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HYDROGEN PIPE DREAMS: WHY BURNING HYDROGEN IN BUILDINGS IS BAD FOR CLIMATE AND HEALTH

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About PSR

Working for over 50 years to create a healthy, just, and peaceful world for both present and future generations, Physicians for Social Responsibility (PSR) uses medical and public health expertise to educate and advocate on urgent issues that threaten human health and survival. Our goals are to slow and eventually reverse climate change and to abolish nuclear weapons.

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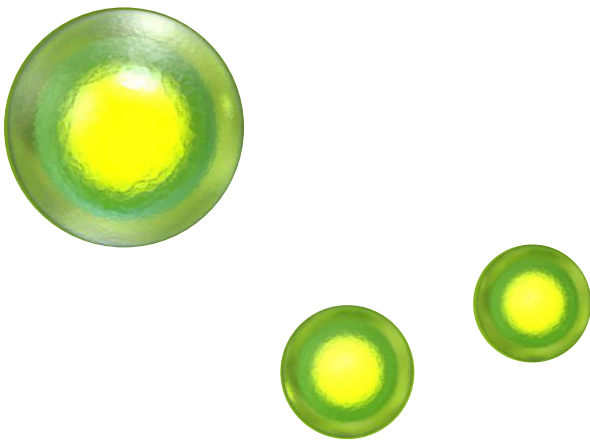


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EXECUTIVE SUMMARY

Fossil fuel companies are advocating blending hydrogen with “natural” gas (methane) for cooking and space and water heating. They claim this will generate heat while lowering the carbon footprint of the methane gas system. In fact, it will not. Most hydrogen gas is derived from methane or coal, both of which are major sources of greenhouse gases, so utilizing hydrogen will actually increase greenhouse gas emissions. And using hydrogen to blend with methane increases the demand for and prolongs our dependence on methane, an extremely potent greenhouse gas. Meanwhile, it distracts from the uptake of renewable energy sources and cost-effective, efficient electric technologies proven to reduce greenhouse gas emissions. With the window closing to address the climate crisis, we cannot afford this false solution.

What is hydrogen and how is it made?

Hydrogen is the most abundant molecule in the universe, but there is very little hydrogen gas; hydrogen is almost entirely found in chemical compounds like water and hydrocarbons. To make hydrogen gas, energy is used to separate hydrogen from these other compounds. Virtually all hydrogen gas (99 percent) in the United States is generated from fossil fuel hydrocarbons, particularly from methane but also from coal gasification.

The pathways of producing hydrogen gas differ significantly in their greenhouse gas intensity. These pathways are typically referred to by colors — most commonly, gray, blue, and green.

Gray hydrogen is made from methane using a process known as steam methane reformation (SMR). In SMR, methane reacts with steam under pressure to produce hydrogen, carbon monoxide, and carbon dioxide. This process requires – obviously – continued use of methane, which has a very high global warming potential. Over its first 20 years in the atmosphere, methane is 84 to 87 times more warming than carbon dioxide.

Blue hydrogen is gray hydrogen (or brown hydrogen made from coal) coupled with carbon capture and storage. These processes require additional energy, making blue hydrogen even more greenhouse gas-intensive. Some but not all of the carbon dioxide produced from making hydrogen is captured and reused or stored.

In this paper, we refer to gray and blue hydrogen as fossil hydrogen, as both derive from fossil fuels.

Green hydrogen is made using 100 percent renewable electricity to separate out hydrogen from water. Only green hydrogen is a zero-emissions fuel and truly renewable. However, less than one percent of the hydrogen currently being produced is green hydrogen, making it virtually nonexistent for large-scale and industrial uses.

While burning green hydrogen is an inefficient, costly way to heat buildings, green hydrogen is very useful for decarbonizing hard-to-electrify industries. In fact, it is critical that we reserve the limited supply of green hydrogen for applications for which it is indispensable, such as fertilizer production. It also has potential for use in steel production, electric grid power-balancing, and long-distance transport, including trucking, shipping, and aviation. Using limited supplies of green hydrogen to inefficiently heat homes and businesses wastes this valuable resource.

Hydrogen blending's six failings

Fossil hydrogen gas should not be blended with methane gas for heating and cooking for multiple reasons. Doing so:



1. Increases greenhouse gases: Blending fossil hydrogen with methane will increase greenhouse gases, putting human health and a livable environment at risk. There is essentially no commercially available green (zero-emissions) hydrogen, and emissions from producing fossil hydrogen gas (gray or blue) can exceed the greenhouse gas emissions from methane or coal. Furthermore, use of hydrogen can cause new and larger leaks in gas pipelines, which also would contribute to increases in greenhouse gases.



2. Maintains dependence on unhealthy methane gas: Blending fossil hydrogen with methane will significantly increase demand for hydrogen, as hydrogen has never before been used for heating in the building sector. This additional demand will drive up the need for methane, from which most hydrogen is made. And even with hydrogen blending, most of the energy for heating homes will still come from methane, due to limitations on the amount of hydrogen that can be blended safely for use in existing appliances. The result: more methane extraction, most of it by fracking; more contamination of water and land; more harms to health, and more greenhouse gas emissions and dangerous global warming.



3. Uses renewable energy inefficiently with little climate benefit: Blending green hydrogen with methane to power home appliances is less efficient than using renewable energy to power cooking and heating appliances directly. Using the limited supply of green hydrogen for blending with methane reduces its availability for industrial uses like fertilizer production, for

which electrification is not a viable solution. It also siphons our limited sources of renewable energy away from the electric grid, where they can be used to power buildings more efficiently than hydrogen. Furthermore, green hydrogen can only be blended safely with methane at 10 to 20 percent by volume; levels above that would require retrofitting or replacing all gas appliances. Yet even a 20 percent blend would only reduce greenhouse gases by at most six percent.



