RAP®

NOVEMBER 2022

REGULATORY ASSISTANCE PROJECT

Getting the hydrogen network we need for decarbonisation

Megan Anderson, Andreas Jahn

There is general agreement in evidence-based analyses and European decarbonisation strategies that hydrogen is best used for hard-to-electrify end uses, and not as a replacement for fossil gas.[1] There are several reasons for this conclusion:

- It takes more energy to create hydrogen and then combust it to meet an end use than to electrify the end use directly.[2]
- Hydrogen is not currently produced in large quantities, and the amounts of zero- or low-carbon hydrogen available are even smaller.[3]
- Even if hydrogen production increases, new or upgraded infrastructure will be required to deliver that hydrogen, which is likely to be more expensive than alternatives for electrification for many end uses.[4]
- Depending on the methods used, the production of hydrogen and its combustion can still cause greenhouse gas emissions and nitrogen oxide pollution.[5]

[1] Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, REPowerEU Plan. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2022%3A230%3AFIN&qid=1653033742483, ("Renewable hydrogen will be key to replace natural gas, coal and oil in hard-to-decarbonise industries and transport."); Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Powering a climate-neutral economy: An EU strategy for energy system integration. https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=COM:2020:299:FIN

[2] Rosenow, J. (2021). Heating with hydrogen: Are we being sold a pup? *Energy Monitor*. https://www.energymonitor.ai/sectors/heating-cooling/heating-homes-with-hydrogen-are-we-being-sold-a-pup

[3] *One Earth*, volume 4, Rosenow, J., & Lowes, R. (2021). Will blue hydrogen lock us into fossil fuels forever? pp. 1527-1529, copyright Elsevier. https://www.sciencedirect.com/science/article/abs/pii/S2590332221006047

[4] Andreola, S., Menos-Aikateriniadis, A., Paxton, A., Preißler, H., Miehling, H., Rehn, M., Sarsfield-Hall, R., & Unger, B. (2021). *No-regret hydrogen: Charting early steps for H_2 infrastructure in Europe*. Agora Energiewende. https://www.agora-energiewende.de/en/publications/no-regret-hydrogen

[5] Zhou, Y., Swidler, D., Searle, S., & Baldino, C. (2022). *Life-cycle greenhouse gas emissions of biomethane and hydrogen pathways in the European Union*. The International Council on Clean Transportation (ICCT). https://theicct.org/publication/life-cycle-greenhouse-gas-emissions-of-biomethane-and-hydrogen-pathways-in-the-european-union; Lewis, A. (2021). Optimising air quality co-benefits in a hydrogen economy: a case for hydrogen-specific standards for NOx emissions. *Environmental Science: Atmospheres*. Royal Society of Chemistry. https://pubs.rsc.org/en/content/articlelanding/2021/ea/d1ea00037c

This consensus is nevertheless thrown by the wayside in the excitement over proposals[6] to ramp up hydrogen production and infrastructure. Instead of focusing on the development of the hydrogen network we need to support a decarbonised energy system, discussion and action too often deteriorate into a singular focus on expanding hydrogen production and infrastructure broadly. In even less useful contributions, incumbent interests use hydrogen as a cloak under which they can perpetuate infrastructure and business models that do not facilitate urgently needed decarbonisation.

The necessity for rapid decarbonisation and the even more immediate need to move away from dependence on fossil gas as a result of Russia's war in Ukraine creates an environment in which solutions that sound simple – such as an increase of hydrogen to replace fossil gas – can seem very attractive. Based on the apparent ease of their implementation, decision-makers may see them as more favourable than a more integrated, and ultimately more resilient, system approach. The enthusiasm for hydrogen can leave other solutions such as energy efficiency and electrification struggling to find support even when they are the more efficient, equitable and effective answer.

