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Hydrogen in Our Homes:
A Dangerous Pipe Dream

Faced with growing demands to replace natural gas with renewable energy and electricity, utilities are shifting to selling a vision of a future powered by hydrogen — specifically, their existing natural gas infrastructure running on 100 percent hydrogen, free of fossil fuels.[1] As the American Gas Association says, "you're going to be hearing a lot about hydrogen in the coming days."[2] While this may be correct, their vision is a fantasy.

What is really being pushed is a dangerous scheme to mix relatively small amounts of "clean" hydrogen into the natural gas fuel stock. This plan would prolong the life of existing fossil fuel infrastructure and let utilities profit from their ongoing dirty investments. Further, using hydrogen in existing fossil fuel infrastructure faces severe technological, environmental, and economic challenges. These proposals to replace natural gas with hydrogen only serve to justify inaction and distract from economically feasible and environmentally sound energy storage solutions.

Hydrogen to the Rescue: Utilities Use Hydrogen to Delay an End to Natural Gas

In response to investor wariness about the future of natural gas in a post-fossil fuel world, and to lucrative subsidies provided by recent infrastructure bills, utilities have released plans to switch from natural gas to hydrogen.[3] While most (about 60 percent) of the hydrogen produced currently is used to refine oil, and an additional 30 percent is used for fertilizer production, the potential market for injecting hydrogen into the natural gas system is much larger.[4]

The federal incentives to make this switch are considerable. The recent infrastructure bill provides $8 billion for the construction of hydrogen hubs,[5] and the Inflation Reduction Act provides up to $3 per kilogram of hydrogen produced.[6] In 2020 and 2021, utilities across the country announced at least 26 hydrogen pilot projects. Many of these projects aim to blend a percentage of hydrogen into their existing natural gas fuel stream.[7] For example, Dominion Energy plans to blend 5 percent hydrogen into the natural gas delivered to buildings in Utah, North Carolina and Ohio.[8] Some utilities, like SoCalGas, are even proposing to supply pure hydrogen to households.[9]

The utilities often claim that this will reduce climate-altering emissions — but there is substantial evidence to the contrary. Many hydrogen proponents suggest that using renewable electricity to source their hydrogen is one path to reducing pollution. But as of 2020, 99 percent of the hydrogen produced in the U.S. was made from fossil fuels.[10] And burning hydrogen produced from fossil fuels in place of natural gas — even if the hydrogen were produced using carbon capture and storage (CCS) — actually has higher emissions than simply burning natural gas.[11]

Other utilities aim to blend hydrogen into the natural gas burned at power plants. By claiming that they will eventually switch to hydrogen as a fuel source, electric utilities can square new natural gas plants with emissions targets. For example, Duke Energy's plans include building 2,000 megawatts of new natural gas-fired capacity despite a pledge to reach carbon neutrality by 2050. Duke claims that the switch to hydrogen will help achieve those goals.[12] In Florida, Chesapeake Utilities began testing a 4 percent mix of hydrogen at its power plant.[13] Los Angeles Department of Water and Power has released plans to rely extensively on hydrogen use at natural gas power plants, claiming that hydrogen is necessary to store energy from wind and solar.[14]

Adding small percentages of hydrogen to the natural gas supply, even if produced from renewable electricity, would have negligible, if any, climate benefits. A 5 percent blend of hydrogen results in much less than a 5 percent reduction in emissions when burned, because hydrogen produces less energy than methane when burned.[15] So at power plants, blending 5 percent hydrogen only reduces natural gas use by 2 percent.[16] Based on this reduction in natural gas use, one European utility group estimates that mixing 20 percent hydrogen into residential gas only reduces carbon dioxide (CO_2) emissions by 6.5 percent.[17] A 20 percent blend is the highest share of hydrogen considered by the American Gas Association in its "net zero" report.[18]

The Rickety Gas Grid Can't Handle Hydrogen

A partial or complete switch to hydrogen appeals to corporations because it would maintain our reliance on the current natural gas system. But the current natural gas pipeline system is made up of a wide mixture of materials, making it very difficult to accurately model the impact of adding hydrogen.[19]

