roaming for EV Charging) project to advance interoperability. California is currently working on implementing the Electric Vehicle Charging Open Access Act, which focuses on customer interaction with the EVSE. This act requires (1) publication of all station locations on the Alternative Fuels Data Center (AFDC) website; (2) disclosure of all fees before a charging event begins, including plug-in fees if not a member of the network; and (3) charge point accessibility to nonmembers of the network, including the ability to accept multiple forms of payment. Implementing these key features will enable broader access for consumers. Other states such as Washington and Massachusetts are also pursuing interoperability initiatives. These projects, as well as government support for interoperability and the use of open standards, could be important in the long-term growth of electric vehicle charging networks.

POWER SUPPLY AND GRID EFFECTS

Electric vehicle charging has the potential to use vast amounts of power, and although it currently does not pose any substantial risk to the grid, this is an issue that should be considered by authorities as the market grows. A frequently cited concern is the exacerbation of evening peak power demand, both on a local and regional level, due to many drivers plugging in after arriving home from work (Brandmayr et al., 2017; National Academy of Sciences, 2015). This could be compounded by increasing use of solar power, which may decline in output at the same time of day that charging demand spikes. Utilities could see some increased costs from this phenomenon. The Sacramento Municipal Utility District in California calculated costs of about $150 per vehicle at 5% fleet penetration using uncontrolled charging patterns. However, these issues may also be increasingly easy to work around as smart charging technology develops (Berkheimer et al., 2014). Many governments are engaged with working group activities, pilot projects, and policy processes to incorporate greater use of smart charging practices, including controlled charging and demand response (see, e.g., Hall & Lutsey, 2017). Even simpler solutions, such as using in-vehicle timers to take advantage of time-of-use rates, could help minimize stress on the electrical grid while also saving money for consumers.

Another area of concern in some areas is the effect of DC fast charging on local distribution infrastructure. These fast charging stations use very high amounts of power for short periods of time, meaning that more expensive upgrades will be needed with a relatively low use rate. This problem could intensify as technology improves: Four European automakers have announced plans to build a network of 400 charging stations capable of charging at 350 kW, more than three times the current industry standard (Herdlitschka & Sedlmayr, 2016). Electrify America will also build charging stations capable of 350 kW charging in the United States (Electrify America, 2017).

These usage patterns and the potential for infrastructure upgrades often cause charging sites to incur high demand charges, a component of electricity rates based on the highest capacity used. For fast charging stations, which use a lot of power but may be less frequently needed by drivers, demand charges can account for 90% of operating costs, which leads to higher rates for drivers (Fitzgerald & Nelder, 2017). Utilities, regulators, and research groups are developing alternative rate structures for workplace and public charging infrastructure, an important step in improving the commercial case for electric vehicle charging (see Fitzgerald & Nelder, 2017; O'Conner & Jacobs, 2017).

Because drivers expect fast charging to be available on demand, smart charging strategies are less practical than for Level 2 charging. However, there are a number of innovative solutions to minimize the grid effects of fast charging. For example, projects in the United Kingdom, Germany, British Columbia, Hawaii, and elsewhere have paired fast charging stations with stationary battery storage (sometimes second-life electric vehicle batteries) in order to mitigate grid impacts and coordinate with renewable energy output (Hall & Lutsey, 2017). Perhaps the most important practice for preventing negative effects for the grid, especially as the fast charging market continues to grow, is to coordinate closely with the utility to site fast chargers near adequate high-capacity electrical infrastructure. The California utility Pacific Gas & Electric has created a comprehensive guide and map tool enabling charging providers to identify which sites have sufficient grid capacity and driver demand (PG&E, 2017). Such coordination will be important for the growth of the electric vehicle charging infrastructure industry.

CHARGING INFRASTRUCTURE PLACEMENT

Ensuring that the electric vehicle charging network operates efficiently and meets driver expectations can be crucial in maintaining future investment and support. One critical step toward maximizing the return on investment is to place charging stations in optimal locations at a local level in order to maximize usage, avoid traffic and parking issues, and minimize stress on the power grid.

A number of studies and models have addressed this issue in depth, both in urban and regional contexts. Table 7 summarizes some of these studies, including their geographic focus, the type of data they include, and the considerations used in choosing locations. These methods, adapted for local context, enable governments and private-sector partners to create guidelines that will maximize the usefulness of infrastructure. Although these studies vary in their approach and the factors they consider, there are commonalities in their use of data from many partners, including municipal governments and utilities. This further emphasizes the need to coordinate efforts between multiple stakeholders when funding and deploying electric vehicle charging infrastructure.

Within a specific location, such as a parking lot, there are additional factors to consider in determining the final placement of charging infrastructure. For instance, it is smart to place the charging posts, where possible, in a position that is accessible to multiple cars at once. This could mean putting it in the middle of a parking lot, where up to six vehicles could use the post, rather than at the edge or a corner, where only two or three vehicles would be able to connect. These stations would ideally be handicapped-accessible, with any tripping hazards covered or removed. Additionally, placing charging stations near the entrance to buildings increases their visibility and their convenience for drivers. However, various additional complicating factors influence these decisions; a number of publications offer more detailed guidelines (see OREF & EVAS, 2016; Webb & Sears, 2017; NYSERDA, 2017).

Table 7. Studies on electric vehicle charging infrastructure placement optimization.

Region	Considerations	Data sources	Citation
Bolzano and South Tyrol, Italy	Parking, transit, power supply	City and provincial GIS data	Harrison & Thiel (2017)
Boston, United States	Parking, driver discomfort, cost	Cell phone location data	Vazifeh et al. (2015)
Beijing, China	Parking, traffic impacts, power supply	Taxi fleet data	Hua et al. (2014)
California, United States	Regional traffic, cost	Travel surveys, past charger utilization	Ji et al. (2014)
Liege, Belgium	Commute patterns, transit, business locations	City and provincial GIS data	Wirges (2016)
Singapore	Traffic impacts, vehicle range	City and national traffic and GIS data	Xiong et al. (2015)
Chicago and South Bend, United States	Energy consumption, cost, parking	Census data, public map data	Yi & Bauer (2016)

COSTS OF ELECTRIC VEHICLE CHARGING INFRASTRUCTURE

Electric vehicle charging infrastructure has seen substantial cost declines over the past several years due to new technological innovation and larger production scale, as with electric vehicle production. For example, since 2009, the city of Amsterdam has seen the costs of their curbside charging stations fall from approximately €12,000 to €2,000 per station. Nonetheless, charging infrastructure also typically requires substantial installation costs and can also incur additional costs for land procurement, administration, and maintenance.