Instead of supporting a hydrogen rush, Europe needs strong regulation and appropriate market design to direct future hydrogen system operators[7] to develop and operate the system needed to serve hard-to-electrify end uses, such as fertiliser production, heavy industry and some limited electricity generation. Policymakers can achieve this goal through three important actions:

- **Unbundle gas and hydrogen networks.** Separate ownership of emerging hydrogen network operators and existing gas system operators (horizontal unbundling).[8] Unbundling is critical to avoid incentives for gas network operators to overbuild or repurpose networks to serve end uses that currently use gas but would be better served through overall system efficiency, energy efficiency measures and electrification.[9]
- **Require efficient system development and operation.** Key to efficient system operation is developing a network fit for purpose. To ensure that hydrogen is going to priority uses first, it is vital to require a no-regrets hydrogen network and hydrogen clusters to serve demand for those hard-to-electrify end uses already known to need alternative fuels. This focus will accomplish two goals: 1) network operators will focus network development to serve end uses for which hydrogen is the best tool for decarbonisation, and not squander it on blending or end uses that do not need it; and 2), network operators will be able to efficiently operate this focused network.
- **Design planning processes to arrive at efficient, integrated solutions.** Integrated planning will help match infrastructure to expected end uses by determining where hydrogen networks will be needed, where power infrastructure may need to be

[6] See, e.g., hello hydrogen. (n. d.) *The future of home heating*. https://www.hellohydrogen.com; Hydrogen Europe. (2022). *Hydrogen technologies can boost the energy performance of buildings*. https://hydrogeneurope.eu/wp-content/uploads/2022/05/220516-EPBD_hydrogen-Europe-Position-paper-1.pdf

[7] The current gas package proposal calls for the development of hydrogen network operators, and the organisation of a new European Network of Network Operators for Hydrogen (ENNOH). Until ENNOH is established in 2031, the European Network of Transmission System Operators for Gas (ENTSOG) will be responsible for hydrogen development plans. European Commission. (2021a). Proposal for a Regulation of the European Parliament and of the Council on the internal markets for renewable and natural gases and for hydrogen (recast), para. (48). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2021:804:FIN

[8] The current proposal allows for gas and hydrogen system operators to be within the same undertaking, but does require legal unbundling (horizontal unbundling). European Commission. (2021b). Proposal for a Directive of the European Parliament and of the Council on common rules for the internal markets in renewable and natural gases and in hydrogen, Art. 63. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021PC0803; Horizontal unbundling is different than vertical unbundling, which separates ownership of transmission and distribution from supply and retail.

[9] Although existing gas system operators may have expertise about existing gas networks that could inform hydrogen network planning, that information can be transferred across operators via market structures. In short, the existence of this knowledge does not justify claims that the operators should be allowed to be owned and operated by the same entity.

augmented to serve additional electrified end uses and, importantly, where pipelines will not be needed. Integrated planning minimises costs, time and overbuilding.[10] To achieve these important goals, policy needs to design planning processes to minimise the implicit incentives of system operators to favour their own networks and to minimise unnecessary redundancies.

The following sections explore the rationale and implications of these three recommendations.

Independent hydrogen network operators, rather than existing gas operators, are better positioned to plan the network we need.

In the absence of very strict regulation limiting hydrogen network development, answering the question of who can own and operate the hydrogen network will be largely determinative of what hydrogen network will be built. If gas network operators are allowed to own hydrogen assets, there will be a strong incentive for those entities to push for hydrogen blending in existing gas pipelines, to upgrade existing pipelines to carry hydrogen instead of gas, and to overbuild new infrastructure to serve end uses that the companies do not want to lose to electrification. In short, turning over hydrogen to gas system operators already facing an uncertain future gives them the pen to write a much more expansive story about how hydrogen can be used, despite the greater efficiency of other options.

There are many reasons, however, why such combined ownership and operation would lead to inefficient outcomes. The table below shows, in five key areas, the potential effects of allowing gas operators to become hydrogen operators, versus implementing requirements that require horizontal unbundling of those owner-operators.

EFFECTS OF GAS AND HYDROGEN BUNDLING VERSUS UNBUNDLING

	BUNDLED GAS AND HYDROGEN OPERATORS	UNBUNDLED HYDROGEN OPERATORS
Use of existing network	X Without clear separation of fossil assets and needs for hydrogen network development, the value of old assets for reuse versus new build is unclear and can be easily manipulated. X Gas operators will be able to act on incentive to reuse networks and invest in significant upgrades for the return on capital.	√ Hydrogen operators will be looking at where demand is likely to occur. X Depending on that demand, hydrogen operators would need to acquire existing gas networks where needed. √ No need to acquire existing networks that are not needed. √ Value of existing assets will be determined by the value to a new system versus to new build. ->Regulation may also be used to avoid overbuilding of networks by hydrogen owners/operators.

