

Natural Gas Leakage In San Francisco: A Climate Perspective



POLICY ANALYSIS CONDUCTED FOR THE CITY AND COUNTY
OF SAN FRANCISCO DEPARTMENT OF THE ENVIRONMENT

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EXECUTIVE SUMMARY

This report is an early step in studying the potentially significant global warming effect of natural gas leakage in San Francisco. I conducted this policy analysis for the City and County of San Francisco Department of the Environment (SFE). My objectives were to estimate the amount of leakage from San Francisco's natural gas distribution system and to formulate policy options to evaluate and address leakage in San Francisco.

My major findings were:

- No accurate method currently exists to estimate the amount of leakage from San Francisco's natural gas distribution system. The magnitude of the problem has not been adequately studied and could potentially be significant.
- Many stakeholders whom I interviewed for my analysis were reluctant to speak openly because of the political climate surrounding safety concerns and the large costs of leak detection and pipeline repair.
- Policymakers will need to overcome several barriers in order to effectively address natural gas leaks from a climate action perspective as well from a public safety perspective: lack of accurate information about leakage, seeing leakage as an acceptable and reasonable part of doing business, lack of financial incentive for utilities to fix non-hazardous leaks, and the political feasibility of higher costs.

I recommend the following policy options to SFE:

- Call upon Pacific Gas and Electric Company, the California Public Utilities Commission, and other stakeholders to work together and conduct a leakage study of San Francisco using a vehicle-mounted methane analyzer device, as has been done in Boston and New York City.
- Call upon the California Air Resources Board to require better leakage studies and to account for the true environmental cost of leaked methane under AB32's Cap-and-Trade program.
- Call upon the California Public Utilities Commission to require utilities to repair leaks based not just on hazard level, but also global warming effect.

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OVERVIEW

The objectives of this policy analysis are to estimate the amount of leakage from San Francisco's natural gas distribution system and to formulate policy options to evaluate and address leakage in San Francisco. I begin by explaining why leakage in the natural gas infrastructure is not only public safety hazard, but also an environmental hazard. Natural gas is primarily composed of methane, a high potency greenhouse gas, and contributes to global warming.

Current regulation of natural gas fails to take into account the effect of leakage on global warming. Regulation has traditionally focused on public safety, but even recent environmental regulations have fallen short of adequately addressing leakage from a climate perspective. At the national level, the United States Environmental Protection Agency's (EPA) efforts to reduce leakage are not mandated but merely voluntary. At the state level, the California Air Resources Board's (CARB) Cap-and-Trade greenhouse gas program largely exempts emissions from natural gas leakage. Recent efforts by state regulators and Pacific Gas and Electric Company (PG&E) to improve safety continue to omit environmental considerations.

The exact magnitude of leakage in San Francisco is unknown. Little information is publically available about San Francisco's natural gas infrastructure, which is owned and operated by PG&E. Over the past few years, accidents and incidents demonstrating poor industry practices have shaken public confidence and created a need to investigate leakage in San Francisco. Utilities and regulators estimate leakage amounts in one of two ways: by using the lost and unaccounted for gas (LUAUF) method or the inventory method. Both methods are flawed. The most accurate way to assess leakage is by detecting and measuring methane levels using a methane analyzer device. Scientists have recently published studies using this method in cities such as New York and Boston, and have found alarmingly high rates of leakage.

Policymakers will need to overcome several barriers in order to effectively evaluate and address leakage from a climate perspective: lack of accurate information about leakage, seeing leakage as an acceptable and reasonable part of doing business, lack of financial incentive for utilities to fix non-hazardous leaks, and political feasibility of higher costs. I conclude my analysis with a few policy recommendations. First, policymakers should require utilities and regulatory agencies to gather more accurate data. Second, they should design policies and regulations to account for the true environmental cost of leakage, such as including the cost of leaked methane under AB32's Cap-and-Trade program, or requiring utilities to repair leaks according to global warming effect as well as hazard level.

Natural gas leakage is a controversial issue. Many stakeholders whom I interviewed for this analysis were reluctant to speak openly because of the political climate surrounding public safety concerns and the large costs of leak detection and pipeline repair. Additionally, many stakeholders prioritize public safety over the environmental consequences of leakage, without considering these problems as connected.

Global warming is the most challenging environmental problem of our time and policy-makers should advance climate action with urgency. Targeting leakage from the natural

gas infrastructure can be one of the most straightforward and effective ways to do so. Policymakers and utilities can fix the problem by utilizing existing technology to detect and repair leaks, without depending on vast behavioral change in the energy consumption patterns of the public. Ultimately, fixing leaks is not just an attractive environmental policy, but also a necessary one if we are to continue to rely on natural gas and hope to mitigate global warming.

INTRODUCTION

Methane leakage from the nation's natural gas infrastructure poses two problems. The first and more commonly publicized problem relates to public safety: natural gas leakage can cause large explosions such as the San Bruno accident in 2010. The second and less publicized problem is environmental. Natural gas is composed primarily of methane, which is a potent greenhouse gas. Leakage contributes to global warming, which threatens economic well-being, public health, natural resources, and the environment. It is in the public interest to mitigate leakage for both public safety and environmental reasons.

This policy analysis is a first step in studying the extent of natural gas leakage in San Francisco. My objectives are to estimate the amount of leakage from San Francisco's natural gas distribution system and to formulate policy options for how SFE could evaluate and address leakage.

After four months of careful research, I found that no accurate method currently exists to estimate the amount of leakage from San Francisco's natural gas distribution system. The extent of leakage is unknown because the issue has been under-monitored and under-studied. However, the magnitude of leakage could potentially be large and have a significant effect on global warming. Policymakers should therefore take steps to better understand and address leakage in order to effectively advance climate action goals.