Figure 5 illustrates the approximate per-station costs of a number of major government programs to fund charging infrastructure, including administrative, installation, and siting costs. As seen in the figure, total costs per Level 2 station range from $5,000 to $15,000, whereas each DC fast charging station can cost $40,000 to $100,000. These wide ranges of values depend on the type of charging station (including its networking capabilities), the setting (urban versus rural, mounted on walls or on posts), and the administrative details of the program.

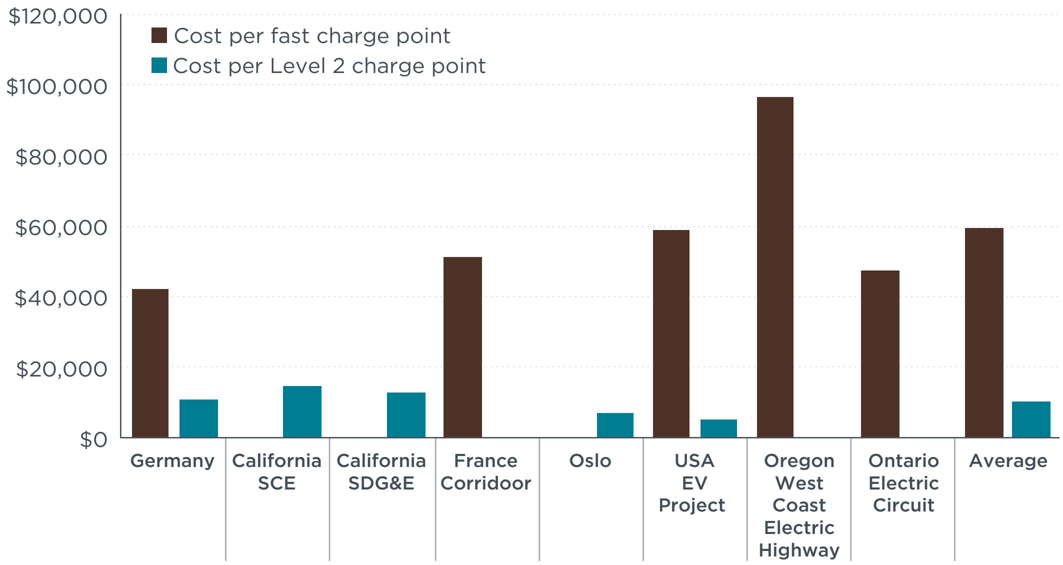

Figure 5. Approximate program-level costs of Level 2 and DC fast charging stations from selected major government charging infrastructure programs.

There are a number of ways to reduce the costs of charging infrastructure construction. Using stations with two connectors rather than one can greatly reduce the cost per outlet. Given sufficient demand, constructing multiple stations in the same area can reduce installation costs and save on the back-end electrical infrastructure. Wall-mounted charging stations typically cost much less than freestanding charging stations. Consulting with utilities beforehand to select sites with sufficient nearby electrical capacity can substantially reduce installation costs, especially for DC fast charging stations or for multi-unit installations. In the future, building codes requiring supporting electrical infrastructure in new buildings will substantially reduce the total costs of installing residential, workplace, and public charging stations.

Governments can also select more basic charging station units to save on costs, but this may increase the risk of stations becoming obsolete or incurring higher costs in the long run. Charging stations with lower power output tend to cost less but are better suited for workplace and residential charging than for situations when drivers are parked for only a few hours. Additionally, although non-networked charging stations (those that cannot communicate with a central server and therefore typically only allow free electricity) are usually cheaper upfront, they do not allow recovery of costs through electricity sales. Furthermore, a greater number of stations may be needed in the long term if drivers gravitate toward free public charging instead of charging at home. Additionally, non-networked chargers will not be able to support variable rates or smart charging programs that could be increasingly useful as the market develops. For these reasons, networked Level 2 stations may have a lower amortized cost than non-networked (free) stations (Webb & Sears, 2017). One compromise is to offer a range of charging power and payment options at areas where many charging stations are needed, from free Level 1 to increasingly expensive Level 2 or even DC fast stations. This allows drivers to select the charging power that best matches their vehicle and travel patterns while paying for the electrical capacity they use, and allowing site hosts to offer more stations and save money.

BUSINESS CASES FOR PUBLIC CHARGING

Governments have largely funded early electric vehicle charging infrastructure in order to advance low-emission transportation, often without an expectation of making back the investment or turning a profit. As the market grows and begins to reach mainstream customers, there is increasing interest in a transition to commercially sustainable charging infrastructure. With this in mind, there are a few promising business models based on electricity sales, increased retail sales, advertising revenue, and automaker-funded stations. Some options are briefly described here, although we emphasize that they are not mutually exclusive.

Perhaps the simplest business model for public charging infrastructure is to sell electricity with a sufficient markup to recover the cost of the charging infrastructure. The limitations of this model are clear: If electricity costs approach the costs of gasoline (on a per-kilometer basis), electric vehicles become less financially attractive and PHEV drivers are more likely to operate on gasoline. Furthermore, even a slight markup in electricity price makes it cheaper for drivers to charge at home if infrastructure is available. The wide-scale viability of an electricity price–based business model depends on the relative cost per mile of driving with electricity versus gasoline. When gasoline costs about $3 per gallon, as is typical in California, electricity cannot cost more than $0.22 per kWh and still be cheaper than driving purely with gasoline in a PHEV. However, when gasoline costs approximately $6 per gallon (€1.414 per liter, comparable to prices in Western Europe), electricity priced at $0.44 per kWh would be cheaper than driving with gasoline in the same vehicle. This basic, illustrative calculation is for the 2016 Chevrolet Volt, achieving 42 miles per gallon (5.6 L/100 km) on gasoline versus 0.32 kWh per mile (0.2 kWh/km) in electricity consumption. This cost-per-mile equivalence implies that this business model is much better suited for European markets and other regions with higher fuel prices than in the United States. Indeed, the curbside charging stations in Amsterdam, where the electricity price is regulated to be cheaper on a per-mile basis than gasoline, are beginning to make a profit through electricity sales alone.

Another option is to base the business case on increased retail sales. Because public electric vehicle charging requires significant time and a new stop on a trip, charging stations may represent a way for retailers to attract new customers and increase sales. This represents an important business model for private-sector charging infrastructure deployment by defraying charging station costs through increased sales at commercial site hosts. There is some early evidence that this approach can be successful. After installing Level 2 charging stations at one of its California locations, a major U.S. retailer found that dwell time for customers using the charging stations was 50 minutes longer than average, a 257% increase (ChargePoint, 2015). This led to an estimated $56,000 in additional sales over 9 months, and the retailer is now installing charging stations at additional locations. Similarly, another study in California found that when electric vehicle drivers stopped to charge at a fast charging station next to a retailer, 50% of drivers shopped during the charging, and among those shopping, the average expenditure was about $18 (Nicholas & Tal, 2017). As the market continues to grow, greater use of this model may benefit drivers and businesses alike.

