

# BURNING THE PUBLIC

## The hydrogen heating pipe dream

**The move away from using polluting fossil gas for heating and cooking threatens to erode gas companies’ consumer base, further raising costs for customers and potentially triggering a death spiral for the gas industry. Gas companies and their lobbyists trying to avert this spiral have argued that consumers should foot the vast bill for building hydrogen infrastructure, a move that could add tens of billions of euros to consumers’ energy bills.**

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### EXECUTIVE SUMMARY

Global Witness analysis of previously undisclosed European lobbying records has found that gas suppliers have argued in favour of making customers pay for the expansion and conversion of gas infrastructure to carry hydrogen claiming that all energy users would benefit. The most likely use of hydrogen for households would be for heating but more affordable and cleaner solutions for decarbonising heating already exist.

The high price of gas has already stretched many European household bills to breaking point and Global Witness has found that Europe gas users could face a bill of €240bn to fund hydrogen infrastructure if gas companies have their way.<sup>1</sup>

With more customers switching to more affordable and less polluting heating systems, like electric heat pumps, fewer gas consumers will be left to shoulder the costs of maintaining and converting the gas grid, piling on further costs. This in turn could prompt more customers to move away from gas, creating a spiral where consumers least able to afford the upfront cost of

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switching or who are otherwise unable to switch face very high costs.

Meanwhile, we found that gas boiler companies are greenwashing their products with hydrogen or hydrogen-blend ready labels, making them appear climate friendly. Consumers may opt for the low upfront costs of a hydrogen ready boiler believing that they are doing their part in reducing emissions. But consumers may find that they continue to burn fossil gas in their home, locking in more emissions for years to come or, if there is a switch to hydrogen, they may be stung by the high running costs, toxic emissions and climate warming impacts of hydrogen.

Vaillant, one of the largest boiler manufacturers working on hydrogen boilers admits on their website “for some installations there will be no tangible benefit of their wall-hung boiler being hydrogen ready as they may never see hydrogen in their lifetime.”<sup>2</sup> British Gas, a UK gas supplier which also sells boilers, advises customers “nobody really knows for sure at the moment” when a transition to hydrogen could happen though any boiler bought today “will probably use natural gas for all its working lifetime.”<sup>3</sup>

Global Witness has also identified misleading adverts and marketing from several major boiler manufacturers stating that the only emission from burning hydrogen is water, when in fact dangerous nitrogen oxides (NOx) are emitted. NOx emissions exacerbate respiratory problems like asthma and has been linked to reduced cognitive performance, especially in children.

This evidence of misleading marketing and self-interested lobbying once again shows that the fossil fuel industry should have no place in setting climate and energy policy. Instead, we need a Fossil Free Politics where fossil fuel lobbyists do not have free access to decision makers but instead are subject to similar restrictions as tobacco lobbyists.

Europe has an opportunity to move away from burning fossil fuels in our homes, end our reliance on gas imports – including from Russia - and limit our exposure to fossil fuel price crises. The EU is in the process of reforming the rules on how Europe’s gas markets work and on how homes and buildings are heated and cooled.

Government support needs to flow to the best solutions that help limit greenhouse emissions and help consumers, not prop up the gas industry’s hydrogen white elephants. Instead, new EU market rules should be adopted that ensure the rapid phase out of gas use across all sectors, including households and industry, by 2035.

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## RECOMMENDATIONS

The EU is currently debating a new framework for gas markets. Rather than funnelling public money into false solutions policy makers working on the gas package should ensure:

- > Market rules are adopted that ensure the rapid phase out of gas use across all sectors, including households and industry, by 2035.
- > Hydrogen blending is excluded, and hydrogen can be encouraged solely where it is the only viable alternative to gas, for example in certain heavy industries. Hydrogen should only be produced using renewable electricity.
- > Network planning by gas distribution system operators is more transparent, and open to participation from stakeholders, including communities, civil society and local governments. Planning should be in line with EU and national climate and energy targets, be based on local heating and cooling plans, and identify those parts of the network that require decommissioning.
- > Energy regulators are tasked to examine the cost-effectiveness of supplying buildings with hydrogen, including costly distribution grid upgrades.
- > Households must not be required to cross-subsidize hydrogen infrastructure from which they do not directly benefit.

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## DECARBONISING HEATING

The world uses more energy for heating than any other purpose. Providing heating for homes, industry and other applications accounts for around half of total global energy consumption according to the International Energy Agency.<sup>4</sup> 28% of the total energy consumed in the EU is specifically used for heating buildings, generating 12% of EU emissions in 2017.<sup>5</sup>

In many countries sprawling infrastructure has been built to facilitate heating with fossil gas. This infrastructure ranges from massive international gas pipelines, to local gas distribution grids, filtering down to gas boilers and stoves; the gas infrastructure in our homes.

According to the European Commission's Climate Target impact assessment, to stay on track for limiting warming to 1.5°C Europe needs to reduce fossil gas consumption in residential buildings by 42% by 2030, compared to 2015 levels.<sup>6</sup> Global Witness believes that the EU should be more ambitious and seek to phase out fossil gas entirely by 2035 in order for the EU to contribute to its fair share of limiting global temperature rises to 1.5°C.<sup>7</sup> Decarbonising heating is therefore pivotal to reducing greenhouse emissions.

One key technology for decarbonising heating is the electric heat pump. Around 1.8 million EU households bought a heat pump in 2020 with the number of heat pumps sold growing 12% every year since 2015.<sup>8</sup>

Heat pumps work by drawing in residual heat from the air or ground outside and boosts its temperature with a pump, a compressor and refrigerants, essentially transferring and intensifying heat rather than creating heat from electrical resistance or burning a fuel.<sup>9</sup> The technology is similar to how a fridge works, but acting in reverse with the unit transferring heat into a building rather than pulling heat out of a fridge.

Like other heating systems, heat pumps can also be used to circulate heat around multiple buildings, a system known as district heating.<sup>10</sup>

If the electricity used to power heat pumps is generated from renewables, then there are very few associated carbon emissions.

The EU is supporting the role out of this low carbon technology as part its plans to reduce dependence on Russian gas and reduce carbon emissions. Through its REPowerEU plan the European Commission is aiming to double the speed of deployment of heat pumps.<sup>11</sup>

## THE GAS GRID DEATH SPIRAL

Gas companies face a problem. If consumers switch to electrified heating systems like heat pumps and away from using gas, those customers might also switch their other gas appliances, like their cooker, to electric systems.

This switch allows consumers to disconnect from the gas grid and avoid paying the charges for maintaining the gas network. But as more consumers opt out of paying for a gas system these costs would then increase for the remaining shrinking customer base, making gas pricier still and in turn incentivising yet more consumers to switch.

This feedback loop, or death spiral, is on the mind of gas industry lobbyists.

In September 2021 representatives of the companies who operate the majority of the German gas grid, Open Grid Europe, Gascade, ONTRAS and Bayernets, met with senior officials from the European Commission. They laid out their problem, as the Commission's minutes, obtained by Global Witness, record.<sup>12</sup>

“[A]s demand declines in the upcoming decades and a smaller number of gas consumers will otherwise have to bear the costs of the remaining methane [fossil gas] infrastructure”.<sup>13</sup>

The impact of such a death spiral is not expected to be even. Homeowners with sufficient funds

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may be able to invest the upfront capital needed for electrified home heating. But, in the absence of government funded electrification schemes, households who are either unable to afford the upfront costs or who as renters are reliant on their landlords, may be stuck with the rising costs of gas.<sup>14</sup>

Government intervention to help everyone switch to fossil free heating systems and manage the retirement of fossil gas infrastructure is therefore essential to avoid the phase out of gas driving up costs for those living in or close to energy poverty.

Gas suppliers though, have a different solution to this death spiral and they are pushing hard to save their business, by lobbying politicians to permit them to pick the pockets of their customers.

## **GAS COMPANIES: MAKE CONSUMERS PAY**

Gas suppliers have been arguing that Europe's gas networks should be expanded and converted to carry hydrogen gas.

At the September 2021 meeting between German gas suppliers and the European Commission, the gas lobbyists argued that "revenues generated with operating CH<sub>4</sub> [fossil gas] networks should be allowed to compensate for high initial H<sub>2</sub> [hydrogen] network costs."

This means that current gas consumers should pay for setting up an expensive hydrogen gas grid.

In an attempt to justify lumbering households, already at the mercy of crisis level gas prices, with a further cost the companies argued that "this should not be considered as undue cross subsidization as methane consumers will benefit from cross mutualization in future."

Mutualisation of investments refers to the sharing of costs and risks between groups.<sup>15</sup>

Though full of jargon, this line appears to show that these gas companies believe that they should be allowed to make fossil gas consumers pay for converting gas grids to hydrogen grids as they think that consumers will benefit from gas companies avoiding the death spiral and supplying hydrogen in the future.

