Executive Summary

In view of the upcoming nuclear phase-out and the planned coal phase-out in Germany, natural gas, besides the use of renewable energy sources, will have to play an important role in the German energy mix. This also holds for the European Union as a whole. In light of the 2050 climate goals, a gradual replacement of fossil gas with renewable and decarbonised gases will be required. To this end, a coherent European gas and hydrogen strategy is needed to ensure planning security for market participants.

Conceptualised within the German national dialogue „Gas 2030“ this roadmap is a contribution of the Federation of German Industries (BDI) towards the ongoing discussion around the “future role of gas”.

In our view the here presented pathways constitute the most cost-effective way forward for the market introduction of renewable and decarbonised gases. Thereby two major goals can be achieved at a time: (1) Reaching the climate targets in Germany (and Europe) and (2) exploiting new industrial potentials. The roadmap highlights the following measures:

- **For the market introduction of renewable and decarbonised gases focus on the industry and transport sector.** In comparison to a blending quota such a strategy can enable competitive technology development and cost reductions already in the short-term, while causing minimum technical and economic impact within different gas consumer groups across the EU.

- **For the initial phase of the market introduction, on-site hydrogen production and existing hydrogen networks should be used.** The latter can be expanded by transforming the existing gas pipelines into hydrogen infrastructure. In the next step, an EU-wide market design for renewable and decarbonised gases is required so as to avoid inconsistent national policies undermining the liquidity of the European gas market.

- **Both domestic production and imports of renewable and decarbonised gases and hydrogen-based fuels will be required in the future.** For this reason, strategic concepts for such import partnerships should be developed already in the short-term.
Policy recommendations in view of the upcoming EU gas package

Lay out the basis of an EU-wide market design for renewable and decarbonised gases.

- Carry out an impact assessment of different infrastructure development scenarios for a large-scale implementation of renewable and decarbonised gases in the EU (i.e. blending quota vs. 100 per cent hydrogen networks vs. synthetic methane vs. combination of different options).

- An EU-wide approach is required in order to prevent national policies hindering the cross-border trade of gas and so the liquidity of the common energy market.

- The market design should reflect the future necessity of imports of renewable and decarbonised gases and fuels as they will be crucial for meeting the European demand.

- Based on the assessment, suggest a target model for the EU.

Introduce an effective go-to-market strategy.

- For the market introduction of renewable and decarbonised gases focus on the industry and transport sector.

- Take advantage of regulatory instruments to support this strategy: (1) monitor an ambitious implementation of RED II by the member states; (2) allow for the accountability of synthetic fuels on the fleet emission reduction targets in the upcoming review processes in 2022 and 2023.

- On the infrastructure side the go-to-market strategy can be supported by on-site hydrogen production and (if applicable) the expansion of local hydrogen networks.

Develop a consistent regulatory framework for renewable and decarbonised gases.

- Implement a consistent EU-wide definition/classification for renewable and decarbonised gases.

- Address the question of a regulatory framework for dedicated hydrogen infrastructure such as 100 per cent hydrogen grids.

- Develop hydrogen quality standards as comparable to today’s natural gas standards.

- Based on the above mentioned implement an EU-wide system for tradable guarantees of origin (GOs), which can be in the next step extended to the trade with third countries.
The term „renewable and decarbonised gases“

The use of the term „renewable and decarbonised“ gases corresponds to the preliminary classification of the gas industry presented at the 32nd Madrid Forum\(^1\). Thereafter biogas, renewable hydrogen, biomethane and renewable synthetic gas are considered as “renewable gases”. “Decarbonised and low-carbon gases” include hydrogen gained from pyrolysis process as well as hydrogen from natural gas reforming combined with CO\(_2\) capture and storage (CCS). For an easier comprehension of the text the term “climate-friendly gases” is used to include both renewable as well as decarbonised gases.

1. Renewable and decarbonised gases: contribution to climate goals and industrial policy relevance

With the completion of the nuclear phase-out and the planned coal phase out the German energy system is confronted with a big challenge. Due to a gradual elimination of two important pillars of the current energy supply, natural gas, besides renewable energy, is gaining an increasingly important role for security of supply and international competitiveness of energy prices in Germany. Against these preconditions, how much time do we need to transfer the gas sector towards CO₂-neutrality?

The BDI study „Climate pathways for Germany“ has shown that a CO₂ reduction of 80 per cent until 2050 compared to 1990 level can be achieved without Power-to-X (PtX) and Carbon Capture and Storage- (CCS) technologies. In the 80 per cent scenario, and until 2040 also in the 95 per cent pathway, natural gas is an important pillar of electricity and heating sector and is indispensable in industrial high temperature and chemical production processes. For the 95 per cent reduction target, implementation of PtX and CCS technologies is, however, required from 2040 onwards.