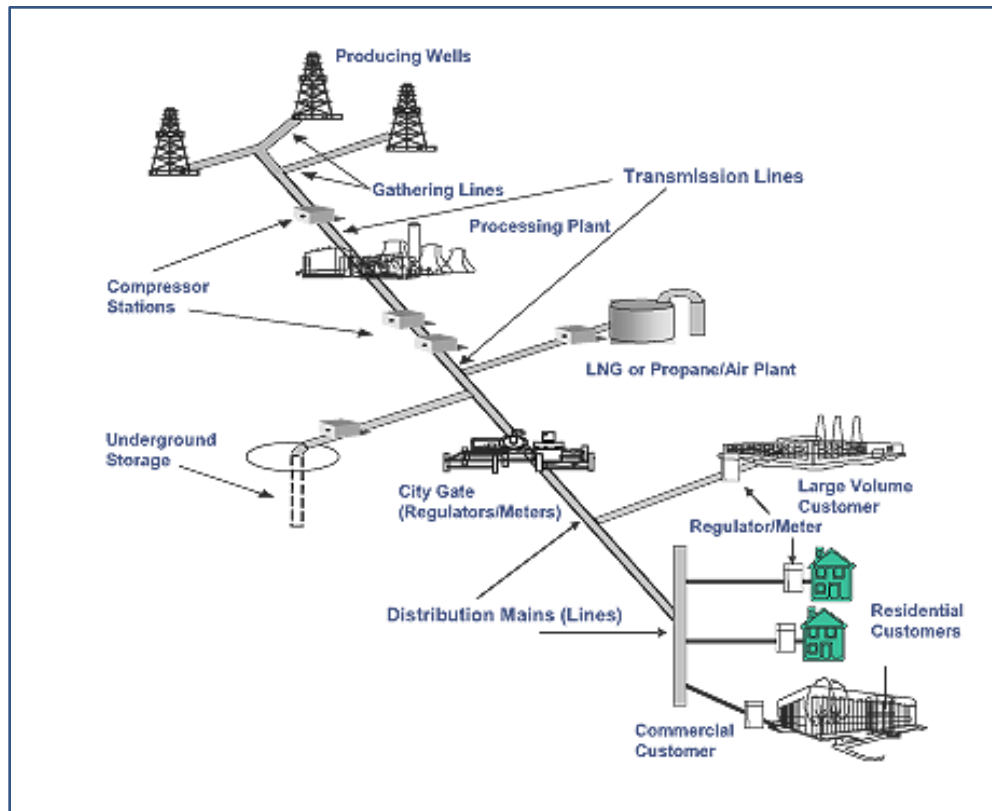


Natural gas pipeline outside of a building
Photo Credit: Flickr Creative Commons / ericeggertson

BACKGROUND ON NATURAL GAS LEAKAGE

NATURAL GAS LEAKAGE

Natural gas leakage occurs throughout the infrastructure system. Many households and businesses rely on natural gas for electricity, heating, cooking, and transportation. Natural gas is first gathered by drilling wells into underground rock formations. Next, natural gas is processed to strip out impurities, and transported through high-pressure transmission pipelines to city gate stations or for temporary storage in underground reservoirs. Finally, natural gas is delivered from the city gate station to end users through low-pressure distribution pipelines.¹ Natural gas often travels hundreds of miles from start to finish, with leakage occurring at all stages of the process from well drilling to city distribution.



Natural Gas Infrastructure

Photo Credit: US EPA Natural Gas STAR Program

Some leaks, called process emissions, are an intentional result of equipment design. Venting gas from pneumatic devices controls gas flows, temperatures, and pressures. Blowdowns release larger amounts of gas and are part of routine maintenance.

Other leaks, known as fugitive emissions, occur through holes or faulty connections between pipes, valves and equipment. Pipes can also leak by incurring damage from any of the following: corrosion, excavation, incorrect operation, equipment failure in the pipe material or weld, natural force damage such as earth movement, temperature, wind, rain, or outside force damage from other equipment.²

Cast iron pipelines are the most leak-prone and contribute the most to distribution system emissions, despite representing only 3% of distribution mains in the United States (US). Cast iron was used for low-pressure distribution mains until the 1950s, after which steel and plastic pipes became more commonly used. Cast iron pipeline are typically connected by joints and sealed with jute packing plus cement or molten lead. Leaks often develop in the packing material over time because of heavy overhead traffic, shifting soil, freeze-thaw weather cycles, and the switch to drier natural gas.³

PUBLIC SAFETY PROBLEM: EXPLOSIONS

Regulators have long recognized that natural gas leakage is a public safety hazard because natural gas is highly flammable. Natural gas is lighter than air, so when natural gas is released outside it will rise and dissipate into the atmosphere. As a safeguard, federal regulations require adding an odorant to natural gas that smells like rotten eggs. Gas companies must maintain a level of odorant in natural gas that an average person can smell at 20% of the concentration needed for an explosion, thus giving people time to detect a leak and evacuate before an explosion occurs.⁴

However, the odorant safeguard can fail. Pipes are buried underground, and natural gas can travel up through the soil and collect in confined spaces such as the foundations of buildings. The odorant can be leached out by the soil in the process, rendering the natural gas odorless and difficult to detect. An explosion occurs when the gas-and-air mixture is within the flammable range (typically between a 4 to 14 percent gas concentration⁵), and accidentally ignites upon a source of ignition such as lighting a match or turning on a light switch.

Over the past few years, some major explosions have received national attention and brought the issue of pipeline safety to the political forefront. Policymakers are particularly concerned because the natural gas infrastructure is aging and lies underneath populated areas.