The only possible direct benefit for household consumers from hydrogen infrastructure would be for households to access hydrogen for their heating and cooking, the main proposed uses of hydrogen in homes.<sup>16</sup>

The German companies were not alone in asking for all gas consumers to help fund hydrogen infrastructure on the basis that all consumers might benefit in the future. According to records obtained by Global Witness, leaders of Uniper, one of Germany's largest energy suppliers<sup>17</sup>, Fluxys, a Belgian based company that operates thousands of kilometres of gas pipelines across Europe<sup>18</sup>, and the major gas lobby group Gas Infrastructure Europe (GIE) personally lobbied top EU energy official Kadri Simson on the same point in February 2022.<sup>19</sup>

The EU officials recorded the groups' request at this high-level lobby meeting; "Transparent mutualisation of H<sub>2</sub> [hydrogen] and CH<sub>4</sub> [fossil gas] costs should be allowed." The background briefing for Simson ahead of the meeting further spelled out that GIE's position was "Allowing a transparent mutualisation of costs between the different parts of the wider energy system – including gas and hydrogen infrastructure – to ensure cost-reflective and stable tariffs for using the gas and hydrogen infrastructure in the long run for the benefit of all energy users".<sup>20</sup>

This demand echoes closely the German grid operators', making gas consumers pay for the costs of hydrogen. The briefing notes for Simson made clear that GIE is in favour of hydrogen being "not only be used in the hard-to-abate sectors, but in particular in other energy intensive sectors

(especially electricity generation) and in heating”.<sup>21</sup>

The campaign for distributing hydrogen through gas grids is also coming from gas grid operators across Europe. In February the Ready4H2 alliance, representing 90 European gas distribution companies and lobby groups<sup>22</sup>, called for local gas networks to be converted to hydrogen in order to deliver “hydrogen to millions of customers”.<sup>23</sup>

The Ready4H2 group describes the possibility of hydrogen heating, cooling and hot water as a “hassle-free conversion of current residential customers from natural gas to 100% hydrogen or a blending of hydrogens” as crucial in many countries.<sup>24</sup>

## THE COST OF CONVERSION

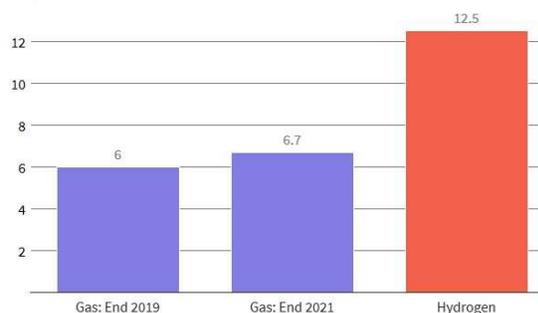
The scale of the bill that could be thrust on consumers for building out hydrogen infrastructure could be vast.

A study by energy consultancy Element Energy for Global Witness estimated that the cost that would be thrust on all gas users for converting and building hydrogen gas infrastructure to carry 100% hydrogen would be €240bn over the 40 years it could be in use.

This estimate assumes that all gas consumers are only asked to pay for some infrastructure costs such as the pipelines that transport hydrogen. If more costs such as for electrolysers and storage are spread between all gas users, then then this bill would become even higher.<sup>25</sup>

The gas lobby group Gas for Climate estimated the cost of building a “Hydrogen Backbone” for Europe at between €27bn and €64bn though this excluded the cost of hydrogen storage, CO2 infrastructure and importantly distribution networks.<sup>26</sup>

Hydrogen could cost twice as much as already high fossil gas prices (Euro Cents/kWh)



Source: Eurostat; Element Energy

Photo credit: © Global Witness

Concerns have been raised about leaks of hydrogen causing climate warming pollution. A recent study warned that hydrogen was twice as potent a greenhouse gas as had previously been understood due to it reacting with other gases in the atmosphere. The study found that hydrogen has a 33 times greater warming potential than carbon dioxide over a twenty-year period.<sup>27</sup>

Key to preventing hydrogen leaks is the use of plastic piping, as hydrogen makes steel and other metals brittle, leading to failures.<sup>28</sup> This means that older metal piping, used both in gas grids and in people’s homes would have to be replaced in order to carry hydrogen, one part of a lengthy and expensive process.<sup>29</sup>

A German gas industry study in 2019 estimated costs for repurposing just German gas distribution networks for 100% hydrogen at between €3.1 and €6.2 billion by 2050. The study also found that expected drop in gas use in the building sector would mean some distribution networks would be shut down lead to operating costs rising up to two and a half times as much as current rates.

The study predicts a death spiral effect from this rise in costs for maintaining the gas grid, even as they convert to hydrogen finding that “If these costs are passed on to the final consumers, such an increase could in turn lead to an even further

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drop in demand and therefore an even stronger related increase in the specific costs.”<sup>30</sup>

The Germany think tank Agora Energiewende, which does not take funding from private companies,<sup>31</sup> considered the possibilities for government intervention to help finance hydrogen heating in a 2021 report. The group concluded that any mechanism that would make hydrogen competitive would load unrealistic costs either onto consumers through high gas prices or onto the taxpayer.

The group further raised death spiral issues, concluding “higher gas prices would most likely lead to a higher heat pump uptake since this option would become cheaper than gas or oil. As a result, the remaining gas customers – those least able to adapt due to the lack of capital or rental accommodation – would be stranded with even higher gas bills, effectively footing the bill for gas infrastructure and hydrogen development.”<sup>32</sup>



Photo credit: © Marina113 / iStock

Conversion of the gas distribution network would not be quick. The gas suppliers' lobby group Ready4H2 ironically brought its own name into question when it reported that only 24% of its members will be “fully ready” for 100% hydrogen in gas grids by 2035, and only 67% said they will be by 2040. In other words, two thirds of pro-

hydrogen gas grid operators in Europe would not be ready to supply 100% hydrogen for nearly 20 years.<sup>33</sup>

The lobbying push by the gas industry threatens to add thousands of euros to household bills, already stretched by soaring fossil gas prices and a cost-of-living crisis, to build hydrogen infrastructure. The pitch assumes that pumping hydrogen into millions of households for hydrogen heating justifies this cost and the long wait for this technology to become available.

As alternative technologies like heat pumps prove to be greener and cheaper, as numerous independent studies have shown, consumers would be left paying for hydrogen infrastructure that may be hardly used.

Repurposing existing gas infrastructure suits gas suppliers, seeking for a way to extend their business model and avoid a death spiral for their industry. But in the face of evidence showing that hydrogen heating is likely to be at best a niche technology, lobbying by gas companies to load costs onto consumers appears to be deeply cynical.

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## **HYDROGEN READY: A PIPE DREAM**

Leading boiler manufacturers are also marketing hydrogen fuelled boilers as a way to decarbonise home heating, though boilers burning 100% hydrogen are presently only at the prototype or pilot phase.<sup>34</sup>

Nevertheless, gas and boiler companies have worked hard to lobby for governments to require gas boilers to be “hydrogen ready” and build public support for the technology among the professionals, plumbers and heating engineers that most consumers rely on to inform their heating system choice.

Hydrogen ready boilers are fossil gas boilers that manufacturers say can be converted to run on 100% hydrogen by a professional changing a few parts taking around an hour, with the parts costing “a few hundred euros” according to one industry executive.<sup>35</sup>

Manufacturers are also marketing “hydrogen blend ready” boilers, which can accept a blend of 80% fossil gas and 20% hydrogen, though such a fuel would significantly increase running costs and provide a maximum of only 7% emissions reductions. (See below in A Blend To Nowhere)

A copy of manufacturing giant Bosch’s draft hydrogen strategy, seen by Global Witness, suggests the company is fully aware of some of the issues with hydrogen. The document acknowledges “hydrogen is expensive” and “high initial investment” is required. Nevertheless, the strategy recommends that “The government & industry should collaborate to incentivise public uptake of hydrogen-ready boilers and mandate them by 2025.” Among the barriers to their strategy though the company identifies “public awareness, familiarity, and general acceptance of the technologies”.

Manufacturers are lobbying for hydrogen ready boilers to be required in the next few years. The website of Bosch’s UK subsidiary Worcester Bosch explains that “Initially, hydrogen-ready

boilers might form a niche market, but a regulatory change mandating their installation would make them a high-volume technology, just as natural gas boilers are today.”<sup>36</sup>

The European Heating Industry (EHI), which represents many of the largest boiler manufacturers has also been supported by the largest European gas lobby groups in a push for hydrogen boilers and other appliances at the EU level.



Photo credit: © Global Witness

EHI together with Eurogas, GIE, G4DS, Liquid Gas Europe and Hydrogen Europe have lobbied the European Commission arguing that the EU should promote hydrogen ready appliances, at the same time as phasing in hydrogen into the gas system.<sup>37</sup> The industry’s call has been heard. Under a proposed new standard new gas boilers sold in the EU could be required to be hydrogen blend ready, able to operate with at least 20% hydrogen blended into the gas supply.<sup>38</sup>

The move would suit existing manufacturers of gas boilers, as the vast majority of components in a hydrogen boiler would be the same as those that they already make, meaning they are able to carry on business largely as usual despite the need to rapidly decarbonise.<sup>39</sup>

The installation of hydrogen ready boilers is seen as a stepping stone to installing hydrogen

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infrastructure. Worcester Bosch explains on its website that “hydrogen-ready boilers are the key to enabling conversion of the existing gas distribution networks from natural gas (which is mostly methane) to hydrogen.”<sup>40</sup>

Given the slow timescale for converting to grids hydrogen, the high costs associated and other concerns with hydrogen boilers, this lobbying by gas and boiler companies is not the best solution to decarbonising heating but instead appears to be self-serving.

