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DVGW Innovation Research Gas:
Roadmap for Increased Climate Protection, Sustainability and Safety

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Editorial

Prof. Dr. Gerald Linke

Dipl.-Ing. Heinrich Busch

Everyone values Gottlieb Daimler's inventions, everyone is aware of Bill Gates' merits. And everyone knows about the historic misjudgements of both men: that the worldwide demand for motorcars would never exceed the million mark – for the mere reason that there is a lack of available chauffeurs. That nobody will ever need more than 640 kilobyte storage capacity.

Since then, the world has undergone a dramatic change. The digital revolution is outpaced by the energy revolution. The nuclear age is now almost history, the age of the renewable energies has only just begun. What conclusions can we draw from this today? Very simple: development potentials of new technologies are often misjudged, frequently underestimated. For the DVGW as one of the leading initiators of the energy transition not to be surprised by innovations, the association needed a compass, a kind of radar. This is exactly what we have created with our DVGW Research Radar: By means of ongoing technology and innovation scouting, we will continue to set a trendsetting course in gas research and to develop the positive effects of the discontinued DVGW innovation offensive. Parallel to our European research activities, we have therefore by means of a members' decision permanently increased the budget for the innovation research gas.

Innovation research helps us to recognise technical challenges early on and to actively accompany them with projects. For this purpose, we scrutinise innovations in all relevant fields of technology for their potential contribution to the future energy system. This allows us to actively co-shape the role of gas.

On the one hand, requirements are placed on the energy supply to continue decarbonisation, to increase efficiency and to incorporate renewable energies. With its low CO_2 emissions, flexibility, availability and economic viability, the energy source gas can make essential contributions in this regard. In this connection, the gas grid, including its storage function, assumes a more system-immanent function that serves the power grid. Questions with regard to the power-to-gas technology and the integration of renewable gases need to be answered. To all these questions, technical solutions must be found to be able to assume this system-serving role and to participate in the national task "Energy transition as industry". A joint course of action with the electricity industry is necessary to advance this systemic approach even more vigorously.

On the other hand it is necessary to develop interfaces to actors from outside the industry. For instance to actors in the fields of information and communication technology who are working on solutions for a future energy grid. Or to actors in the traffic sector to guarantee low-carbon mobility through the use of natural gas. This is the only way in which we can succeed in keeping natural gas and renewable gases successful in their traditional markets and in developing new options. We would like to express our collegial thanks to all the salaried and unsalaried members of the DVGW Group who are involved in the DVGW innovation research project work. You are all making an essential contribution to the fact that our association with its great tradition is today perceived as a strong competence network of research. We are pioneers of opportunities, not prophets of risks. After all, Gottlieb Daimler and Bill Gates were mistaken.

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From a R&D Radar to a Roadmap for the DVGW Research

With the energy transition, new avenues to a more decentralised, low-carbon energy supply are being explored. Against this background, the DVGW has undertaken a strategic assessment of its research work in the lead project "Research & Development Radar" during the year 2015. This was done with the objective of assessing the future viability of different gas technologies and to preconceive development steps for the next 15 years ahead. An extensive assessment of the situation preceded the R&D Radar and comprised political and social trends. Together with experts from science and economy, the DVGW has worked on a broad analysis and assessment – the lead scenario "Gas as partner of the energy transition" was defined as leading parameter. This is because it stands to be expected that the dynamic development towards decarbonisation of the energy industry will continue in the future. This will further accelerate the necessity for innovations with regard to technologies, procedures and processes.

Strategic objectives for the energy source gas

The scenario "Gas as partner of the energy transition" describes the role of gas as permanent partner of the current transformation process in the energy industry. In a system that largely dispenses with other fossil energy sources, gas remains the central partner of the renewable energies. The driving force behind this is the cooperative and trusting relationship between politics and industry – in an increasing measure also on an international basis.