[10] Integrated planning can also help to identify where existing pipelines may be repurposed for hydrogen usage.

EFFECTS OF GAS AND HYDROGEN BUNDLING VERSUS UNBUNDLING		
	BUNDLED GAS AND HYDROGEN OPERATORS	**UNBUNDLED HYDROGEN OPERATORS**
Planning	√ Combined owner will have information about existing gas network. X This expertise may be useful or may be used to argue for reuse of existing networks, even when not needed. X Without improved planning processes, it will be difficult for regulators or third parties to push back against these conclusions. X Operators have incentive to minimise transparency around gas grid data to maintain their own business advantage. X Economy of scale is limited to voluntary cooperation. X Ownership and operational structures will be fragmented, as in the gas grid.	√ Hydrogen operator will be able to plan for the hydrogen network needed to serve anticipated hydrogen end uses without being tethered to existing network. √ Can prioritise areas for network development based on immediate needs, unencumbered by gas network needs. X Hydrogen operator will not have information about existing gas network but could negotiate with gas operator about acquiring that information as needed. -> Regulation may also be used to require the sharing of certain information across networks to facilitate hydrogen network development.
Funding	X Public funds allocated to hydrogen network development will go to combined operator. X Will require detailed accounting requirements to ensure that those funds are spent on hydrogen development, and not on perpetuating gas networks. X Will also require compliance reviews and consequences for failures to comply.	√ Funds for hydrogen network development will go directly to hydrogen network developers.
Gas network future	X Allowing for gas operators to become hydrogen operators sends a signal that gas operators should develop a business model around delivering alternative gases, without limiting that role. X Does not send a message about a more fundamental shift in role given increased electrification.	√ Hydrogen operators will be able to proceed immediately to develop a business model and network to meet hydrogen end uses.

EFFECTS OF GAS AND HYDROGEN BUNDLING VERSUS UNBUNDLING		
	BUNDLED GAS AND HYDROGEN OPERATORS	**UNBUNDLED HYDROGEN OPERATORS**
Gas network decommissioning	X Gas operators will have less incentive to focus on system decommissioning where needed, risking delays in electrification and attendant infrastructure development. X Without the need to outline and value synergies, gas undertakings have an incentive to overstate benefits of using the existing gas grid and understate areas of the gas network that should be decommissioned.	√ Hydrogen operators can focus on determining which areas of existing gas networks will be most beneficial to acquire to build hydrogen network most efficiently.

Development of a network fit for purpose will improve network operation.

How efficiently the hydrogen network is developed will also impact how efficiently it can be operated – and thus how effectively hydrogen is used as a tool for decarbonisation. A no-regrets hydrogen network that focuses energy and resources on specific areas that will need hydrogen to decarbonise – such as certain heavy industry and fertilizer production – will eliminate the fossil fuels or grey hydrogen currently used, thus reducing large amounts of greenhouse gases efficiently. Developing hydrogen clusters in these areas will keep operational costs in check. By contrast, allowing for a network that is built to opportunistically serve end users may result in an ungainly, cobbled-together network. Such a network would not only be expensive, but it would also squander hydrogen on uses that may not need it. And consumers would bear the brunt of the costs to build and operate such a network over the long-term.

Development of the gas network suffered from many mistakes that could serve as cautionary tales for development of the hydrogen network. European law designates owners of gas networks as the operators of those networks.[11] In addition, in some cases, mainly at the distribution level, those network operators are not fully unbundled from gas suppliers or from end-use operation of district heating networks.[12] This combined set of interests led to operator-driven gas networks, rather than a strategic plan to efficiently serve consumers.

[11] European Commission. (2009). Directive 2009/73/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in natural gas and repealing Directive 2003/55/EC, Article 9, 1(a) and Article 24. https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex%3A32009L0073

[12] Only half of current transmission system operators are currently unbundled. European Commission. (2021c). Commission staff working document: Impact assessment report accompanying the proposal for a Directive of the European Parliament and of the Council on common rules for the internal markets in renewable and natural gases and in hydrogen (recast), Impact assessment report accompanying the proposal for a Regulation of the European Parliament and of the Council on the internal markets for renewable and natural gases and for hydrogen (recast), Part 2, FN 11. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=SWD%3A2021%3A455%3AFIN&qid=1639998727689

