Zero Emissions Platform paper

“Facts on low-carbon hydrogen – A European perspective”

We have read the study ‘How green is blue hydrogen?’ by Howarth & Jacobson [1] and recommend readers to be very cautious as the conclusions from this study do not apply to Europe.

Howarth & Jacobsen assess and draw conclusions on the climate benefit of low-carbon hydrogen. The following points summarise the assumptions in the study:

- Upstream fugitive methane emissions are assumed to be 3.5% for natural gas. This number does not apply to Europe, nor on a global scale, where methane emissions are stated to be ten times lower [3, 4].
- The study also assumes that hydrogen is produced by steam methane reforming (SMR) with a carbon capture rate of 76%. This is low when compared with planned low-carbon hydrogen production units in Europe, where low-carbon hydrogen will mainly be produced by auto-thermal reforming (ATR), where a capture rate of more than 92% is planned to be achieved.
- The study assumes that the energy to run the hydrogen production is produced separately, requiring significant natural gas and generating corresponding CO_2 emissions. However, a low-carbon hydrogen plant is substantially energy-neutral. In reality, proper system integration can result in hydrogen production with carbon capture and storage (CCS) with net-zero power demand. In any case, if there is remaining power demand, it can be covered with a low-carbon hydrogen-fired gas turbines combined cycle power plant.

When the analysis is performed based on assumptions and conditions that are relevant for low-carbon hydrogen plants in Europe, the climate benefit of low-carbon hydrogen is significant. Low-carbon hydrogen is a cost-effective and climate-effective technology that will help Europe to meet its medium- and long-term climate targets.

Moreover, the European Union (EU) understood and anticipated some key questions on the manufacturing of low-carbon hydrogen by adopting a regulatory framework based on full life-cycle analysis of greenhouse gas (GHG) emissions and by taking into account upstream fugitive emissions, as outlined in the regulation on a EU Taxonomy for Sustainable Activities (European Taxonomy).

1. The need for a technology-neutral approach

The production of low-carbon hydrogen is crucial to enable substantial reductions in GHG emissions and for the cost-efficient decarbonisation of energy-intensive European industrial sectors. Hydrogen is an efficient energy carrier and can be used in a wide range of applications in all sectors of the economy. Combining hydrocarbon resources and/or residual process streams to produce hydrogen with CCS improves environmental performance.

As the effects of anthropogenic climate change become more and more severe, it is one of the highest priorities to take direct action against climate change. This requires radical changes in the short term. Assessing complex climate-driven industrial interventions needs a scientific and neutral approach, with trustworthy assumptions for the technological interventions that are currently being developed in the EU.

2. Important when using modelling – assumptions and input data define the result

When using any kind of modelling tool to provide insights into complex issues, it is crucial to use the right assumptions. In the case of the climate impact of low-carbon hydrogen, the assumptions, boundary conditions and input data are at least as important as the modelling tool itself.

This is especially important when providing simple quantitative results in complex matters – using a fairly simple model – aimed at policymakers.

3. Assumptions used in the study and other questionable items

<u>Methane emissions</u>

The study uses 3.5% emission rate of methane from natural gas and a 20-year global warming potential.

Howarth & Jacobson assume upstream fugitive methane emissions of 3.5% for natural gas. This does not apply to Europe and is not a representative value on a global scale. Methane emissions from gas production on the Norwegian Continental Shelf [2] amount to 0.03%, while on a global level these emissions amount to 0.23% in 2019 [3]. A value similar to the one for Norway is reported for other countries in Northwest Europe [4, using GHG emission data reported to UNFCCC]. A recent study of the Dutch natural gas system reports that downstream fugitive emissions related to gas transmission and storage amount to about 60% of those from the Exploration and Production (E&P) sector [4]. Therefore, in this study, the upstream leakage rate reported [3] is increased from 0.23% to 0.36%. Further downstream emissions, from local distribution, are not considered relevant for large-scale gas consumers such as SMRs.

Technology and capture rate

The study only refers to one of the technologies used to manufacture low-carbon hydrogen, steam methane reforming (SMR), and a “best carbon capture case” that only assumes capture of about 70% of the overall CO_2 from a natural gas reforming process.

Planned projects in Europe [5] will entail CO_2 capture rates of more than 90%, and in some cases more than 95%, engaging auto-thermal reforming (ATR) technologies with pre-combustion carbon capture.

ATR technology is proven and already widely used for methanol and ammonia production at the same scale as the hydrogen production capacities of the planned projects. The carbon dioxide is within the product stream and therefore at a high pressure. It can easily be removed using standard industry removal technologies; this has also been proven at planned capacities [6, 7].

SMR technologies with post-combustion carbon capture also target the 90% capture rate, with reference to the Hyper project [8].

Energy use

The study assumes that energy to run the hydrogen production is added separately to the process, needing significant amounts of natural gas with corresponding CO_2 emissions. In reality, low-carbon hydrogen production with CCS can be realised without adding energy or power, through proper system integration [9]. Should the process need additional electrical energy, this would be renewable energy or electricity from energy production combined with CCS. Nevertheless, revamping an existing portfolio of modern power plants with hydrogen as the primary energy input is a logical, versatile and efficient development concept that can be deployed quickly.