This scenario is based on the following criteria:

- The decarbonisation of the energy industry and the development of renewable energies are expedited;
- Lasting progress will be made in the international climate protection negotiations, also with regard to the reduction of further emissions;
- The EU Emissions Trading System will be successfully reactivated and expanded;
- Many applications in the field of renewable energies will increasingly become ready for the market; and
- The interlinking of energy infrastructures (power, gas) with certain sectors will be advanced (for instance with regard to the creditability of alternative grid extension measures to enable alternative uses of the gas grid)

The following strategic objectives can be derived from this:

- Diversification of the sourcews of supply and import routes for natural gas
- Improved physical integration of gas infrastructures into an overall future energy system
- Expansion of renewable gas production
- Development of innovative solutions and technologies to increase efficiency
- Opening up new business segments, for example in the mobility sector

19 concrete technology segments were examined in the R&D Radar with regard to this lead scenario. This comprised the necessary research and development steps for this lead scenario to be implemented. The R&D Radar supports the DVGW and its members in finding a stalwart and sustainable gas strategy.

Opportunities will be used, risks anticipated and taken into account early on and R&D gaps will be identified to be able to accurately allot required funds.

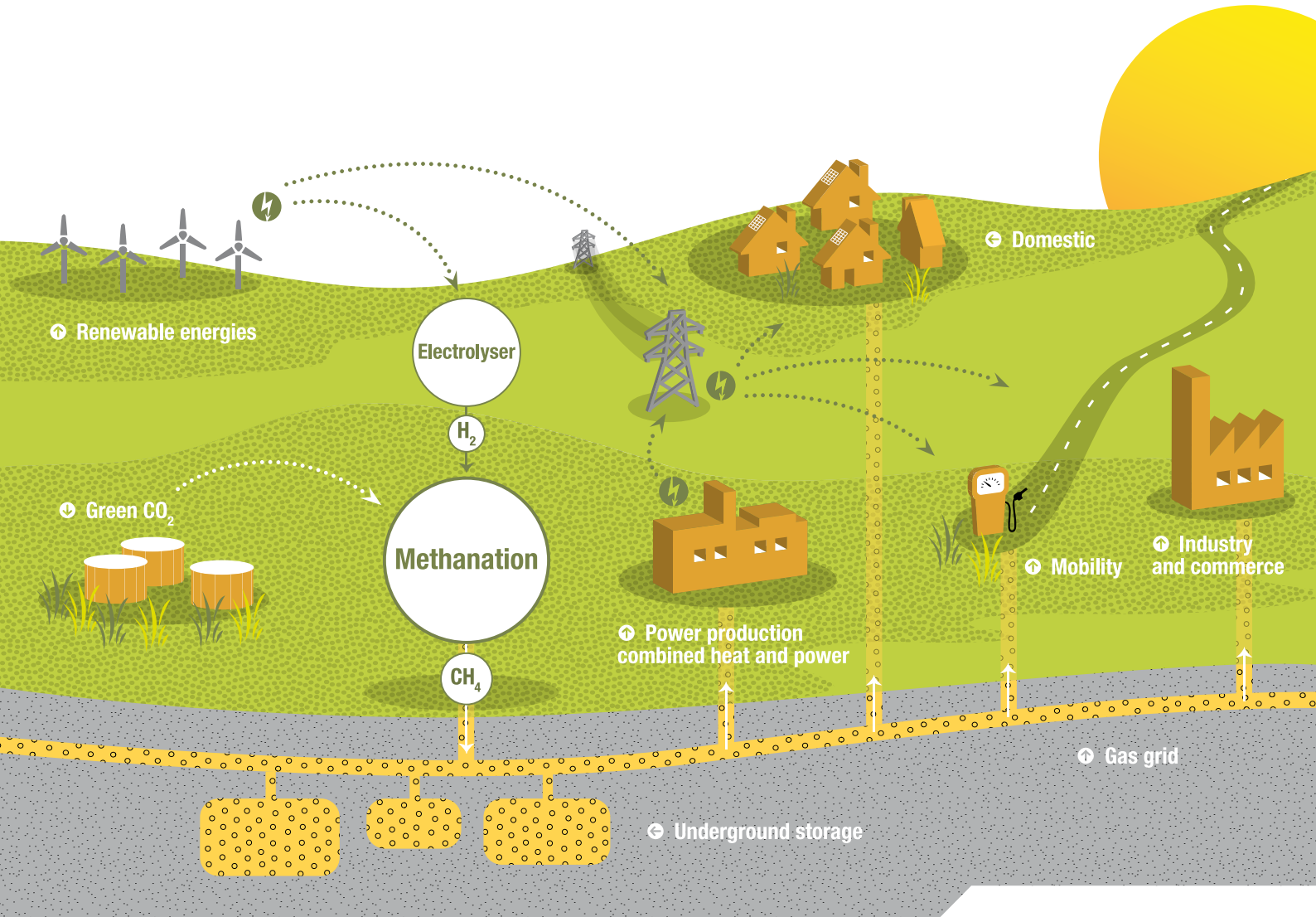
The R&D Radar thus serves as basis for internal and external discussions on the further development of the gas industry.

