Proposal: All-Electric Renovations Ordinance

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INTRODUCTION

In 2019, San Francisco declared a climate emergency and called for immediate action to limit global warming to 1.5 degrees Celsius[i] – which led the City to revise its climate action goals to commit to 100% renewable electricity by 2025, a 61% reduction in citywide carbon emissions by 2030, and net-zero greenhouse gas (GHG) emissions by 2040.[ii] San Francisco's approach to achieving these goals was informed by years of stakeholder engagement that preceded the 2021 San Francisco Climate Action Plan, which centers equity and a just transition as the foundation for strategies and actions to systematically reduce carbon emissions citywide.[iii]

Three distinct terms are used in this policy proposal:

New Construction – A building that has never been occupied.

Major Renovation – Gutting and rehabilitation, or addition, where the scope of work is similar to new construction. (See p. 3 for detail)

Existing Building Retrofit (or 'Retrofit') **–** a limited project with the purpose of improving energy performance – such as replacement of a boiler.

Energy use in buildings makes up 44% of San Francisco's carbon emissions. Burning natural gas in buildings is a major contributor to climate change and negatively impacts health and safety, especially in communities where residents are more likely to experience environmental justice issues like poor air quality. For the City to achieve its net-zero 2040 goal, emissions associated with both existing buildings and new construction must be eliminated.

In 2020, San Francisco adopted the *All-Electric New Construction Ordinance* to reduce the health and safety hazards of piping combustible natural gas throughout a dense city in a seismically active location and to help prevent irreversible damage from climate change. The *All-Electric New Construction* Ordinance prohibits gas piping and appliances in newly constructed buildings but does not impact additions or renovations.

In San Francisco's urban environment, it is common to expand and renovate existing buildings. Modernizing and repurposing existing structures is an essential strategy in the preservation and expansion of local housing stock. Renovation is critical for maintaining the City's unique character and extending the lifespan of building materials helps reduce embodied carbon emissions.

During renovations, owners voluntarily commit to significant design and construction work including the installation of new equipment. Systems that contribute to a building's primary energy use and associated emissions commonly last decades. To meet San Francisco's target of net-zero emissions by 2040, carbon-emitting systems installed today would need to be replaced before the end of their normal service life.

San Francisco is considering extending its all-electric new construction requirements to major building renovations. The policy would affect projects where the proposed scope of work is comparable to new construction. Such projects would be held to the same standard as new construction, which would

benefit public health and safety, minimize air pollution, and reduce carbon emissions from fossil-fuel combustion.

This document provides basic context and a proposal to adopt an ordinance requiring all-electric major renovations. It highlights priorities previously identified by stakeholders as well as considerations with important consequences for the health and welfare of San Francisco residents and businesses.

This proposal does not extend to the replacement of individual pieces of equipment in existing buildings, nor to existing building alterations where the scope of work is significantly less than in new construction. The 2021 San Francisco Climate Action Plan proposes several actions that in combination will comprehensively decarbonize existing buildings, which will be addressed by separate proposals. Legislation implementing each action will be informed by additional stakeholder outreach to advance public safety and health, climate action and racial equity.

Timeline Leading to Proposal

2019 – Climate Emergency declared in San Francisco

2020 – Zero Emission Buildings Task Force informs All-Electric New Construction Ordinance and all-electric requirement for municipal new construction and renovations

2021 – San Francisco revises GHG emission targets to net zero by 2040 and 2021 San Francisco Climate Action Plan provides strategies for equitable and just transition

2023 – Electrification at time of equipment replacement required for municipal facilities

PROPOSAL

San Francisco's *All-Electric New Construction Ordinance* (Building Code Section 106A.1.17) applies to new construction projects that submitted an initial building permit application after June 1, 2021. In alterations and additions to existing buildings where structural, mechanical, electrical, and plumbing systems are replaced or substantially modified, building codes require the area of work to be upgraded to current standards for fire and seismic safety, accessibility, and energy performance. This proposal would expand the all-electric requirement to limited, specific circumstances when a building is renovated or substantially expanded and building systems are proposed to be replaced. Installing electric equipment avoids the need to retrofit new gas-using systems installed today to all-electric in the near future.