On September 9, 2010, a segment of natural gas transmission pipeline operated by PG&E ruptured in a residential area in San Bruno, California. The explosion and resulting fire killed eight people, destroyed 38 homes and damaged 70 others. PG&E estimated the accident released 47.6 million standard cubic feet of natural gas into the atmosphere. The resulting investigation by the National Transportation Safety Board (NTSB) determined

that the cause of the accident was a fracture in a partially welded seam of one of six steel pipe sections that were installed in 1956. Five of the six sections would not have met industry quality control standards at the time. Furthermore, the weld defect in the failed section would have been visible when it was installed, indicating that PG&E either overlooked or ignored industry standards.⁶

On February 8, 2011, a gas main exploded and killed five in Allentown, Pennsylvania. The cause of the explosion was a 12-inch low-pressure main made of cast iron and installed in the 1920s.⁷

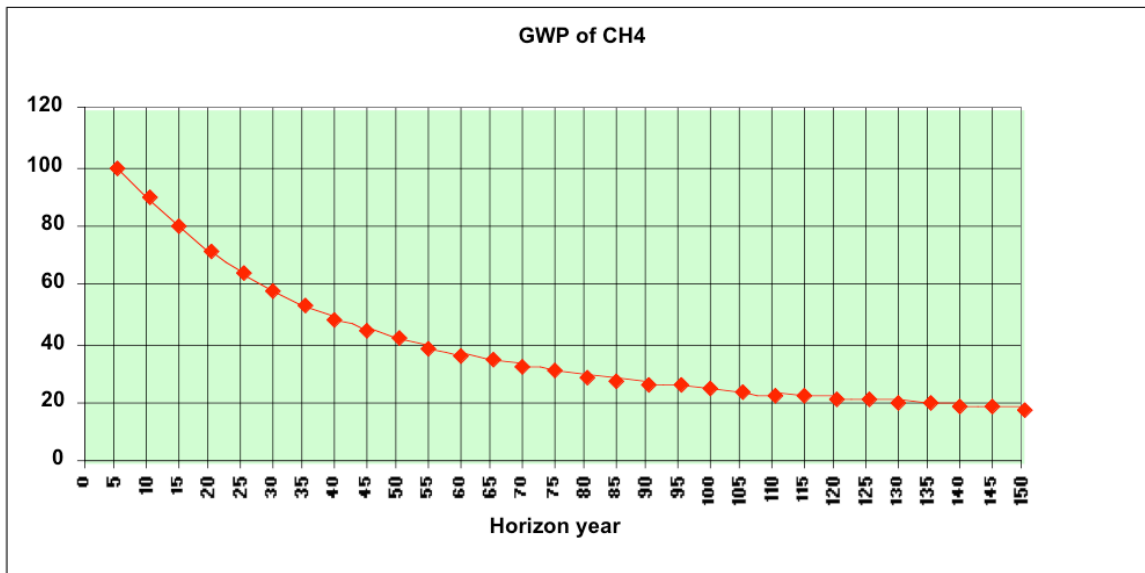
While the San Bruno and Allentown incidents are two of the most prominent explosions in recent years, they are by no means isolated incidents. In fact, accidents occur on a regular basis. The US Department of Transportation Pipeline and Hazardous Materials Safety Administration (PHMSA) keeps records of reported nationwide pipeline incidents. Over the past 20 years from 1993-2012, accidents in the national gas distribution system have caused 2,611 reported incidents, 296 fatalities, 1,133 injuries, and over 959 million dollars in property damage. This averages to 131 incidents, 15 fatalities, and 57 injuries a year.⁸ Accidents in the natural gas transmission system have caused 1,892 reported incidents, 42 fatalities, 209 injuries, and over 1.5 billion dollars in property damage over the past 20 years.⁹ This averages to 95 incidents, 2 fatalities, and 10 injuries a year.

ENVIRONMENTAL PROBLEM: GLOBAL WARMING

Not only does natural gas leakage pose a public safety problem, it also poses an environmental problem because it contributes, perhaps significantly, to global warming. Federal US energy policy has promoted natural gas as a climate-friendly bridge fuel towards alternative energy. However, the climate advantage of natural gas is diminished after taking leakage into account because natural gas is composed primarily of methane, a potent greenhouse gas.

Pipeline quality natural gas is composed of 95-98 percent methane, which has a global warming potential (GWP) many times greater than carbon dioxide. According to the EPA, methane has a GWP of 21,¹⁰ which means that the emission of 1 unit of methane has a global warming effect equivalent to the emission of 21 units of carbon dioxide over the 100-year time horizon following these emissions.¹¹ (Carbon dioxide's atmospheric lifetime is 100 years and is commonly used as a baseline to compare other greenhouse gases.) The Intergovernmental Panel on Climate Change (IPCC) provides higher GWP figures than the EPA: methane has a GWP of 25 over a 100-year time horizon, and 72 over a shorter 20-year time horizon.¹² It is important to understand that methane's GWP can vary based what time horizon is used, and this in turn significantly effects how methane emissions are evaluated and prioritized against other sources of emissions. Figure 1, based on IPCC calculations, shows how the GWP of methane can vary from 100 over a short 5-year time horizon to less than 20 over a 150-year time horizon.

Figure 1: GWP of Methane (CH₄)



Source: Dessus 2008¹³

Because methane's atmospheric lifetime is only 12 years,¹⁴ not 100 years like carbon dioxide, policymakers should use a shorter time horizon to evaluate methane emissions in order to fully account for its near-term global warming effect. In fact, using a longer time horizon significantly under-represents the large effect that methane emissions have on global warming in the near-term. The EPA states, "Methane's relatively short atmospheric lifetime, coupled with its potency as a greenhouse gas, makes it a candidate for mitigating global warming over the near-term (i.e., next 25 years or so)."¹⁵ Policymakers could substantially advance climate action during their own political terms by strategically targeting sources of methane leakage.