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## PAINTING A FOSSIL GAS BOILER GREEN

Mike Foster, CEO of the UK gas and boiler industry body the EUA told the press that hydrogen ready boilers represent “huge development in the industry’s efforts to address consumer concerns about climate change”.

Foster described how “consumers want to do their bit to reduce the impact of their homes and help deliver a greener future, but are concerned about the cost of some low carbon technologies.” Hydrogen ready boilers he presented as an “affordable low carbon heat and hot water solution”.<sup>41</sup>

Four of the largest gas boiler manufacturers: Ideal, Baxi, Vaillant and Worcester Bosch have collectively said that new hydrogen ready boilers will cost upfront no more than equivalent fossil gas systems.<sup>42</sup> The running costs of hydrogen boilers though are likely to be far higher than alternative heating systems (see below in Cost: A Burning Problem).

Worcester Bosch has already begun marketing ‘Hydrogen blend ready’ boilers with the description boldly printed in large green type across its latest commercial gas boiler. The boiler featured in an advert in Installer magazine, and the magazine’s Twitter account in July 2022.<sup>43</sup>

In an Instagram video aimed at professionals, Worcester Bosch told installers that all their current boilers are “hydrogen blend ready” and that professionals can “give your customers confidence that when they buy a hydrogen blend ready boiler, their home will be future-proofed for many, many, years to come.”<sup>44</sup>

However, most boilers installed today will likely never burn hydrogen. British Gas, a subsidiary of Centrica, advises customers on their website “nobody really knows for sure at the moment” when a transition to hydrogen could happen though any boiler bought today “will probably use natural gas for all its working lifetime.”<sup>45</sup>

Vaillant, one of the largest boiler manufacturers working on hydrogen boilers admits on their website “We do not expect to see a mass roll out of hydrogen boilers until the early 2030’s as it is unlikely that homes, which are currently on the gas grid, will have a hydrogen supply to their doorstep much before then.” And “For some installations there will be no tangible benefit of their wall-hung boiler being hydrogen ready as they may never see hydrogen in their lifetime.”<sup>46</sup>

With no timeline for hydrogen supplies becoming available to households, and severe doubts over the cost, health and safety of using hydrogen for heating it seems likely that for most customers hydrogen readiness is merely green paint.

Boiler manufacturers appear to be seizing on customers’ interest in reducing their carbon emissions to sell them a fossil gas boiler, greenwashed as hydrogen ready to make it appear more climate friendly when instead customers could switch to genuinely greener and cheaper alternatives.

This greenwashing is likely to set back attempts to reduce emissions from heating as consumers continue burning fossil gas in the home, when they could switch to genuinely lower carbon alternatives that would also be better value in the long run.

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## NOXIOUS EMISSIONS MISSING IN MARKETING

Several boiler manufacturers' adverts and marketing material for hydrogen boilers also raise concerns as they misleadingly state that burning hydrogen produces no emissions or only produces water.

While school chemistry class teaches us that burning hydrogen in pure oxygen only produces water, burning hydrogen in air produces concerning levels of dangerous nitrogen oxides (NO and NO<sub>2</sub>, collectively referred to as NOx).<sup>47</sup>

Research by the US Environmental Protection Agency has showed even short-term exposure to NOx exacerbates respiratory problems, particularly asthma, and particularly in children.<sup>48</sup> Research has also linked ongoing NO<sub>2</sub> exposure to reduced cognitive performance, especially in children.<sup>49</sup>

NOx is also produced by gas boilers burning fossil gas as well as other gas appliances.<sup>50</sup> Indoor NOx emissions from fossil gas appliances have already been shown to exceed public health guidelines.<sup>51</sup> Concerns have been raised that in the future as other sources of NOx emissions are phased out, like internal combustion vehicles, home combustion of hydrogen could become the dominant source of NOx in cities.<sup>52</sup>

The German boiler manufacturer Viessmann ran Facebook adverts in November and December 2021 telling the public "We can only reach the [climate] targets if we consider hydrogen to be a key player. From electricity supply to home heating, hydrogen can help to reduce our CO<sub>2</sub> emissions."<sup>53</sup> The company's accompanying video on its website attempts to reassure the public saying that hydrogen "poses no danger to nature or the environment" and that it's "absolutely safe" as well as being "emission free" with "a high degree of efficiency".<sup>54</sup>

Despite the company's claims that it is safe, hydrogen is flammable in a wider range of

concentrations than fossil gas and requires less ignition energy, meaning it explodes far more easily.<sup>55</sup> A study from engineering consultancy Arup for the UK government found that hydrogen boilers could cause four times as many explosions in the UK as fossil gas boilers, though steps could be taken to make them safer.<sup>56</sup>

The company's claims about hydrogen being emission free in particular elides the danger of NOx emissions from burning hydrogen. A separate Viessmann web page on hydrogen boilers does state that their boilers produce "NOx emissions as a result of hydrogen combustion" however consumers seeing their Facebook adverts may not see this detail.<sup>57</sup>

Worcester Bosch states on its web page explaining hydrogen boiler technology that "The only by-product of burning hydrogen gas is water".<sup>58</sup>

This claim, which ignores the NOx emissions is echoed by fellow boiler manufacturer Baxi, a subsidiary brand of BDR Thermea, which states in its press release describing a trial of hydrogen boilers "The only by-product of burning hydrogen is water."<sup>59</sup> The UK gas supplier British Gas, which sells boilers from several brands, similarly tells consumers on its webpage about hydrogen boilers "The only by-product of burning hydrogen gas is water".<sup>60</sup>

A video produced by Vaillant on their hydrogen pilot project, shown at a UK trade show similarly included the claim that "when you burn hydrogen the only products of combustion are water vapour, nothing else". When Global Witness asked about the claim in Vaillant's video, staff were quick to admit that in fact NOx is emitted by the boiler and that the video is incorrect.<sup>61</sup>

This widespread omission of dangerous pollutants from manufacturers' marketing for hydrogen boilers is misleading and irresponsible, especially when discussing a new technology where the risks may not be widely understood. The health and safety risks from hydrogen boilers

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are real and must be taken into account in discussions of the technology.

## **COST: A BURNING PROBLEM**

In addition to the costs of converting the gas grid to carry hydrogen, the running costs of fuelling a hydrogen boiler relative to its competitors is one of the biggest obstacles to hydrogen heating taking off.

A study by energy consultancy Element Energy for Global Witness recently found that an average European household could face an estimated cost annual cost of €1,580 for hydrogen if hydrogen heating was adopted. This annual bill would be twice as much as an average fossil gas bill based on average European prices at the end of 2021.<sup>62</sup>

A study for BEUC, the European Consumer Organisation, modelled costs of different low carbon heating options for a range of archetypal homes in different European countries in 2040. It found that “heat pumps are the most cost effective route to decarbonisation of home heating” across the countries and different homes analysed. Across the countries analysed hydrogen boilers cost between 60-120% more than a heat pump in a single-family home.<sup>63</sup>

A study by the International Council of Clean Transportation similarly found that air source heat pumps would be the most cost-effective residential heating technology compared to hydrogen boilers or hybrid systems involving both. The study looked at expected costs in 2050 for a typical EU family home and found that heat pumps would cost at least 50% less than hydrogen boiler systems. The running costs of a hydrogen boiler dominating its overall cost. The study included scenarios that would increase the expected cost of renewable electricity by 50% and reduced the cost of hydrogen, but heat pumps were still the most cost effective.<sup>64</sup>

One reason why the running costs of hydrogen boilers are higher is the technology’s relative inefficiency compared to heat pumps.

Burning gas in a home is limited to a theoretical maximum efficiency of 100%, that would be if all the energy in the gas is released as heat through perfect combustion. A well installed modern condensing gas boiler is rated to be over 90% efficient.<sup>65</sup> Hydrogen boilers might expect a similar level of efficiency as a modern gas boiler.<sup>66</sup>

On the other hand, an electric heat pump can be more efficient as rather than generating heat by combustion, it instead transfers heat. The fuel, electricity, is mainly used to power a pump and a compressor to transfer the heat rather than generate heat itself.

Through this system a well installed heat pump, depending on its size, type and the climate, can expect an average efficiency of 250% to nearly 400% over a year. In other words for one unit of electricity put into a heat pump you can expect three or four units of heat to be put into a building on average.<sup>67</sup>



Photo credit: © imacoconut / iStock

Heat pumps do have a cost downside; in most cases they cost more upfront to buy and install in

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a home than gas boilers. Heat pumps do require outside space, a hot water cylinder and a home may require changes to radiators. More efficient heat pumps also operate at a lower temperature compared to gas or hydrogen boilers and ideally need the building to be well insulated for it to operate at its ideal efficiency.<sup>68</sup>

One recent study looked at the relative costs of heat pumps and hydrogen in renovated and unrenovated homes finding that heat pumps would be cheaper regardless of whether a home was insulated or not. Switching to heat pumps in the 2030s without renovating would leave households approximately €20,000 better off than with a hydrogen boiler over 20 years. Those relative savings increased to €30,000 if the home was renovated.<sup>69</sup>

## **HYDROGEN – SEEING IN COLOUR**

A key factor in the cost of hydrogen is how it is made. The lowest carbon type of hydrogen is green hydrogen, which made by splitting water through electrolysis using renewable electricity.