4. Increases costs: The high costs of hydrogen production and delivery could result in dramatic increases in fuel costs for people using methane for heating and cooking. These price increases will hurt all gas users, but low-income households will suffer most. To realize significant emissions reductions, higher concentrations of hydrogen would be necessary. This, however, would necessitate switching out current gas appliances for hydrogen-compatible appliances, at considerable cost to consumers.



5. Raises safety risks: Hydrogen ignites more easily and is more explosive than methane, thus increasing the danger of explosions in buildings. It places lives at risk.



6. Perpetuates health inequities: The production of hydrogen from methane further contributes to air pollution, as will burning hydrogen gas in buildings. Burning methane emits pollution that contributes to asthma, heart disease, and premature deaths. Black, Indigenous and People of Color, who already face disproportionate health burdens due to air pollution and climate change, will again be harmed disproportionately. Thus, using hydrogen and methane for heating and cooking will perpetuate and deepen existing health inequities.

A Call to Action

PSR opposes the blending of hydrogen with methane for combustion in homes and other buildings. In its place, we support effective decarbonization and electrification strategies that will protect health, safety, and the climate. We encourage health professionals, policymakers, and the public to **take action**:

1. Oppose plans to blend hydrogen with methane for heating and cooking in buildings.
2. Support the use of green hydrogen for hard-to-electrify industries.
3. Oppose the use of green hydrogen to justify maintaining or developing fossil fuel infrastructure.
4. Educate policy makers, colleagues, and the public about the unacceptable climate, health, and safety impacts of hydrogen combustion for heating and cooking.

Policy Recommendations

1. Promote and expand the direct use of renewably generated electricity to heat buildings. Support options such as promoting efficient electric appliances like heat pumps through point-of-purchase rebates; emissions performance standards for buildings; all-electric building codes; renewable requirements for electricity production, and expanded energy storage to enhance grid resilience and performance.
2. As part of the process for considering permits for hydrogen projects, require an Environmental Impact Assessment, Comprehensive Health Impact Assessment, and a cost-effectiveness analysis comparing burning hydrogen with lower-pollution options including energy efficiency, renewable energy, and energy storage options.
3. Require accounting of the full-lifecycle greenhouse gas emissions of producing hydrogen. Greenhouse gas emission inventories must take all those emissions into account.
4. Require certification of “green” hydrogen to assure it is produced using truly renewable, and 100 percent renewable, energy sources.
5. State public utility commissions and state legislatures should not allow gas utilities to raise ratepayer rates to purchase hydrogen for blending, nor should they allow hydrogen to qualify for “clean heat” credits.

INTRODUCTION

There is no time for false solutions

In 2021, in an unprecedented action, the *New England Journal of Medicine* and over 200 other health journals published a joint “Call for Emergency Action to Limit Global Temperature Increases, Restore Biodiversity, and Protect Health.” They stated:

The science is unequivocal: a global increase of 1.5° C above the pre-industrial average and the continued loss of biodiversity risk catastrophic harm to health that will be impossible to reverse.*

Fossil fuel companies are advocating blending hydrogen with “natural” gas (methane) for cooking and space and water heating. They claim this will generate heat while lowering the carbon footprint of the methane gas system. In fact, it will not. Most hydrogen gas is derived from methane or coal, both of which are major sources of greenhouse gases, so utilizing hydrogen will actually increase greenhouse gas emissions. And using hydrogen derived from fossil fuels to blend with methane increases the demand for and prolongs our dependence on methane, an extremely potent greenhouse gas. Meanwhile, it distracts from the uptake of renewable energy sources and cost-effective, efficient electric technologies proven to reduce greenhouse gas emissions. With the window closing to address the climate crisis, we cannot afford this false solution.

The climate crisis is already a health emergency, affecting people across the United States and around the world with poor air quality, extreme heat, extreme cold, wildfires, hurricanes, flooding, droughts, and vector-borne illnesses and causing disease, injury, hunger, and deaths.¹ Limiting the expansion of the leaking methane gas infrastructure is an essential component of reining in life-endangering climate change. According to the Intergovernmental Panel on Climate Change, limiting greenhouse gases, especially methane, will have both climate and health benefits.²

What is hydrogen and where does it come from?

Hydrogen is the most abundant molecule in the universe, but there is very little hydrogen gas; hydrogen is found almost entirely in chemical compounds like water and hydrocarbons. To make hydrogen gas, energy is used to separate hydrogen from these compounds. The majority of hydrogen gas in the United States – 99 percent – is produced from fossil fuels, most of it methane; some comes from coal gasification.^{3,4} Worldwide production of hydrogen gas is responsible for greenhouse emissions equivalent to around 830 million metric tons of carbon dioxide per year.⁵ That is comparable to almost twice the 2020 emissions limit of the State of California (431 million metric tons),⁶ which, if it were its own country, would be the fifth-largest economy in the world.⁷

The pathways for producing hydrogen gas differ significantly in the amount of greenhouse gases they produce. These pathways are typically referred to by colors — gray, blue, and green being the most common.

*Atwoli L, Baqui AH, Benfield T, et al. Call for Emergency Action to Limit Global Temperature Increases, Restore Biodiversity, and Protect Health. *N Engl J Med*. 2021 Sep 5. DOI: 10.1056/NEJMe2113200. <https://www.nejm.org/doi/10.1056/NEJMe2113200>

Fossil hydrogen by any other name is bad for the planet

Fossil hydrogen may be deceptively labeled. Its proponents sometimes call it low-carbon, clean, gray, blue, turquoise, black, or brown. By any name, using fossil hydrogen in pipelines will exacerbate the climate crisis.

The only form of hydrogen whose production does not emit greenhouse gases is green hydrogen – and the amount of green hydrogen produced is miniscule.