Power plants capable of using hydrogen are already in use, mainly at refineries. Usually, the hydrogen content is not higher than 30 mol%.

Hydrogen firing at higher concentrations in gas turbine combustors is in full development, available at industrial scale. An example is the Hyflexpower project, which will burn hydrogen at an existing gas-fired co-generation plant that provides power and heat to a paper mill in West-Central France. Hyflexpower is a demonstration project with a primary goal to test combustion with a new type of burner, with any combination of natural gas and hydrogen, up to 100% hydrogen with low NOx emissions by 2023 [10].

Another example is the Nuon Magnum three-unit power plant, a 1.32 GW gas-fired combined-cycle power plant located in Eemshaven, Netherlands that has been operational since 2014. An innovative hydrogen conversion project is currently under development, converting one of the units to run on hydrogen by 2023 [11]. It is worth noting that the Nuon Magnum plant was initially designed as an integrated gasification combined-cycle (IGCC) plant, including a full-scale CCS pre-combustion technology

[11]. The engineering of the combined cycles was initially based on high concentration levels of hydrogen firing in the combustors of the gas turbines.

For the present assessment, the average CO_2 footprint of power generation in Northwestern Europe is used for the electricity demand. The corresponding fugitive natural gas emission (0.23% [3]) is based on a modern combined cycle power plant with a nominal efficiency LHV of 54%.

Storage of captured CO_2

The study highlights that storing captured carbon dioxide indefinitely is “an optimistic and unproven assumption”. However, CCS has been operational in Europe for over 25 years, with the Sleipner facility in Norway, having stored approximately 1 million tonnes of CO_2 per year since 1996, and the Snøhvit facility, also in Norway, stores up to 0.7 million tonnes per year since 2008. Monitoring has proven that geological storage of CO_2 is a permanent and secure storage method.

4. What would be the result when applying relevant assumptions and data?

The IEA maintains a database of advances in low-carbon hydrogen technology [5]. The database covers all projects commissioned worldwide since 2000 to produce hydrogen for energy or climate change mitigation purposes. It also includes projects where the objective is either to reduce emissions related to producing hydrogen for existing applications or to use hydrogen as an energy carrier or industrial feedstock in new applications that can be a low-carbon technology. The database includes projects that are in their planning or construction phase. From this database, three notable planned projects have been selected for the analyses.

The following approach has been adopted:

- Prepare a set of relevant, general assumptions; see Table 1.
- Select relevant projects: H-vision [12], H21 [13], Hynet [6]. Publicly reported technical key performance data have been used (Table 2).
- Calculate the GHG footprint per unit of heat energy output.

Figure 1 shows the resulting GHG footprint per unit of heat energy for the three selected projects. Also shown in the figure is the footprint of natural gas combustion.

Figure 1. The low-carbon hydrogen projects GHG footprint for three different planned projects in Northwest Europe. The H-vision project’s energy input is mainly fuel gas (FG). H21 and the HyNet energy project’s input is mainly natural gas (NG). Table 3 gives the GHG reduction of the low-carbon project relative to the combustion of natural gas.