Advertising revenues are another option on which to base a charging station business model. Gasoline stations already have increasingly integrated advertisements on pumps and signage; electric vehicle charging stations could offer a similar opportunity for advertising, which could generate revenue to offset initial costs. Such an idea is most appropriate for high-traffic, high-visibility locations such as malls, restaurants, and busy highway rest areas. California-based Volta Charging is pursuing this business model, providing free Level 2 charging at high-traffic retail locations in several U.S. cities, paid for by advertising revenue from large video screens attached to each station. In some cases, advertising revenue may not completely offset the initial installation costs but could be integrated with other tactics to form a profitable business case.

Automobile manufacturers could also fund charging stations by integrating their overall electric vehicle deployment and infrastructure into their unique customer proposition. As discussed in the introduction, charging infrastructure is seen as a key driver of electric vehicle uptake. Therefore, to fuel future sales of their electric vehicles, automakers have an interest in creating a robust charging infrastructure network. The most obvious example of this is Tesla's proprietary Supercharger network, consisting of 5,043 charge points at 790 locations, 2,636 of those in North America (as of December 31, 2016) (Golson, 2017). In addition, Tesla communicates to owners via text message when new Supercharger stations come on line. However, many other automakers are helping to fund more open charging networks. BMW, Ford, and Nissan all provide subscriptions to EVgo, a major U.S. fast-charging network, and are helping to fund the expansion of that network. In Europe, BMW, Daimler, Ford, and Volkswagen Group (including Audi and Porsche) have announced a joint venture to construct a network of ultrafast charging stations across Europe, beginning with 400 sites in 2017 (Herdlitschka & Sedlmayr, 2016). This automaker investment signals a commitment to the technology and an understanding of the relationship between charging infrastructure and vehicle sales, and could be an important contribution to the private-sector charging infrastructure industry.

VI. HOME AND WORKPLACE CHARGING INFRASTRUCTURE

Although this report primarily focuses on public charging infrastructure, we recognize that private charging, both at home and at the workplace, represents the majority of electric vehicle charging. This section highlights some emerging best practices by governments to support home and workplace charging infrastructure.

HOME CHARGING INFRASTRUCTURE PROGRAMS

Among early adopters, the vast majority of charging events have been carried out with private home charging infrastructure (see, e.g., Figenbaum & Kolbenstvedt, 2016; Idaho National Laboratory, 2015). In general, private home charging has not been a major barrier, as most vehicles come with Level 1 or Level 2 charging equipment. However, purchasing and installing more advanced Level 2 stations with higher charging power and features such as internet connectivity or timers can add additional costs for electric vehicle drivers. As longer-range BEVs become more available, Level 1 charging could be insufficient for many drivers; therefore, affordable and convenient Level 2 home charging would be increasingly important.

A number of governments operate programs to defray the added costs of charging infrastructure. The United Kingdom's Office for Low Emission Vehicles will pay up to 75% of the hardware and installation costs (up to £500) for a hardwired Level 2 station (OLEV, 2016c). Likewise, Québec offers up to $600 CAD for the cost and installation of a 240 V station (Gouvernement du Québec, 2012). In the United States, a number of states offer similar rebates or incentives, such as Washington, D.C. ($1,000), Oklahoma (75%), Delaware (50%), Maryland (40%), Louisiana (36%), and Oregon (25%) (ChargePoint, 2017a). Utilities in some parts of the United States also offer incentives, up to several hundred dollars, for home charging stations, indicating the growing role of utilities in expanding the electric vehicle market (Salisbury & Toor, 2016). Consistent incentives for higher-capacity home charging stations may help to make electric vehicles more accessible and increase the viability of long-range vehicles in the future.

BUILDING CODE REGULATIONS

Electric vehicle charging infrastructure requires robust electrical wiring and safety equipment beyond what is included in most construction. Retrofitting existing wiring to accommodate the high power consumption of electric vehicle charging equipment can greatly increase the cost of installation; conversely, pre-installing the necessary electrical infrastructure for charging equipment is relatively inexpensive. A number of governments at various levels have crafted regulations to promote charging infrastructure, especially through mandating "make-ready" infrastructure in buildings.

One pioneering use of building requirements to promote electric vehicles was California's Green Building Standards Code, which required in 2015 that 3% of all parking spaces in commercial buildings include make-ready infrastructure for charging stations (including dedicated panel and circuit capacity) (CARB, 2015). This regulation has since been expanded to include more parking spaces and higher-powered charging infrastructure. In some cities, standards are more progressive. In Los Angeles, for example, all single-family homes require a dedicated 240 V outlet and circuit capacity for a Level 2 charger, and there are additional requirements for make-ready infrastructure in multi-unit residential and commercial buildings.

Similar regulations have also been implemented in Europe. A new European Union directive is set to require an electric vehicle charging point in every new or refurbished home beginning in 2019 (Hyundai Motor Europe, 2016). The city of London now requires electric vehicle charge points at 20% of parking spaces in all new developments, as well as make-ready infrastructure for an additional 20% of spaces (Greater London Authority, 2016). The government of Germany is considering new policies mandating charge points or make-ready infrastructure in all new buildings, as well as policies to streamline the construction of charging stations in existing buildings (Harendt & Mayer, 2015). Similar policies may help to boost electric vehicle uptake and driver satisfaction in these quickly growing markets.

MULTI-UNIT DWELLINGS

Early adopters of electric vehicles have tended to be relatively wealthy drivers living in single-family homes with private garages. However, as the market grows and expands to more diverse clientele, charging infrastructure will adapt. One of the most pressing questions is how to address multi-unit dwellings, where residents frequently do not have dedicated parking spots, instead parking in a shared garage or on the street. As such, many residents cannot access a dedicated residential charge point.

A number of cities and countries have created programs specifically targeting drivers in multi-unit dwellings and others without access to off-street parking. One potential solution is to simply build public curbside charging stations in the areas where the potential demand is relatively high, a model followed by Amsterdam and other cities in the Netherlands. The United Kingdom also operates a curbside charging station program. A few cities in North America, including Philadelphia, Los Angeles, Berkeley, and Montreal, operate similar programs, but they are temporary pilots (Berkeley Office of Energy and Sustainable Development, 2017; CBC News, 2015; Glovas, 2015; LADWP, 2017).