From an international perspective there are further drivers behind the development of PtX technologies and hydrogen-based energy concepts besides the expected contribution to climate protection measures. After Japan, which presented its national hydrogen strategy already in 2017, other states outside as well as within the EU such as China, Australia, UK, France, the Netherlands and Austria work on comparable concepts. In Japan and China energy security as well as the development of a global technology leadership are the main drivers for the technology development on this field.

Therefore, we observe the development of an innovative market with new export chances for the German and the European industry. “Innovative” since it is a market of systemic solutions, which is marked by a high complexity. For example, the market introduction of fuel cell vehicles can only

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Market share of German and European manufacturers in the production of eletrolysers (left side) and other PtX technologies (right side) in 2016

Quelle: Frontier Economics & IW 2018

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succeed if the hydrogen fuel station infrastructure is available and the respective hydrogen production supply chain is established. Consequently, a PtX-innovation can only become a successful product if combined with a respective system.

It is probably the strength of German and European manufacturers in the developments of such systemic concepts which explains the current high global market share in PtX technologies (see the chart on). In order to maintain and expand this market share, while confronted with the global competition, a strategic technology development is required for the European Union.

2. Why there is a need for a roadmap?

In the year 2017 renewable energies have covered around 18 per cent of the electricity consumption in the European Union and 38 per cent in Germany. These shares were reached gradually over the past years. The temporary fluctuating composition of the electricity mix from fossil and renewable energies is hardly noticeable for most of the end-consumers and has no physical impact on cross-border electricity trading within the European internal market. One electron remains the same in its characteristics regardless of whether it was produced with renewable or fossil energy sources.

In view of the 2050 climate goals the gradual replacement of natural gas with renewable and decarbonised gases will be required. This long-term goal and the way to get there should be approached in the upcoming European future gas package. This is a challenging task, as the process of CO₂ reduction in the gas sector has more dimensions than that in the electricity sector, inter alia due to the different chemical characteristics of “green” gases and the respective infrastructure and consumer requirements.

A blending quota of renewable and decarbonised gases does not represent an effective policy instrument for a market introduction of renewable and decarbonised gases.

There is a range of possibilities, to make gas „greener“, which all have their advantages and disadvantages. As long as „green molecules“ correspond to the chemical formula of methane (CH₄), a blending of these gases is rather uncomplicated for both end-consumer and the interconnection of the German gas grid to its European neighbours. The limiting factors remain rather on the production side. These are especially the low efficiency rate and the high production costs of synthetic methane as well as the scarce resources of biomethane and the resulting competition for its utilisation between different consumer sectors.

An alternative approach is a direct blending of „green“⁴ or „blue“⁵ hydrogen into the existing gas grid. In comparison to synthetic methane the advantages of the blending process of hydrogen are the high degree of efficiency and the low production costs. A „gas mix“ from CH₄ and H₂ is, however, depending on the blending composition of a different fuel with respective different characteristics in the combustion process. Such volatility in gas quality represents a technical challenge for end-consumers, especially some gas utilising industries (see Info Box). Comprehensive technical retrofit measures would be required in order to avoid negative impacts on industrial processes.

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⁴ Produced in the electrolysis process with renewable electricity.
⁵ Gained in the process of natural gas reforming. The released CO₂ will be stored underground (Carbon Capture and Storage) or used in another process (Carbon Capture and Usage).
On the short- to middle-term a blending-in of hydrogen into the existing gas grid can thus only be conducted in a range, in which the sensible installations will not be affected (such as max. 1.5 per cent) or only punctually in the grid areas, where no sensitive installations are connected (see Info Box). To enable an area-wide blending already on the short-term capital intensive retrofit measures at consumer level would be required, partly with technologies, which are currently still in the research or in test phase (e.g. membrane technology). Finally, hydrogen blending to natural gas would increase energy costs for all end-consumers of gas, regardless of their willingness to pay.

For a first market introduction of renewable and decarbonised gases focus on the industry and transport sector.

Focusing on application areas with a strong technological lever in the industry and transport sector could lead to a competitive technological development along with the required cost reductions already short-term while avoiding potential negative effects on the overall system. Especially some specific industry sites with a high demand for material use of hydrogen could ensure large consumption volumes necessary for the market scale-up. At the same time, infrastructure adaptation will only be required to a limited extend. The hereby achieved reductions in hydrogen production costs should support the introduction of renewable and decarbonised gases in other sectors in the next step. This is especially true for the transition of the heating sector where already in today’s existing buildings hydrogen blending of until 10 per cent (volumes) are technically feasible.