Gray hydrogen is made from methane using steam methane reformation (SMR). In SMR, methane reacts with steam under pressure to produce hydrogen, carbon monoxide, and carbon dioxide.⁸ This process requires – obviously – continued use of methane, which when leaked into the atmosphere has a very strong heat-trapping effect. Over a 20-year period, methane’s Global Warming Potential (GWP)* is 84 to 87 times greater than that of carbon dioxide.⁹

When burned, hydrogen emits primarily water and nitrogen oxides, and no carbon dioxide.¹⁰ The greenhouse gas emissions are associated with the production of gray hydrogen: leaks of methane across the methane supply chain, and greenhouse gas emissions emitted from the SMR process.

Blue hydrogen is gray hydrogen or brown hydrogen (made from coal) coupled with the capture and storage of the carbon dioxide that is generated. However, not all the carbon dioxide produced in the process is captured and reused or stored. Most notably, blue hydrogen, like other hydrogen made from fossil fuels, generates greenhouse gases from upstream methane leaks and in the SMR process, and none of those emissions are captured.

In this paper, we refer to all hydrogen made with fossil fuels as “fossil hydrogen.”

Green hydrogen is made with an electrolyzer through a process known as electrolysis, which uses electricity to separate water into hydrogen and oxygen. Because it uses 100 percent renewable electricity to do this, it is a zero-carbon-emissions fuel and truly renewable. However, in 2018 green hydrogen made up less than one percent of the hydrogen produced in the world.¹¹

Because of the very limited supply of green hydrogen, most hydrogen blended with methane gas today will be fossil hydrogen and will increase greenhouse gas emissions.

*According to the U.S. Environmental Protection Agency, “The Global Warming Potential (GWP) was developed to allow comparisons of the global warming impacts of different gases. Specifically, it is a measure of how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide (CO₂). The larger the GWP, the more that a given gas warms the Earth compared to CO₂ over that time period.” Environmental Protection Agency (EPA). Understanding Global Warming Potentials. <https://www.epa.gov/ghgemissions/understanding-global-warming-potentials>

EXPANDING THE USE OF FOSSIL HYDROGEN IS A THREAT TO THE CLIMATE

Blending hydrogen with methane gas is a new use for hydrogen in the United States. This proposed use would significantly increase the demand for fossil hydrogen, and consequently, the demand for methane gas. That would have dire consequences for the climate.

Hydrogen is touted as a zero-emissions fuel, but it is the production of hydrogen, not its combustion, that generates greenhouse gases.¹² To turn hydrogen into a gas requires energy from other sources, and it is the greenhouse gas emissions of that energy that determine hydrogen's climate impact. All too often, the calculation of the carbon intensity of hydrogen gas fails to include the greenhouse gases released in extracting and transporting the methane from which fossil hydrogen is made, or the additional greenhouse gases that are generated when additional processes are used to capture carbon dioxide and create blue hydrogen. These sources are known as the full "lifecycle" emissions, and they need to be taken into account. When lifecycle greenhouse gas emissions are considered, fossil hydrogen actually contributes more greenhouse gases than methane to produce the same amount of heat.¹³

Gray hydrogen climate impacts

Producing gray hydrogen generates high greenhouse gas emissions, both from the carbon dioxide generated during the hydrogen production process and from the upstream methane leaks into the atmosphere, also called "fugitive emissions."^{14,15} Methane must be extracted and transported to the hydrogen production site, and that methane leaks from wells, wellsite gas processing, compressor stations and pipelines.¹⁶ When all those emissions are accounted for, gray hydrogen lifecycle emissions are 30 percent higher than an equivalent amount of energy from methane.¹⁷

Blue hydrogen climate impacts

Companies within the United States¹⁸ and the United Kingdom¹⁹ have proposed transforming gray hydrogen to blue by using carbon capture and storage, or CCS, to reduce the release of the greenhouse gases produced by steam methane reformation and coal gasification. However, capturing CO₂ has disadvantages. Because it is an energy-intensive process, it produces additional greenhouse gas emissions.²⁰ Furthermore, it captures CO₂ at widely varying rates, from 56 percent to a theoretical high of 90 percent.²¹ (In practice, CCS has not lived up to the theoretical capture rate of 90 percent.²²) Finally, commercial-scale, long-term storage of CO₂ may not be feasible; there is uncertainty that

Lifecycle emissions measure the actual climate impact

Lifecycle emissions include all the greenhouse gases that are emitted in the extraction, processing, transport, and use of a fuel. Only when all these aspects are assessed will we have a full and accurate rendering of the fuel's impact on the climate.

CO₂ can be stored indefinitely without leakage.²³ So long as CCS remains in unproven realm of the research and development,²⁴ we cannot rely on it to protect the climate.*

Even if the industry were able to slash leakage rates and achieve optimal carbon capture rates, blue hydrogen would still produce more than three metric tons of CO₂-equivalent for every metric ton of hydrogen.²⁵ (CO₂-equivalent is a metric used to compare emissions from various greenhouse gases.) For blue hydrogen to be a carbon-neutral fuel, methane leak rates would have to drop precipitously to less than 0.1 percent and carbon capture rates would have to reach 90 percent. This technological capacity is not at hand.

Once lifecycle emissions are included, blue hydrogen is worse than coal. That was the finding of a peer-reviewed study that concluded that the “greenhouse gas footprint of blue hydrogen is more than 20 percent greater than burning methane gas or coal for heat and some 60 percent greater than burning diesel oil for heat.”²⁶ The authors add, “We suggest that blue hydrogen is best viewed as a distraction, something that may delay needed action to truly decarbonize the global energy economy...”

