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Classification of renewable synthetic methane (E-SNG)

1. BACKGROUND

Alongside energy and resource efficiency, the direct use of renewable energies, the electrification of many processes and CO_2 capture and storage, hydrogen and gaseous or liquid energy sources or raw materials based on hydrogen (hydrogen derivatives) will also play an important role in Germany's energy transition towards net zero. These hydrogen derivatives also include renewable synthetic methane (E-SNG).

SNG stands for 'Synthetic Natural Gas' or 'Substitute Natural Gas' and refers to natural gas substitutes with the same physical properties as fossil-based natural gas. These can be obtained from fossil fuels such as coal or oil by chemical synthesis or produced from renewable energies through the methanation of CO_2 with renewable hydrogen using the power-to-gas process. The latter variant is referred to here as renewable synthetic methane (E-SNG), but experts also use terms such as renewable gas, wind gas, electric natural gas (eNG) or renewable methane (EE-methane, e-methane). E-SNG therefore belongs to the group of renewable or green gases alongside hydrogen and biomethane.

E-SNG is an option for defossilising the energy system and thus for achieving far-reaching climate protection targets such as net zero. The discussion surrounding E-SNG is contentious and sometimes too fragmented. With this paper, the National Hydrogen Council (NWR) is attempting to create more structure and focus in this respect. The purpose of the paper is therefore not to make specific recommendations on how to deal with E-SNG in terms of energy and climate policy, but rather to clarify perspectives and positions in a systematic and transparent manner, and thus provide a clearer basis for the necessary, ultimately political, decisions that have to be made.

2. DESCRIPTION OF PROCESSES RELATED TO E-SNG

The basis for the production of E-SNG is hydrogen. In terms of the further processing into methane, only hydrogen production pathways that are not based on natural gas (i.e., methane), such as in the case of green hydrogen, make sense and are relevant.

E-SNG can be used directly as a climate-neutral energy source in today's existing gas infrastructure which includes over 500,000 km of gas networks (including approx. 200,000 km for low-pressure supply), over 250 TWh of gas storage, over 30 GW of gas-fired power plants and CHP units, vehicles, industrial applications for material utilisation or high-temperature process heat. Nevertheless, it can be assumed that this infrastructure will be utilised to a lesser extent in the future.

To produce E-SNG by synthesising green hydrogen and CO_2 into methane using power-to-gas methods, a CO_2 source is required, as with other carbon-based hydrogen derivatives (methanol, synthetic fuels, etc.). This CO_2 can be obtained from biological sources (biogas plants, biomass power plants, biofuel production, etc.), from the air (direct air capture – DAC) or from industrial sources (industrial processes such as cement works, fossil-fuelled power plants), where this industrial CO_2 can be of biological or fossil origin.

In the case of biological CO_2 or via DAC, this closes the CO_2 cycle via the atmosphere within a short time. The carbon in E-SNG therefore only serves as a hydrogen carrier and does not cause any additional CO_2 emissions into the atmosphere when the E-SNG is burnt, unless it is removed from the carbon cycle via CCS or through long-term incorporation into products or avoided at source. Under these conditions, the production and utilisation of E-SNG is carbon-neutral.

The net-zero nature of E-SNG results, on the one hand, from the climate-neutral production of the hydrogen required and, on the other, from the use of CO_2, which closes the CO_2 cycle in the short term or does not add any additional fossil-based CO_2 to the atmosphere. In addition to CO_2 emissions, the emissions of methane (as a direct greenhouse gas) and hydrogen (as an indirect greenhouse gas) generated in the various stages of the process chain must also be taken into account for the climate assessment.

Methane synthesis can also be integrated into biogas plants, typically doubling the methane yield of biogas plants with the aid of green hydrogen.

As a carbon-neutral energy source, E-SNG can be utilised directly in the existing gas infrastructure due to its having properties that are identical to natural gas. This includes all transport, storage and utilisation options for natural gas: pipelines, LNG infrastructures, gas storage facilities, gas-fired power plants, CHP plants, vehicles, industrial applications for material utilisation and process heat. The potential utilisation of existing global LNG infrastructures (terminals, ships, pipelines) could lead to the development of a global market for E-SNG. Direct use is the predominant way in which E-SNG is used.

E-SNG can be converted back into green hydrogen using reforming processes. E-SNG thus serves indirectly as a hydrogen carrier or transport and import vector for energy. If the CO_2 produced during utilisation or reconversion is captured and recycled, carbon-neutral cycles can be created. Where hydrogen and CO_2 sources are located in different places, transport systems for CO_2 are required, similar to transportation for CCS (ships, terminals, pipelines, etc.). Where CO_2 is stored in geological formations (CCS), a CO_2 sink is created in the event of previous use of CO_2 from biological sources or DAC.