The most common way of creating hydrogen in Europe though by blasting fossil gas with steam, this is then known as grey hydrogen. If carbon capture processes are added to a grey hydrogen process, then it is referred to as blue hydrogen.

### **BLUE HYDROGEN'S CLIMATE PROBLEM**

96% of Europe's hydrogen is currently produced from fossil gas generating significant carbon emissions.<sup>70</sup> Globally hydrogen production results in close to 900Mt of CO<sub>2</sub> emissions per year,<sup>71</sup> about as much as the EU's annual CO<sub>2</sub> equivalent emissions from domestic transportation, international aviation and shipping put together.<sup>72</sup>

Blue hydrogen is also not zero emissions and has been criticised as potentially locking in fossil fuel infrastructure for decades.<sup>73</sup> A recent study by scientists at Stanford and Cornell University

found that once methane leakage rates in fossil gas production and transportation are taken into account, greenhouse emissions from blue hydrogen may actually be higher than for burning fossil gas.<sup>74</sup>

Global Witness found that one of the few fossil hydrogen plants in the world that uses a carbon capture system, Shell's Quest project in Canada, captures just 48% of the plant's carbon emissions. The plant has the same carbon footprint as 1.2 million petrol cars, despite the company using the project to boast of how it is tackling global heating.<sup>75</sup>

Using blue hydrogen for home heating would require at least a third more fossil gas to be used to make and transport the hydrogen than would have been used by just burning the fossil gas.<sup>76</sup>

With gas as its main feedstock, the price of blue hydrogen would always be higher than the price of fossil gas and issues like the current dependence on fossil fuel exporting states like Russia would be perpetuated. Given the current and forecast high cost of gas, this would make blue hydrogen prohibitively expensive. Green hydrogen avoids these problems, but producing, compressing, transporting and finally burning hydrogen adds inefficiencies which raise costs.<sup>77</sup>

These inefficiencies add up. Agora Energiewende estimated that for every 100 units of electricity only 61 units of heat would be generated from a hydrogen boiler<sup>78</sup>, giving a system efficiency of 61%. Other estimates are less positive with one academic estimating only a 46% system efficiency.<sup>79</sup>

With both boilers burning green hydrogen and heat pumps relying on renewable electricity their relative efficiency is a good way of exploring their relative cost. Heat pumps face inefficiencies from transmitting electricity through the grid and then the positive efficiency of the heat pumps themselves.

The efficiency of a heat pump varies but with a grid transmission efficiency of 90% and assuming a heat pump operating at a 300% efficiency a whole heat pump system works out to 270% efficient. This means that a heat pump based system gives out over four times as much heat as a green hydrogen boiler for the same amount of electricity.<sup>80</sup>

In terms of a whole countries' energy system this means far more renewable energy generation would be needed to fuel green hydrogen boilers as heat pumps.<sup>81</sup>

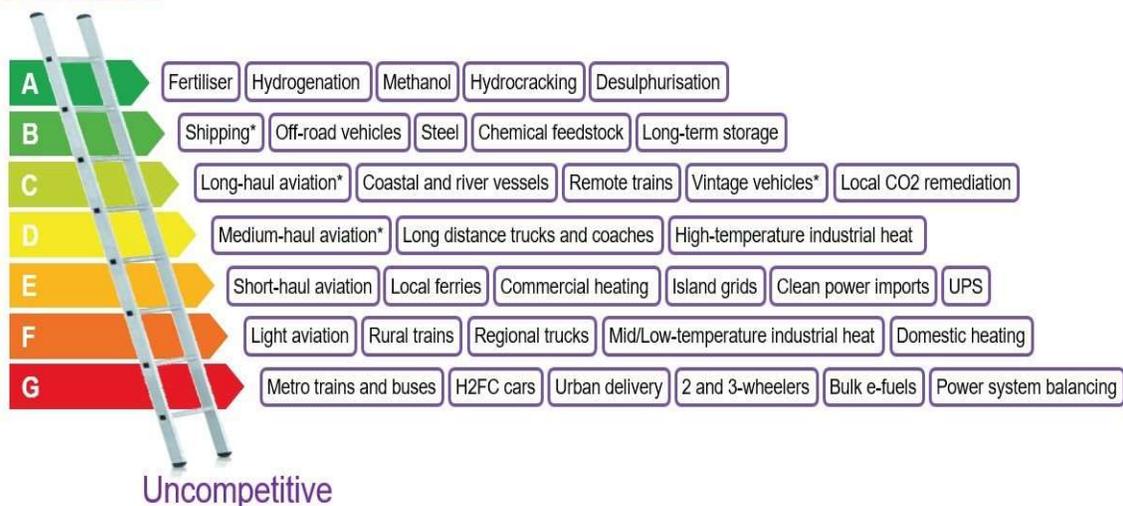
A study by academics at Imperial College estimates the cost per household in the UK of heat pumps and hydrogen heating with different colours of hydrogen. They found that the average cost of hydrogen heating per household would be between £1410 and £1880 per year with green hydrogen, with a lower estimate of £1150 per year with blue hydrogen (though this might now be significantly higher after the recent surge in gas prices).<sup>82</sup> In contrast the system cost of heating with electric heat pumps would be far cheaper at between £790 and £880 per year for a household.<sup>83</sup>

Another study looked at the costs of different technologies for decarbonising heating in the UK, including hour by hour simulations of weather and taking into account the challenge of generating and storing power all year round. It found that using hydrogen heating would cost about twice as much as heat pumps.<sup>84</sup>

Consumers buying a hydrogen ready boiler may think it is a cheaper option, with its upfront cost being comparable to a gas boiler. However, the high cost of blue hydrogen and the inefficiencies involved in heating with green hydrogen mean that a hydrogen boiler would be very expensive to run compared to alternatives like heat pumps.

Marketing hydrogen boilers without consumers having this information is highly problematic. Given the high costs of hydrogen heating, policy makers should ensure that the costs of converting distribution grids to hydrogen are not passed on to household consumers.

## Unavoidable



\* Via ammonia or e-fuel rather than H2 gas or liquid

Source: Liebreich Associates (concept credit: Adrian Hiel/Energy Cities)

Photo credit: © Liebreich Associates

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## A BLEND TO NOWHERE

European gas lobby groups have called for the EU to allow hydrogen to be “blended” into gas distribution grids as a way to boost production and consumption of hydrogen. Blending hydrogen into the grid would provide “hydrogen producers with a ready source of demand” as Ready4H2 put it.<sup>85</sup>

Gas companies believe that adding up to 10% or 20% hydrogen by volume into the gas supply can be carried out without major changes to infrastructure.<sup>86</sup>

Even a low blend would entail significant costs. A European Commission analysis estimated that “the costs for end users and infrastructure operators to adapt to a 5% blending level (by volume) would amount to around €3.6bn per year.”<sup>87</sup>

Hydrogen blending is also dubious as a strategy for reducing emissions. Hydrogen’s energy density is around a third of fossil gas’, meaning that a 20% blend of hydrogen would only contribute 7% of the gas’ energy content when burned. This also means that the best possible emissions reduction would be 7% if the hydrogen had no associated emissions.<sup>88</sup>

Putting together the high cost and limited emissions reductions, a recent study found that hydrogen blending would be among the most expensive possible ways to limit CO2 emissions.<sup>89</sup>

## HYDROGEN: CHAMPAGNE OF ENERGY

Mixing hydrogen into the fossil gas supply would also use up a scarce resource in an untargeted way, when instead it could be prioritised in sectors where it is essential for decarbonisation. The idea has been likened to adding champagne into the water supply.<sup>90</sup>

Hydrogen is currently a significant feedstock for chemicals and fertiliser and can provide high temperature heat for decarbonising processes

like steel making. Some proponents of hydrogen have marketed it as a ‘Swiss army knife’ option.

Hydrogen experts like Bloomberg NEF founder Michael Liebreich have attempted to debunk the idea of the Hydrogen Swiss army knife writing “Just because you could \*technically\* do something with clean hydrogen, it doesn't mean you will.” The widely referenced hydrogen ladder ranks potential uses of hydrogen from the unavoidable use cases, where there are few or no alternatives to hydrogen, to the uncompetitive, where hydrogen is wholly unsuitable. Domestic heating lingers far down the ladder at the uncompetitive end of the scale.<sup>91</sup>

Similarly, a January 2022 study on potential uses of hydrogen by the International Renewable Energy Agency found residential heating to be the lowest priority use of hydrogen of the potential uses they studied.<sup>92</sup>

Given the massive emissions from existing hydrogen production decarbonising this existing industry should also be a priority for new green hydrogen production.

Given the likely high demand for hydrogen from other sectors, the high cost, and other health and safety issues, there are severe doubts over hydrogen heating ever becoming more than a niche technology.

A 2021 report by the International Energy Agency projected hydrogen as only having a niche role, with only 2% of energy demand in the buildings sector being supplied by hydrogen.<sup>93</sup> Analysts at McKinsey projected heat pumps to dominate the heating systems sold per year and did not project any hydrogen boilers in the market.<sup>94</sup>

The Intergovernmental Panel on Climate Change found in their 2022 report on mitigating climate change that less than 0.5% of buildings would be heated by hydrogen in 2050 in their scenarios limiting warming to 1.5°C without overshoot.<sup>95</sup>

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## RESPONSES

In response to questions regarding this report British Gas told Global Witness that “we fully and publicly support the de-carbonisation of heating and have been clear that this will require a mix of technologies.”