Hydrogen blending can cause more gas leaks from pipes

Blending hydrogen with methane can cause more gas leaks as hydrogen gives rise to “embrittlement” of the steel pipes making up the gas transmission system. Embrittlement occurs when metals become more brittle because of diffusion of hydrogen into the material. This can cause cracks and accelerate fatigue crack growth in pipes, especially in high-pressure transmission pipelines.²⁷ It can also degrade the polymers used to seal joints in the gas distribution system,^{28, 29} allowing additional methane to leak from pipe joints in buildings, a source of climate-changing emissions that is often overlooked.^{30, 31}

Hydrogen leakage may not have as severe an impact on the climate as methane leakage, but its impact is not zero.³² Hydrogen triggers chemical

*CCS poses risks to health as well as to the climate. Should the extensive network of pipelines needed to carry compressed CO₂ to a storage site rupture, exposure to this heavier-than-air substance would be potentially lethal. The rapidly accelerating symptoms and outcomes of exposure include respiratory acidosis, confusion, dimmed sight, tremors, unconsciousness, convulsions, coma and death. U.S. Environmental Protection Agency. Appendix B – Overview of Acute Health Effects. <https://www.epa.gov/sites/default/files/2015-06/documents/CO2appendixb.pdf>

reactions that prolong the life of methane in the atmosphere. Until recently, the only published calculation of hydrogen's global warming potential (GWP) was 5.8 over a 100-year time horizon.³³ The most recent research, which considers hydrogen's impact in the stratosphere, estimated the GWP for a 100-year time horizon was actually twice as large: 11, with an uncertainty range of 6 to 16. For a 20-year time horizon, it was estimated the GWP for hydrogen was 33, with an uncertainty range of 20 to 44.³⁴ The researchers concluded that, to realize the benefits of a green hydrogen economy, minimizing hydrogen leaks during production, storage, distribution, and use must be a priority. In the leak-prone infrastructure of the methane gas system, that will not be possible for decades.

Emissions accounting

Unfortunately, governments sometimes fail to count these associated emissions, resulting in an inaccurate characterization of hydrogen's climate impact. For example, in the Infrastructure and Jobs Act signed into law by President Biden, \$9.5 billion was allocated to develop "clean hydrogen," but it did not specify that lifecycle emissions be counted or that it be green hydrogen.³⁵ This lack of specificity opens the door to climate-damaging forms of hydrogen being used under the misleading term "clean." Similarly, the European Commission voted in 2021 to define blue hydrogen as "low-carbon."

The stakes for miscounting emissions from hydrogen are high. The Chair of Intergovernmental Panel on Climate Change (IPCC) Working Group warned,

The scientific evidence is unequivocal: climate change is a threat to human wellbeing and the health of the planet. Any further delay in concerted global action will miss a brief and rapidly closing window to secure a livable future.³⁶

The blending of fossil hydrogen with methane will accelerate climate change, not reduce it, and will exacerbate the associated health emergency facing the world.

HYDROGEN BLENDING WILL LOCK IN RELIANCE ON METHANE



Spotlight: American Medical Association Acknowledges Harms of Fossil Hydrogen

In June 2022, the American Medical Association (AMA) acknowledged the harms of fossil hydrogen, passing a resolution recognizing “the health, safety, and climate risks of current methods of producing fossil fuel-derived hydrogen and the dangers of adding hydrogen to natural gas.”

The AMA further resolved to “advocate to appropriate government agencies such as the EPA and the Department of Energy, and federal legislative bodies, regarding the health, safety and climate risks of current methods of producing fossil fuel derived hydrogen and the dangers of adding hydrogen to natural gas.”

American Medical Association, 2022. Preliminary Report. <https://www.ama-assn.org/system/files/a22-refcmte-d-report-annotated.pdf>

Hydrogen blending is a sophisticated technique that allows the gas industry to significantly expand the demand for fossil hydrogen where it has never been used before, and in so doing to extend demand for methane into the future. That plan is already well underway, with pilot programs testing hydrogen/methane blends in multiple countries including the United Kingdom, Germany, the Netherlands, Australia, South Korea, Japan, and parts of the United States. Their stated goal is to determine the blend’s safety and viability in residential and commercial buildings.³⁷

At a time when carbon dioxide and methane emissions must be drastically reduced, the public is falsely promised a “low-carbon” gas system realized through hydrogen blending. In reality, the gas industry will use more methane to make fossil hydrogen than it would take to deliver methane directly. Moreover, this would solidify the nation’s reliance on the methane gas system even if we were to blend the methane with green hydrogen. The gas system would continue to expand,³⁸ thus propping up an industry that contaminates the land, air and water through fracking and relies on an infrastructure that leaks methane into the atmosphere,³⁹ driving world temperatures ever upwards.

Hydrogen blending prolongs the reliance on methane gas and expands the demand for it. To maximize the health benefits of mitigating climate change, the use of fossil hydrogen to heat buildings must be avoided.

USING GREEN HYDROGEN FOR HEATING IS AN INEFFICIENT USE OF RENEWABLE ENERGY

Green hydrogen made with 100 percent renewable electricity is the only form of hydrogen that can be considered zero-emission. While theoretically green hydrogen could reduce greenhouse gases when blended with methane, it won't be available for decades at the quantities needed. **Currently, green hydrogen makes up less than one percent of all commercially available hydrogen worldwide.**⁴⁰ Even if all the green hydrogen projects currently planned across the world were to come online by 2030, they are only estimated to reach eight million metric tons.⁴¹ The projects would not meet current demand for hydrogen for industrial uses in the U.S. alone, estimated at 10 million metric tons.⁴² Moreover, the pace of renewables installation will be insufficient to meet increased demands of both the electrification of vehicles, buildings and other sectors, and the growing demand for green hydrogen in the industrial sector.⁴³ We have a long way to go to meet our goals for the electric grid alone: the U.S. currently has only 20 percent renewable and clean energy on the electric grid, with the potential of reaching 50 percent by 2030.⁴⁴

The majority of hydrogen gas available today and in the foreseeable future will be made from methane and thus will increase the demand for that climate-damaging fossil fuel.