An addition to an existing building may fall into one of three categories, below. This proposal would apply to:

- Installing new systems serving the addition (e.g., installing a heating system when adding a new housing unit in an existing structure)
- Making significant changes to central systems in an existing building that serve an addition (e.g., the 2016 Museum of Modern Art renovation which consisted of a 10-story, 170,000 square foot addition and replacement of the central plant in the existing 5-story structure)

This proposal would not apply to:

- Adding conditioned space without replacing or significantly modifying existing gas-fueled equipment

In each situation above, fossil-fuel piping and appliances pose the same hazards to health and safety and the same urgency for replacement by 2040. In addition, the retail cost of gas is more volatile than electricity, and gas prices are projected to escalate faster than electricity prices from 2025 to 2040.

APPLICABILITY

Two new terms are proposed for the major renovation policy: "Major Renovation" and "Substantial Upgrade to Mechanical Systems". This proposal would apply to a project that meets both definitions.

To align with existing codes and enforcement procedures, the proposed definition of a "Major Renovation" cites existing criteria in state and local building codes that identify when various requirements apply. The cited sections are included on the following page.

Major Renovation

Draft Building Code Definition	Explanation
Major Renovation *is an alteration or addition to an existing building that includes Substantial Upgrade to Mechanical Systems, and:* *i. A Non-Structural Alteration that is a "substantial change" pursuant to San Francisco Building Code 503.11.1;*[iv] *OR* *ii. Substantial Structural Alteration as defined by San Francisco Existing Building Code 202; OR* *iii. An addition that is a Substantial Improvement as defined by San Francisco Existing Building Code Section 202.*	Major Renovation means replacing mechanical systems and either: Substantially move, remove, repair, or modify walls or ceilings on 2/3 of floors or more; or Modify structural elements supporting 30% or more of total floor and roof area; or Expand the building, and the valuation of the addition is 50% or more of the building's previous market value.

Substantial Upgrade to Mechanical Systems

Draft Building Code Definition	Explanation
Substantial Upgrade to Mechanical Systems *is an alteration or addition to an existing building where the proposed project:* *i. Replaces space heating and hot water heating system for the entire building; OR* *ii. Installs space heating and water heating systems that will serve 80% or more of total conditioned floor area of the proposed building; OR* *iii. Installs space conditioning or water heating systems serving the area of addition.*	A 'substantial upgrade' either: Replaces everything: the entire heating and hot water heating system. Replaces most of the equipment that heats and provides hot water to the building. Adds on to the building, and installs new systems that serve the new area.

California Building Code Section 202

Substantial Structural Alteration. *An alteration in which the gravity load-carrying structural elements altered within a 5-year period support more than 30 percent of the total floor and roof area of the building or structure. The areas to be counted toward the 30 percent shall include mezzanines, penthouses, and in-filled courts and shafts tributary to the altered structural elements.*

Substantial Improvement. *… any repair, alteration, addition or improvement of a building or structure, the cost of which equals or exceeds 50 percent of the market value of the structure, before the improvement or repair is started. If the structure has sustained substantial damage, any repairs are considered substantial improvement regardless of the actual repair work performed. The term does not, however, include either of the following:*

1. *Any project … required to correct existing health, sanitary or safety code violations … [provided the project] is the minimum necessary to ensure safe living conditions.*
2. *Any alteration of a historic structure, provided that the alteration will not preclude the structure's continued designation as a historic structure.*

San Francisco Building Code

The following is a section, rather than a definition, which triggers compliance with current structural safety requirements.

503.11.1 Non-structural alterations. *Whenever alteration work in a building or structure involves substantial changes to elements such as walls, partitions or ceilings, on 2/3 or more of the number of stories excluding basements, the building or structure as a whole shall comply with Section 304.4. The term "substantial change" includes the addition, removal, repair or modification of such elements. All such work included in alteration permits issued within two years of the date of a permit application shall be included in the determination of whether the application is proposing substantial change to the building or structure.*

Removal and replacement of interior gypboard or plaster in Type V (wood framed) R3 occupancy (one or two residential units) is not to be considered as "Substantial Change".

LIMITATIONS AND EXCEPTIONS

San Francisco Building Code Section 106A.1.17 prohibits natural gas heating, cooling, water heating, cooking, and clothes drying in new construction. Section 106A.1.17.1 also prohibits permits that would alter, modify, or otherwise convert all-electric buildings into mixed-fuel buildings.

San Francisco Building Code Section 106A.1.17 allows the DBI Director to modify requirements for an all-electric building on a case-by-case basis if qualified professionals verify that it is infeasible to build all-electric. DBI regulations (Administrative Bulletin 112)[v] explain the circumstances when an exception is

necessary and the specific processes to ensure all other options are exhausted before gas may be allowed.