Knowing the exact amount of leakage is necessary to compare the advantages of natural gas to other fossil fuels. Scientists have determined that natural gas can be the cleanest fossil fuel because it produces around half as much carbon as burning coal, and three-quarters as much carbon as burning oil.¹⁶ However, this is only true as long as system-wide leakage remains low. A 2012 analysis (Alvarez et al.) estimates that system-wide leakage exceeds the 3.2% threshold beyond which natural gas becomes worse for the climate than coal.¹⁷ The Environmental Defense Fund has set a national goal of reducing leakage to 1% of total supply, warning: "If we don't reduce the leaks of uncombusted gas from wells and pipelines, we may squander any climate advantage of this fuel source for decades or more."¹⁸

REGULATION OF NATURAL GAS LEAKAGE

Historically, policymakers did not design regulations to account for the global warming effect of leakage because global warming was not a known problem. In the 1800s and early 1900s, gas for gaslights was manufactured from coal and government regulations focused on the hazards of carbon monoxide poisoning. After the transition to natural gas, which is not toxic but highly flammable, policymakers re-designed regulations to address the risk of explosions from leaks. The concern about the global warming effect of natural gas leakage is relatively new to the regulatory arena. While some agencies have advanced voluntary and market-based regulatory mechanisms over the past two decades, no regulation accounts for the full environmental cost of leakage as of yet.

PUBLIC SAFETY REGULATION

Federal and state agencies share responsibility for natural gas regulation. At the federal level, the Federal Energy Regulatory Commission (FERC) regulates interstate transmission of natural gas and the US Department of Transportation Pipeline and Hazardous Materials Safety Administration (PHMSA) regulates natural gas pipeline safety.¹⁹ Each state's Public Utility Commission regulates local energy utilities, approves retail natural gas sales to ensure fair prices to customers, enforces state and federal pipeline safety regulations, and inspects utility work.²⁰



Natural gas pipeline

Photo Credit: Flickr Creative Commons / mattandashley

Federal and state pipeline safety standards require monitoring pipelines for leaks and grading the leaks according to hazard level. Utility inspectors determine hazard level according to the amount of leaking gas, its proximity to buildings or subsurface structures, the extent of pavement, and the soil type.²¹ However, neither federal regulation²² nor California state regulation²³ specifies an exact timeline for repair. Instead, regulatory

agencies issue non-mandatory industry guidance, and in practice the timeline for repair can differ from operator to operator and state to state.

Per PHMSA's general guidance, leaks can be rated as follows. A Grade 1 leak "represents an existing or probable hazard to persons or property, and requires immediate repair". A Grade 2 leak is "non-hazardous at the time of detection, but justifies scheduled repair based on probable future hazard". Grade 2 leaks can be repaired, or inspected and cleared, anywhere from within 5 business days to 15 months, or on a normal routine basis. A Grade 3 leak is "non-hazardous at the time of detection and can be reasonably expected to remain non-hazardous". Grade 3 leaks are typically not scheduled for repair. They require re-evaluation during the next scheduled survey or within 15 months until the utility re-grades the leak.²⁴ Additionally, some utilities go beyond a Grade 3 rating and classify some non-hazardous leaks as "non gradable" (NG).²⁵

Non-hazardous leaks may not pose a significant public safety risk, but they do contribute to global warming. Current industry practices allow these leaks to remain unfixed for many months, if not indefinitely.

ENVIRONMENTAL REGULATION

Over the past two decades, federal and state environmental agencies have tried to address natural gas leakage in various ways. At the national level, the EPA created a voluntary program to encourage utilities to reduce leakage when cost effective. At the state level, CARB's Cap-and-Trade program accounts for many sources of greenhouse gas emissions, but largely exempts natural gas leakage. Ultimately, none of these recent programs adequately remedy the environmental problem.

The EPA has known that methane leakage contributes to global warming for decades. It launched the Natural Gas STAR Program in 1993, which is a "flexible, voluntary partnership that encourages oil and natural gas companies—both domestically and abroad—to adopt cost-effective technologies and practices that improve operational efficiency and reduce emissions of methane, a potent greenhouse gas and clean energy source."²⁶ EPA expanded this program internationally in 2006 by creating Natural Gas STAR International²⁷ and also currently chairs the Steering Committee of the Global Methane Initiative, an international public-private partnership that advances cost-effective, near-term methane abatement.²⁸ However, all of these programs are only voluntary and encourage companies to make improvements when cost-effective. PG&E has been a part of the EPA Natural Gas STAR since 1994.²⁹

The California Global Warming Solutions Act of 2006 (AB32) does not establish any particular rule to regulate fugitive methane emissions. It set the goal of reducing greenhouse gas emissions in California to 1990 levels by the year 2020, and charged CARB with its implementation.³⁰ CARB created a cap-and-trade market mechanism that establishes a statewide cap and allows industries to purchase and trade permits for their emissions. However, the program entirely exempts vented and fugitive emissions from natural gas production and transmission, and reported vented and fugitive emissions from

natural gas distribution.³¹ A compliance regulation only exists for natural gas that is delivered and combusted by end users.³²

Functionally, however, the Cap-and-Trade program does account for distribution system leakage in very small part. CARB and utilities estimate emissions from natural gas by considering all the gas that is delivered to city gate station as being delivered to end users and combusted into carbon dioxide.³³ Assuming a small percentage of leaked methane, the city gate methodology includes that amount in the overall combustion figure. However, this methodology is problematic because it grossly undervalues the global warming effect of leaked methane by counting it as carbon dioxide. The program therefore does not provide the appropriate economic incentive for companies to fix leakage because it does not account for the true environmental cost of leaked methane.