Governments can also work with residents and property owners to install charging infrastructure in shared parking facilities and promote consumer awareness in multi-unit dwellings. California has created the emPower the People program, which assists residents in advocating for charging infrastructure in multi-unit dwellings, and also provides materials to property owners to reduce the costs and clarify the benefits of adding charging infrastructure in their buildings (California Plug-In Electric Vehicle Collaborative, 2017). Nonetheless, the costs of installing stations in multi-unit dwellings can be high: A recent study in California estimated average installation costs of $5,400 per Level 2 charge point, more than three times the average cost for installation in a single-family home (Turek et al., 2017).

There is growing recognition of the challenges in this field, and some governments may be interested in making substantial financial investments in this area. The government of France, for example, subsidizes 50% of the costs (up to €1,300) for shared stations in multi-unit residential buildings through the ADVENIR program, with a goal to fund 5,700 charge points (AVERE-France, 2016). Although broader funding programs in other countries (such as OLEV's Homecharge scheme in the United Kingdom) may be used to install charge points in multi-unit dwellings in some cases, dedicated funding such as this may help to increase awareness and create stronger business cases for multi-unit dwellings.

Electric utilities may also be a major actor in this field, especially when they are able to use ratepayer money for infrastructure investments. California's three major utilities have each announced plans to deploy thousands of charging stations in the state; in each case, multi-unit dwellings are a major focus (CPUC, 2017). Regulators in the northeastern United States are currently working with utilities to accelerate charging infrastructure construction in that region, including in multi-unit dwellings. Although much work is required to make electric vehicles advantageous for all electricity sector stakeholders, these electric companies could be crucial to expanding the electric vehicle market for drivers living in multi-unit dwellings.

WORKPLACE CHARGING

In many markets, dedicated workplace charging infrastructure for employees plays a role in the charging ecosystem. Workplace charging can serve as the primary charging opportunity for drivers without a dedicated home charge point, allowing increased flexibility for drivers who commute with their electric vehicle and more all-electric miles for those who drive PHEVs. Several governments have created schemes to support workplace charging infrastructure, as summarized below.

In the United States, the Department of Energy operated the Workplace Charging Challenge from 2013 to 2017 to promote and track workplace charging infrastructure deployment, with the goal of achieving a factor of 10 increase in the number of workplaces offering charging by 2018. As of late 2016, the 757 partner workplaces of the Challenge had installed more than 7,000 Level 2 and Level 1 stations, as well as 136 fast charging stations (U.S. DOE, 2017b). At a regional level, the metropolitan areas of San Jose (with approximately 1,700 charge points), Detroit, San Francisco, and Portland, Oregon, have the most workplace charging infrastructure registered through this program (Heywood & Olexsak, 2017). Only a few cities (including San Jose, Detroit, and Raleigh, North Carolina) have more workplace charging than public charging, although these stations are likely to be highly clustered, and many other workplaces may provide charging points without participating in this program. For example, a major U.S. charging network provider, ChargePoint, estimates that approximately 40% of their charge points are at private workplace locations, totaling almost 14,000 points in their network alone (Alternative Fuels Data Center, 2017; ChargePoint, 2017b).

Noting the caveats above about the limited data on workplace charging, we present data on workplace charging and public charging data in Figure 6 for the 15 major U.S. metropolitan areas with the highest shares of new vehicles that were electric in 2016. The chart includes public charging as above, with workplace charging reported through U.S. DOE's Workplace Charging Challenge; both are reported in terms of charge points per million residents to better compare markets of different sizes. As shown, there is an approximate alignment with the markets with high electric vehicle uptake and relatively high public-plus-workplace charging availability. The three markets with the highest workplace charging per capita—San Jose, Detroit, and San Francisco—are shown.

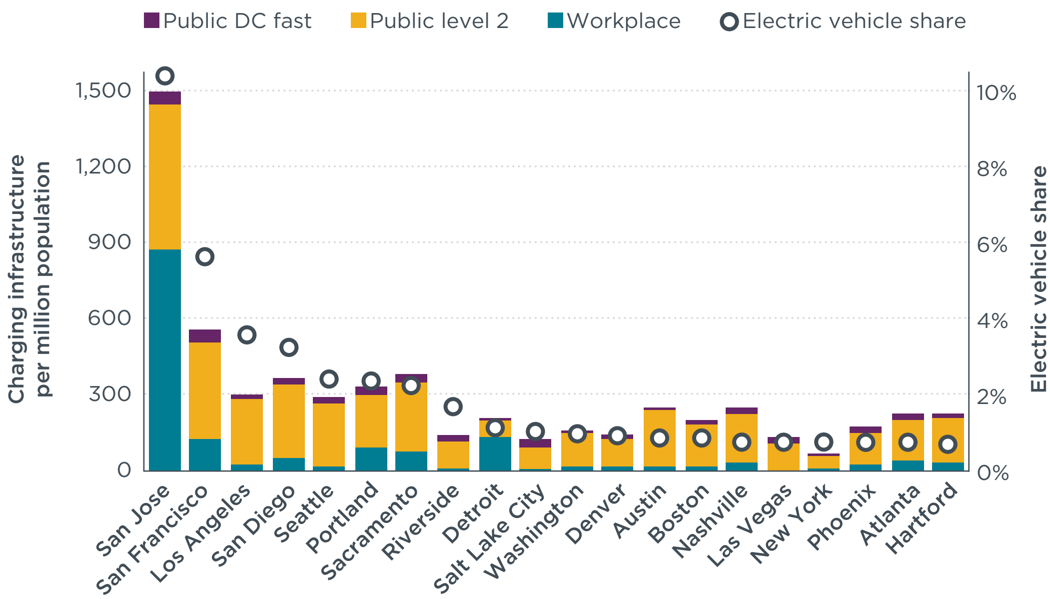

Figure 6. Public and workplace charging per million population and electric vehicle sales share for the 15 major U.S. metropolitan areas with the highest electric vehicle uptake.