Furthermore, a go-to market in the identified application areas in this roadmap can partly be incentivized by the pending regulatory adjustments (RED II, EU Review processes on fleet emission thresholds). In this way, the cost effectiveness of the go-to-market of renewable and decarbonised gases can be increased since, especially in the beginning of the roadmap, the consumer groups with the highest willingness to pay are addressed.

A roadmap can guide smart infrastructure investments.

The implementation of renewable and decarbonised gases requires investments in both infrastructure, production and consumption side, which however are more economically efficient as compared to an “all-electric-world”. 6 This is due to the fact that existing gas infrastructure can be used and transformed for the use of renewable and decarbonised gases.

The roadmaps conceptualised in this paper demonstrate a pathway for the synchronisation of the measures on the infrastructure, production and consumption side which will make planning and investment climate more secure for infrastructure providers as well as for industrial and private consumers.

Within the elaboration of this roadmap the need for an evaluation (including cost estimation) of the systematic advantages and disadvantages of various scenarios of potential future infrastructures has been identified. From the perspective of the German industry such an evaluation is indispensable for making political and regulatory decisions with a wide-reaching impact on the overall system in Germany and in the EU.

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Info box: Technological limits of hydrogen blending

Consumer requirements

Some of the industrial end-consumers such as the glass and ceramic industry are highly sensitive to variations of the gas composition and quality. In those particular cases already the smallest variations in temperature have an impact on the final products (e.g. functional characteristics, optic and quality). Furthermore, hydrogen additions into the existing natural gas grid could have implications on the material use of natural gas in the chemical industry. Blending in a share of above 1.5 per cent in certain processes is already classified as critical. The adjustment to a new constant “gas mix” is partly technically feasible, however, especially the fluctuations in the gas quality are a limiting factor for a gradual blending-in of hydrogen into the gas grid.

In addition, a current norming for natural gas vehicles sets a limit to a maximum of 2 per cent hydrogen concentration. For a higher hydrogen blending quantity e.g. CNG filling stations do not provide a warranty for the security of the vehicle.

By using a membrane technology a filtering of the gas mix from the public grid at the entry point to the consumer could be implemented. However, this technology is still at the research stage. In addition, a progressive measurement and control technology could minimize the negative effects of fluctuations in the gas composition. For the implementation of this technology at industrial scale further experimental development and tests in the industrial praxis would be required. Generally, it is considered that in sensitive industrial processes high fluctuations in gas quality would undermine energy efficiency of production due to production losses and not equally balanced operation modes.

Limiting factors on the infrastructure side

According to a study of the German Gas and Water Association (DVGW) from the year 2014 a safe operation of gas turbine fleet in Germany is possible until a concentration of 1% of hydrogen in the fuel gas. This is referring to the machine fleet during the time of examination of the study. According to the turbine manufacturers today a blending-in concentration of until 5 per cent would be technically feasible. However, thereby caused potential changes of NOx-emissions must be considered. Gas turbines of today’s type of construction have an even higher hydrogen tolerance rate, without the NOx-problematic.

In addition, the hydrogen concentration is unequally distributed in the case of an area-wide blending into the grid. At certain points so called “hydrogen bubbles” could develop in which the average blending value could exceed the average concentration. Before conducting a comprehensive hydrogen blending it should be clarified how to deal with such situations in the future.
3. An industry- roadmap for the market introduction of renewable and decarbonised gases.

3.1. Illustration Roadmap 1: Areas of application in consumer sectors.

<table>
<thead>
<tr>
<th>Industry</th>
<th>Transport</th>
<th>Buildings</th>
<th>Electricity</th>
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<tbody>
<tr>
<td>Refineries</td>
<td>Chemical processes</td>
<td>Steel (Investments in DRP)</td>
<td>CCS for CO2-intensive processes with limited CO2-avoidance alternatives</td>
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<tr>
<td>Chemical processes</td>
<td>Steel (H2 blending in DRP)</td>
<td>High-temperature processes</td>
<td>Solid biomass for low/middle- and biomethane for high-temperature processes</td>
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<tr>
<td>Non-electrified railway</td>
<td>Passenger vehicles; lorries</td>
<td>CNG/LNG advanced biofuel blending</td>
<td>Air and maritime transport</td>
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<tr>
<td>Comprehensive H2-readiness monitoring of existing appliances</td>
<td>Improvement H2-readiness of new appliances (&gt;10 %)</td>
<td>Selective H2-blending in model regions</td>
<td>Experimental testing of H2 technologies</td>
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<tr>
<td>2019</td>
<td>2025</td>
<td>2030</td>
<td>Post-2030</td>
</tr>
</tbody>
</table>

Source: BDI.