PG&E'S CURRENT EFFORTS

After the San Bruno disaster in 2010, PG&E has made efforts to improve public safety by introducing a number of new plans and proposals. On August 26, 2011, PG&E released a Natural Gas Transmission Pipeline Replacement or Testing Implementation Plan, which details a 3-year, \$1.8 billion effort to test 783 miles of pipeline using high-pressure water, replace another 186 miles, install 228 automated shutoff valves on gas lines, and modify 199 miles of pipe so they can be inspected by in-line tools that can detect the type of flaws that led to the San Bruno disaster.³⁴ On February 27, 2013, PG&E unveiled a 5-year, \$1.2 billion plan to upgrade electric and natural gas infrastructure specifically in San Francisco, including replacing the last 26 miles of cast-iron natural gas pipeline with modern, corrosion-resistant plastic pipe.³⁵ Lastly, PG&E's 2014 rate case, which will remain under consideration by the California Public Utilities Commission (CPUC) for the remainder of 2013, proposes a number of changes to routine maintenance and operations. One proposal is to purchase a number of leak detectors manufactured by Picarro that are 1,000 times more sensitive than the leak detection equipment PG&E currently uses. Another proposal is to accelerate the schedule for leak repair. PG&E proposes to accelerate fixing Grade 2 leaks from 18 months to 15 months, and to accelerate fixing Grade 3 leaks from rechecking every five years to rechecking and repairing within 15 months.³⁶

These plans and proposals make significant progress in the right direction. However, the focus is on public safety. Policymakers have not discussed whether these plans sufficiently remedy the global warming effect of methane leakage. While re-inspecting and fixing a Grade 3 leak within 15 months is certainly better than waiting for 5 years, many thousands of such leaks exist throughout the system and waiting 15 months may be too long from a climate perspective.

RECENT LEAKAGE FINDINGS

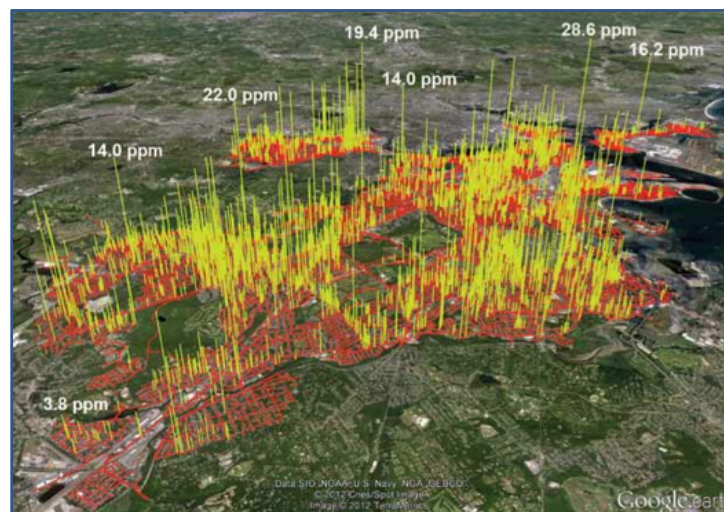
The scientific community has begun to discover alarmingly high leakage rates throughout the natural gas system, demonstrating the need for more research and stronger regulation.

A 2011 study (Howarth et al.) of well-site leakage estimated methane emissions from venting and leaks over the lifecycle of a well to be 3.6% to 7.9% of total production for shale-gas production and 1.7–6.0% for conventional gas production.³⁷ A 2012 study conducted by the National Oceanic and Atmospheric Administration (NOAA) and the University of Colorado in Boulder measured 4% leakage at a field near Denver; the same research team also reported 9% leakage rates from a field study in the Uinta Basin of Utah.³⁸ The method of natural gas extraction can also make a difference. Researchers from Cornell University discovered that methane leakage from fracking wells could be 30 percent greater than, or perhaps double, the leakage from conventional natural gas wells.³⁹



Upper Right: Gas wellhead in Sutter Buttes, California
Photo Credit: Flickr Creative Commons / calwest

Researchers have also recently discovered high rates of leakage from urban distribution systems. In 2012, Boston University Professor Nathan Phillips drove over every one of Boston's 785 miles of roads to test for elevated levels of methane higher than the normal background of 2 parts per million. He found 3,300 leaks, six of which were large enough to be hazardous.⁴⁰