A number of other jurisdictions have also created programs to accelerate employer charging installations. The province of Québec's Branché au Travail program funds 50% of the costs, up to $5,000 CAD per station, for businesses and municipalities offering free charging to their employees (Gouvernement du Québec, 2017). The Massachusetts Electric Vehicle Incentive Program offers grants for workplace charging that provide 50% of the funding (up to $25,000) for hardware costs to employers installing Level 1 and Level 2 stations (EEA, 2017). The United Kingdom's OLEV has launched the Workplace Charging Scheme, which provides rebates up to £300 per charge point for up to 20 charge points, to defray initial purchase and installation costs for organizations providing off-street employee or fleet charging (OLEV, 2016b). France's ADVENIR program funds workplace and public charging on company property, with a goal of installing 6,300 such charge points through 2018. The program will cover 40% of the costs per charge point, up to €1,000 for employee and fleet stations and €1,500 for public stations (AVERE-France, 2016). The Norwegian EV Association works with businesses to build charging infrastructure for employees and customers, and has created a comprehensive guide on regulations, costs, pricing, siting, and more. In the past, tenders from Enova have funded workplace charging infrastructure (Norsk Elbilforening, 2017).

As the electric vehicle market continues to grow, workplace charging may further grow in importance. Because cars charging at a workplace tend to be plugged in for many hours during the middle of the day, it is an ideal setting for smart charging programs and could further the integration between electric vehicles and daytime renewable energy (especially solar). Research has shown that people are 20 times as likely to buy an electric vehicle if there is access to charging infrastructure at their workplace (Olexsak, 2014). An electric vehicle owner who lives in an apartment that does not offer overnight charging could consequently be especially interested in workplace charging. However, when creating funding programs or awareness campaigns to promote workplace charging availability, governments may consider data reporting requirements in order to identify further trends and best practices in this important field.

VII. DISCUSSION

As with the electric vehicle industry as a whole, charging infrastructure technology is changing quickly. New developments such as superfast and inductive charging are making their way out of laboratories and could further change the industry. This report provides a snapshot of the state of public charging infrastructure deployment as of late 2016, highlighting prominent actions and progress in the major electric vehicle markets in Asia, Europe, and North America.

FINDINGS

On the basis of our analysis of major electric vehicle markets that make up about 90% of global electric vehicle sales, we find that the availability of public charging is generally linked with electric vehicle uptake. As illustrated in Figure 7, national vehicle markets with higher electric vehicle uptake tend to have more publicly available charging infrastructure. The basic national statistics in the figure indicate the need to build charging stations to help meet charging demand and increase electric vehicle consumer confidence as the market develops. The general market statistics also show that there are underlying differences among countries that are worthy of much deeper investigation.

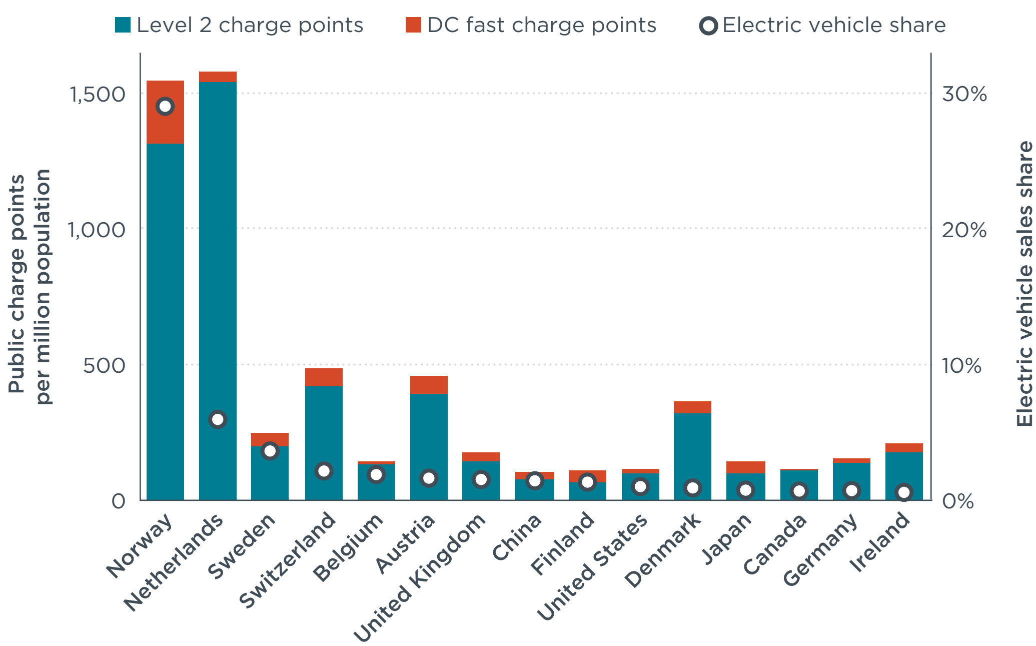

Figure 7. 2016 electric vehicle sales shares and public charge points per million population in major national markets.

The variation across national markets led us to analyze the differing local charging infrastructure characteristics and underlying factors that were emerging through 2016. When analyzing local-level data, we find that different patterns emerge among the top global electric vehicle markets. Figure 8 compiles several of the results from this paper's analysis to depict electric vehicle uptake and the relative availability of public charging infrastructure. The figure shows the major metropolitan areas with the highest electric vehicle shares in Norway, China, the Netherlands, California, and Sweden in 2016. When local-level uptake and charging infrastructure data were unavailable for 2016, China data are from 2015 as marked. These markets represent the highest electric vehicle shares among major metropolitan areas around the world, with electric vehicle shares ranging from 3% in Gothenburg, Sweden, to 36% in Bergen, Norway. To give a sense of the scale of these markets, cumulative electric vehicle sales in Oslo, Shanghai, Beijing, San Francisco, and Los Angeles each number more than 50,000.