What we do know is that a close investigation of natural gas infrastructure shows that there is little worth saving. Only 30 percent of the existing U.S. gas distribution mains were installed in the 2000s, and nearly 10 percent of distribution mains either have no known installation date or were built before 1940.[20] These older pipes are particularly prone to leakage, contributing to an estimated 659,000 leaks from the gas distribution system in the U.S. annually.[21]

Estimates of total leakage in the distribution system vary but are significant. Local distribution pipes in large metropolitan areas leak as much as 6 percent of the gas they carry.[22] In 2011, local distributors reported that, on average, 1.6 percent of the gas delivered was "lost-and-unaccounted-for."[23] A 2022 analysis of six U.S. cities found that despite eight years of repair efforts, methane leakage remained high, largely from undetected sources.[24] Larger transmission pipelines self-report significant or serious accidents (reporting covers a limited portion of events) only once per 3,000 miles annually.[25]

Evidence shows that non-white, lower-income people bear the brunt of natural gas leaks.[26] Policies such as redlining have reduced the ability of Black people to access credit necessary for energy efficiency retrofits, and as a result Black neighborhoods are more likely than white neighborhoods to have aging appliances.[27] Aging appliances are less likely to work as designed and may be particularly dangerous when used with hydrogen.[28] For example, it is relatively common for people to use matches to light their gas burners when the sparkers are broken in their old stoves, leading to more unburned gas escaping from the stove.[29]

Even recently installed appliances can leak natural gas. Modern water heaters have been shown to leak substantial quantities (about 0.4 percent of combusted) natural gas.[30] Gas stoves also emit unburned methane, even when not in use, resulting in the escape of about 0.8 to 1.3 percent of the gas used for the stove.[31] In addition to explosion risks, hydrogen is a potent greenhouse gas in its own right: when emitted, one ton of hydrogen is responsible for 33 times as much warming as one ton of CO_2 over the first 20 years.[32]

Buildings Don't Need Gas Hookups

The hydrogen pitch depends in part on the flawed assumption that there is no other way to eliminate natural gas use in buildings. Buildings that use natural gas primarily use it for heating and cooking, tasks that could easily be electrified.[33] Electrification skeptics cite "realistic renovation rates" as a reason to decarbonize the gas supply (implying that retrofitting buildings for electricity would take too long).[34] However, hydrogen is not compatible with current appliances or pipelines. A report commissioned by the California Public Utilities Commission found that delivering even 5 percent blended hydrogen into natural gas would be "concerning" because of increased leakage from older gas infrastructure.[35]

The public would benefit immensely from a switch to electricity for residential energy. According to the National Renewable Energy Laboratory, electrification can decrease fossil fuel-related carbon emissions by 41 percent (from 2005 levels).[36] These immediate emissions reductions grow as renewables replace fossil fuels in electric generation.[37] Natural gas appliances also emit dangerous pollutants such as particulate matter, nitrous oxides, carbon monoxide, and formaldehyde, which are linked to respiratory illness and cardiovascular disease. Operating a gas-powered stove and oven for an hour can raise indoor pollution to levels that exceed national air quality standards.[38] Hydrogen also emits nitrogen dioxide, a pollutant that can form particulate matter.[39]

Hydrogen won't redeem fracked gas power plants

Promises to keep natural gas power plants open and eventually use hydrogen hide the inconvenient reality that these current power plants cannot actually use significant blends of hydrogen as fuel. Modern gas turbines have very strict fuel mix requirements.[40] While technology to convert hydrogen to electricity with fuel cells exist, turbines for gas plants that run on pure hydrogen are still in the early stages of pilot demonstration and technological development.[41] Corporations prefer turbines that burn hydrogen to fuel cells in part because of "fuel flexibility"— in other words, they want to keep using natural gas.[42]