Conversion into a roadmap

In a second step, concrete research topics were developed and structured into superordinate topic groups. The newly created structure in DVGW Research with the Innovation Group Gas ensures a fast and targeted definition of the central topics renewable gases, grid concepts / grid operation / grid control, efficient use of gas as well as mobility with gas.

These are the topic focal points, which are of paramount importance to the gas industry, and at which the DVGW will primarily aim its research activities.

With the roadmap, the DVGW has presented its medium-term research programme. It serves to secure the sustainability of natural gas, the generation and use of renewable gases and to make long-lasting use of the merits of our gas infrastructures.



Renewable gases

Gas is the only fossil energy source that can in future be 100 percent produced in a regenerative manner. The efficient production and integration of gases from renewable sources into the gas infrastructure is therefore an essential requirement for rendering the energy source gas viable for the future. With the integration of RE gases into the gas system it is possible to realise CO_2 savings in all sectors that are connected to the gas grid. Analysis and description of the potential of renewable gases is viewed as a high-priority task. Current political constraints prevent the integration or infeed of renewable gas into the natural gas infrastructure, although the potentials are seen considerably more positive as far as the sustainably produced biomethane is concerned, without any negative influences on groundwater or soil to be expected.

Biogases

Fermentative biogas generation methods have reached a high technological maturity in recent years. In the meantime, approx. 9,000 biogas plants are operated in Germany. Current challenges in this sector concern mostly the improvement of regulatory market conditions. Technological and economic improvement potentials are revealed in the processing and conditioning of biogases to reach natural gas quality. Future options in the biogas production from fermentative processes arise from the additional use of the CO_2 contained in biogas for PtG processes. These volumes can be utilised by applying the process of methanation, coupled with the power-to-gas technology. Thus, the capacity of biogas production in Germany could be increased to approx. 20 billion m^3 per year. This must be substantiated by research work, which apart from procedural assessments must also comprise assessments from a safety point of view. Coupling with PtG consequently offers a future option, in particular for existing biogas plants, to guarantee their continued operation and to avoid "stranded investments".

In this connection, the thermo-chemical generation of synthetic natural gas (SNG) by means of biomass gasification is of interest, as it facilitates an expansion of the usable biomass spectrum and basically allows for larger plant sizes with specifically lower plant costs. The focus here is on research topics in the field of process technology and their optimisation in view of a stable operation of the synthetic gas production. Because of the necessity of verifying the results in practical applications, such projects will be closely associated with demonstration projects.

Power-to-gas and electrolysis

Power-to-gas is the central element when it comes to the needs-based integration of renewable power into our energy system and the decarbonisation of different sectors. The compilation of a power-to-gas roadmap, technology assessments and optimisations as well as demonstration projects are at the core of developments. The already ongoing and completed power-to-gas projects have succeeded in sparking interest in this topic both in the general public and in sectors close to the industry. Now it is necessary to show the path to market launch and implementation. This applies to different actors in this sector, both on the side of the providers and on the side of the users. In this case too, research work must be accompanied by attendant surveys and improvements of the basic legal conditions.