If a building receives an exception allowing mixed-fuel construction, current rules:

- Allow gas, but limit its use to the minimum extent necessary to resolve the constraint and
- Require the building to be wired for a future update to all-electric.

In special circumstances the regulations in Administrative Bulletin 112 offer a more lenient path to allow gas use to the minimum extent necessary. These existing exceptions would also apply to Major Renovations:

> **Electric Utility Infrastructure:** Electric utility infrastructure is always installed in new construction, and aging electric infrastructure is generally replaced in major renovations – including mixed-fuel projects. DBI's current regulation allows mixed-fuel construction if all-electric design would require greater electric service capacity and increase the timeline for electric service to a degree that would threaten success of the project.
>
> For renovations, the regulations in Administrative Bulletin 112 should be simplified, consistent with the following:
>
> **Table 1: Guiding Principles for Utility Infrastructure Feasibility Exceptions**

Situation	Approach
All-electric requires the same or greater electric service. *And* Utility improvements do not delay the project.	Build all-electric
All-electric requires greater electric service. *And* Utility improvements cannot be completed within project timeline.	First, verify or reduce electric capacity needs.[vi] If utility improvements significantly delay project completion, mixed-fuel should be allowed.
All-electric requires an on-site transformer where there was none previously and mixed-fuel doesn't require a transformer.	Verify or reduce electric capacity needs.[i] If the project needs a transformer to be all-electric, then mixed fuel should be allowed.
All-electric requires far greater electric service.	A significant greater electrical service is a cause for concern. It is likely that a power-efficient design can narrow the gap[i] – and may resolve the issue.

> Efficient design and careful equipment selection can moderate peak demand. With power-efficient design, the electric service capacity needed for all-electric can be very similar to mixed-fuel construction.

Electric utility infrastructure requires time to construct – whether a building is mixed-fuel or all-electric. Utility energization delays are a widespread concern for new construction and major renovations. In 2023 California mandated that PG&E improve delivery of electric service projects, and in September 2024 the California Public Utilities Commission set firm timelines for energization for both mixed-fuel and all-electric projects.

To understand whether fuel would delay a project, the minimum information needed is:

- How long will the project take to construct after permits are approved?
- What is the difference in electric service and electric infrastructure timeline, if any?

Small Infill Sites: In buildings with limited street frontage (less than 75 linear feet), DBI's existing regulation recognizes all-electric construction may be physically infeasible if:

1. An electrical transformer is necessary if the building is all-electric, but not necessary if the building is mixed fuel, AND
2. The existing building does not have a transformer, AND
3. There is no feasible location for a transformer on the property.

With power efficient design, it is rare all three constraints to apply – but if they do, mixed-fuel construction is allowed.

Commercial Food Service: Gas piping is allowed exclusively for specific commercial food service equipment for a specific commercial food service establishment (see 106A.1.17 *Exception (2)(i)*). Preserving this exception for renovations would allow existing restaurants to retain gas use for cooking while eliminating other gas uses.

EPCA Appliances: The US Department of Energy has adopted efficiency standards for certain equipment under the auspices of the federal *Energy Policy and Conservation Act* (EPCA Appliances). To align with a federal court ruling, appliances covered by federal appliance energy efficiency standards may be installed regardless of fuel, provided all applicable codes are met. All buildings must comply with *Design Guidelines for Public Safety and Electric Ready Construction*. Natural gas piping may be installed to the minimum extent necessary for operation of gas-fueled appliances specified and installed in the proposed project.

Two additional special circumstances are proposed for Major Renovations only:

100% Affordable Housing: Major renovations that renovate or create 100% Affordable Housing units are proposed to phase in based on the date that a building permit application is filed:

- Prior to July 2027: Exempt
- July 1, 2027 – Dec 31, 2030: Allows mixed-fuel construction to the minimum extent necessary, based on a finding by the Mayor's Office of Housing and Community Development.
- After January 1, 2031: All-electric is mandatory

Convert Office to Multifamily Residential: Major renovations converting an existing office building to multifamily residential and apply for permit prior to January 1, 2031 are proposed to be exempt from this ordinance.

However, other regional and state requirements continue to apply.

During the first two years of implementation, 290 applications for new construction permits were received, and no applications for exception were submitted.[vii]

COSTS AND BENEFITS

Cost analyses are available for new construction and for retrofits. A retrofit is a limited project, where the purpose is to improve energy performance. A major renovation is very different: As discussed in prior sections a Major Renovation is a comprehensive improvement where the scope of work – and cost structure – is much more similar to new construction than a simple retrofit. The larger the proportion of a building undergoing renovation, the more a new construction analysis is applicable. Major renovations are large projects with extensive scopes of work, so **analyses of costs and savings in new construction best represent the impact of the Major Renovations Ordinance**. For completeness, this section also provides cost data for small retrofit projects.