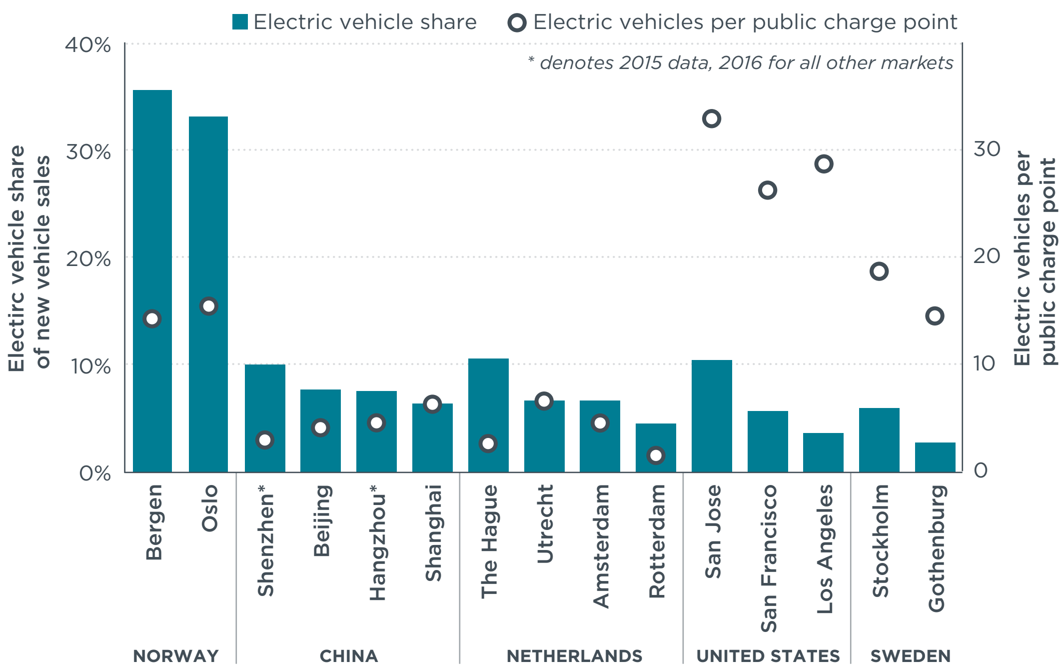

Figure 8. Electric vehicle sales share and public charge points per electric vehicle in selected leading markets.

This local-level analysis reaffirms that the electric vehicle charging ecosystem is evolving differently in the various markets. By selecting major metropolitan areas within the most prominent national electric vehicle markets, we get a glimpse of the emerging patterns of charge points per electric vehicle. In Norway, the electric vehicle share has been highest, and there is one public charge point per 14 to 17 electric vehicles. The major China markets more typically have 3 to 6 electric vehicles per charger, and they also tend to have 30 to 40% of their charging as DC fast charging, whereas most other markets are below 15% DC fast. In the Netherlands, where private parking and charging are less common, 2 to 7 electric vehicles per public charger is more typical. Electric vehicle owners in California more frequently have access to home charging in their private garages or to charging at their workplaces, and there is roughly one public charger per 25 to 30 electric vehicles. In addition, we find that the various electric vehicle markets have greatly differing mixes of public fast charging, workplace charging, and supporting policies to help encourage the charging market.

CONCLUSIONS

These findings do not permit definitive, universal conclusions about such a quickly moving industry with so many differences across the various markets. However, we do offer several high-level conclusions about the status of charging infrastructure and exemplary practices that help point toward the path forward.

Charging infrastructure availability varies dramatically at a local level, and there is no universal benchmark for the amount of charging infrastructure required. Although national-level numbers of charge points allow easy comparisons across markets, these statistics hide the high level of variation among regions and cities within a single country. Moreover, characteristics such as the balance between regular and fast charging can also vary widely within a single country. Certain regions and metropolitan areas typically lead in both electric vehicle uptake and charging infrastructure availability. We identify an average of one charge point for every 7 electric vehicles, with about one in every five charge points a DC fast charger. However, as shown in Figure 8, the electric vehicle/charge point ratio varies by a factor of 10 even among the leading global markets. This variability may stem from the varied roles of public charging in different city contexts. For example, in the Netherlands cases, public charging appears to effectively take a role that is more like that of residential or workplace chargers elsewhere. In other cases, more often in California, public charging supplements home and workplace charging. The clear broader conclusion from all these developments is that as the global electric vehicle market grows—likely by at least an order of magnitude by 2025—so too will the need for much more public charging infrastructure.

Although we find that public charging infrastructure is a key to growing the electric vehicle market, there is no universally accepted benchmark or global threshold for the extent of charging required. This work corroborates other research that indicates the importance of developing charging infrastructure in unison with electric vehicle deployment. In our analysis, both standard and DC fast charging infrastructure are statistically linked to electric vehicle uptake, as are consumer purchase incentives and factors such as population density and the prevalence of multi-unit dwellings. The leading electric vehicle markets of Norway and the Netherlands have more than 10 times as many public charge points per capita as average markets, and leading markets such as California and China had 3 to 5 times the average. However, there is also significant unexplained variability in our statistical analysis that goes beyond charging infrastructure availability. As routinely indicated in other studies, consumer incentives, vehicle policy, and consumer awareness campaigns are also key components of electric vehicle market development. Although there is no single ideal global ratio or benchmark for charging, comparisons of similar markets still offer an instructive way to understand where and how charging is relatively insufficient. Lagging electric markets can strive toward the leading benchmarks of comparable cities, while top markets continue to set new benchmarks as the market and its charging infrastructure coevolve.

Multifaceted and collaborative approaches have been most successful in promoting early charging infrastructure buildout. Governments at the local, regional, and national levels around the world have used varied strategies to promote public and private charging infrastructure. In leading markets, programs have engaged many stakeholders through integration of driver feedback on charger deployment, implementation of smart charging systems, distribution of funding to local governments, creation of public-private partnerships, and consultation with utilities to minimize grid impacts and limit costs. To address changing needs in this growing market, leading governments have created and provided consistent funding for separate programs to target several difficult market segments, such as curbside charging stations, multi-unit dwellings, and intercity fast charging stations. In all cases, it is important to make programs transparent and easily accessible for electric vehicle owners and industry stakeholders.

OPPORTUNITIES AHEAD

Despite this government support and falling costs, there are still a number of challenges to the further development of global electric vehicle charging networks. Charging infrastructure still suffers from fragmentation, inconsistent data availability, and a lack of consistent standards in most markets. Open standards for vehicle–charge point communication and payment may mitigate these issues by enabling interoperability between charging networks, increasing innovation and competition, and reducing costs to drivers. Led by successful efforts in the Netherlands, a number of public and private efforts promote these open standards and a more robust market. Governments may wish to mandate data collection and the use of open standards for publicly funded projects, an approach adopted in several programs. The success of such initiatives will be increasingly important as the market grows and smart charging develops.

This study also raises additional questions for future research. The analysis focuses on public charging, but more research into home, workplace, and fast charging availability is needed to create a fuller understanding of the complex charging ecosystem. Because each charging type lessens the need for the others to an extent, a clearer relationship between electric vehicle stock and charge points may emerge when all types of charging are considered. As the market develops, the need for public and other charging types will shift with vehicle technology (e.g., longer-range electric vehicles) in uncertain ways. As the electricity sector embraces more intermittent renewables, the location and timing of charging could shift from the home overnight charging paradigm to daytime public and workplace charging. Another important area for deeper analysis is how the right amount, types, and locations of charging can encourage PHEV drivers to use electricity for a greater proportion of their driving. Going forward, another key question is how to ensure that the cost of public electric vehicle charging remains competitive with the comparable per-kilometer cost of conventional internal-combustion vehicles.