3 ASPECTS OF CLASSIFICATION

TECHNICAL MATURITY

The power-to-gas process is technically mature and the individual technologies are available on an industrial scale or are scalable to a large degree.

Systems that utilise CO_2 from the air (DAC) are an exception.

The processes and plants for electrolysis, compression, transport and storage have the highest level of technological readiness at TRL 9, followed by methanation at TRL 8 and CO_2 provision. In terms of CO_2 provision, the technical maturity differs for the various CO_2 sources: While the maturity for biological and industrial CO_2 point sources is high, there is still a need for development and scaling for DAC systems (in the TLR 4-9 range).[1]

The large-scale and economically feasible availability of CO_2 via DAC plants can therefore only be expected in the longer term. Technologies for obtaining CO_2 from biological sources or fossil or industrial processes are available with a high degree of technological readiness (TRL 7-9) and in the short term.[2]

The recovery of hydrogen from E-SNG via steam reforming is technically mature. The large-scale capture of CO_2 via ATR plants as well as transport via pipeline and storage are state of the art.

CONVERSION EFFICIENCY

The overall efficiency of the power-to-gas process is between 39 and 62 per cent when CO_2 point sources are used and 36 to 56 per cent when CO_2 is provided by DAC if the waste heat is not used. The greatest losses occur in electrolysis, followed by methanation. Further technological developments are expected to increase efficiency here, particularly in the utilisation of waste heat. Compression and transportation of E-SNG, on the other hand, are – like natural gas – very efficient. Optional reconversion of E-SNG to hydrogen leads to additional losses, which is why direct utilisation of E-SNG is preferable from an energy efficiency point of view. Compared with other hydrogen derivatives, efficiencies for E-SNG are on a similar level to ammonia and methanol and therefore higher than Fischer-Tropsch fuels, LOHCs or liquid hydrogen.

With regard to the classification of efficiency levels in comparison to other processes, a rough distinction can be made between five positions:

- The first position considers the efficiency levels to be fundamentally attractive, given the use of the existing gas infrastructure (lower technical effort and costs for transport, storage and use) and therefore deems the direct use of E-SNG to be sensible.
- The second position takes a positive view of the overall balance, including efficiency levels from generation, transport and storage through to the use of E-SNG due to the lower consumption of resources compared to the development of new infrastructures and applications.

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1 Bisotti et al, Chemical Science.
2 Sterner, Pinkwart et al., 19 Import options for green hydrogen and derivatives – An overview of efficiencies and technology readiness levels, Int. Journal of Hydrogen, 2024, https://doi.org/10.1016/j.ijhydene.2024.10.045.

- The third position assesses the efficiency levels in comparison to hydrogen as problematic, also in view of the rather sceptical assessment with regard to other aspects (perpetuation of the gas infrastructure and fossil or process emissions, costs, additional resource consumption, etc.).
- The fourth position views lower efficiencies as problematic from the fundamental perspective of resource conservation.
- The fifth position does not consider the question of technical efficiency to be fundamentally decisive, but instead focuses on the overall economic effect that can be achieved by tapping into the potential of cheap renewable energies globally for their import and in the overall balance (costs, emissions, further use vs. conversion of infrastructures).

TECHNICAL NECESSITY AND DEMAND

With regard to the necessity of E-SNG, different points of view continue to exist:

- The first position recognises a technical necessity for the use of E-SNG, as there are processes for which net zero cannot be achieved in the foreseeable future through electrification or the use of hydrogen (chemical industry, glass industry, lime, cement and brick production). In total, demand in 2045 will be in the double-digit TWh range[3]. In addition to industry, there is demand for E-SNG in the electricity sector for long-term storage in the double-digit TWh range as long as the hydrogen infrastructure and the hydrogen itself are not in place or available.
- The second position believes there are climate-neutral alternatives for all the industrial processes in question, at least in the longer term (from biomass for the steel industry to other hydrogen derivatives that are needed anyway in the chemical industry or CCS in the cement industry), as well as sufficient alternatives for the longer transition period, including in the area of E-SNG, that are also acceptable for the net zero pathway (e.g., natural gas in underutilised hydrogen-capable gas-fired power plants), with which other challenges (infrastructure competition, etc.) can be reduced.

AVAILABLE QUANTITY

The technical potential of E-SNG depends on the available quantities of green hydrogen and CO_2. The amount of green hydrogen available is, in turn, dependent on the supply of renewable electricity and water.