As a result, gas networks across Europe are diverse in size, end uses served and customer base:

- There are now at least 45 fossil gas transmission system operators (TSOs) in 25 Member States.[13]
- Those TSOs do not serve Member States equally, however. For example, there are only two TSOs in France while there are 16 in Germany.
- Operation is similarly diverse. In Germany, for example, parallel pipelines are owned and operated by different entities, whereas in other Member States parallel pipelines are operated by the same TSO.[14]

At the distribution level, the ownership and operation are similarly varied, and there is not the same clear boundary between transmission and distribution networks as there is in the power sector. For example, in Germany:

- There is a large difference in the size of distribution system operators' (DSOs') networks. Only 19 of the 703 fossil gas DSO networks are longer than 4,000 km. More than 300 DSOs own and operate networks of fewer than 250 km.
- Only 33 of the 703 have more than 100,000 customers, and thus only those 33 must adhere to general unbundling requirements.
- 499 DSOs fulfil the de minimis exemption threshold of fewer than 15,000 connected gas customers and therefore enjoy additional exemptions from German performance-based regulation.

The variation in gas network size and structure has made it difficult to design consistent and efficient regulation. For example, the diversity in gas networks made implementation of third-party access and retail competition more difficult in the gas sector than in the power sector. Third-party supplier offers reached consumers more slowly because those third-party suppliers had to first overcome the specific local conditions of each gas network and compete with a vertically integrated incumbent.[15]

By contrast, although pieces of the hydrogen network are in place for existing users, the future hydrogen network benefits largely from a blank canvas upon which policymakers and regulators can design an efficient and fit-for-purpose system. Moreover, by prohibiting ownership bundling across the gas and hydrogen networks, as discussed above, the hydrogen network can be developed without the historical baggage of the fossil gas network. Instead, separating these entities creates the opportunity to set up an efficient structure that serves consumers by minimising costs from the beginning. Direction as to how these networks are operated could allow for greater system efficiency than in the fossil gas networks. For example:

- Up to a certain level, many operational costs are one-time costs that are reduced per capita or per customer when leveraging economies of scale. These costs could be shared

[13] There are 43 members in ENTSOG, but there are also TSOs that are not ENTSOG members. (including the Associated Member in Estonia) https://www.entsog.eu/members; but see European Commission, 2021, part 2, FN 11 (60 registered TSOs).
[14] Energie-Chronik. (2012 May). E.ON verkauft das Ruhrgas-Netz für 3,2 Milliarden Euro [E.ON sold Ruhrgas network for 3.2 billion euro]. https://www.udo-leuschner.de/energie-chronik/120507.htm
[15] Agency for the Cooperation of Energy Regulators (ACER) and Council of European Energy Regulators (CEER). (2012). Annual report on the results of monitoring the internal electricity and natural gas markets in 2011. https://www.acer.europa.eu/Official_documents/Acts_of_the_Agency/Publication/ACER%20Market%20Monitoring%20Report%202012.pdf ; Bundesnetzagentur. (2007). Monitoringbericht 2007 der Bundesnetzagenur für Elektrizität, Gas, Telekommunikation, Post und Eisenbahnen [Monitoring report 2007 of the German Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railways]. https://www.bundesnetzagentur.de/SharedDocs/Mediathek/Monitoringberichte/Monitoringbericht2007.pdf?__blob=publicationFile&v=3

fairly if regulation includes requirements on network size to ensure that operational costs are similar from one network to another.

- Minimum network size requirements could also ensure that exemptions from unbundling, regulation, or transparency requirements, for example, are not exploited to the advantage of one system operator over another. Such requirements could also ensure that exemptions do not render overall requirements meaningless, as is the case with German DSOs.
- As there will be fewer end users of hydrogen, and fewer that need lower-pressure gas delivery, hydrogen operators will need to serve fewer consumers on the distribution side of the network. Given this shift, there may no longer be a need for a general distinction between TSOs and DSOs for hydrogen and eliminating this separation may lead to more efficient network operation.

In short, unbundling network operators will also allow for the development of an efficient and fit-for-purpose hydrogen network that suffers neither from the mistakes of the gas network, nor attempts to rework that network for hydrogen. Policymakers can put regulators a step ahead by ensuring a situation in which networks are not only developed to use hydrogen efficiently, but are also efficient to operate and regulate.