- **Hydrogen**
- **Synthetic methane/synthetic fuels**
- **Biomass**
- **Other measures**

Please see Roadmap 2 for required technical framework and policy instruments on the same timeline.

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7 The arrows indicate the beginning of the market launch of certain technologies in the identified application areas/ implementation of required regulatory measures/ infrastructure measures etc., they, however, do not provide a termination date of those measures.
3.2. Illustration Roadmap 2°: Gas grid infrastructure, technical aspects of the infrastructure, supply options and regulatory instruments.

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<th>Gas infrastructure</th>
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<td>virtual H₂ contracting</td>
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<td>Expansion of existing</td>
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<td>hydrogen networks</td>
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<td>Testing of measurement and</td>
<td>control technology</td>
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<td>Improving H₂-readiness of</td>
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<td>Developing standards for H₂</td>
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<th>PtX in Germany</th>
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<td>„Realabore“</td>
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<td>Large-scale PtX projects in</td>
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<td>Germany (and EU)</td>
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<th>PtX Imports</th>
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<tr>
<td>Establishment of international PtX partnerships</td>
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<td>Demonstration projects for PtX imports</td>
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<th>Regulatory instruments</th>
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<td>Certificates of Origin H₂</td>
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<td>Market support program PtX</td>
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<td>Market introduction ICAO</td>
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<td>Review-RED II</td>
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<td>Int. Certificates of Origin H₂/Sym-Fuels</td>
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<td>taxes for PtX electricity</td>
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<td>Impact assessment</td>
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<td>infrastructure scenarios</td>
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<th>2019</th>
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Source: BDI.

Please note that the here above presented policy instruments and technical frameworks are to be regarded in line with the areas of application presented in Roadmap 1.

° The arrows indicate the beginning of the market launch of certain technologies in the identified application areas/ implementation of required regulatory measures/ infrastructure measures etc., they, however, do not provide a termination date of those measures.

On the application side the roadmap starts with those industrial sectors, which already use hydrogen from gas reforming in their industrial processes today. Therefore, a gradual replacement by renewable or decarbonised hydrogen in these sectors could be realised without considerable disruptive impacts on the overall system. In this section, technical opportunities and required measures for a successful market introduction of renewable and decarbonised gases will be described by sector.

Please note that the following detailed description only refers to phase I of Roadmap 1 presented (p.12). For a detailed description of phase II and III see the German version of the paper.

Industry sector

Refineries: Green hydrogen in the fuel production

In refineries hydrogen is gained from natural gas reforming today. It is used for the desulphurisation of products such as diesel and gasoline. The gradual substitution of this fossil hydrogen with hydrogen produced by renewable energies would be a cost-efficient and already available option for bringing renewable hydrogen into the economic circle. In September 2018, a demonstration project by Audi and the BP refinery Lingen showed that the use of renewable hydrogen is technically feasible at large industrial sites. This example also shows that especially the refinery sector is ideal for the „kick-off“ of a first go-to-market strategy for renewable hydrogen.

The RED II created a regulatory basis for the accountability of renewable hydrogen in the refinery process towards renewable energy targets in accordance with Article 25. Thereafter renewable hydrogen represents a further option for achieving this target besides the already successfully ongoing measures such as the blending of biodiesel and bioethanol. Depending on the costs of electricity the use of renewable hydrogen in refinery processes can be price-competitive in comparison to other fulfilment options already today. For this reason, we call upon member states to make use of this possibility in the context of the national implementation of RED II.

In comparison to other options to fulfil decarbonisation targets renewable hydrogen has the potential to become economically efficient, depending on the price ratio of additional charges to the electricity price. In this way, there is the potential for a hydrogen market of about 177 000 tons, only in Germany. The substitution of other energy sources by hydrogen, which is currently generated from fossil energy sources in refineries, could already help reducing a total of 1.7 bn tons of CO₂ in Germany. The production of hydrogen generated from renewable energies could, besides providing a climate-neutral fuel for the industry, contribute to release congestions in the grid (for instance, hydrogen could be produced in a situation when there is renewable energy in excess which cannot be transported or absorbed by the system).

Key take away:

Make use of the possibility provided by RED II to take hydrogen into account towards renewable energy targets on national level to allow for an efficient go-to-market strategy for renewable and decarbonised gases in the refinery sector.

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Chemical industry: renewable hydrogen as basic material in chemical supply chains

About one fourth of the natural gas consumption in the chemical industry is used for material purposes. The natural gas reforming process which is used to produce hydrogen is part of it. Hydrogen then enters as a raw material into the downstream supply chain and is especially used to produce ammonia and methanol. The latter substances then again build new elements to produce a number of other basic chemical materials, which can be traded as commodities or will be purified into special chemistries in further procedural steps.