- The first position recognises that the potential for green hydrogen can also be transferred to E-SNG. The CO_2 sources have a limiting effect. Biological and industrial sources are technically simple and cheap to develop, but limited in terms of quantity. For example, 300 TWh of E-SNG could still be produced from the sustainable quantities of CO_2 expected in Germany in 2045, of which around 170 TWh would be based on biological sources. This potential would also be sufficient to cover the demand for E-SNG in 2045. It is undisputed that biological CO_2 from sewage treatment and biogas plants will be permanently available as long as people live in Germany and agriculture is practised. In addition, CO_2 cycles can be closed via a CO_2 infrastructure such as pipelines and storage facilities. The global potential of biological and industrial CO_2 sources is significantly higher, and usable import infrastructures for E-SNG are available in Germany. Over 500 million tonnes of biological CO_2 alone is available worldwide today. The utilisation of CO_2 (CCU) is in competition with the storage of CO_2 (CCS). In the course of the transformation to net zero, however, industrial sources will decline sharply in the long term.

[3] NWR white paper on hydrogen demand of 3 May 2024.

- The second position sees the potential of sustainable climate-neutral CO_2 for Germany, Europe and the global context as a very limited resource, especially given the regional overlap in terms of CO_2 supply and favourable production conditions for green hydrogen as well as other CO_2 demand for the provision of derivatives (methanol, synthetic aviation fuels, etc.) or, in the longer term, with regard to the creation of technical CO_2 sinks. This applies also and in particular for the period until DAC technology is widely available at reasonable cost. This position maintains that the use of CO_2 from industrial processes is justifiable in terms of climate policy for a very short period of time at best and believes geological storage for these emissions in the longer term is needed.

ECOLOGICAL PERSPECTIVE

Like hydrogen or other hydrogen derivatives, E-SNG can replace fossil fuels and thus avoid CO_2 emissions. What is special about E-SNG is that this can already be done today using existing gas infrastructures and applications. Beyond this primary assessment, however, the comparative assessment of ecological aspects for different products or production routes can also play a role. The ecological assessment of E-SNG is initially based on the resources used to produce green hydrogen (water, electricity); under the same site conditions, there are no differences here for the various hydrogen-based energy sources or raw materials. Beyond the use of pure hydrogen, the provision of CO_2 and the systems and infrastructure used are particularly relevant.

The question of the release of methane and hydrogen is also important. Emissions of methane (for the E-SNG pathway) and hydrogen (for the pure hydrogen pathway) have an impact on the climate. Methane is a directly effective greenhouse gas, while hydrogen is an indirectly effective greenhouse gas (in the context of chemical interactions in the atmosphere). Our current scientific understanding is that the specific greenhouse effect (Global Warming Potential –GWP) of methane is greater than that of hydrogen, although significantly greater uncertainties remain for hydrogen.

Different ecological assessments result primarily from the different classification of methane emissions:

- The first position considers the methane emissions produced in the course of the E-SNG process chain not to be decisive in the overall context of all ecological effects and the uncertainties regarding the climate impact of hydrogen.
- The second position also sees significant ecological advantages through the possibility of faster displacement of non-sustainable energy sources or raw materials. Utilising the existing infrastructure saves resources for the construction of new infrastructures for hydrogen and other derivatives. This position sees E-SNG as an important instrument for the temporal and local shifting and storage of renewable energy. It can also serve to secure a purely regenerative electricity supply and the rapid phase-out of coal and natural gas.
- The third position sees the methane emissions from the E-SNG process chain (especially in long-distance transport, infrastructure and applications) as a relevant ecological disadvantage of E-SNG.

Irrespective of this, there is no disagreement on the issue that methane or hydrogen slip should be avoided for all green gases or minimised by means of suitable technical measures. Experience from the natural gas infrastructure could be utilised here.

ECONOMIC PERSPECTIVE

An infrastructure focused purely on hydrogen requires high investment costs. There are also different perspectives on E-SNG:

- The first position considers the additional costs for methanation to be low compared to the additional costs for the development of a pure hydrogen economy (due to new storage facilities, pipelines, power plants, applications). It also recognises the opportunity of integration into biogas plants for the cost-effective integration of hydrogen or renewable energies into the existing energy networks without additional costs for the provision of CO_2.
- The second position predicts higher production costs compared to the hydrogen route due to the additional costs of the E-SNG route (caused by lower efficiency, additional plant investments and the procurement of climate-neutral CO_2) and therefore no cost advantages over hydrogen. It also sees the risk that new hydrogen infrastructures will become obsolete or unprofitable due to the continued use of the existing E-SNG gas infrastructure.