Switching to hydrogen is likely to add significant costs. Using just 30 percent hydrogen could raise costs by $6.9 to $11.6 per megawatt hour, but only reduce CO_2 emissions by 4.8 to 11 percent.[43] For comparison, solar costs about $36 per megawatt hour but is capable of reducing 100 percent of the emissions from natural gas power plants, making it between 1.7 and 6.7 times more cost-effective than hydrogen at reducing emissions.[44]

Chesapeake Utilities had to modify its gas plant to even use 4 percent hydrogen; to use more hydrogen, the company had to completely replace the turbine.[45] Turbines are the most expensive component of new gas plants, contributing to more than half of direct costs to build a power plant.[46] Other factors like the need to build wider pipes, which existing plants may not have room for, add to the cost of retrofitting.[47]

Using hydrogen in power plants may have significant air pollution impacts. Hydrogen burned for electricity generation can produce six times more nitrous oxides — harmful pollutants that can cause respiratory illness and contribute to the formation of smog — than natural gas.[48] Even an industry-led study of a New York power plant using new technology found a significant increase in nitrous oxide (NO_x) emissions when co-firing with hydrogen.[49]

Proponents claim that they need to burn hydrogen at power plants to provide energy storage when renewable sources are not available.[50] However, this relies on outdated assumptions about other storage technologies, which are now capable of supporting a fully renewable grid at comparable costs to the current system.[51] Using hydrogen at natural gas plants has dramatically higher roundtrip energy losses than other long-term electricity storage technologies.[52]

When using hydrogen produced from renewables to power gas turbines, more than 71 percent of the energy is lost or used during hydrogen production, compression, transport, storage, and combustion.[53] That's about three times the loss of mechanical and battery storage systems, which typically lose 15 to 25 percent of the energy they store.[54] In other words, it is much more efficient and practical to use renewable energy coupled with battery storage.

Hydrogen isn't just a storage technology for renewable energy; it's also a backdoor for natural gas-produced energy to remain in the grid, under the guise of "blue hydrogen," or hydrogen produced from natural gas but with carbon capture and sequestration equipment attached.[55] Producing hydrogen from natural gas, with or without CCS, will not produce meaningful emissions reductions. Burning hydrogen in place of natural gas, even when produced with CCS, actually has higher emissions than simply burning natural gas.[56]

Small Amounts of Hydrogen Pose Big Risk to People's Health and Safety

Even blending relatively small amounts of hydrogen with natural gas could pose tremendous risk to people who use gas in their homes or live near gas storage facilities and pipelines. Adding hydrogen into the mix will increase the risk of pipeline blowouts and explosions of gas-powered appliances. Unlike natural gas, hydrogen cannot be mixed with an odorant, which means that leaks could go undetected — amplifying the risks to health and safety.

Hydrogen is even leakier than fracked gas

Hydrogen is the smallest element and is very likely to leak from pipelines designed for natural gas.[57] Depending on the type of material and on the construction of the pipeline, hydrogen leaks at about three to five times the rate of methane.[58]

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For example, more than half of distribution pipelines that carry gas into homes are made of plastic, a material that hydrogen can diffuse through.[59] Hydrogen's small size allows it to leak through threaded fittings, gaskets, and valve stems.[60]

The higher pressures necessitated by hydrogen may exacerbate leakage. Since hydrogen has only one-third the energy of methane (by volume), delivering the same amount of energy through current pipelines would require significantly raising the operating pressure.[61] Even the best-designed pipes are prone to leaks when added supply increases operating pressure on local distribution lines.[62]

Hydrogen can also damage pipelines, increasing the risk of cracks and ruptures.[63] Many natural gas pipelines are made of metals that, when exposed to hydrogen, are at risk of embrittlement, or the weakening of metals' fatigue resistance, toughness, and tensile strength, among other problems.[64] Embrittlement is particularly hard to predict and control because it is heavily affected by differences in temperature, flow rate, material condition, pressure, and impurities.[65] Despite these dangers, hydrogen transport is regulated far less in the U.S. than in other countries.[66]