In the context of local, state, and federal net zero emissions goals and rules, gas systems will need to be converted to electric eventually. The most cost-effective time to upgrade to efficient heat pumps and other electric systems is when new equipment is installed. During major renovations, building systems are at their most accessible, undergo redesign, and are replaced or substantially modified.

New construction studies compare the construction of a baseline, mixed-fuel building with the construction of an all-electric alternative, holding constant other aspects of design such as building shape, structural systems, and use. New construction entails design and installation of utility infrastructure, electrical systems, piping systems, and mechanical systems serving the building. This scenario is directly comparable to an addition where new building systems are installed or the gutting and rehabilitation of an existing building.

The retrofit studies consider a baseline of like-for-like replacement of existing gas-powered equipment and the reuse of existing utility service, gas supply piping, and electric infrastructure. This baseline is compared to the installation of electric systems serving the same function including modifications to wiring, infrastructure, and electric utility service. The scope of work for the electric retrofit scenario is inherently greater than like-for-like replacement; in some cases, walls or other aspects of structure are modified to accommodate differences in the size or ventilation requirements of new heat pumps.

The studies suggest construction and utility costs associated with all-electric renovations tend to be modest. In comparison to the cost of new office construction in San Francisco in 2022 (more than $440 per sq ft excluding land[viii]), the proposal would generate additional costs in the range of 0.2% to 0.7%. For other building uses, all-electric construction may reduce or increase renovation costs, but the impact is modest.

Restaurants are a notable exception, where specific sanitation hot water requirements, utility infrastructure cost, and a not-yet-developed secondary market for electric commercial cooking equipment may pose more significant challenges. Reflecting this concern, this proposal would maintain the existing exception for specific commercial food service cooking processes. Table 1 summarizes recent studies of the incremental construction and utility cost for all-electric new construction and retrofits.

Table 1. Incremental Cost Per Square Foot for All-Electric Construction[ix]

Use	Incremental Construction Cost ($/Sq Ft)		
	New Construction and **Major Renovations**	Existing Building **Retrofit** – Low	Existing Building **Retrofit** - Higher
Single family	-$2.14	$2.27	$3.92
Multifamily 2-3 floors	-$0.64	-	$6.92
Multifamily 5-10 floors	-$0.47	-$1.94	$12.12
Office	-$1.19	-	$2.95
Retail	$0.00	-$0.01	-
Small Hotel	-$14.56	-$2.53	-$0.34
Quick Service Restaurant (Excluding cooking)	$13.39	-	$19.83
Quick Service Restaurant (With cooking equipment)	$28.47	-	$28.59
Full-Service Restaurant (With cooking equipment)	$39.50	-	-

The analyses cited in Table 1 exclude tax benefits or incentive payments available. Table 2 considers the approximate tax benefits available in combination with representative local and regional incentives.[x] Tax benefits are emphasized because of their scalability and despite current uncertainty federal law has historically been more consistent over time than rebate funding. The cost per square foot of all-electric major renovations is similar to or less than mixed-fuel construction prior to incentives.

Table 2. Incentives Supporting Residential All-Electric Renovations and Retrofits

Funding Source	Program Name	Maximum Funding Per Household	Description
State	TECH Clean California	$1800 to $8,800	Heat pump water heater rebate program with kickers for climate-friendly refrigerants, electric panel upsizing, and low-income households
Federal	HEEHRA Multifamily	$14,000	For low- and moderate-income households. Covers 100% and 50% of installation cost, respectively
Bay Area	BayREN EASE	80% of project cost	Regional program for weatherization, serving households under 120% AMI
Federal	25C Homeowner tax credit	$3,200 per year	Provides a 30% tax credit for heat pumps and qualified electrical & efficiency upgrades. Expires December 2025.
State	GoGreen Home + Equitable Building Decarbonization	0% interest for 10 years	The CEC's Interest-Rate Buydown (IRDB) program assists low-income households with energy upgrades, including heat pumps.