Fluxys emphasised their focus on using hydrogen for decarbonising hard to electrify industrial sectors saying “Our approach to provide Belgium with the necessary hydrogen infrastructure takes shape in cooperation with the industry, the authorities, neighbouring operators, distribution system operators and other stakeholders. We envision to build, in line with market needs, hydrogen infrastructure in industrial clusters, establish connections between them and with neighbouring countries resulting in an interconnected European hydrogen ‘backbone’ as the cornerstone of a well-functioning hydrogen economy in Europe.”

Worcester Bosch, Vaillant, Ontras and Fluxys acknowledged questions from Global Witness but did not comment. Baxi, Veissmann, Bayernets, Gascade, Open Grid Europe, Uniper and GIE did not respond to requests for comment.

## CONCLUSION

Reducing carbon emissions from buildings is vital to achieve climate targets. Improving energy efficiency standards and ending the burning of fossil fuels in homes are crucial to making this happen.

Independent studies conclude that hydrogen boilers will likely be at best a fringe technology, more expensive and less efficient than good alternatives like heat pumps, but this has not stopped gas and boiler companies, together with their lobbyists promoting hydrogen heating.

Hydrogen readiness is being deployed to greenwash fossil gas boilers with many major boiler manufacturers making misleading claims that gloss over the NOx emissions from their units. Given the high cost of hydrogen boilers and

the massive expense of converting gas grids, most ‘hydrogen ready’ boilers are unlikely to ever see the gas and will instead keep burning fossil fuels for their lifespan.

Boiler manufacturers appear to be cynically and misleadingly marketing hydrogen ready boilers, taking advantage of customers’ desire to take climate action, to allow themselves to continue to sell fossil gas boilers and avoid changes to their business models.

Gas suppliers fear a death spiral induced by customers choosing to electrify their homes and move away from gas heating. Despite the concerns over the costs of hydrogen heating its possibility is being deployed to justify making current gas consumers pay for setting up an expensive hydrogen network, a cost that would likely fall on the shoulders of the least wealthy.

Making consumers pay for the billions of euros it would cost to build hydrogen infrastructure is fundamentally unfair and the use of hydrogen heating to justify it appears cynical.

The lobbying around hydrogen heating yet again shows that the fossil fuel industry has no place in setting climate and energy policy. Instead, we need a Fossil Free Politics where fossil fuel interests have been firewalled off from policy makers, similar to existing restrictions on tobacco lobbyists.<sup>96</sup>

After decades of denial, delay and greenwashing over 270,000 Europeans have signed a European Citizens Initiative calling for legislation prohibiting advertisements for fossil fuels, a ban that could prevent greenwashing of false solutions in the future. If the petition reaches one million signatures the European Commission will be legally obliged to respond.<sup>97</sup> European Union citizens can add their name through the Global Witness [website](#).

## RECOMMENDATIONS

The EU is currently debating a new framework for gas markets. Rather than funnelling public

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money into false solutions policy makers working on the gas package should ensure:

- > Market rules are adopted that ensure the rapid phase out of gas use across all sectors, including households and industry, by 2035.
- > Hydrogen blending is excluded, and hydrogen can be encouraged solely where it is the only viable alternative to gas, for example in certain heavy industries. Hydrogen should only be produced using renewable electricity.
- > Network planning by gas distribution system operators is more transparent, and open to participation from stakeholders, including communities, civil society and local governments. Planning should be in line with EU and national climate and energy targets, be based on local heating and cooling plans, and identify those parts of the network that require decommissioning.
- > Energy regulators are tasked to examine the cost-effectiveness of supplying buildings with hydrogen, including costly distribution grid upgrades.
- > Households must not be required to cross-subsidize hydrogen infrastructure from which they do not directly benefit.

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## ENDNOTES

- <sup>1</sup> Global Witness, September 2022, "Heating Homes With Gas Is Expensive, Heating With Hydrogen Could Cost Double"
- <sup>2</sup> Vaillant, "When we expect hydrogen boilers to become mainstream", <https://www.vaillant.co.uk/for-installers/business-support/industry-drivers-and-legislation/hydrogen/hydrogen-boilers-mainstream-2404425.html>
- <sup>3</sup> British Gas, 21/1/2022, "Hydrogen boilers: everything you need to know", <https://www.britishgas.co.uk/the-source/greener-living/hydrogen-boilers.html>
- <sup>4</sup> IEA, 11/2021, "Heating", <https://www.iea.org/fuels-and-technologies/heating>
- <sup>5</sup> ECOS, 10/12/2020, "Five Years Left: How ecodesign and energy labelling can decarbonise heating", <https://ecostandard.org/wp-content/uploads/2020/12/Five-Years-Left-How-ecodesign-and-energy-labelling-Coolproducts-report.pdf>
- <sup>6</sup> Agora Energiewende, 1/2022, "12 Insights on Hydrogen", [https://static.agora-energiewende.de/fileadmin/Projekte/2021/2021\\_11\\_H2\\_Insights/A-EW\\_245\\_H2\\_Insights\\_WEB.pdf](https://static.agora-energiewende.de/fileadmin/Projekte/2021/2021_11_H2_Insights/A-EW_245_H2_Insights_WEB.pdf) p24 European Commission, "Climate Target impact assessment", figure 58 – 2030 MIX scenario which achieves around 55% GHG reductions by 2030. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020SC0176>; Graph data available at [https://ec.europa.eu/clima/document/download/ec1acac9-10fe-4eeb-915f-cad388990e0f\\_en?filename=2030\\_climate\\_target\\_plan\\_figures\\_en.xlsx](https://ec.europa.eu/clima/document/download/ec1acac9-10fe-4eeb-915f-cad388990e0f_en?filename=2030_climate_target_plan_figures_en.xlsx)
- <sup>7</sup> Global Witness and others, 17/6/2021, "European Civil Society Gas Manifesto", <https://caneurope.org/content/uploads/2021/06/Fossil-Gas-Manifesto-2021.pdf>
- <sup>8</sup> IEA, 11/21, "Heat Pumps", <https://www.iea.org/reports/heat-pumps>
- <sup>9</sup> National Grid, "How do heat pumps work?", <https://www.nationalgrid.com/stories/energy-explained/how-do-heat-pumps-work>
- <sup>10</sup> IEA, 17/11/2020, "Heat pumps in district heating and cooling systems", <https://www.iea.org/articles/heat-pumps-in-district-heating-and-cooling-systems>
- <sup>11</sup> European Commission, 18/5/2022, "REPowerEU: A plan to rapidly reduce dependence on Russian fossil fuels and fast forward the green transition", [https://ec.europa.eu/commission/presscorner/detail/en/IP\\_22\\_3131](https://ec.europa.eu/commission/presscorner/detail/en/IP_22_3131)
- <sup>12</sup> Email from Bayernets, Gascade, OGE and ONTRAS to European Commission, 5/7/2021, "Exchange of views with Gas TSOs", [https://www.asktheeu.org/en/request/10072/response/34173/attach/3/R%20Exchange%20of%20views%20with%20Gas%20TSOs%20Redacted.pdf?cookie\\_passthrough=1](https://www.asktheeu.org/en/request/10072/response/34173/attach/3/R%20Exchange%20of%20views%20with%20Gas%20TSOs%20Redacted.pdf?cookie_passthrough=1)
- <sup>13</sup> European Commission, 12/10/2021, "Minutes from the meeting with German TSOs Bayernets, OGE, Gascade, Ontras 29/09/2021 - 18:00-18:45 (online/MS Teams)", [https://www.asktheeu.org/en/request/10072/response/34173/attach/4/Minutes%20from%20the%20meeting%20with%20German%20TSOs%20final%20docx%20Redacted.pdf?cookie\\_passthrough=1](https://www.asktheeu.org/en/request/10072/response/34173/attach/4/Minutes%20from%20the%20meeting%20with%20German%20TSOs%20final%20docx%20Redacted.pdf?cookie_passthrough=1)
- <sup>14</sup> Agora Energiewende, 1/2022, "12 Insights on Hydrogen", [https://static.agora-energiewende.de/fileadmin/Projekte/2021/2021\\_11\\_H2\\_Insights/A-EW\\_245\\_H2\\_Insights\\_WEB.pdf](https://static.agora-energiewende.de/fileadmin/Projekte/2021/2021_11_H2_Insights/A-EW_245_H2_Insights_WEB.pdf) p22
- <sup>15</sup> <https://www.investopedia.com/terms/m/mutualization-of-risk.asp#:~:text=Key%20Takeaways.group%20of%20investors%20or%20businesses.>
- <sup>16</sup> Northern Gas Networks, "Our Hydrogen Home", <https://www.northerngasnetworks.co.uk/current-business-plan/our-hydrogen-home-welcome-to-green-gas/#:~:text=The%20homes%20are%20fitted%20with,urns%20orange%20rather%20than%20blue.>
- <sup>17</sup> Uniper, "About Us", <https://www.uniper.energy/about-uniper>
- <sup>18</sup> Fluxys, "About Fluxys", [fluxys.com/en/company/fluxys-group/about-fluxys](https://fluxys.com/en/company/fluxys-group/about-fluxys)
- <sup>19</sup> European Commission, 1/2/2022, "Meeting with GIE on Security of Supply and the Hydrogen and Gas markets and decarbonisation package", [https://www.asktheeu.org/en/request/10738/response/36791/attach/7/20220102%20TMU%20meeting%20minutes%20Kadri%20Simson%20with%20GIE.docx%20Redacted.pdf?cookie\\_passthrough=1](https://www.asktheeu.org/en/request/10738/response/36791/attach/7/20220102%20TMU%20meeting%20minutes%20Kadri%20Simson%20with%20GIE.docx%20Redacted.pdf?cookie_passthrough=1)
- <sup>20</sup> European Commission, 1/2/2022, "Meeting with GIE" [https://www.asktheeu.org/en/request/10738/response/36791/attach/12/20220127%20CAB%20SIMSON%20850%20Meeting%20with%20GIE%20President%20final%20Redacted.pdf?cookie\\_passthrough=1](https://www.asktheeu.org/en/request/10738/response/36791/attach/12/20220127%20CAB%20SIMSON%20850%20Meeting%20with%20GIE%20President%20final%20Redacted.pdf?cookie_passthrough=1)
- <sup>21</sup> European Commission, 1/2/2022, "Meeting with GIE" [https://www.asktheeu.org/en/request/10738/response/36791/attach/12/20220127%20CAB%20SIMSON%20850%20Meeting%20with%20GIE%20President%20final%20Redacted.pdf?cookie\\_passthrough=1](https://www.asktheeu.org/en/request/10738/response/36791/attach/12/20220127%20CAB%20SIMSON%20850%20Meeting%20with%20GIE%20President%20final%20Redacted.pdf?cookie_passthrough=1)
- <sup>22</sup> Ready4H2, "About Ready4H2", <https://www.ready4h2.com/>
- <sup>23</sup> Ready4H2, 3/22, "Europe's Local Hydrogen Networks", [https://www.ready4h2.com/files/ugd/597932\\_0b861a4e18cb47d188852e7497024e79.pdf](https://www.ready4h2.com/files/ugd/597932_0b861a4e18cb47d188852e7497024e79.pdf)
- <sup>24</sup> Ready4H2, 3/22, "Europe's Local Hydrogen Networks", [https://www.ready4h2.com/files/ugd/597932\\_44ca5c9ebcd94662a7e4232dd0336adc.pdf](https://www.ready4h2.com/files/ugd/597932_44ca5c9ebcd94662a7e4232dd0336adc.pdf), p12
- <sup>25</sup> Global Witness, September 2022, "Heating Homes With Gas Is Expensive, Heating With Hydrogen Could Cost Double"
- <sup>26</sup> Gas for Climate, 7/2020, "European Hydrogen Backbone", [https://gasforclimate2050.eu/wp-content/uploads/2020/07/2020\\_European-Hydrogen-Backbone\\_Report.pdf](https://gasforclimate2050.eu/wp-content/uploads/2020/07/2020_European-Hydrogen-Backbone_Report.pdf); Gas for Climate, "Who we are", <https://gasforclimate2050.eu/gas-for-climate/who-we-are/>
- <sup>27</sup> Recharge, 8/4/2022, "Hydrogen 'twice as powerful a greenhouse gas as previously thought': UK government study", <https://www.rechargenews.com/energy-transition/hydrogen-twice-as-powerful-a-greenhouse-gas-as-previously-thought-uk-government-study/2-1-1200115>
- <sup>28</sup> GTM, 30/11/2020, "Green Hydrogen in Natural Gas Pipelines: Decarbonization Solution or Pipe Dream?", <https://www.greentechmedia.com/articles/read/green-hydrogen-in-natural-gas-pipelines-decarbonization-solution-or-pipe-dream>