Certain types of underground natural gas storage facilities can be damaged by hydrogen, resulting in hydrogen sulfide production, leakage, and bacterial growth.[67] While salt caverns are well suited to hydrogen, many places do not have these geologies. For example, according to SoCalGas, there are no salt caverns (the ideal hydrogen storage geology) in California.[68]

Storage wells pose high risk of accidents as they are often not even designed for methane storage.[69] For example, in 2016 the Aliso Canyon storage facility in California leaked methane for months.[70] Gas production wells that have been repurposed to be storage wells last for decades (median age of 74 years), are likely to exhibit design-related deficiencies, and rarely incorporate protective measures to enhance their structural integrity.[71]

Hydrogen can damage appliances

Hydrogen gas travels at a high speed, making flashback (when flame travels back toward the source) in burners more likely, thereby necessitating different water heaters, boilers, and stoves that can accommodate a mix of hydrogen and methane.[72] Lower air requirements make hydrogen more likely to burn backward into pipes, generating high-pressure explosions that destroy buildings and throw shrapnel.[73]

The higher temperatures required for burning hydrogen also stress appliances.[74] The reaction of older boilers to hydrogen is largely unstudied.[75] According to a report from the University of California at Riverside, household appliances would need to undergo "significant modifications" to be compatible with blends of hydrogen that exceed 5 to 20 percent.[76] Poorly adjusted and maintained appliances cannot handle any level of hydrogen mixing.[77]

Hydrogen is very flammable and hard to detect

Explosion is more likely with hydrogen, as igniting hydrogen requires significantly less energy than natural gas.[78] Hydrogen is 14 times as flammable as natural gas and can be ignited by static electricity.[79] Friction, heat, and electrical fields can all ignite hydrogen.[80] Because of hydrogen's reactivity with atmospheric oxygen, leaks can easily result in gas cloud explosions.[81]

Much like natural gas, hydrogen is odorless and colorless, but unlike natural gas there are no known odorants small enough to travel with hydrogen and act as an early warning of leakage.[82] Odorants may also contaminate fuel cells — an additional challenge for making hydrogen detectable.[83] No single hydrogen sensor meets the U.S. Department of Energy's performance, cost, and reliability targets.[84] Hydrogen requires less air to burn, and hydrogen fires are very pale, making them hard to see.[85] Ventilation is less effective for addressing hydrogen leaks, as the gas ignites at a lower mixture of air than natural gas, and can even explode outside on low-wind days.[86]

Hydrogen is odorless, colorless, and 14 times more flammable than natural gas. With no known odorants small enough to travel with hydrogen to act as early leakage warnings, detecting hydrogen fires requires the use of specialized sensors — none of which currently meet the U.S. Department of Energy's performance, cost and reliability targets.

New hydrogen infrastructure would be extremely expensive

Currently, there are just 1,500 miles of hydrogen pipelines[87] — compared to the 300,000 miles of large interstate gas pipelines and the more than 2.1 million miles of distribution natural gas pipelines.[88] Converting natural gas pipelines to hydrogen (blends above 20 percent would require new pipelines) is very expensive, requiring new materials, sensors, welding, valves, and compressor technology.[89] Pipelines built to transport hydrogen can be up to 68 percent more expensive than natural gas pipelines.[90] Even small-diameter hydrogen pipelines cost more than $1 million per mile.[91] SoCalGas' Angeles Link project would require billions to build hundreds of miles of new pipeline.[92]

Piggybacking current gas infrastructure does not do much to reduce the price tag. By one estimate, modifying current pipelines may only be 20 percent cheaper than building entirely new hydrogen pipelines.[93] Compressor stations built for natural gas also do not work well with hydrogen,[94] so a switch to hydrogen would mean substantial changes to (or even replacement of) the more than 1,400 compressor stations.[95]

Natural gas monopolies can only afford these exorbitant costs by passing the price (plus profit) of approved infrastructure forward in energy bills.[96] Lower-income households and renters are disproportionately impacted by these increased bills. In 2020, nearly 20 percent of households reduced or forwent basic necessities to cover energy bills, and almost 10 percent kept their houses at unsafe or unhealthy temperatures to reduce costs.[97] Black households are more than twice as likely to report energy insecurity than white households.[98]