4 STRATEGIC CLASSIFICATION

The present positions on the use of E-SNG in the transformation towards net zero reflect different perspectives on the strategic role of E-SNG, hydrogen and the existing infrastructure. A symbiosis of the positions would look like this:

- **Utilisation of existing infrastructures as a transitional option**
  E-SNG can play a valuable role in the transition phase by enabling the utilisation of existing LNG terminals and gas storage facilities as well as the integration of biogas. These infrastructures already exist and can be used directly for E-SNG and adapted for other hydrogen derivatives without the need for new, time-consuming authorisation procedures. Parallel to the utilisation of E-SNG, the expansion of the hydrogen infrastructure should be driven forward. This includes both the import of hydrogen and the conversion of existing gas-fired power plants to utilise hydrogen as an energy source. The gradual introduction of hydrogen and the use of E-SNG for backup and redundancy purposes are combined to provide a practical solution that ensures a stable energy supply.
- **Focus on technological shift toward hydrogen and innovation**
  The long-term strategy should prioritise the rapid expansion of the hydrogen infrastructure and the necessary technological shift in industry and energy applications. Accordingly, the development of hydrogen technologies such as hydrogen power plants and fuel cells must be accelerated through innovation and investment. From this perspective, the large-scale use of E-SNG, even as a transitional solution, is more likely to hinder the transformation.
- **Future prospects for E-SNG as a flexible, decentralised component**
  In regions where the switch to pure hydrogen cannot be fully realised in terms of technology or infrastructure, E-SNG could continue to play an important role. Here, E-SNG can act as a flexible component in a mixed strategy that combines biogas, E-SNG and hydrogen to ensure a secure, low-carbon energy supply.
- **Future prospects for E-SNG as a permanent, central component**
  For a variety of reasons (from resource availability to geopolitics and as a transport vector for hydrogen to tap into cheap, renewable energy sources available worldwide), E-SNG is seen as a permanent solution option for utilising the gas infrastructure alongside LNG, biomethane and natural gas.

5 SUMMARY AND OUTLOOK

E-SNG is a climate protection option in the defossilisation of all sectors that should be explored further. The renewable gas has a special role among hydrogen derivatives due to its having properties that are identical to those of natural gas, which results in both advantages (e.g., utilisation of existing infrastructures and application technologies) and disadvantages (e.g., release of methane).

Internationally, E-SNG is being addressed differently in the context of climate protection and energy policy strategies. The spectrum ranges from broad support through to the topic being discussed selectively or not at all.

The specific classification of the role of E-SNG is the result of complex and sometimes very differentiated individual assessments and the evaluation of the underlying interactions. These assessments lead to different and sometimes contentious positions. To explain the different overall assessments, it is therefore useful and necessary to take a differentiated look at the individual assessments in the areas of technical development, demand, resource availability, economic and ecological assessment and strategic classification.

The individual assessments are partially shaped by different analytical findings in the scientific and technical field and partially by different economic, strategic and political considerations and their contextualisation. In some areas, the disparities between the individual assessments can and should be narrowed through deeper or broader fact-finding or improved monitoring processes.

In other areas, however, the differences in the assessments are due to different expectations for the future, some of which are difficult to quantify, or core beliefs that are difficult to change, which ultimately make it necessary to strike a balance when it comes to decisions on policy direction. Given the uncertainties that exist, political decisions must be made promptly if otherwise resource-intensive technology pathways are developed in parallel and threaten to devalue investments that have already been made. However, prioritisation of the previously described aspects of classification and decisions on policy direction can be done in many ways. Alongside improvements to fact-finding and monitoring processes, political decisions will ultimately need to be made here, too.

The prerequisites and implications of differently structured decisions on the broad or selective use of E-SNG are sometimes far-reaching. Initially, this relates to the range of funding and supporting measures across the entire value chain:

- What impact is there for (German and European) funding and supporting measures in the area of E-SNG production (at home and abroad)?
- What impact is there for (German and European) funding and supporting measures in the area of infrastructure expansion and, if necessary, infrastructure maintenance for hydrogen, methane and possibly also CO_2?
- What impact is there for (German and European) funding and supporting measures in the area of applications?

Taking a transparent, differentiated approach to making and justifying the corresponding policy decisions is also important with regard to the social, economic and geopolitical acceptance of a ramp-up of the hydrogen economy and for the development or trade relationships and integration of the markets for hydrogen and hydrogen derivatives.