- <sup>29</sup> Guardian, 21/3/2020, "Is hydrogen the solution to net-zero home heating?", <https://www.theguardian.com/science/2020/mar/21/is-hydrogen-the-solution-to-net-zero-home-heating>; Frazer-Nash, 10/2018, "Logistics of Domestic Hydrogen Conversion", [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/760508/hydrogen-logistics.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/760508/hydrogen-logistics.pdf)
- <sup>30</sup> Umwelt Bundesamt, 12/2019, "Gas Roadmap for the Energy Transition – A Sustainable Climate Contribution of the Gas Sector" [https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2019-04-15\\_cc\\_12-2019\\_roadmap\\_gas\\_2.pdf](https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2019-04-15_cc_12-2019_roadmap_gas_2.pdf), p5, 33
- <sup>31</sup> Agora Energiewende, "Agora Energiewende", <https://www.agora-energiewende.de/en/about-us/agora-energiewende/>
- <sup>32</sup> Agora Energiewende, 1/2022, "12 Insights on Hydrogen", [https://static.agora-energiewende.de/fileadmin/Projekte/2021/2021\\_11\\_H2\\_Insights/A-EW\\_245\\_H2\\_Insights\\_WEB.pdf](https://static.agora-energiewende.de/fileadmin/Projekte/2021/2021_11_H2_Insights/A-EW_245_H2_Insights_WEB.pdf)
- <sup>33</sup> Recharge, 14/12/2021, "Gas distributor group Ready4H2 says majority of members would not be ready for hydrogen until 2040", <https://www.rechargenews.com/energy-transition/gas-distributor-group-ready4h2-says-majority-of-members-would-not-be-ready-for-hydrogen-until-2040/2-1-1123484>
- <sup>34</sup> Viessmann, "Hydrogen boilers: how they work and whether you need one", <https://www.viessmann.co.uk/heating-advice/how-do-hydrogen-boilers-work>; Homebuilding and renovating, "Hydrogen Heating: Government Urged to Fast-Track Hydrogen Boilers Rollout", <https://www.homebuilding.co.uk/news/hydrogen-heating>; British Gas, 21/1/2022, "Hydrogen boilers: everything you need to know", <https://www.britishgas.co.uk/the-source/greener-living/hydrogen-boilers.html>
- <sup>35</sup> H&V News, 17/11/2020, "Industry agreement reached on 'hydrogen-ready' boiler definition", <https://www.hvnplus.co.uk/news/industry-agreement-reached-on-hydrogen-ready-boiler-definition-17-11-2020/>; Worcester Bosch, "Hydrogen-fired boiler", <https://www.worcester-bosch.co.uk/hydrogen>; Worcester Bosch, "Hydrogen – Technical information", <https://www.worcester-bosch.co.uk/professional/hydrogen-technical-information>; Euractiv, 1/12/2021, "EU ponders 20% hydrogen-ready standard for gas boilers", <https://www.euractiv.com/section/energy-environment/news/eu-ponders-20-hydrogen-ready-standard-for-gas-boilers/>
- <sup>36</sup> Worcester Bosch, "Hydrogen-fired boiler", <https://www.worcester-bosch.co.uk/hydrogen>
- <sup>37</sup> EHI and others, 18/6/2020, "Renewable and decarbonized gases", [https://www.asktheeu.org/en/request/11340/response/38322/attach/6/2%20Ares%202020%203583824%20annex%20Redacted.pdf?cookie\\_passthrough=1](https://www.asktheeu.org/en/request/11340/response/38322/attach/6/2%20Ares%202020%203583824%20annex%20Redacted.pdf?cookie_passthrough=1)
- <sup>38</sup> Euractiv, 1/12/2021, "EU ponders 20% hydrogen-ready standard for gas boilers", <https://www.euractiv.com/section/energy-environment/news/eu-ponders-20-hydrogen-ready-standard-for-gas-boilers/>
- <sup>39</sup> Worcester Bosch, "Difference between natural gas and hydrogen boiler", <https://www.worcester-bosch.co.uk/professional/hydrogen-technical-information>
- <sup>40</sup> Worcester Bosch, "Hydrogen-fired boiler", <https://www.worcester-bosch.co.uk/hydrogen>; Worcester Bosch, "Hydrogen – Technical information – what is a hydrogen ready boiler", <https://www.worcester-bosch.co.uk/professional/hydrogen-technical-information>
- <sup>41</sup> H&V News, 29/7/2021, "Four manufacturers make 'hydrogen-ready' boilers cost pact", <https://www.hvnplus.co.uk/news/four-manufacturers-make-hydrogen-ready-boilers-cost-pact-29-07-2021/>
- <sup>42</sup> The Engineer, 3/8/2021, "Big Four make price promise on domestic hydrogen boilers", <https://www.theengineer.co.uk/content/news/big-four-make-price-promise-on-domestic-hydrogen-boilers/>
- <sup>43</sup> Installer, "Introducing The Bosch Condens 7000 WP", <https://www.installeronline.co.uk/introducing-the-bosch-condens-7000-wp/>; Twitter, 12/7/2021, @Installermag, <https://twitter.com/Installermag/status/1546772676232052737>
- <sup>44</sup> Instagram, 21/5/2022, @worcesterboschprofessional [https://www.instagram.com/tv/Cddwqxll7\\_X/?utm\\_source=ig\\_web\\_copy\\_link](https://www.instagram.com/tv/Cddwqxll7_X/?utm_source=ig_web_copy_link)
- <sup>45</sup> British Gas, 21/1/2022, "Hydrogen boilers: everything you need to know", <https://www.britishgas.co.uk/the-source/greener-living/hydrogen-boilers.html>
- <sup>46</sup> Vaillant, "When we expect hydrogen boilers to become mainstream", <https://www.vaillant.co.uk/for-installers/business-support/industry-drivers-and-legislation/hydrogen/hydrogen-boilers-mainstream-2404425.html>
- <sup>47</sup> Environmental Science: Atmospheres, 2021, A. Lewis, "Optimising air quality co-benefits in a hydrogen economy: a case for hydrogen-specific standards for NOx emissions", <https://pubs.rsc.org/en/content/articlepdf/2021/ea/d1ea00037c>
- ENDS, 30/7/2021, "Scientist warns of NOx urban pollution from hydrogen boilers", <https://www.endsreport.com/article/1723633/scientist-warns-nox-urban-pollution-hydrogen-boilers#:~:text=%E2%80%99CBY%20the%202040s%2C%20hydrogen%20combustion,associated%20with%20low%20income%20households.>
- <sup>48</sup> EPA, 1/2016, "Integrated Science Assessment (ISA) for Oxides of Nitrogen – Health Criteria", <https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=310879>
- <sup>49</sup> American Journal of Public Health, 13/3/2019, Payne-Sturgis et al, "Healthy Air, Healthy Brains: Advancing Air Pollution Policy to Protect Children's Health", <https://ajph.aphapublications.org/doi/full/10.2105/AJPH.2018.304902>
- <sup>50</sup> Environmental Science: Atmospheres, 2021, A. Lewis, "Optimising air quality co-benefits in a hydrogen economy: a case for hydrogen-specific standards for NOx emissions", <https://pubs.rsc.org/en/content/articlepdf/2021/ea/d1ea00037c>
- <sup>51</sup> RMI, 2020, "Gas Stoves: Health and Air Quality Impacts and Solutions", <https://rmi.org/insight/gas-stoves-pollution-health>; Vox, 11/5/2020, "Gas stoves can generate unsafe levels of indoor air pollution", <https://www.vox.com/energy-and-environment/2020/5/7/21247602/gas-stove-cooking-indoor-air-pollution-health-risks>
- <sup>52</sup> Environmental Science: Atmospheres, 2021, A. Lewis, "Optimising air quality co-benefits in a hydrogen economy: a case for hydrogen-specific standards for NOx emissions",