Similar to the refinery sector a gradual substitution of fossil hydrogen by renewable hydrogen would provide a good opportunity to integrate renewable hydrogen into the economic cycle. At the same time, it would contribute to further CO₂ emission savings. However, the use of renewable hydrogen in the chemical supply chains has, in comparison to the refinery sector (if RED II Art. 25 is nationally implemented), a cost factor of 3 to 6 and is thus, from the point of view of today’s regulatory framework, far from being economically feasible. However, the current cost difference to get to a broad use of “blue” hydrogen in the chemical industry is a lot lower.

The technological learning curves that could be achieved in the refinery sector will most probably not be sufficient in order to compensate for this cost difference in the short- to middle-term in the chemical industry sector. Thereby, it is important to point out that in the mid-term both production methods of hydrogen will have to be maintained.

To balance out the production costs of decarbonised and renewable hydrogen, levies and taxes will have to be adjusted, so to decrease the electricity costs. In case the required adjustments will be delayed, or the measures will not lead to the desired effects, a cross-sectorial market introduction program for a limited capacity (GW) and for a limited time line should be considered.

**Key take away:** An adjustment of the current tax and levy system within an overall sector coupling strategy will be required to bring down the costs of renewable electricity for a cost-efficient production of renewable hydrogen.
Steel industry: investments in direct reduction plants (DRP)

Today, CO₂ emissions of the German steel industry amount to about 60 bn tons per year and make up 6.6 per cent of the overall German emissions. A significant reduction of CO₂ emissions would only be possible with a transformation to direct reduction plants using gaseous fuels such as natural gas and hydrogen, since in Western Europe furnace plants are already operating at the technical and thermodynamical optimum.

Using scrap iron for electrical steel production provides already a low carbon production technology option for 30 per cent of the produced raw steel today. However, the limited availability of this scrap iron and the product portfolios of the processing pathways further limit the possible share of scrap iron-based steel production. In order to achieve a wider-reaching reduction of CO₂ emissions, a transformation of the primary steel production will be required.

Besides the considerable potential for CO₂ emission reductions a transformation of steel production towards direct reduction plants (DRP) creates further possibilities for a market introduction of PtX technologies and the use of hydrogen at larger scale. Thereby, the direct reduction process offers the required flexibility which is necessary for a successful market introduction for renewable and decarbonised gases: A gas-based direct reduction plant can switch easily between natural gas or hydrogen or any mix of both gases.

However, the technology transformation towards the use of direct reduction plants requires intensive upfront investments. The investment expenses for the greenfield construction of an integrated steel mill based on the direct reduction technology amount to about 400-450 € per ton of raw steel production capacity. However, those investments have to be compared with the retrofit of a furnace or a steel mill in an already existing plant parc, where producing a ton of steel costs less than 150€. Infrastructure measures in coking and sinter plants are to be counted in here.

In view of the required investment costs it must be assumed that until 2050 both production processes - the current furnace production pathways and the direct reduction installations - will still have to be maintained.

To incentivise the transformation process from the current furnace process towards a direct reduction metallurgy and to flank the required private investments in the aforementioned order of magnitude, effective support programs will be needed already in the near-term from the side of the Federal government and the European Union.

**Key take away:** A support program for investments in direct reduction plants is needed to incentivise the use of renewable and decarbonised gases in the steel sector.
Transport Sector

Blending of advanced biofuels

Natural gas as a fuel for the transport sector only plays a minor role in Europe today. For road traffic CNG and LNG (more for heavy carriage) is used at the moment. The use of natural gas could provide an important contribution to reduce CO₂ emissions in the transport sector as well as to improve local air quality due to its considerable lower NOₓ-emissions. There are already first applications of LNG for ships in place.

The blending of advanced biofuels (inter alia on the basis of biomethane) into CNG and LNG provides an opportunity to reduce CO₂ emissions, above all, in view of the set EU fleet emission reduction thresholds for the transport sector. For this reason, the Federation of German Industries assumes in its study “climate paths for the transport sector 2030” a demand of biomethane of about 105 to 194 PJ for the year 2030 or of until 3 bn CNG vehicles until 2030.

Creation of appropriate framework conditions for synthetic fuels and direct hydrogen use in the rail transport

A further important option to achieve CO₂ reductions in the transport sector is the use of hydrogen as a fuel (in most cases in combination with a fuel cell) and in form of synthetics fuels (based on renewable energies, water und CO₂, but also the application of bio waste and industrial residual waste is possible). Already today a blending of synthetic fuels could lead to immediate positive effects for the climate in the road traffic sector or in freight transport. However, the current regulatory framework today does not provide for the possibility of accounting those synthetic fuels towards the EU fleet emission reduction thresholds.