To more effectively assess the consequences of policy decisions for or against wide or selective use of E-SNG, it is important to be aware of the different contexts of climate and environmental protection, social acceptance, the economy, industrial, technology and innovation policy, as well as strategic issues, and place them in the context of the European and global debate.

In this respect, it is important with regards to policy decisions to recognise that some of the differences in classification result from expectations regarding future developments that are difficult to quantify as well as from core beliefs and fundamental interests. New policy decisions are needed in this area. The system of 'coordinates', or classification aspects, and descriptions of the various positions presented here offers a suitable frame of reference and justification for these policy decisions in two respects:

- (1) There is a need for transparency in political prioritisation or hierarchisation between the different coordinates;
- (2) Policy (non-)prioritisation should be accompanied by a systematic and comprehensible weighing of possible trade-offs regarding aspects classified as having lower priority.

It is important, useful and necessary to provide full and transparent information on how and why such fundamental decisions have been made.

THE GERMAN NATIONAL HYDROGEN COUNCIL

H2 NATIONALER WASSERSTOFFRAT

On 10 June 2020, the German Federal Government adopted the National Hydrogen Strategy and appointed the German National Hydrogen Council. The Council consists of 26 high-ranking experts in the fields of economy, science and civil society. These experts are not part of public administration. The members of the National Hydrogen Council are experts in the fields of production, research and innovation, industrial decarbonisation, transportation and buildings/heating, infrastructure, international partnerships as well as climate and sustainability. The National Hydrogen Council is chaired by former Parliamentary State Secretary Katherina Reiche.

The task of the National Hydrogen Council is to advise and support the State Secretary's Committee for Hydrogen with proposals and recommendations for action in the implementation and further development of Germany's National Hydrogen Strategy.

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APPENDIX: CATEGORISATION MATRIX

Classification dimensions	Core positions					Remarks/comments
A) Technological maturity						
1) Conversion efficiency	a)	b)	c)	d)	e)	
	Efficiencies are considered fundamentally attractive in view of the utilisation of the existing gas infrastructure and the direct use of E-SNG is therefore considered sensible.	The overall balance (including efficiency levels) is assessed as positive due to the lower consumption of resources compared to the construction of new infrastructures and applications.	Efficiency levels are viewed as critical given the skeptical assessment of the other dimensions.	Lower efficiencies are criticised from the fundamental perspective of resource conservation.	Technical efficiencies are not considered to be decisive; instead, the focus is on the overall economic effect in the global development of large potentials of favourable renewable energies.	Fact-finding to reveal relevant potential to narrow gap between positions, role of core beliefs limited
2) Technical necessity and demand	a)	b)				
	Technical necessity for the use of E-SNG; expected demand in the double-digit TWh range in 2045; in addition to industry, there is a need for E-SNG in the electricity sector as long-term storage in the double-digit TWh range.	Long-term use of climate-neutral alternatives; sufficient alternatives that are also justifiable for the climate neutrality pathway, even in the longer transition period.				Limited potential of fact-finding to narrow gap between positions, core beliefs play a major role
3) Available quantity	a)	b)				
	Transfer of the potential for green hydrogen also to E-SNG; restriction: CO_2 sources, biogenic and industrial sources are technically accessible, but limited in terms of quantity.	Potential for sustainable climate-neutral CO_2 only available to a very limited extent, also in view of the regional overlap between CO_2 supply and cheap green hydrogen				Relevant potential for convergence of positions through fact finding, major role of fundamental convictions
4) Ecological perspective	a)	b)	c)			
	Methane emissions and uncertainties regarding the climate impact of hydrogen are not considered to be decisive.	Significant ecological advantages due to the possibility of faster displacement of non-sustainable energy sources or raw materials.	Negative ecological impacts due to methane emissions from the E-SNG process chain.			Fact-finding to reveal relevant potential to narrow gap between positions, role of core beliefs limited.
5) Economic perspective	a)	b)				
	Low additional costs for methanisation compared to the additional costs for setting up a pure hydrogen economy.	No cost advantages over hydrogen, due to the additional costs of the E-SNG route.				Fact-finding to reveal relevant potential to narrow gap between positions, role of core beliefs limited
B) Strategic classification						
	a)	b)	c)	d)		
	Utilisation of existing infrastructures as a transitional option.	Focus on technological shift toward hydrogen and innovation.	Future prospects for E-SNG as a flexible, decentralised component.	Future prospects for E-SNG as a permanent, central component.		Limited potential of fact-finding to narrow gap between positions, core beliefs play a major role