Blending hydrogen is limited by end-use appliances

Even if there were enough green hydrogen to blend with methane, it confers a minimal climate benefit at the low levels of blending we are likely to see. Several factors suggest that the concentration of hydrogen that can be blended with methane will necessarily be constrained. The first limitation of blending hydrogen has to do with home appliances such as gas-burning heating systems, water heaters, and stoves. Appliances developed and tested to burn methane cannot burn high quantities of hydrogen safely. Gas properties such as explosivity, flammability, ignition, dispersion, and ability to carry odorants for leak detection all differ when hydrogen is added to methane.

How much blending a gas system can withstand without undue risks to safety is being studied by countries around the world. While the issue is affected by many factors, including the purity of the methane and the manufacturing standards for the appliances, estimates for a safe proportion of hydrogen, without having to retrofit or replace appliances manufactured to burn methane, generally fall between five and 20

A Better Alternative Already Exists: The Heat Pump

“Heat pumps offer an energy-efficient alternative to furnaces and air conditioners for all climates. Like your refrigerator, heat pumps use electricity to transfer heat from a cool space to a warm space, making the cool space cooler and the warm space warmer...Because they transfer heat rather than generate heat, heat pumps can efficiently provide comfortable temperatures for your home.”

U.S. Department of Energy,
<https://www.energy.gov/energysaver/heat-pump-systems>

percent by volume.^{45,46} Australia’s national hydrogen plan limits blending of hydrogen to 10 percent by volume,⁴⁷ while the U.K. Health and Safety Executive report and Canada’s national hydrogen plan both concluded that concentrations of hydrogen in methane of up to 20 percent by volume were safe.^{48,49} However, a study by Fraunhofer Institute for Energy Economics cautioned, “In order to exceed a 20 percent hydrogen blending threshold, it would be necessary to completely and abruptly switch distribution grids to 100 percent hydrogen supply,”⁵⁰ which consequently would mean installing all new hydrogen-compatible pipes and appliances.

Blending is insufficient to meet climate targets

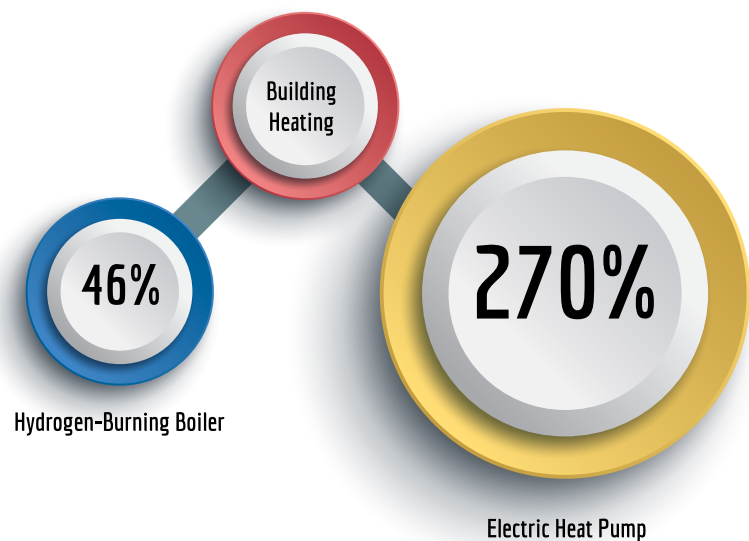
A second limitation to blending hydrogen is its low density. A U.S. congressional report explains why: “Hydrogen has the highest energy content by weight of any fuel, but has comparatively low density, so it requires a greater physical volume for the same energy as other fuels.”⁵¹ This low density means a hydrogen blend of 20 percent by volume provides only about seven percent by energy content. The difference in density also means there is not a linear relationship between volume and greenhouse gas reductions: **A 20 percent blend by volume only reduces greenhouse gases by at most six percent,**⁵² and higher blends, which can have a greater impact on climate, cannot be realized without huge investments in new gas infrastructure, including new end-use appliances, new gas meters, new pipes, and larger compressor stations. To reach zero emissions from burning gas, 100 percent green hydrogen is needed. However, that supply of green hydrogen does not exist and will not exist for decades: Less than one percent of hydrogen gas today is green.⁵³

Heat pumps are more efficient than green hydrogen

A broad consensus has emerged that the direct use of electricity should be maximized whenever it is technically viable and practical.⁵⁴ Delivering electricity generated by a renewable energy source and using it directly for heating and cooking is far more efficient than using renewable energy to make green hydrogen to then blend with methane and burn to heat buildings or cook food.

That option is readily available today, thanks to highly efficient electric heat pumps for heating and cooling and induction cooktops for cooking. Heating a building with a heat pump is a far more efficient use of renewable energy than is hydrogen blending, even with green hydrogen. In comparing two zero-emission scenarios — using electricity from 100 percent renewables to power heat pumps, or burning 100 percent green hydrogen in a hydrogen-compatible boiler — heat pumps have been found to be five to six times more efficient.⁵⁵ That is significant, given that space and water heating in buildings represents almost one-sixth of total energy demand in the US today.⁵⁶ Furthermore, providing sufficient clean hydrogen for all home heating needs would require more than 80 million metric tons of green hydrogen a year.⁵⁷ This is an eight-fold jump even from the current 10 million metric tons of *fossil* hydrogen produced in the U.S. for petroleum refining and ammonia production.⁵⁸ The amount of renewable energy needed to make that amount of green hydrogen would be enormous: According to the International Energy Agency, to produce even the amount of hydrogen made today would, if made using hydrolysis, result in an electricity demand that exceeds the total annual electricity generation of the European Union.⁵⁹

Figure 1: Energy Efficiency Comparison: Heat Pumps 6x More Efficient



The Energy Transitions Commission, 2021



Spotlight: Using Green Hydrogen to Balance the Grid

“Grid balancing” is storing energy during periods of high renewable energy production and low power demand in order to absorb excess renewable energy. The stored energy can be sent back to the grid at periods of low production from renewables and high demand.