RATIONALE

The 2021 Climate Action Plan lays out strategies and supporting actions to systematically decarbonize the entire building stock by 2040. This proposal is designed to address the risks to health, safety, resilience, and equity posed by natural gas infrastructure, indoor combustion of natural gas, and climate change:

Health: Exposure to the pollutants produced from gas appliances is detrimental to human health. The combustion of natural gas emits a wide range of air pollutants, such as carbon monoxide (CO), nitrogen oxide (NOx), and particulate matter (PM), that have been linked to various acute and chronic health effects including asthma in children, respiratory illness, cardiovascular disease, and premature death.[xi] Combustion of gas in buildings is responsible for 31% of NOx emissions from stationary sources in the Bay Area.[xii] In homes with combustion appliances, indoor concentrations of NOx are about twice as high as outdoors.[xiii] All-electric buildings eliminate both indoor and outdoor air pollution from burning gas on-site.

Safety: Reducing the reliance on gas improves resilience by reducing fire risk and simplifying building systems and maintenance. Gas plumbing in buildings poses fire, explosion, and public safety risks. On average in the United States, a gas or oil pipeline catches fire every four days, results in an injury every five days, explodes every 11 days, and leads to a fatality every 26 days.[xiv] For example, on February 6, 2019, a gas line explosion on Geary Street burned five buildings.[xv] In 2010, the explosion of a gas pipeline in San Bruno resulted in eight fatalities and destroyed an entire neighborhood.[xvi]

Resilience: To meet modern safety, efficiency, and functional requirements, modern gas equipment requires electricity to function; gas appliances installed today will not operate during an electric power outage. In addition, gas line ruptures caused 40% of the fires in San Francisco after the 1989 Loma Prieta earthquake.[xvii] Even today, PG&E has estimated that after a 7.9 earthquake, it would take six months to restore gas services citywide while electricity could be restored in less than a week. The 2020

Lifelines Performance Project recommended that the city require electrification of existing buildings to accelerate disaster recovery.[xviii]

Equity: Low-income communities and communities of color spend a disproportionate amount of income on health care and suffer greater rates of asthma due to poor indoor air quality. Zero emission homes are an important opportunity to deliver social equity benefits.

Climate Change: Natural gas is a non-renewable combustible fuel that is mostly comprised of methane, a greenhouse gas that is 82 times more potent than carbon dioxide.[xix] The elimination of natural gas is necessary to achieve the City's climate goals.[xx] In 2020, the buildings sector accounted for 44% of the city's carbon footprint, with most of the emissions from the use of natural gas.[xxi]

END NOTES

[i] San Francisco Board of Supervisors (2019) Declaring a Climate Emergency in San Francisco – Resolution 160-19. https://sfbos.org/sites/default/files/r0160-19.pdf

[ii] San Francisco Environment Code Chapter 9 (2021) https://bit.ly/SFGHGGoals

[iii] San Francisco 2021 Climate Action Plan https://sfenvironment.org/climateplan

[iv] As of January 1, 2026 this specific code provision will move to San Francisco Existing Building Code Section 305.5, with no modification.

[v] San Francisco Department of Building Inspection (2020) "Administrative Bulletin 112: Implementation of All Electric New Construction Regulations". https://codelibrary.amlegal.com/codes/san_francisco/latest/sf_building/0-0-0-100198#JD_AB-112

[vi] Practices that reduce electric capacity depend upon building size and occupancy. Examples for multifamily and commercial: right-size equipment, reduce heating water distribution temperature, reduce heating load, select power-efficient equipment, update lighting, install load management controls. Examples for single family: 120V combined washer/dryer, cold weather mini-split or window-heat pump, combined air-source heat pump delivering hot water and space heating, induction range instead of separate cooktop and wall oven, battery-assisted induction range, dynamic load management for electric vehicle charger, or plug-in microwave oven. These are illustrative examples where there is often an opportunity to offset equipment cost by reducing or eliminating electric service upsizing.

[vii] As of July 2023, the Department of Building Inspection has not received an application for exception on the basis of infeasibility. Results for the first year of implementation are summarized in:

> San Francisco Environment Department and Department of Building Inspection (2023) "All-Electric New Construction Update". Report to the Commission on the Environment. https://www.sfenvironment.org/media/13954

A similar report is scheduled for release in October 2023.

[viii] Turner & Townsend (2022) International Construction Market Survey, accessed April 17, 2023.