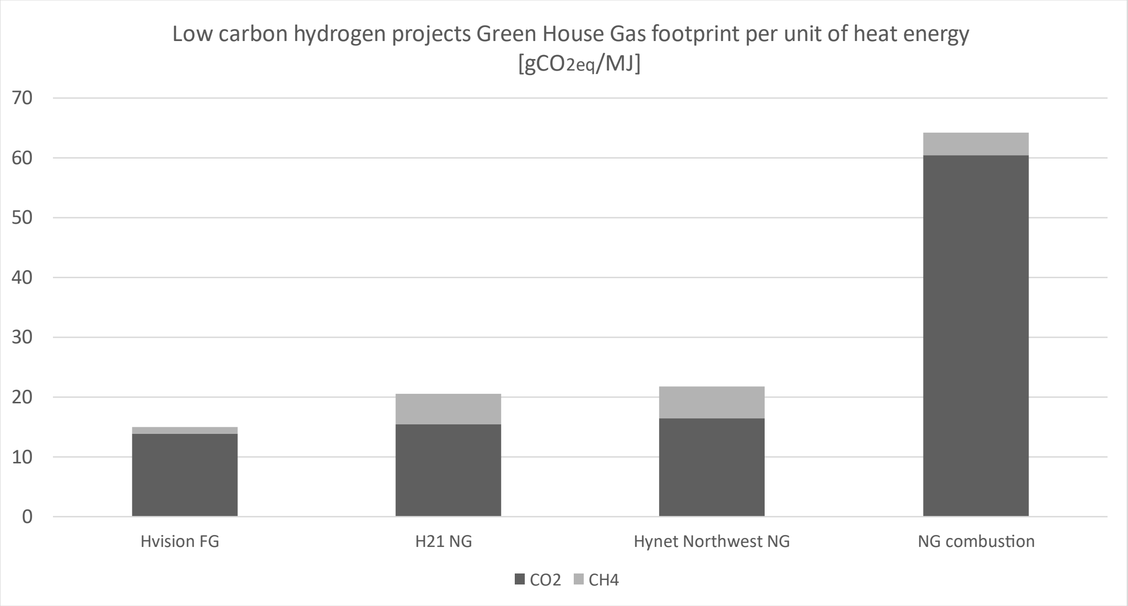

Table 1. Relevant general assumptions

Description of relevant general assumptions	Value	Unit	Reference	Remarks
Methane leakage	0.23%		[3]	
CO_2 emissions from natural gas production	20	g/kWh	[14]	
Emissions from natural gas combustion	54.9	g/MJ	[15]	
Average emission power in Northwest Europe	350	g/kWh	[16]	Subject to stacked merit order of power assets
Mass factor CO_2eqv for CH_4	85			20 year horizon

Table 2. Key technical performance data and resulting GHG emissions

	Units	H-vision [12]	H21 [13]	Hynet [6]	Natural gas combustion
Feedstock	MWth	946	1686	378	755
H_2 out	MWth	750	1300	300	
Power consumption	MWe	66	53.8	22.9	
NG	MWth	94.6	1686	378	

FG	MWth	851	0	0	
Capture rate		94.0%	95%	97%	
CO_2 not captured	g/kWh	16.7	15	7.4	
Direct emission	g/MJ	4.6	4.2	2.1	54.9
Indirect emission (natural gas production upstream and midstream)	g/MJ	0.7	7.2	7.0	5.6
Indirect emission power	g/MJ	8.6	4.0	7.4	
Total CO_2 emissions	g/MJ	14	15	16	60.5
Natural gas fugitive	g CH_4/MJ	0.013	0.06	0.06	0.04
Equivalent CO_2 emissions	g/MJ	1.087	5.16	5.27	3.8
Total emissions	g/MJ	15.0	20.6	21.7	64.2

5. Results on low-carbon hydrogen from other studies

When comparing the carbon emissions of any product or service, it is vital to compare like with like and define the boundary conditions consistently. Commonly, carbon emissions are compared at three different levels and for meaningful discussions it is vital to agree on these concepts.

The H21 project has reviewed the entire H21 System [17]. There are three areas to consider when evaluating the emissions of the H21 system:

- Scope 1 emissions are associated with the production of hydrogen and carbon at the hydrogen production unit.
- Scope 2 emissions include the electrical consumption of the plant and the compression requirements (both CCS and hydrogen).
- Scope 3 emissions include the embodied emissions of natural gas outside the system boundary.

The H21 project reports scope 1, 2 and 3 emissions to be reduced by 59% compared to natural gas combustion for the entire H21 system.

Table 3 compares the carbon footprint reduction of the three selected projects with natural gas combustion.

Table 3. Carbon footprint reduction for the three selected projects compared to natural gas combustion. Figure 1 shows the relative contribution from natural gas and CO_2*.*

H-vision	H21 natural gas	Hynet
77%	68%	66%

6. EU regulation on the manufacturing of low-carbon hydrogen

Since the adoption of the European Taxonomy [18], the manufacturing of low-carbon hydrogen from natural gas with CCS is recognised as a sustainable economic activity, delivering a benefit for climate change mitigation.

The Taxonomy takes into account the climate footprint of all technologies and sources for energy generation by applying robust life-cycle analysis and scientific carbon accounting.

7. Conclusions

Low-carbon hydrogen technology is available today, is a cost-effective steppingstone paving the way for renewable hydrogen and kick-starting a European hydrogen economy, while network planning and generation capacity construction can occur in the most cost-effective and coordinated way.

In their paper, Howarth & Jacobsen use assumptions that are not applicable for the European energy system and industry facilities. However, this paper uses starting points and conditions that are relevant to Europe, to demonstrate that low-carbon hydrogen is a technology that has a significantly lower climate footprint than natural gas combustion – typically around 70% lower.

EU regulations on the manufacturing of low-carbon hydrogen, such as the EU Taxonomy for Sustainable Activities, are based on full life-cycle assessment of GHG emissions and setting clear thresholds for CO_2 emissions per unit hydrogen produced.

This means that using hydrogen derived from natural gas reforming with CCS – low-carbon hydrogen – will lead to significant cuts in GHG emissions, as fuel or feedstock in industry, power and transport sectors. Low-carbon hydrogen is a cost-effective and climate-effective technology that will help Europe to meet its medium and long-term climate targets.

References

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About the Zero Emissions Platform

The Zero Emissions Platform (ZEP) is a European Technology and Innovation Platform (ETIP) under the Commission's Strategic Energy Technology Plan (SET-Plan) and acts as the EU's technical adviser on the deployment of Carbon Capture and Storage (CCS), and Carbon Capture and Utilisation (CCU) under Horizon2020 R&I programme (grant agreement 826051).

ZEP supports the European Union's commitment to reach climate neutrality by 2050, defined as net-zero GHG emissions by 2050. To this end, CCS technologies represent readily available and cost-efficient pathways for the decarbonisation of industrial and energy sectors in the European Union. Some applications of CCU – where CO_2 is stored in a manner intended to be permanent – can also contribute to this goal.