Planning the hydrogen network we need.

A critical part of ensuring that the hydrogen network serves decarbonisation goals – and importantly, does not hinder progress – is a planning process that places the hydrogen network within the context of an integrated energy system. Theoretically, such planning could occur even without unbundling network operators. Strict regulation, which included enough sidebars to limit the hydrogen network to one that is developed and operated efficiently, could achieve this goal, no matter who was doing the planning. In practice, however, without an unbundled hydrogen operator, the same incentives outlined in the table above could infect planning processes. Demand for hydrogen and attendant infrastructure could still be used to perpetuate gas networks serving end uses that could be served more economically through electrification or other means.[16] Similarly, infrastructure needs could still be inflated based on assertions by the gas network operators, who – because they hold all of the information about existing networks – could claim infrastructure is needed in areas that are likely more efficiently served by the electric sector.

Today's planning reveals how challenging it can be to build an efficient network even when gas and electric network operators are unbundled. Currently, monopoly system operators largely do all energy network planning. This situation is already problematic because system operators have a bias to increase revenues by making capital expenditures into a larger asset base – costs of which are borne by consumers. This incentive weighs against realistic demand projections, energy efficiency and operational solutions, all of which could result in more efficient system operation, with benefits for consumers. Consequently, planning processes already suffer where a lack of transparent information underpinning proposals for new infrastructure can put system operators in the powerful position of shaping the best story for their bottom line and stakeholders.

Extending planning power for a hydrogen network to gas operators will compound this

[16] Comparisons to electrification must include production, transmission, distribution and operational costs. Production costs for hydrogen will be significantly different than for fossil gas, but network and operation costs of a fossil gas system might be comparable.

problem. Gas operators have every incentive to maintain and expand their existing networks, and they can do several things that are counterproductive for the hydrogen network needed for a decarbonised system:

- Argue for maintenance and expansion of existing gas grids based on the idea that these networks will be needed for blends of fossil gas and hydrogen, and later for supplying hydrogen to end uses that do not fall within the hard-to-electrify categories.
- Use fees from gas networks to cross-subsidise hydrogen network development – something explicitly allowed by the current gas package draft.[17]
- Assert that expertise about the existing gas infrastructure is needed for hydrogen network development, without acknowledging other methods of information sharing where needed.

These approaches are currently playing out as gas network operators see a justification for growth, despite existing decarbonisation and gas reduction targets.[18]

Achieving a targeted hydrogen network requires independent, integrated and transparent planning processes, and unbundling acts as another safeguard towards achieving this goal. In short, unless network planning processes are completely reorganised to require an independent entity to coordinate and plan the networks making up the energy system, each network operator will have incentives to expand its network as much as possible. To avoid this outcome, policymakers and regulators need to use all the tools at their disposal to design transparent, integrated planning processes that can arrive at the most efficient paths to decarbonisation, at least cost to consumers.

Conclusions

For hydrogen to be an effective decarbonisation tool, policy needs to direct its development to ensure that it is being developed in the right areas for the right end uses only, and does not become a distraction that props up gas undertakings. The hydrogen network offers an opportunity to develop new infrastructure that does not carry the baggage of the past. Adopting the structure of fossil gas network development, without questioning whether those structures are useful, would only be another mistake with long-lasting consequences. Instead, by looking at the history of the gas network, one can see that it was developed in response to historical conditions and not as a result of systematic, strategic planning.

It is critical to learn from mistakes of the past rather than letting them propagate in future networks. Policymakers have a great chance to regulate hydrogen in a manner than serves decarbonisation goals and minimises costs to consumers.

[17] European Commission, 2021a, Art. 4.

[18] Anderson, M., Rosenow, J., Bürger, V., & Braungardt, S. (2022). Fossil gas infrastructure first, energy efficiency never? *Eceee summer study on energy efficiency.* https://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2022/3-policy-finance-and-governance/fossil-gas-infrastructure-first-energy-efficiency-never/; Webster, B. (2022 October 3). New homes built with gas boilers after developers lobby against green rules. *Open Democracy*. https://www.opendemocracy.net/en/new-build-homes-gas-boilers-heat-pumps-developers-lobby-government

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Belgium · China · Germany · India · United States

Rue de la Science 23
B – 1040 Brussels
Belgium

+32 2-789-3012
info@raponline.org
raponline.org