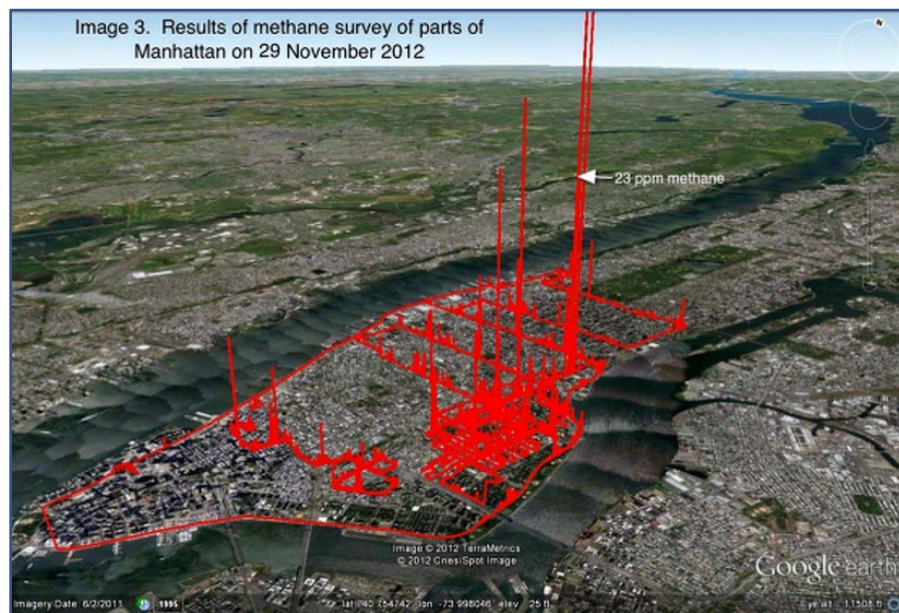


Map of Methane Leakage in Boston
Photo Credit: Nathan Phillips⁴¹

Phillips conducted his research using a car-mounted methane analyzer to detect leaks and a GPS mapping system to record their location.⁴² Phillips used a methane analyzer manufactured by Picarro, which is equipped with Cavity Ring-Down Laser Spectrometer measuring equipment and is one of the most sensitive leak detection technologies available today. Picarro's methane analyzer can recognize the chemical signature of different sources of methane, and can thus distinguish between older methane from fossil fuels and newer methane from decaying garbage in sewer systems, for example.⁴³

A white paper by Boston-based Conservation Law Foundation, released on November 2012, further expanded upon the leakage problem in Boston. Author Shanna Cleveland looked utility reports of LUAF to estimate that 700,000 to 3.6 million tons of CO₂e are lost per year. This represents 4% of total greenhouse gas emissions in Massachusetts and \$38.8 million a year in costs that are passed on ratepayers.⁴⁴

Researchers have conducted a similar study in New York City. In November and December of 2012, Damascus Citizens for Sustainability commissioned Gas Safety, Inc. (GSI) to conduct a leakage analysis. GSI researchers obtained data by driving down 160 miles of Manhattan streets, and also used a Picarro methane analyzer.⁴⁵ Not only did the GSI researchers detect leaks, but they also used the data to estimate the total amount of leakage from the distribution system serving New York City. In a report published on March 11, 2013, authors Robert Ackley and Bryce F. Payne Jr. estimated the leakage level to be above 5%.⁴⁶



Map of Methane Leakage in Manhattan
Photo Credit: Robert Ackley and Bryce F. Payne Jr.⁴⁷

LEAKAGE IN SAN FRANCISCO

PUBLIC CONFIDENCE

The extent of leakage in San Francisco is currently unknown. This lack of information is troubling given recent leakage findings in Boston and New York, and local accidents that have lowered public confidence in PG&E.

The San Bruno accident of 2010 led to an extensive investigation by NTSB. NTSB determined that the primary cause of the accident was a weld defect in a steel pipe that would not have met industry standards at the time.⁴⁸ The overarching cause of the accident was poor oversight as a result of state and federal grandfathering policies for pre-1970 pipes, which allowed the defective pipe to remain undetected. As is quite possible that other segments of defective pipe exist in PG&E's system, NTSB urges stronger oversight in the form of audits, evaluations, and better monitoring and recordkeeping.⁴⁹

Other accounts of incidents and malpractices further underscore the need for better regulatory oversight. For example, a December 16, 2010 San Francisco Gate article reported that PG&E was having trouble following federal law requiring that workers who check for gas leaks be properly trained. Additionally, workers did not always comply with the law when linking up gas lines with different allowable pressures, sometimes being unaware that they were doing so.⁵⁰ Another San Francisco Gate article, dated December 14, 2012, reported that PG&E workers lied about inspecting underground electrical equipment. This poses a dangerous situation because faulty equipment could lead to blackouts, fires, and explosions, such as a 2005 blast in a vault near Union Square that sent a manhole cover hurtling 30 feet and seriously injured a passer-by.⁵¹

Furthermore, a 2012 NBC Bay Area investigation found lengthy and numerous repair delays. PG&E failed to fix 988 leaks in the time required by state regulators. Twelve of these leaks were rated as Grade 1 and should have been repaired immediately. Instead, eleven of them took up to 90 days to fix and one took between 4-6 months to fix. The NSBC investigation found one Grade 2 leak at a home in Danville that had not been fixed for 29 months, even though state guidelines require that Grade 2 leaks be fixed within 18 months. As of October 2011, there were a total of approximately 51,000 detected leaks throughout the system. There may in fact be more leaks because PG&E management pressured inspectors to grade leaks down to allow for more time to meet repair deadlines. Additionally, the leak detection equipment that PG&E has used is not the best available technology. PG&E recently partnered with Picarro to test 104 miles of pipeline and found 159 previously undetected leaks, 20 of which are graded as hazardous.⁵² PG&E is proposing to buy Picarro leak detectors in their 2014 case.⁵³ (While Picarro and PG&E may have tested some areas of San Francisco, the data are not publically available.)

History of PG&E

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The history of PG&E started with the San Francisco Gas Company, which was incorporated August 31, 1852. The San Francisco Gas Company introduced gaslights to San Francisco in 1854. Gas was manufactured from coal and the distribution mains were made from cast iron shipped from Philadelphia. The original gas works facility that manufactured gas from coal was located on the lot bounded by First, Fremont, Howard, and Natoma Streets in the northeast part of San Francisco. By 1855, the San Francisco Gas Company had 12 miles of street mains and two gas-holding facilities at First and Howard Streets. At the time, San Francisco much smaller than today, consisting of Montgomery, Washington, Sacramento, California, Clay, Stockton and Battery streets. It is unclear to what extent, if at all, the original infrastructure is still used. It stands to reason, however, that the oldest pipes are located in the northeastern part of San Francisco.