<https://pubs.rsc.org/en/content/articlepdf/2021/ea/d1ea00037c>

<sup>53</sup> Meta Ad Library, Advert Ids 475478720373457 and 1218893148606507, [https://www.facebook.com/ads/library/?active\\_status=all&ad\\_type=all&country=ALL&view\\_all\\_page\\_id=1417908485169365&search\\_type=page&media\\_type=all](https://www.facebook.com/ads/library/?active_status=all&ad_type=all&country=ALL&view_all_page_id=1417908485169365&search_type=page&media_type=all)

<sup>54</sup> Viessmann, "Hydrogen – energy source with fascinating potential", <https://www.viessmann.family/en/what-we-offer/climate-solutions/hydrogen/h2-knowledge>

<sup>55</sup> US Department of Energy, The Office of Energy Efficiency and Renewable Energy, "Safe use of hydrogen", <https://www.energy.gov/eere/fuelcells/safe-use-hydrogen#:~:text=Specifically%2C%20hydrogen%20has%20a%20wide.design%20of%20safe%20hydrogen%20systems.>

<sup>56</sup> Recharge, 7/8/2021, "Hydrogen in the home would be four times more dangerous than natural gas: government report", <https://www.rechargenews.com/energy-transition/hydrogen-in-the-home-would-be-four-times-more-dangerous-than-natural-gas-government-report/2-1-1047218>

<sup>57</sup> Viessmann, "Hydrogen boilers: how they work and whether you need one", <https://www.viessmann.co.uk/heating-advice/how-do-hydrogen-boilers-work>

<sup>58</sup> Worcester Bosch, "Hydrogen-fired boiler", <https://www.worcester-bosch.co.uk/hydrogen>

<sup>59</sup> Baxi, 3/8/2021, "Baxi demonstrates its hydrogen boiler in UK's first hydrogen house", <https://www.baxi.co.uk/news/baxi-demonstrates-its-hydrogen-boiler-in-uks-first-hydrogen-house>

<sup>60</sup> British Gas, 21/1/2022, "Hydrogen boilers: everything you need to know", <https://www.britishgas.co.uk/the-source/greener-living/hydrogen-boilers.html#:~:text=The%20only%20by%2Dproduct%20of.a%20a%20country%20by%202050.>; British Gas, "Boiler Marketplace", <https://www.britishgas.co.uk/boiler-marketplace/configure>

<sup>61</sup> Video shown at InstallerShow 2022 by Vaillant. 22/5/2022

<sup>62</sup> Global Witness, September 2022, "Heating Homes With Gas Is Expensive, Heating With Hydrogen Could Cost Double"

<sup>63</sup> BEUC, 2/2022, "The Consumer Costs of Decarbonised Heat", [https://www.beuc.eu/sites/default/files/publications/beuc-x-2021-111\\_consumer\\_cost\\_of\\_heat\\_decarbonisation\\_report.pdf](https://www.beuc.eu/sites/default/files/publications/beuc-x-2021-111_consumer_cost_of_heat_decarbonisation_report.pdf)

<sup>64</sup> ICCT, 10/3/2021, "Hydrogen For Heating? Decarbonization Options For Households In The European Union In 2050", <https://theicct.org/publication/hydrogen-for-heating-decarbonization-options-for-households-in-the-european-union-in-2050/>

<sup>65</sup> Heating Hub, 5/9/2020, "Boiler efficiency calculator | Most efficient boilers | Energy saving tips", <https://www.theheatinghub.co.uk/boiler-efficiency-guide-and-energy-saving-tips>

<sup>66</sup> Vaillant, "Hydrogen for Heating", <https://www.vaillant.co.uk/for-installers/business-support/industry-drivers-and-legislation/hydrogen/hydrogen-for-heating-2404424.html>

<sup>67</sup> IEA, 11/21, "Heat Pumps", <https://www.iea.org/reports/heat-pumps;> [https://www.icax.co.uk/Seasonal\\_Performance\\_Factor.html#:~:text=The%20Seasonal%20performance%20Factor%20\(SPF,to%20the%20heat%20pump%20falls.](https://www.icax.co.uk/Seasonal_Performance_Factor.html#:~:text=The%20Seasonal%20performance%20Factor%20(SPF,to%20the%20heat%20pump%20falls.)

<https://www.iea.org/reports/heat-pumps;> [https://www.icax.co.uk/Seasonal\\_Performance\\_Factor.html#:~:text=The%20Seasonal%20performance%20Factor%20\(SPF,to%20the%20heat%20pump%20falls.](https://www.icax.co.uk/Seasonal_Performance_Factor.html#:~:text=The%20Seasonal%20performance%20Factor%20(SPF,to%20the%20heat%20pump%20falls.); European Commission, 2019, "Hydrogen use in EU decarbonisation scenarios", [https://joint-research-centre.ec.europa.eu/system/files/2019-04/final\\_insights\\_into\\_hydrogen\\_use\\_public\\_version.pdf](https://joint-research-centre.ec.europa.eu/system/files/2019-04/final_insights_into_hydrogen_use_public_version.pdf)

<sup>68</sup> Guardian, 23/10/2021, "Air source heat pumps: how the costs and savings stack up", <https://www.theguardian.com/money/2021/oct/23/air-source-heat-pumps-how-the-costs-and-savings-stack-up>

<sup>69</sup> Agora Energiewende, 1/2022, "12 Insights on Hydrogen", [https://static.agora-energiewende.de/fileadmin/Projekte/2021/2021\\_11\\_H2\\_Insights/A-EW\\_245\\_H2\\_Insights\\_WEB.pdf](https://static.agora-energiewende.de/fileadmin/Projekte/2021/2021_11_H2_Insights/A-EW_245_H2_Insights_WEB.pdf); Oko-Institut, 2021, "Die Wasserstoffstrategie 2.0 für Deutschland", <https://www.stiftung-klima.de/app/uploads/2021/05/Oeko-Institut-2021-Die-Wasserstoffstrategie-2.0-fuer-Deutschland.pdf>

<sup>70</sup> European Commission, "Hydrogen", [https://energy.ec.europa.eu/topics/energy-systems-integration/hydrogen\\_en#:~:text=Hydrogen%20accounts%20for%20less%20than.CO2%20emissions%20in%20the%20p%20cess.](https://energy.ec.europa.eu/topics/energy-systems-integration/hydrogen_en#:~:text=Hydrogen%20accounts%20for%20less%20than.CO2%20emissions%20in%20the%20p%20cess.)