The use of hydrogen in railway could lead today to CO₂ emission reductions in the short-term and could play an important role for the scale-up of the fuel cell technology. Since 2017 fuel cell locomotives in Germany are already used in a test run. From 2020 on a serial maturity of the technology is expected to be reached. Then, the operation of hydrogen fired trains on non-electrified rail section could be realised.

In the long run the use of synthetic fuels is above all expected in the aviation and maritime transport. However, a successful market launch would be rather an option for road traffic in the first place.

Application of synthetic fuels for passenger cars and trucks

In case synthetic fuels will be accountable towards the fleet emission targets for the European Review processes in 2022 (for lorries) and 2023 (for passenger cars), it is likely that synthetic fuels will be applied in the passenger and freight transport already in the beginning of phase II. It is important that the required amount of synthetic fuels is available, both domestically and abroad, to cover the demand which would be induced by the fleet emission reduction thresholds, once the regulation would be amended to allow so. When substituting 8 to 10 per cent¹¹ of the fuels applied in the transport sector by synthetic fuels the demand for hydrogen could increase to 1.5 bn t/a in Germany which corresponds to an electrolyser capacity of about 17 GW (assuming 4000 full load hours).

Key take away: Enable accountability of synthetic fuels towards EU fleet emission targets („well-to-wheel“ approach“)

¹¹ Required quantity to reach sector targets 2030 for the transport sector (results of the national mobility platform)
Building sector

The building sector, which consists of residential buildings and non-residential buildings, currently is responsible for about 30 per cent of all CO₂ emissions and 35 per cent of the energy demand in Germany. In the EU the building sector even accounts for 40 per cent of the energy demand. This implies that the highest potentials to reduce CO₂ emissions are hidden in the building sector, even though there has been a continuous improvement of energy efficiency. To reach the 2050 climate target goals a gradual transformation of the building sector towards low CO₂ intense energy sources will have to be achieved. To make use of renewable energy sources in the most efficient way, an overall energetic retrofitting of the building sector would be required, which currently only advances at a slow pace.

The building sector is to the largest part heated by gas installations in Germany: Out of a total of 21 bn heaters in residential and non-residential buildings in Germany 14 bn (that means a share of two thirds) are gas installations. A blending of renewable or decarbonised gases in the existing gas-based heating supply infrastructure is thus an efficient opportunity to reach the CO₂ emission targets in the building sector.

Biomethane as an energy source of the heating sector is already an option today. In the future, hydrogen could play an important role for CO₂ emission reductions in the heating sector. An option would be the operation of pure hydrogen grids or, alternatively, a blending of hydrogen into the gas or methane grid. For this reason, the following measures would be necessary in the short or middle term.

Selective hydrogen blending in model regions

In the short- and middle term new heating installations in model regions should be tested. There are both, installations with hydrogen blending as well as installations where a 100 per cent hydrogen application would be possible (after the role model of H21 in Leeds, UK). Suitable for this are grid areas in which no industrial clients or gas fuel filling stations are connected or planned, and which have a high hydrogen compatibility in the distribution grid.

A wide-reaching verification of the hydrogen compatibility in the infrastructure

A first estimation of some German associations in the building sector, such as DVGW, figawa and BDH, come to the result that a hydrogen blending of a level of maximum 10 per cent (volume) in today’s installations would be feasible. However, a wide-reaching testing is still necessary to verify this result.

Improving hydrogen compatibility of new heating devices

According to the information of installation manufacturers a share of 20 per cent of hydrogen would be possible with new installations. To be able to reach this goal the following aspects would be required:

- The technical framework conditions – security, efficiency and lifetime
- Creation of the control and certification conditions for hydrogen blending
- New developments, e.g. flame detection, material burner, boiler material, sealings, barrel valves, etc.

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12 Source: Eurostat.
13 Source: Bundesverband der Deutschen Heizungsindustrie e. V.
Electricity Sector

In the electricity sector the Federation of German Industries expects the application of renewable and decarbonised gases only from the year 2040 on (95-per cent-pathway of the BDI “climate pathway study”)\(^\text{14}\). Until then, the completion of the nuclear phase out and the implementation of the planned coal phase out will constitute a central challenge for the electricity sector in Germany. The fuel switch from coal to gas will lead to considerable emission reductions but will also require a consequent adjustment of the electricity market design.

According to the Federation of German Industries’ study „Climate paths for Germany“, in 2050, the installed gas capacity will amount for between 61 and 75 GW. The corresponding generation capacity amounts to about 50 TWh per year and will have to be produced with the help of renewable and decarbonised gases in the 95 per cent path. If at the time the proposed 50 TWh will be produced with hydrogen or synthetic methane cannot be predicted with certainty from today’s point of view. To make the technology options feasible, further research and development for hydrogen technologies and the implementation of pilot projects for local electricity production with 100 per cent hydrogen (e.g. near industry sites) will be required.