Currently in the U.S. when there is high demand and low renewable energy production, grid operators turn on fossil fuel plants, but we need other options in the future. Green hydrogen electrolyzers paired with wind turbines can make hydrogen when the wind is blowing but demand is low (typically at night) and the hydrogen can be made back into electricity through a non-emitting fuel cell to power the grid.* Hydrogen is one solution for grid balancing that is being tested in the United States.**

An appropriate role for green hydrogen in a low-carbon future

While burning hydrogen to heat buildings is an inefficient use of this scarce resource, green hydrogen can decarbonize hard-to-electrify industries. It’s critical to reserve the limited supply of green hydrogen for applications for which it is currently used, such as fertilizer production and oil refining. It also has the potential to be used for steel production, electric grid power system balancing, and long-distance transport, including trucking, shipping, and aviation.⁶⁰ Using the limited supply of green hydrogen to inefficiently heat homes and businesses wastes a valuable clean fuel.

The limited amount of renewable energy available over the next couple of decades is more efficiently used for powering heat pumps.

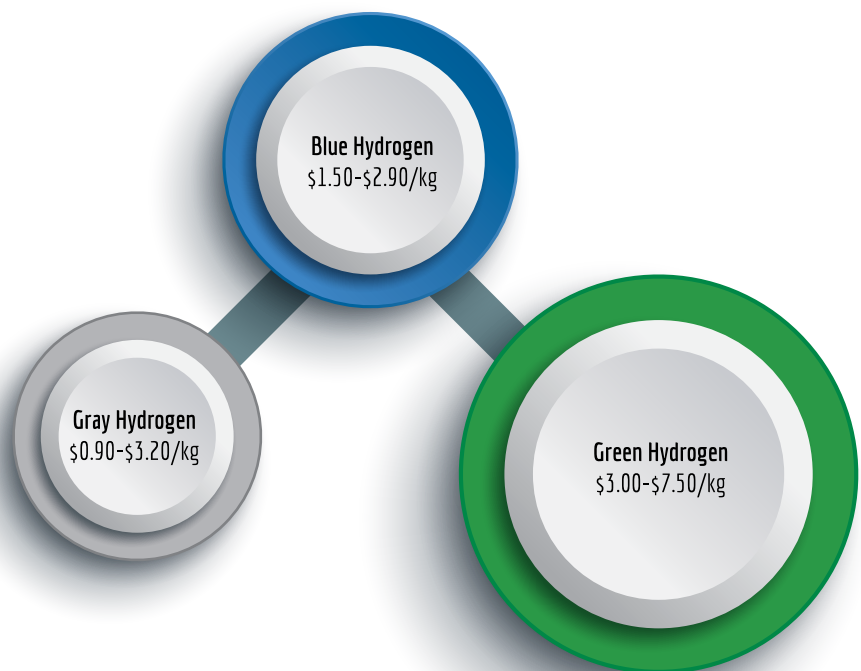
*Stamatakis E, Perwög E, Garyfallos E, Millán MS, Zoulias E, Chalkiadakis N. Hydrogen in Grid Balancing: The European Market Potential for Pressurized Alkaline Electrolyzers. *Energies*. 2022; 15(2):637. <https://doi.org/10.3390/en15020637>

**U.S. Department of Energy (DOE). Department of Energy Hydrogen Program Plan. 2020. <https://www.hydrogen.energy.gov/pdfs/hydrogen-program-plan-2020.pdf> Accessed 4/20/22

BLENDING HYDROGEN WILL INCREASE CONSUMER COSTS

Blending hydrogen with methane will increase the cost of gas-based cooking and space and water heating. The cost of making even gray hydrogen will always be greater than the cost of the methane from which it is produced. As for blue hydrogen, the International Energy Agency estimates that adding carbon capture and sequestration to an SMR plant will increase costs by 50 percent in capital costs, an additional 10 percent for fuel costs, and a doubling of operational costs for CO₂ transport and storage.⁶¹ As for green hydrogen, its production cost is currently twice as high as that of gray hydrogen.⁶²

Figure 2: Cost Comparison of Three Modes of Hydrogen Production



International Energy Agency, 2019

The Biden administration announced its goal to reduce the price of what they consider “clean” hydrogen (blue and green) to one dollar per kilogram (kg) in one decade,⁶³ but even that is still more expensive than current prices of methane. Even if the target of one dollar per kg of hydrogen were reached, the additional costs of delivering hydrogen would further drive up the cost. To move the same energy content of hydrogen compared to methane requires higher volumes of hydrogen gas, necessitating larger compressor stations and more energy to move the hydrogen through pipelines. In addition, because hydrogen is derived

from methane, using fossil hydrogen gas would drive up prices in homes for gas used for heating and cooking.⁶⁴ And as the price of methane rises, so too will the price of methane-derived hydrogen.

To eventually reach near-zero levels of greenhouse gas emissions, the gas system would have to be transitioned to accommodate high blends of green hydrogen or even 100 percent green hydrogen. This transition would require replacing miles of transmission and distribution pipes, compressors, storage tanks, meters, and other components.⁶⁵ It would also require that all gas appliances — furnaces, boilers, water heaters, gas stoves, etc. — be replaced because they would not be able to burn hydrogen safely at such high blends.⁶⁶ More inspections and additional safety monitoring tools would also be necessary,⁶⁷ at considerable cost.⁶⁸ These enormous costs of transforming the methane gas distribution system would be passed on to ratepayers and taxpayers.