<sup>71</sup> IEA, 11/2021, "Hydrogen", <https://www.iea.org/reports/hydrogen>

<sup>72</sup> European Environment Agency, "EEA greenhouse gases - data viewer", <https://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer>

<sup>73</sup> Recharge, 22/11/2021, "Using blue hydrogen for heating would lock in fossil fuels for decades while cutting emissions by only 65%", <https://www.rechargenews.com/energy-transition/using-blue-hydrogen-for-heating-would-lock-in-fossil-fuels-for-decades-while-cutting-emissions-by-only-65-/2-1-1102004>

<sup>74</sup> Energy Science and Engineering, Howarth and Jacobson, 12/8/2021, "How green is blue hydrogen?", <https://onlinelibrary.wiley.com/doi/full/10.1002/ese3.956>

<sup>75</sup> Global Witness, 20/1/2022, "Hydrogen's Hidden Emissions", <https://www.globalwitness.org/en/campaigns/fossil-gas/shell-hydrogen-true-emissions/>

<sup>76</sup> IEEFA, 5/2022, "Russia Sanctions and Gas Price Crisis Reveal Danger of Investing in "Blue" Hydrogen", [https://ieefa.org/sites/default/files/2022-05/Russia%20Sanctions%20and%20Gas%20Price%20Crisis%20Reveal%20Danger%20of%20Investing%20in%20Blue%20Hydrogen\\_May%202022.pdf](https://ieefa.org/sites/default/files/2022-05/Russia%20Sanctions%20and%20Gas%20Price%20Crisis%20Reveal%20Danger%20of%20Investing%20in%20Blue%20Hydrogen_May%202022.pdf)

<sup>77</sup> Hydrogen Science Coalition, 15/4/2022, "Hydrogen for heating? A comparison with heat pumps (Part 1)", <https://h2sciencecoalition.com/blog/hydrogen-for-heating-a-comparison-with-heat-pumps-part-1/>

<sup>78</sup> Agora Energiewende, 1/2022, "12 Insights on Hydrogen", [https://static.agora-energiewende.de/fileadmin/Projekte/2021/2021\\_11\\_H2\\_Insights/A-EW\\_245\\_H2\\_Insights\\_WEB.pdf](https://static.agora-energiewende.de/fileadmin/Projekte/2021/2021_11_H2_Insights/A-EW_245_H2_Insights_WEB.pdf) p27

<sup>79</sup> Hydrogen Science Coalition, 15/4/2022, "Hydrogen for heating? A comparison with heat pumps (Part 1)", <https://h2sciencecoalition.com/blog/hydrogen-for-heating-a-comparison-with-heat-pumps-part-1/>

<sup>80</sup> Agora Energiewende, 1/2022, "12 Insights on Hydrogen", [https://static.agora-energiewende.de/fileadmin/Projekte/2021/2021\\_11\\_H2\\_Insights/A-EW\\_245\\_H2\\_Insights\\_WEB.pdf](https://static.agora-energiewende.de/fileadmin/Projekte/2021/2021_11_H2_Insights/A-EW_245_H2_Insights_WEB.pdf)

[energiawende.de/fileadmin/Projekte/2021/2021\\_11\\_H2\\_Insights/A-EW\\_245\\_H2\\_Insights\\_WEB.pdf](https://www.energiawende.de/fileadmin/Projekte/2021/2021_11_H2_Insights/A-EW_245_H2_Insights_WEB.pdf) p28

<sup>81</sup> Hydrogen Science Coalition, 15/4/2022, "Hydrogen for heating? A comparison with heat pumps (Part 1)", <https://h2sciencecoalition.com/blog/hydrogen-for-heating-a-comparison-with-heat-pumps-part-1/>

<sup>82</sup> IEEFA, 5/2022, "Russia Sanctions and Gas Price Crisis Reveal Danger of Investing in "Blue" Hydrogen", [https://ieefa.org/sites/default/files/2022-05/Russia%20Sanctions%20and%20Gas%20Price%20Crisis%20Reveal%20Danger%20of%20Investing%20in%20Blue%20Hydrogen\\_May%202022.pdf](https://ieefa.org/sites/default/files/2022-05/Russia%20Sanctions%20and%20Gas%20Price%20Crisis%20Reveal%20Danger%20of%20Investing%20in%20Blue%20Hydrogen_May%202022.pdf) p7

<sup>83</sup> Energy Conversion and Management, 15/6/2022, Olympios et al., "Delivering net-zero carbon heat: Technoeconomic and whole-system comparisons of domestic electricity- and hydrogen-driven technologies in the UK", Volume 262, <https://www.sciencedirect.com/science/article/pii/S0196890422004459#b0045>

<sup>84</sup> Cassarino and Barrett, 1/1/2022, "Meeting UK heat demands in zero emission renewable energy systems using storage and interconnectors", <https://www.researchsquare.com/article/rs-629226/v1>

<sup>85</sup> Ready4H2, 3/22, "Europe's Local Hydrogen Distribution Networks PART 3: A roadmap for local gas distribution networks to become the leading hydrogen distribution infrastructure", [https://www.ready4h2.com/files/ugd/597932\\_44ca5c9ebcd94662a7e4232dd0336adc.pdf](https://www.ready4h2.com/files/ugd/597932_44ca5c9ebcd94662a7e4232dd0336adc.pdf); Ready4H2, 3/22, "Europe's Local Hydrogen Networks PART 1: Local gas networks are getting ready to convert", p12; Eurogas, 9/21, "Hydrogen and decarbonised gas market package Eurogas Recommendations", p7, <https://www.eurogas.org/wp-content/uploads/2022/01/210901-DEF-Eurogas-recommendations-Hydrogen-and-decarbonised-gas-market-1.pdf>; GIE, 24/11/2021, "GIE Position on Blending Hydrogen into Existing Gas Infrastructure", [https://www.gie.eu/wp-content/uploads/filr/5592/GIE\\_Position\\_Paper\\_on\\_Hydrogen\\_Blending.pdf](https://www.gie.eu/wp-content/uploads/filr/5592/GIE_Position_Paper_on_Hydrogen_Blending.pdf)

<sup>86</sup> GIE, 24/11/2021, "GIE Position on Blending Hydrogen into Existing Gas Infrastructure", [https://www.gie.eu/wp-content/uploads/filr/5592/GIE\\_Position\\_Paper\\_on\\_Hydrogen\\_Blending.pdf](https://www.gie.eu/wp-content/uploads/filr/5592/GIE_Position_Paper_on_Hydrogen_Blending.pdf), p4; ENSTOG, GIE and Hydrogen Europe, 5/2021, "How To Transport And Store Hydrogen – Facts And Figures", [https://entsog.eu/sites/default/files/2021-05/ENTSOG\\_GIE\\_HydrogenEurope\\_QandA\\_hydrogen\\_transport\\_and\\_storage\\_FINAL\\_0.pdf](https://entsog.eu/sites/default/files/2021-05/ENTSOG_GIE_HydrogenEurope_QandA_hydrogen_transport_and_storage_FINAL_0.pdf)

<sup>87</sup> Recharge, 19/5/2022, "REPowerEU: More than a million tonnes of green hydrogen will be used for gas blending in 2030, says Commission", <https://www.rechargenews.com/energy-transition/repowereu-more-than-a-million-tonnes-of-green-hydrogen-will-be-used-for-gas-blending-in-2030-says-commission/2-1-1221967>

<sup>88</sup> IRENA, 4/2022, "Global Hydrogen Trade to Meet the 1.5°C Climate Goal: Technology Review of Hydrogen Carriers", <https://www.irena.org/publications/2022/Apr/Global-hydrogen-trade-Part-II>, p104

<sup>89</sup> Recharge, 5/5/2022, "Hydrogen blending in gas grid would lead to 'limited CO2 benefits and a large increase in energy costs': Irena", <https://www.rechargenews.com/energy-transition/hydrogen-blending-in-gas-grid-would-lead-to-limited-co2-benefits-and-a-large-increase-in-energy-costs-irena/2-1-1213821>

<sup>90</sup> Energy Flux, 16/12/2021, "EU embraces wasteful hydrogen blending", <https://www.energyflux.news/p/eu-embraces-wasteful-hydrogen-blending>

<sup>91</sup> Michael Liebreich, 15/8/2021, "The Clean Hydrogen Ladder [Now updated to V4.1]", <https://www.linkedin.com/pulse/clean-hydrogen-ladder-v40-michael-liebreich/>; <https://twitter.com/mliebreich/status/1426902536280281090?lang=gl>

<sup>92</sup> IRENA, 2022, "Geopolitics of the Energy Transformation: The Hydrogen Factor", <https://www.irena.org/publications/2022/Jan/Geopolitics-of-the-Energy-Transformation-Hydrogen>, p14

<sup>93</sup> IEA, 5/2021, "Net Zero by 2050 A Roadmap for the Global Energy Sector", <https://www.iea.org/reports/net-zero-by-2050> p197

<sup>94</sup> McKinsey, "The net-zero transition: What it would cost, what it could bring", <https://www.mckinsey.com/business-functions/sustainability/our-insights/the-net-zero-transition-what-it-would-cost-what-it-could-bring#> p29

<sup>95</sup> IPCC, "Climate Change 2022, Mitigation of Climate Change, Working Group III contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change", [https://report.ipcc.ch/ar6wg3/pdf/IPCC\\_AR6\\_WGIII\\_FinalDraft\\_FullReport.pdf](https://report.ipcc.ch/ar6wg3/pdf/IPCC_AR6_WGIII_FinalDraft_FullReport.pdf), p1051

<sup>96</sup> Fossil Free Politics, <https://www.fossilfreepolitics.org/>

<sup>97</sup> Ban Fossil Fuel Ads, <https://banfossilfuelads.org/>