In January 2019, the European turbine manufacturers have committed themselves to produce hydrogen compatible turbines (for 100 per cent hydrogen) until 2030 for a respective demand and to deliver first machines already in the year 2020 which run reliably with a 20 per cent hydrogen share in the gas mix.

Post-2030

Carbon Capture and Storage (CCS) for industrial processes which are difficult to decarbonise

The Federation of Germany Industries’ study „Climate paths for Germany“ concludes that the 95 per cent CO\(_2\) reduction goal can only be achieved with the help of a selective application of CCS technologies. The use of PtX technologies or hydrogen offers an alternative to CCS by reducing process emissions in the steel production, in steam reforming processes in the chemical industry and emissions in refineries. However, for the cement industry CCS technologies provide the only option for an effective CO\(_2\) reduction in the production processes.

The CO\(_2\) abatement costs of CCS technologies can, in certain cases of application and depending on the hydrogen price, be below the costs of PtX technologies. For this reason, the option of using CCS as a complement to PtX technologies (e.g. in combination with combustion of the biomass) should not be excluded from today’s point of view.

Synthetic fuels in the aviation and shipping industry

The use of synthetic fuels is the most efficient way forward to reduce CO\(_2\) in the aviation and shipping sector which is known today. In both sectors the use of fuel cells is also being tested.

As soon as synthetic fuels can be imported into the European Union at competitive prices an introduction of synthetic fuels in the aviation sector would be conceivable. So long, airlines will also use quantities stemming from German demonstration plants. Beyond that, German airlines could make use of

\(^{14}\) BDI (2018). Klimapfade für Deutschland.
An industry roadmap for the market introduction of renewable and decarbonised gases

3.2. Gas grid infrastructure and regulatory measures: Overarching EU-wide policy measures (compare Roadmap 2)

The following section looks at the required technical framework and necessary policy instruments for a successful market introduction of renewable and decarbonised gases according to Roadmap 2 (p. 13).

EU-wide infrastructure impact assessment of market design options for climate-friendly gases

To develop a European market design for renewable and decarbonised gases evaluation of different scenarios of the infrastructure development is required. The Federation of German Industries recommends an evaluation of the following options:

- **Parallel gridinfrastructures for hydrogen and methane**: Development of a large-scale hydrogen grid, which covers hydrogen demand of large-scale industrial consumers and that of the transport sector. The natural gas grid continues operation, capacity adjustment might be required. As a next step, gradual replacement of natural gas by synthetic methane and biomethane.

- **100 per cent hydrogen**: Establishment of a national or even a European hydrogen network by transforming the existing natural gas infrastructure and building new dedicated hydrogen pipelines. This can be implemented either by converting local grids directly to 100 per cent hydrogen (e.g. H21 Leeds) or by gradual hydrogen blending or by a mixture of both measures.

- **Gas-mix-scenario**: Operation of small hydrogen networks, which serve only major consumer groups, and implementation of a hydrogen blending quota into the natural gas grid; in the next step, substitution of fossil gas by synthetic methane.

The decision for one of the presented options is closely linked to the future course of the energy transition. Thus, it depends on various factors, such as technological learning curves of PtX technologies, potentials for renewable energy expansion in Germany and in the EU, electricity grid expansion (specifically for Germany) and available import forms of PtX-gases and fuels.

At the same time, the decision for one of the options cannot be taken on the national level but requires an EU-wide solution. Inconsistent national strategies and regulation could have negative impact on the liquidity of the common gas market and would require technical adjustment of the gas interconnectors. For this reason, the Federation of German Industries advises that a European-wide scenario evaluation (impact assessment) should be included in the upcoming gas package.

Furthermore, all suggested market design options raise the question of a regulatory framework for dedicated hydrogen infrastructure, which should be addressed. In the existing gas regulatory framework hydrogen is treated only in the context of blending with gas and the existing private hydrogen island-networks are not subject to gas infrastructure regulation.
Improvement of infrastructure hydrogen-readiness

According to the assessment of the Federation of German Industries an area-wide hydrogen blending quota today is only possible until a maximum hydrogen concentration of 2 per cent due to the technical limitations mentioned in chapter II. Furthermore, from an overall systemic point of view the direct use of the limited available resources of (especially green) hydrogen in industry and transport sectors should be prioritised in the short- to middle-term against hydrogen blending.

Since, however, a large-scale area-wide use of hydrogen (in a 100 per cent grid or as a blend) is probably going to be crucial for achieving CO₂ reductions on the long run, early measures on infrastructure and consumer side should be taken in order to address current technological hurdles for the implementation of higher hydrogen shares.