Electric vehicle charging infrastructure, as indicated above, will need to grow with electric vehicle deployment. Global electric vehicle growth has averaged more than 50% annual growth per year from 2013 to 2016. Taking into account the various technology improvements, battery cost reductions, auto industry announcements, and policy developments that are under way, this growth appears likely to persist for years to come. With regulatory policies that require greater electric vehicles sales nationally, reinforced with preferential access for electric vehicles locally, the annual growth could be even higher. This means that electric vehicles on the world's roads could increase from 2 million in early 2017 to well over 10 times that number by 2025 (see Lutsey, 2015). Our work assesses the level of public charging infrastructure, on a per-capita and per–electric vehicle basis, that has enabled the initial leading markets to emerge. To aid in the transition, lagging markets will have to strive toward today's leading charging infrastructure benchmarks for comparable cities. Top markets will continue to set new benchmarks as the electric vehicle charging infrastructure evolves.

The expansion of charging infrastructure networks will create many opportunities. Governments can catalyze these markets with policy, share in the initial infrastructure investments, and pave the way for business cases to improve and eventually thrive. Electric power utilities in many regions could especially play a key role as they seek mutual benefits for the broader network and the electric vehicle market (see Hall & Lutsey, 2017). As with the broader electric vehicle market, charging infrastructure is changing quickly, causing further challenges beyond responding to the growth in charging. It is important that governments and the private sector coordinate their deployment activities to ensure that convenient, affordable, and reliable public charging infrastructure is available to all electric vehicle drivers. There is still much more work to do, but cities, national governments, public utilities, and the private sector are making great strides toward developing a robust charging infrastructure network, setting the foundation for the transition to electric mobility.

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ANNEX

Table A-1. Sources and local level of charging infrastructure data in selected markets.

Country or region	Lowest level of analysis	Number of metropolitan areas	Sources
Austria	Bezirk	3	E-tankstellen-finder, 2017; LEMnet, 2017
Belgium	Arrondissement	5	Open Charge Map, 2017
China	Prefecture-level city	11	EVCIPA, 2017; ICCT project for EV100, personal communication, April 13, 2017; Yurui, 2017
Denmark	Province	4	LEMnet, 2017; Open Charge Map, 2017
Finland	Region	3	Nobil, 2017; Open Charge Map, 2017
Germany	Kreis	65	LEMnet, 2017; Open Charge Map, 2017; YellowMap AG/ADAC e. V. München, 2017
Japan	Prefecture	13	Nippon Charge Service, 2017
Netherlands	COROP region	9	Netherlands Enterprise Agency, personal communication, February 2, 2017
Norway	County	3	Nobil, 2017
Québec	Region	2	Electric Circuit, 2017; Tesla, 2017
Sweden	County	5	Nobil, 2017
Switzerland	Canton	5	LEMnet, 2017; Open Charge Map, 2017
United Kingdom	District	24	OLEV, 2017; Open Charge Map, 2017
United States	County	277	U.S. DOE, 2017a

Table A-2. List of metropolitan area definitions used in analysis.

Country or region	Definition of metropolitan area	Source
China	City (市)	China Central Government
Europe	Metropolitan region	European Commission
Japan	Major metropolitan area and metropolitan area	Statistics Japan
Québec	Administrative regions (2 selected)	Government of Québec
United States	Census bureau statistical area	U.S. Census Bureau

Table A-3. Summary of three multiple linear regressions for electric vehicle uptake.

	Independent variable	Coefficient	Standard Error	t Stat	*P* value	Beta
Electric vehicle share	Incentive (weighted BEV/PHEV)	0.0000059	0.0000003	18.01	0.00000	0.618
	DC fast charge points per million population	0.0004200	0.0000400	10.87	0.00000	0.319
	Level 2 charge points per million population	0.0000300	0.0000031	9.77	0.00000	0.289
	Percent of households in multi-unit dwellings	0.0297600	0.0057000	5.22	0.00000	0.169
	Population density (residents per km^2)	0.0000073	0.0000015	4.76	0.00000	0.128
Battery electric vehicle share	Incentive (BEV)	0.0000036	0.0000003	13.55	0.00000	0.569
	DC fast charge points per million population	0.0003400	0.0000300	11.71	0.00000	0.428
	Percent of households in multi-unit dwellings	0.0180600	0.0042400	4.26	0.00003	0.174
	Level 2 charge points per million population	0.0000063	0.0000023	2.74	0.00640	0.101
Plug-in electric vehicle share	Level 2 charge points per million population	0.0000300	0.0000014	19.08	0.00000	0.547
	Incentive (PHEV)	0.0000015	0.0000001	15.43	0.00000	0.424
	DC fast charge points per million population	0.0001200	0.0000200	6.81	0.00000	0.194
	Population density (residents per km^2)	0.0000042	0.0000007	5.86	0.00000	0.156

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May 11, 2022

Planning Commission
Attn: Jonas Ionin
49 South Van Ness Avenue, Suite 1400
San Francisco, CA 94103

Dear Commissioners:

On May 3, 2022, Mayor Breed submitted the following substitute legislation:

File No. 220036-2

Ordinance amending the Planning Code to create Electric Vehicle Charging Location and Fleet Charging as Automotive Uses, allow conversion of Automotive Service Stations to Electric Vehicle Charging Locations without Conditional Use authorization and principally permit conversion of other Automotive Uses to Electric Vehicle Charging Locations, revise zoning control tables to reflect these changes, and require annual reporting by the Planning Department regarding Electric Vehicle Charging Location and Fleet Charging project approvals; affirming the Planning Department's determination under the California Environmental Quality Act; and making findings of consistency with the General Plan, and the eight priority policies of Planning Code, Section 101.1, and findings of public necessity, convenience, and welfare under Planning Code, Section 302.

The proposed ordinance is being transmitted for review.