Scaling up green hydrogen is more costly than decarbonizing buildings through electrification because of the difference in efficiency between green hydrogen and heat pumps.⁶⁹ As governments and regulatory bodies contemplate the path to zero emissions, future costs are important. In one reputable cost-effectiveness study, conducted by the International Council on Clean Transportation, heat pumps were found to be 50 percent less expensive than hydrogen boilers powered by 100 percent hydrogen.⁷⁰

If the U.S. were to rely heavily on hydrogen instead of heat pumps, it would drive up fuel prices and require large investments in new appliances and gas infrastructure. Little would be obtained in the way of climate protection.

SAFETY RISKS OF HYDROGEN

Appliances May Not Stand Up to Hydrogen

NaturalHy, a European Commission-supported project set up to investigate whether hydrogen could be delivered safely via the existing European natural gas network, concluded,

“The practical aspect that has not been considered is the lifelong physical integrity of gas utilization equipment since all current end-use equipment has been designed, tested and approved for natural gas and not mixtures containing hydrogen.”⁷²

Blending hydrogen with methane isn't just more expensive; it also presents additional safety hazards. Hydrogen ignites more easily and is more explosive than methane.⁷¹ NaturalHy, a European-funded project to study hydrogen blending, warned that “poorly adjusted appliances” should not be used with blended hydrogen.⁷² It is unknown how many U.S. appliances would fall into that vague category. Moreover, methane is already leaking inside residential and commercial buildings when appliances are in use and when they are turned off.^{73,74} Hydrogen could make these leaks more dangerous. The U.S. National Renewable Energy Laboratory noted that that gas leakage from seals at joints in service lines in confined spaces may increase safety risk and noted that “this topic warrants additional risk assessment.”⁷⁵ In the United Kingdom, a comprehensive risk assessment conducted by Hy4Heat evaluating a theoretical methane-hydrogen blend predicted that the number of explosions per year and the risk of injuries from in-home explosions would be four times higher with a 20 percent blend of hydrogen compared to methane alone. The assessment notes that the risk could be reduced with excess flow valves.⁷⁶ The safety risks of blending hydrogen with methane in buildings in the United States remains unknown.

Blending gas can result in changes to heating value, flame stability, and flashback. The risk of flashback is an important parameter for evaluating the safety of appliances inside the home. Flashback can occur when the flame is burning at a higher speed than the incoming gas is traveling and thus travels up into the gas line.⁷⁷ The flame is extinguished, but gas may continue to build up. Flashbacks can lead to appliance shutdown and damage to the appliance and can be a safety hazard because they can lead to gas leaks in enclosed areas.⁷⁸ According to a theoretical analysis of the risk of flashback in appliances designed for burning methane, hydrogen blends with more than 10 percent hydrogen would have an increased risk of flashback,⁷⁹ while an experimental analysis found the flashback limit was 25 percent hydrogen.⁸⁰ The experimental analysis also found that a 10 percent hydrogen blend increased the burner temperature by 63 percent compared to operating with methane gas; such a high temperature may degrade the burner material and also increase the risk of flashback.⁸¹

Methane leaks inside buildings and hydrogen could make these leaks more dangerous

Two recent studies have documented methane leaks from appliances in the home even when the appliances are turned off.^{73, 74}

There are no long-term studies of the durability of household appliances exposed to hydrogen.⁸² In fact, the U.S. Department of Energy's Hydrogen Program Plan concludes that "Additional R&D is also needed to assess the compatibility of hydrogen blends with equipment designed for using natural gas (e.g., building appliances)."⁸³ In the U.K., the Health and Safety Executive found that for hydrogen blending above 20 percent, modern appliances fitted with flame failure devices may shut down and default to a safe condition. For some older types of gas appliance not fitted with flame failure devices, there may be an increased risk of flame failure leading to internal gas escapes.⁸⁴ The United States has different manufacturing standards for appliances and a comparable risk assessment for U.S. appliances was not found in this review.

In California, as of the time of this writing, SoCalGas is constructing a model home to test the safety of blending hydrogen with methane in appliances.⁸⁵ It isn't clear from SoCalGas's press statement if they plan to test the blended hydrogen on a sample of appliances that reflects the variety and age of gas cooking stoves, dryers, water heaters, boilers, furnaces, etc. found in the U.S., but such studies are needed. Those studies should be conducted by independent researchers. Most hydrogen demonstration projects are co-sponsored by fossil fuel companies,^{86,87,88,89} and few studies of safety and health are conducted by researchers not receiving funding from fossil fuel interests.

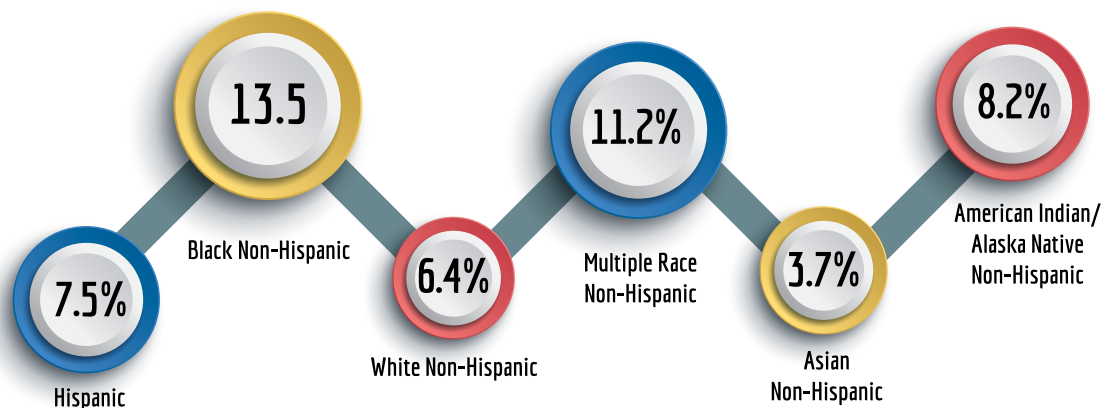
Blending hydrogen increases safety risks. More independent research is necessary to determine if or how hydrogen can be delivered into residential and commercial buildings safely. It will take decades of planning, infrastructure updates, and the development of new regulations to implement. In any case, people should not be subjected to the extra dangers. Electric appliances are available now and will always be safer than hydrogen.