For the consumer side the following preconditions have to be fulfilled in order to allow for a blending quota above 2 per cent:

- **Membrane technology** for the separation of pure natural gas from a hydrogen-gas-mix reaches market maturity and is available to consumers at competitive price.

- A concept for **financing of investments in membrane technology**, similar to the existing model for L-H gas switch (in Germany), has been developed and implemented.

- **Experimental testing of advanced measurement and control technology** has been conducted successfully under the conditions of a strong fluctuating gas composition. The technological market maturity has been confirmed.

- **Incentives for investments** in measurement and control technology have been created.

From an overall systemic perspective, the use of the existing infrastructure should have priority before new constructions. On infrastructure side measures for the retrofit of the gas grids should be taken in the middle term. Already today, a blending of 10 per cent is feasible in a number of gas distribution grids in Germany. In addition, the question of fluctuating gas quality composition regarding the operation of hydrogen compatible gas turbines and motors as well as hydrogen compatibility of gas storage will have to be addressed.

Creating a European market for guarantees of origin (GOs)

The Federation of German Industries supports the introduction of a certification system for renewable and decarbonised gases. Guarantees of origin (GOs) are not only a useful instrument for consumer disclosure, they could also provide a market-based solution to incentivise the production and use of renewable and decarbonised gases, in a way that they could even be an alternative to state-funded support schemes. In a further stage, GOs could also be a tool to certify European-wide standards for imports of renewable and decarbonised gases coming into the European Union.

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15 At certain grid areas, where no sensible end-consumer are connected, 10 per cent could be possible.
The following aspects are of major importance for a successful introduction of such instruments:

- Precondition of a well-functioning system of guarantees of origin for renewable and decarbonised gases is a **European-wide standardised classification scheme** of different types of renewable and decarbonised gases. The determining factor of this terminology should be the CO₂ emission factor of the respective gases.

- In addition, **standards and procedures of the GO system should be harmonized across Europe**, so that certificates are tradable Europe-wide and can be recognized cross-border. Here the set standards (CEN 16325) of the GO system in the electricity sector could serve as an example.

- GOs of renewable and decarbonised gases need to be accountable towards the CO₂ emission reduction and renewable energy targets and thresholds for end-consumers. In this way, GOs would besides their transparency function have an additional purpose which would upgrade the overall value of GOs. Precondition would be the above-mentioned standardisation of gas terminologies.

- A well-functioning European-wide GO system should also allow for a mass balancing. In this way, renewable hydrogen could be for instance injected in a model region (such as the building sector) and then be contractually sold to industrial clients elsewhere (“book and claim”) which then, ideally, would be able to account the green characteristics of the renewable or decarbonised gas towards its renewable energy targets (such as indicated in RED II).

There are already some positive examples and pilot projects in place, such as CertiHy and ERGaR, to create a European-wide certification scheme. The Federation of German Industries supports the further development of those European projects.

### Imports of renewable and decarbonised gases and fuels

In order to meet future demand for renewable and decarbonised gases and fuels both production in the EU as well as imports from third countries will be necessary. The imports will, however, require new concepts of trade and cooperation before a liquid market as compared to today’s market for fossil fuels can develop.

The upcoming gas package provides a good opportunity to start working on such concepts and establish the regulatory basis for first demonstration projects for international supply chains of climate-friendly gases and fuels as currently already pursued by Japan and Australia. Such concepts can partly benefit from the existing instruments such as energy partnerships with third countries and/or the existing energy trade relations. Due to the favourable weather conditions for renewable energy production many of todays’ fossil fuel exporters can potentially “transform” to the exporters of low-carbon gases and fuels.

Besides the aspects of production, the international demonstration projects should focus on transport as especially for hydrogen this is still quite an undiscovered field with limited technology options besides pipeline transport available on the market such as LOHC\(^\text{16}\) or hydrogen liquefaction by cooling. These options, however, are currently associated with efficiency losses and high costs. As it should be the objective of the EU to establish a diversified supply for renewable and decarbonised gases and

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\(^{16}\) Liquified organic hydrogen carrier.
fueals these options should be analysed and tested with further research targeted at the improvement of existing and potentially developing new technology.

**Final Remarks**

The Federation of German Industries welcomes the active and open deliberations of both the European Union and the German Government on the future role of the commodity gas and the closely related question of the market introduction strategy of hydrogen and power-to-x technologies.

From the point of view of the German industry the turning away from an “all-electric” focus of the energy transition is crucial for a cost-efficient, consumer-friendly transformation of the energy sector that will foster innovation and business opportunities in Germany and in the European Union at the same time.

**Impressum**

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