Angela Calvillo, Clerk of the Board

By: Erica Major, Assistant Clerk
Land Use and Transportation Committee

c: Rich Hillis, Director
Tina Tam, Deputy Zoning Administrator
Corey Teague, Zoning Administrator
Lisa Gibson, Environmental Review Officer
Devyani Jain, Deputy Environmental Review Officer
AnMarie Rodgers, Director of Citywide Planning
Dan Sider, Chief of Staff
Aaron Starr, Manager of Legislative Affairs
Joy Navarrete, Environmental Planning

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MEMORANDUM

TO: Deborah Raphael, Director, Department on the Environment
Jeffrey Tumlin, Executive Director, San Francisco Municipal Transportation Agency
Carla Short, Interim Director, Public Works

FROM: Erica Major, Assistant Clerk, Land Use and Transportation Committee

DATE: May 11, 2022

SUBJECT: LEGISLATION INTRODUCED

The Board of Supervisors' Land Use and Transportation Committee has received the following proposed substitute legislation, introduced by Mayor Breed on May 3, 2022:

File No. 220036-2

Ordinance amending the Planning Code to create Electric Vehicle Charging Location and Fleet Charging as Automotive Uses, allow conversion of Automotive Service Stations to Electric Vehicle Charging Locations without Conditional Use authorization and principally permit conversion of other Automotive Uses to Electric Vehicle Charging Locations, revise zoning control tables to reflect these changes, and require annual reporting by the Planning Department regarding Electric Vehicle Charging Location and Fleet Charging project approvals; affirming the Planning Department's determination under the California Environmental Quality Act; and making findings of consistency with the General Plan, and the eight priority policies of Planning Code, Section 101.1, and findings of public necessity, convenience, and welfare under Planning Code, Section 302.

If you have comments or reports to be included with the file, please forward them to me at the Board of Supervisors, City Hall, Room 244, 1 Dr. Carlton B. Goodlett Place, San Francisco, CA 94102 or by email at: erica.major@sfgov.org.

cc: Joseph Sweiss, Department on the Environment
Charles Sheehan, Department on the Environment
Anthony Valdez, Department on the Environment
Kate Breen, San Francisco Municipal Transportation Agency
Janet Martinsen, San Francisco Municipal Transportation Agency
Joel Ramos, San Francisco Municipal Transportation Agency
David Steinberg, Public Works
Bryan Dahl, Public Works
John Thomas, Public Works
Lena Liu, Public Works

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May 11, 2022

File No. 220036-2

Lisa Gibson
Environmental Review Officer
Planning Department
49 South Van Ness Avenue, Suite 1400
San Francisco, CA 94103

Dear Ms. Gibson:

On May 3, 2022, Mayor Breed submitted the following substitute legislation:

File No. 220036-2

Ordinance amending the Planning Code to create Electric Vehicle Charging Location and Fleet Charging as Automotive Uses, allow conversion of Automotive Service Stations to Electric Vehicle Charging Locations without Conditional Use authorization and principally permit conversion of other Automotive Uses to Electric Vehicle Charging Locations, revise zoning control tables to reflect these changes, and require annual reporting by the Planning Department regarding Electric Vehicle Charging Location and Fleet Charging project approvals; affirming the Planning Department's determination under the California Environmental Quality Act; and making findings of consistency with the General Plan, and the eight priority policies of Planning Code, Section 101.1, and findings of public necessity, convenience, and welfare under Planning Code, Section 302.

This legislation is being transmitted to you for environmental review.

Angela Calvillo, Clerk of the Board

By: Erica Major, Assistant Clerk
Land Use and Transportation Committee

Attachment

c: Joy Navarrete, Environmental Planning
Don Lewis, Environmental Planning

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MEMORANDUM

TO: Deborah Raphael, Director, Department on the Environment
Jeffrey Tumlin, Executive Director, San Francisco Municipal Transportation Agency
Carla Short, Interim Director, Public Works

FROM: Erica Major, Assistant Clerk, Land Use and Transportation Committee

DATE: January 18, 2022

SUBJECT: LEGISLATION INTRODUCED

The Board of Supervisors' Land Use and Transportation Committee has received the following proposed legislation, introduced by Mayor Breed on January 11, 2022:

File No. 220036

Ordinance amending the Planning Code to create Electric Vehicle Charging Location and Fleet Charging as Automotive Uses, allow conversion of Automotive Service Stations to Electric Vehicle Charging Locations without Conditional Use authorization, revise zoning control tables to reflect these changes, and require annual reporting by the Planning Department regarding Electric Vehicle Charging Location and Fleet Charging project approvals; affirming the Planning Department's determination under the California Environmental Quality Act; and making findings of consistency with the General Plan, and the eight priority policies of Planning Code, Section 101.1, and findings of public necessity, convenience, and welfare under Planning Code, Section 302.

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January 18, 2022

Planning Commission
Attn: Jonas Ionin
49 South Van Ness Avenue, Suite 1400
San Francisco, CA 94103

Dear Commissioners:

On January 11, 2022, Mayor Breed submitted the following legislation:

File No. 220036

Ordinance amending the Planning Code to create Electric Vehicle Charging Location and Fleet Charging as Automotive Uses, allow conversion of Automotive Service Stations to Electric Vehicle Charging Locations without Conditional Use authorization, revise zoning control tables to reflect these changes, and require annual reporting by the Planning Department regarding Electric Vehicle Charging Location and Fleet Charging project approvals; affirming the Planning Department's determination under the California Environmental Quality Act; and making findings of consistency with the General Plan, and the eight priority policies of Planning Code, Section 101.1, and findings of public necessity, convenience, and welfare under Planning Code, Section 302.

The proposed ordinance is being transmitted for review.

Angela Calvillo, Clerk of the Board

By: Erica Major, Assistant Clerk
Land Use and Transportation Committee

c: Rich Hillis, Director
Tina Tam, Deputy Zoning Administrator
Corey Teague, Zoning Administrator
Lisa Gibson, Environmental Review Officer
Devyani Jain, Deputy Environmental Review Officer
AnMarie Rodgers, Director of Citywide Planning
Dan Sider, Chief of Staff
Aaron Starr, Manager of Legislative Affairs
Joy Navarrete, Environmental Planning

BOARD of SUPERVISORS

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January 18, 2022

File No. 220036

Lisa Gibson
Environmental Review Officer
Planning Department
49 South Van Ness Avenue, Suite 1400
San Francisco, CA 94103

Dear Ms. Gibson:

On January 11, 2022, Mayor Breed submitted the following legislation:

File No. 220036

Ordinance amending the Planning Code to create Electric Vehicle Charging Location and Fleet Charging as Automotive Uses, allow conversion of Automotive Service Stations to Electric Vehicle Charging Locations without Conditional Use authorization, revise zoning control tables to reflect these changes, and require annual reporting by the Planning Department regarding Electric Vehicle Charging Location and Fleet Charging project approvals; affirming the Planning Department's determination under the California Environmental Quality Act; and making findings of consistency with the General Plan, and the eight priority policies of Planning Code, Section 101.1, and findings of public necessity, convenience, and welfare under Planning Code, Section 302.

This legislation is being transmitted to you for environmental review.

Angela Calvillo, Clerk of the Board

By: Erica Major, Assistant Clerk
Land Use and Transportation Committee

Attachment

c: Joy Navarrete, Environmental Planning
Don Lewis, Environmental Planning