[ix] Table 1 summarizes the following, available at: https://localenergycodes.com/content/resources

> TRC, P2S Engineers (2022) "2021 Non-Residential Alterations Reach Code Cost-Effectiveness Analysis" updated January 27, 2022
>
> Frontier Energy, Bruceri & Associates (2022) "Existing Multifamily Residential Building Upgrades" updated March 7, 2022
>
> Frontier Energy, Bruceri & Associates (2021) "Existing Single Family Residential Building Upgrades", updated August 27, 2021
>
> Goyal and Faramond (2022) "2022 Code: Nonresidential New Construction Reach Code Cost Effectiveness Study", updated November 16, 2022

Frontier Energy, Bruceri & Associates (2023) "2022 Cost-Effectiveness Study: Multifamily New Construction", updated February 28, 2023

Frontier Energy, Bruceri & Associates (2022) "2022 Cost-Effectiveness Study: Single Family New Construction", updated September 12, 2022

Additional contributing resources:

Pande, Feng, Yun Wei, and Nakajima (2022) "All-Electric Multifamily Compliance Pathway" 2022 Codes and Standards Enhancement (CASE) Initiative supporting 2022 California Energy Code. https://title24stakeholders.com

Applied Development Economics (2022) "Socioeconomic Impact Analysis of Proposed Amendments to Regulation 9, Rule 4: Residential Central Furnaces; and Regulation 9, Rule 6: Natural Gas-Fired Boilers and Water Heaters." https://www.baaqmd.gov/rules-and-compliance/rule-development/building-appliances

[x] Rebates are typically a significant incentive resource for housing serving low-income residents. But incentive programs have specific budgets and are typically authorized for 1 to 3 years before sunset, renewal, or overhaul. To provide context, Table 2 considers the incentives available today as representative of the resources expected to be available over the next 3-5 years.

Table 2 does not consider additional resources available to rehabilitate deed-restricted affordable housing such as competitively allocated Low Income Housing Tax Credits (LIHTC) and the Low-Income Weatherization Programs (LIWP) for single family and multifamily. It also does not consider programs that directly serve income-qualified residents, such as the Weatherization Assistance Program (WAP), the Low Income Heating Assistance Program (LIHEAP), or California's Equitable Building Decarbonization program providing direct installation of electrification measures to income-qualified households.

[xi] See for example:

UCLA Fielding School of Public Health (2020) "Effects of Residential Gas Appliances on Indoor and Outdoor Air Quality and Public Health in California". coeh.ph.ucla.edu/effects-residential-gas-appliances-indoor-and-outdoor-air-quality-and-public-health-california

Lin, Brunekreef, Gehring (2013) "Meta-analysis of the effects of indoor nitrogen dioxide and gas cooking on asthma and wheeze in children". academic.oup.com/ije/article/42/6/1724/737113, and

Nicole (2014) "Cooking Up Indoor Air Pollution". ehp.niehs.nih.gov/doi/pdf/10.1289/ehp.122-A27

[xii] Bay Area Air Quality Management District Figure (2022) "*Final Staff Report for Proposed Amendments to Building Appliance Rules 9-5 and 9-6".* Figure 5-2. https://bit.ly/BAAQMDRule9-4_9-6StaffReport

[xiii] US Environmental Protection Agency "Nitrogen Dioxide's Impact on Indoor Air Quality," accessed April 19, 2023. https://www.epa.gov/indoor-air-quality-iaq/nitrogen-dioxides-impact-indoor-air-quality

[xiv] Kelso (2018) "Pipeline Incidents Continue to Impact Residents" www.fractracker.org/2018/12/pipeline-incidents-impact-residents/

[xv] ABC 7 News (2019) "NTSB releases preliminary report on gas line explosion in San Francisco" abc7news.com/ntsb-releases-preliminary-report-on-gas-line-explosion-in-san-francisco/5160531/

[xvi] Wikipedia (2019) en.wikipedia.org/wiki/San_Bruno_pipeline_explosion

[xvii] Earthquake Safety Implementation Program (2017) "Study of options to reduce post-earthquake fires in San Francisco ESIP Task A.6.i, Table 2.

[xviii] San Francisco Lifelines Council (2020) "Lifelines Restoration Performance Project" https://onesanfrancisco.org/lifelines

[xix] San Francisco Environment Department (2017) Methane Math: How cities can rethink emissions from natural gas" sfenvironment.org/sites/default/files/fliers/files/methane-math_natural-gas-report_final.pdf

[xx] San Francisco Environment Department (2019) Focus 2030: A Pathway to Net Zero Emissions. sfenvironment.org/sites/default/files/fliers/files/sfe_focus_2030_report_july2019.pdf

[xxi] San Francisco Environment Department (2023) 2020 Sector-Based Greenhouse Gas Emissions Inventory at a Glance sfenvironment.org/climate