San Francisco Gas Company merged with other gas companies over time and PG&E was incorporated in 1905.

Natural gas came later to San Francisco than to other US cities. No source of natural gas was found near the Bay Area until 1926, when exploration companies discovered natural gas fields at Buttonwillow, located 28 miles west of Bakersfield and 250 miles southeast of San Francisco. In 1929, natural gas was also found at Kettleman Hills, located 49 miles northwest of Buttonwillow. PG&E built a 250-mile long pipeline from Buttonwillow and Kettleman Hills to Milpitas on the southern tip of the San Francisco Bay. From there, PG&E built a branch of pipeline along the eastern shore of the Bay to Oakland and Richmond, while the main stem continued 44 miles north to San Francisco.

PG&E continued to expand and build infrastructure across California. As of 1952, it had acquired a total of 520 other companies. Today, PG&E is one of California's three largest energy utilities, servicing most of Northern and Central California.

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Coleman, Charles M. *PG&E of California: The Centennial Story of Pacific Gas and Electric Company 1852-1952*. New York: McGraw-Hill Book Company, 1952. Print.

Jones, E.C. "The History of Gas Lighting in San Francisco." *Pacific Gas and Electric Company: Historical and Descriptive*. Central California: Reprint from Journal of Electricity Power and Gas, 132-159. Print.

LEAKAGE ESTIMATION METHODS

No researchers have published a scientific leakage study of San Francisco as of yet. Currently, the best data that is publically available are industry estimates. One method of estimating leakage is the LUAF method, which utilities report to regulatory agencies such as PHMSA and the CPUC every year. Over the past ten years, PG&E reported an average gas loss of 2%.⁵⁴ The reported percentages are PG&E wide. No further granularity of data is publically available, and so there is no LUAF figure specifically for San Francisco.

However, the LUAF method is a rough and inaccurate way to estimate system leakage. Unaccounted-for gas is simply the measured volumetric difference between the amount of gas purchased and the quantity of gas sold, whether it is more or less, and does not always indicate a leak. Several other factors can contribute to LUAF besides leakage. For example, gas volume fluctuates according to temperature or metering pressure. If temperature or pressure differs between the output and input end, there will be LUAF even if there is no leakage. Inaccurate gas meters and gas theft also contribute to LUAF.⁵⁵ Furthermore, the LUAF method does not distinguish between process and fugitive emissions. It is important to note that the most public utility commissions consider some lost gas to be a reasonable part of utility operations, and allow the cost of LUAF to be passed on to ratepayers.



Residential gas meters on the side of an apartment building
Photo Credit: Flickr Creative Commons / mkrigsmann

Another way that utilities and regulatory agencies assess leakage is by using the inventory method. Regulatory agencies assign a leak rate, or emissions factor, to different types of pipe material or equipment. Utilities use these emissions factors to report leakage amounts to regulatory agencies. However, this method is also flawed. First, utilities typically do not measure leakage to verify if the emissions factor is accurate. Second, emissions factors are based on a 1996 report by the EPA and the Gas Research Institute (EPA/GRI) which has since been discredited for having small sample sizes, having only tested 21 samples of cast iron pipe and 6 samples of plastic pipes.⁵⁶ A more recent study conducted in 2006 by Comgas in Brazil suggests that the EPA/GRI's estimates are too low by almost half. The Comgas study is more credible than the EPA/GRI study because it used a larger sample

size of 900 pipes and employed more random selection. However, Comgas excluded 15.4% of the data that showed suspiciously or inexplicably high leak rates, so their analysis could also be flawed.⁵⁷

Given the methodological flaws described above, the inventory method is quite inaccurate. Even so, the method is widely used by regulatory agencies such as CARB, the EPA, and other environmental organizations such as The Climate Registry (TCR).

Further adding to the confusion surrounding actual leakage levels, these agencies all report different leakage amounts. One reason for inconsistent numbers is that agencies use different emissions factors. In 2011, PG&E reported 244,951 metric tons carbon-dioxide equivalent (CO₂e) of fugitive emissions to CARB under AB32,⁵⁸ while reporting 233,831 metric tons CO₂e of leaked methane to the EPA under Subpart W.⁵⁹ These reported emissions differ because EPA and CARB used different emissions factors. A second inconsistency is that agencies have different guidelines, also called reporting protocols, for what sources of emissions to report. For example PG&E reported 517,426 tons CO₂e of fugitive natural gas emissions to TCR in 2011. This figure is nearly twice as high as the amounts reported to CARB or EPA, largely owing to the inclusion of emissions from residential customer meters in the TCR reporting. A third inconsistency exists between year-to-year emissions calculations, which are larger than one might expect assuming that system leakage stays relatively constant from one year to the next. For example, PG&E reported 517,426 tons CO₂e in 2011, 1,131,458 tons CO₂e in 2010, and 949,130 tons CO₂e in 2009 to TCR. This inconsistency also comes from using different reporting protocols. PG&E relied on TCR's draft protocol for guidance in 2009 and 2010, and began reporting some fugitive emissions consistent with EPA Subpart W for 2011 instead. (There were several sources that PG&E had been reporting to TCR that were not covered by Subpart W and for those sources PG&E largely kept the old methodology.)

I conclude that there is currently no reliable way to estimate the amount of distribution system leakage in San Francisco because estimation methods are inaccurate and agencies apply estimates differently. Furthermore, reported estimates encompass all of PG&E's service territory. No further granularity of data is publically available, and thus deriving leakage estimates for specific areas such as San Francisco is not possible. Policymakers need more accurate and location-specific leakage data than what is currently available in order to make informed decisions about how to address leakage.