Even "clean" hydrogen can be dirty

When burned, the heat from hydrogen produces nitrous oxides, which are harmful pollutants and precursors to particulate matter and ozone.[99] NO_x pollution also contributes to the formation of tropospheric ozone, which causes more than 1 million premature deaths annually.[100] Because taking steps to reduce NO_x emissions from combustion lowers efficiency and raises costs, operators tend to prioritize energy efficiency and to neglect NO_x impacts.[101] It is particularly challenging to reduce NO_x emissions from water heaters and stovetops.[102] A literature review of 14 studies found that a mix of just 5 percent hydrogen in residential natural gas raised NO_x emissions by an average of 8 percent compared to traditional natural gas.[103]

So-called "blue hydrogen" produced from natural gas using carbon capture and storage can have a worse greenhouse gas footprint than traditionally produced hydrogen. After accounting for methane leakage associated with hydrogen produced from fracked gas, CCS facilities that achieve high capture rates (which none have done to date) would still have significant greenhouse gas footprints.[104] In fact, natural gas-sourced hydrogen produced using CCS may have only 9 to 12 percent lower emissions than hydrogen produced without CCS.[105] Burning hydrogen in place of natural gas, even when produced with CCS, actually has higher emissions than simply burning natural gas.[106]

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Hydrogen's Water Requirements Are Incompatible With Water Scarcity in Many Regions

Alarmingly, hydrogen is also extremely water intensive, which poses significant hurdles for scaling up production.[107] The U.S. Department of Energy's call for 50 million metric tons of hydrogen production each year by 2050[108] could require up to 1 trillion gallons of freshwater annually,[109] including in areas struggling with historic drought.[110] One trillion gallons of water is equal to the annual water use of over 33 million Americans.[111]

The amount of water needed to produce hydrogen varies with the method of production; the chemical reaction alone requires 1.2 to 2.4 gallons of water per kilogram of hydrogen produced. The process also requires vast quantities of water for cooling, raw water treatment, and water disposal.[112] Finally, upstream energy production itself uses water, with fossil fuels using substantially more water compared to renewables like wind and solar.[113]

Seawater is sometimes used as a water source in hydrogen production to reduce stress on nearby freshwater sources. But this requires desalination, which greatly increases the amount of water and electricity required, and thus poses a threat to some projects' feasibility.[114] Further, the disposal of wastewater and brine produced during the desalination process can have harmful impacts on waterways and ecosystems.[115]

Conclusion: We Don't Need Hydrogen for Heating and Electricity

Rather than doubling down on hydrogen for heating and electricity in the hope that it will rescue bad investments, public policy should commit to powering homes with affordable renewable electricity. Unlike hydrogen, renewable electric alternatives have a proven track record at low costs.

Across their lifetimes, solar and wind energy projects cost $36.50 and $40 per megawatt hour, respectively, in 2020, down from $248 and $123.50 per megawatt hour just over a decade earlier.[116] These levelized costs are far cheaper than generating electricity from new nuclear or coal power plants, and are often cheaper than natural gas plants.[117] Moreover, advances in storage and reliability technologies have torpedoed the fossil fuel industry's claim that 100 percent renewable energy is not possible because "the wind doesn't always blow and the sun doesn't always shine." Scientific advances now mean that off-the-shelf, commercially available technology could support a power grid without any fossil fuels.[118]

One-fourth of households in the U.S. already rely entirely on electricity for their energy needs.[119] While colder states are more likely to use natural gas for heating, improvements to heat pump technology mean that many new homes are all-electric even in these areas; for example, 7 percent of households in both New York and Michigan are all-electric.[120]

A hydrogen future would be an expensive and frightening mess. But these outcomes could be easily avoided so long as political leaders recognize these hydrogen blending schemes for what they are: A last ditch attempt to protect a dying industry from safer, more effective technologies. It's time to fight for a renewable and electric future — one that we have the power to win.

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