BLENDING HYDROGEN PERPETUATES HEALTH INEQUITIES

Maintaining reliance on methane gas will perpetuate already-existing health inequities associated with burning fossil fuels. Black, Indigenous and People of Color (BIPOC) are exposed to more nitrogen oxides⁹⁰ and other ambient (outdoor) air pollution from burning fossil fuels than white people,⁹¹ and are more likely to suffer from air pollution-related illnesses like asthma.⁹²

Black, Indigenous and People of Color are also more likely to be exposed to higher concentrations of indoor pollution. Due to decades of discriminatory housing policies, Black, Indigenous and People of Color are more likely to rent homes compared to white people. Rental units often have older and inadequately ventilated stoves, which can result in higher levels of indoor air pollution.⁹³ Ninety percent of rental homes have inadequate mechanical venting, according to the National Center for Healthy Housing.⁹⁴ Cooking with methane without exhaust ventilation, as would occur in gas stoves without a working range hood, often generates nitrogen dioxide concentrations in the home that exceed outdoor thresholds set by the Environmental Protection Agency (EPA) for this dangerous pollutant.^{95, 96} (EPA does not currently regulate indoor air quality.)

Figure 3: Current Asthma Prevalence in Children by Race and Ethnicity (2017-2019)



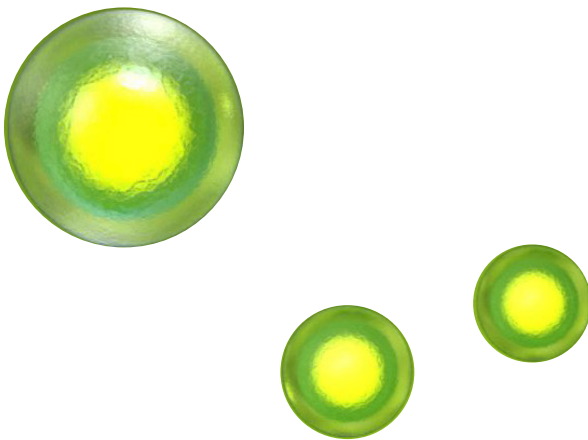
Adapted from Centers for Disease Control and Prevention, 2021⁹⁷

These conditions put already-vulnerable populations in harm's way. Producing hydrogen from methane⁹⁸ is likely to increase pollution near environmental justice communities, and burning hydrogen gas at higher levels of blending will increase nitrogen oxides (NOx),^{99, 100} including nitrogen dioxide (NO₂) which can exacerbate asthma symptoms and is a likely cause of asthma.¹⁰¹ Exposure to NO₂ is also linked to increases in emergency department visits and hospital admissions for asthma¹⁰² and

is associated with higher rates of dementia in older adults.¹⁰³ Expanding fossil hydrogen into homes and businesses is not worth the risk to public health when NOx-free appliances like heat pumps and electric and induction stoves are readily available.

Health inequities are further magnified by climate change, making the reduction in greenhouse gases a necessary element of health equity. To meet greenhouse gas reduction targets, methane-burning appliances will have to be phased out. The transition should favor heat pumps and electric stoves because they are more efficient to operate, reduce air pollution, and reduce greenhouse gas emissions. All these benefits will reduce air pollution and contribute to a just transition to zero emissions.

Hydrogen perpetuates the air pollution-related health inequities driven by burning fossil fuels in buildings and should be avoided.



CONCLUSION

Physicians for Social Responsibility (PSR) opposes the blending of hydrogen with methane and coal for combustion in homes and other buildings because hydrogen derived from methane will exacerbate the climate crisis and its associated health impacts. With the window to address the climate crisis closing, we cannot afford to pursue false solutions like fossil hydrogen. Acting now, we can limit the damage. According to the IPCC, limiting greenhouse gases, especially methane, will have both climate and health benefits.¹⁰⁴

Burning hydrogen in homes and businesses also poses undue risks to health and safety. There are available and effective solutions to address heating needs now. That's why PSR supports effective decarbonization and electrification strategies that will protect health, safety and the climate.

Take action

There is still time to stop the blending of fossil hydrogen with methane gas. Advocates can educate the public and policymakers that blending fossil hydrogen with methane for use in homes and businesses is bad for the climate, is costly, and harms human health. Here's how you can take action:

1. Oppose plans to blend hydrogen with methane for heating and cooking in buildings.
2. Support the use of green hydrogen for hard-to-electrify industries.
3. Oppose the use of green hydrogen to justify maintaining or developing fossil fuel infrastructure.
4. Educate policy makers, colleagues, and the public about the unacceptable climate, health, and safety impacts of hydrogen combustion for heating and cooking.

Policy recommendations

1. Promote and expand the direct use of renewably generated electricity to heat buildings. Support options such as promoting efficient electric appliances like heat pumps through point-of-purchase rebates; emissions performance standards for buildings; all-electric building codes; renewable requirements for electricity production, and expanding energy storage systems to enhance grid resilience and performance.
2. As part of the process for considering permits for hydrogen projects, require an Environmental Impact Assessment, Comprehensive Health Impact Assessment, and a cost-effectiveness analysis comparing burning hydrogen with utilizing lower-pollution options including energy efficiency, renewable energy, and energy storage options.
3. Require accounting of the full lifecycle greenhouse gas emissions of producing hydrogen. Greenhouse gas emission inventories must take all those emissions into account.
4. Require certification of “green” hydrogen to assure it is produced using truly renewable, and 100 percent renewable, energy sources.
5. State public utility commissions and state legislatures should not allow gas utilities to raise ratepayer rates to purchase hydrogen for blending, nor should they allow hydrogen to qualify for “clean heat” credits.

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