POLICY RECOMMENDATIONS

Over the course of my research, I discovered that natural gas leakage is a politically controversial issue because of the political sensitivity surrounding safety concerns and the costs of leak repair. The fairness of PG&E's recent 1.8 billion pipeline safety plan, which the CPUC ultimately decided would be financed one-third by PG&E shareholders and two thirds by ratepayers, was highly contested. Many stakeholders whom I interviewed for my analysis did not want to be identified. Additionally, many stakeholders focus on public safety instead of the environmental consequences of leakage, without seeing those problems as two sides of the same coin.

Policymakers need to overcome several barriers in order to effectively address natural gas leakage from a climate action perspective as well as from a public safety perspective. These barriers are not unique to California, but exist across the US.

The first barrier is lack of accurate information about leakage. Current methods of estimating leakage are flawed and underestimate the magnitude of the problem. Policymakers need better information about how much and where leakage occurs in order to make informed decisions. Sensitive technology now exists for detecting and mapping leaks, which can provide policymakers with significantly better quality information than estimation methods. Researchers have recently used this new technology to study leakage in Boston and New York. Policymakers across the country should require better data, or work with researchers, utilities, and other stakeholders to conduct leakage studies in their jurisdictions.

The second barrier is considering leakage an acceptable and reasonable part of doing business. Public utility commissions typically allow for a certain amount of lost gas, and permit utilities to pass the charge for the lost gas onto customers. This practice may have been reasonable in the past when the sole concern was public safety. However, given that the global warming effect of methane leakage is now well established and the technology exists for detecting and fixing leaks, system leakage should no longer be viewed as reasonable.

The third barrier is the lack of financial incentive for utilities to fix non-hazardous leaks. Utilities are typically not allowed to recover costs that do not directly relate to safety and delivery certainty, and fixing non-hazardous leaks does not count. Therefore, utilities are disincentivized from fixing non-hazardous leaks because they cannot recover their costs from doing so. Policymakers should change this incentive structure to allow utilities to address non-hazardous leaks.

The fourth barrier is the political feasibility of higher costs. Advancing climate action will require more extensive leak detection and accelerated timelines for leak repair. If the utility performs more work, costs will increase and be paid by ratepayers, utility company shareholders, or some combination of the two. The increased costs of leak repair may be partially offset by savings from reduced lost gas. However, assuming that the price of natural gas remains at currently low levels for the near future, the cost of leak repair will probably outweigh the revenue gain from reduced leakage.

Many of these barriers will have to be addressed in large part by state public utility commissions. One way they ensure fair pricing for consumers is through rate cases, during which they review and pre-approve the work that utilities are able to cost-recognize, or charge ratepayers for, each year. Rate cases are open to public review and debate as well. Ultimately, solving the leakage problem depends on public utility commissions deciding that the increased costs are appropriate because leak repair will improve public safety and mitigate global warming.

I conclude my analysis with specific recommendations for how SFE can evaluate and address leakage in San Francisco.

SFE should call upon PG&E, the CPUC, and other stakeholders to share information and conduct a leakage study in San Francisco using a vehicle-mounted methane analyzer device as was done in Boston and New York City. A potential research partner is the Environmental Defense Fund, which is conducting a nation-wide distribution system leakage study.

SFE should also call upon other regulatory agencies to account for the environmental cost of methane leakage and to design policies accordingly. CARB should require better leakage studies and include the environmental cost of leaked methane under AB32's Cap-and-Trade program. The CPUC should institute policies or incentives for leak repair that take global warming effect as well as hazard level into account. The CPUC should establish an accelerated timeline for leak grading and repair that aligns with climate action goals, and evaluate the greenhouse gas reductions achieved by those repairs.

Some possible regulatory options for the CPUC to consider are funding non-hazardous leak repair by allowing cost recovery in rate cases; establishing a shareholder reward for meeting emission reduction goals; imposing a fine on PG&E corporation (not to be passed on to ratepayers) per metric ton of methane emitted; or disallowing the cost of LUAF to be passed on to ratepayers. It is important to note that a combination of these strategies may be most effective. For example, given the currently low price of natural gas, disallowing the cost of LUAF as a stand-alone policy will not provide utilities with a strong economic incentive to fix leaks. Ultimately, the CPUC is in the best position to design a policy that furthers climate action goals while considering other criteria such as political feasibility, ease of implementation, cost effectiveness, and fairness to ratepayers.

To conclude, all stakeholders - regulatory agencies, utilities, and the environmental and scientific communities - should work to evaluate and fix leaking natural gas infrastructure. Global warming may be a relatively new problem for natural gas regulation, given the long history of natural gas use, but it is the most serious environmental problem of our time. Therefore, policymakers and stakeholders should advance climate action with urgency: there is no time to lose.

ACRONYM INDEX

AB32.....California Assembly Bill 32, California Global Warming Solutions Act of 2006

CARB.....California Air Resources Board

CO2e.....Carbon Dioxide Equivalent

CPUC.....California Public Utilities Commission

EPA.....US Environmental Protection Agency

FERC.....Federal Energy Regulatory Commission

GRI.....Gas Research Institute

GSI.....Gas Safety, Inc.

GWP.....Global Warming Potential

IPCC.....Intergovernmental Panel on Climate Change

LUAF.....Lost and Unaccounted For Gas

NOAA.....National Oceanic and Atmospheric Administration

NTSB.....National Transportation Safety Board

PG&E.....Pacific Gas and Electric Company

PHMSA.....US Department of Transportation Pipeline and Hazardous
Materials Safety Administration

SFE.....City and County of San Francisco Department of the Environment

TCR.....The Climate Registry

US.....United States

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