The following aspects are of special importance for the roadmap with regard to power-to-gas:

- Description of required adaptation measures in the grid and at the customer plants for the long-term conversion to high hydrogen concentrations
- Consideration of further economic sectors by means of sector coupling, apart from the electricity industry in particular in the fields of industry, mobility and heat
- Standardisation of the manufacture of electrolysers to enable large-scale production
- Optimisation of infeed locations in view of the gas grid's intake potential
- Possible reallocation of natural gas lines to (partial) hydrogen operation
- Use of membrane technologies for hydrogen separation
- Provision of CO_2 for methanation
- Needs-based optimisation of the PtG plant operation mode and coupling with other renewable gas production technologies

A high priority is in this connection seen for the topic of standardisation. Compiling a licensing code of practice for power-to-gas plants can create an effective support tool for decision-making. This code of practice should be developed within the scope of the research road map. Further optimisation of electrolysis and methanation methods is very important for the power-to-gas technology, as it will entail function improvements, cost reductions and economies of scale. As these technological development and optimisation tasks constitute complex and cost-intensive research projects, these projects are undertaken in cooperation with the technology suppliers.

Demonstration projects

Demonstration projects are of central importance during the development phase of a technology. For this reason, the DVGW will advocate supporting the demonstration of additional and novel applications of power-to-gas, for instance by means of accompanying scientific research. The existing DVGW instruments of the power-to-gas roadmap will continue to be applied and extended to a European level. In addition, the DVGW cluster “Gas generation and energy system” will undertake a continuous monitoring of power-to-gas demonstration projects in Germany and Europe.

The EU Horizon 2020 project STORE&GO, which is coordinated by the DVGW, is the European flagship project in the field of power-to-gas. Within the scope of this project, different methanation technologies are tested at three selected sites in Europe and are demonstrated for use in the gas and electricity industry. A consortium of 27 partners is working on this project. The emphasis is on the demonstration of novel methanation technologies and the integration of PtG plants in power grids and gas grids as storage and flexibility element. Further key activities in this project concern legal, regulatory, business and economic aspects.

Grid concepts, grid operation and grid control

The development of innovative grid concepts, but also of concepts for grid operation and control is of crucial importance when gas in the future assumes a role as partner in the energy transition. Joint solutions with the electricity industry are required to also work out concrete technical solutions with the assistance of information and communication technology – a closed solution for smart grids. In the course of concept development, the focus is on a sector spanning approach to link the power grid with the gas grid. Thus, the synergies of both systems can be used.

Comparison

Regenerative power	Gas
volatility	flexible / projectable
"non-"storable	storable
incomplete infrastructure	nationwide infrastructure
production not coupled to need	just on demand provision

Cellular grid structures

For cost and efficiency reasons, it is necessary to link the two systems at an as low as possible voltage level. For this reason, cellular and multimodal power supply structures are pursued. A multitude of technical challenges has to be met in developing the innovative cellular approach. This leads us to the superordinate question which technical ramifications the consistent implementation of the objective to balance the provision and the requirement of any type of energy at the lowest possible level will entail. How can the set-up of energy cells and their interfaces be designed in the end?

The overall system will be formed by linking or overlapping individual cells. Irrespective of today's circumstances, the system has to be completely redesigned from the bottom up, starting with the smallest cells. New topologies and technologies reaching across different energy sources are of special importance for an optimum linking of the cells. The newly designed system must then be optimised in view of a reliable and stable system operation. To this end, it is in particular necessary to define and distribute tasks and responsibilities to ensure that system stability can be maintained.

The basic regulatory conditions are currently seen as the largest hurdle for the practical implementation of such concepts. Legal and economic aspects must therefore be incorporated in this connection so as to do justice to the role of power-to-gas as coupling and load shifting element between power grid and gas grid.

Combined gas and power grid automation

A prerequisite for coupling the gas and power grids is the reliable and safe exchange of required information. In so far, the importance of Information and Communication Technology (ICT) will increase significantly.

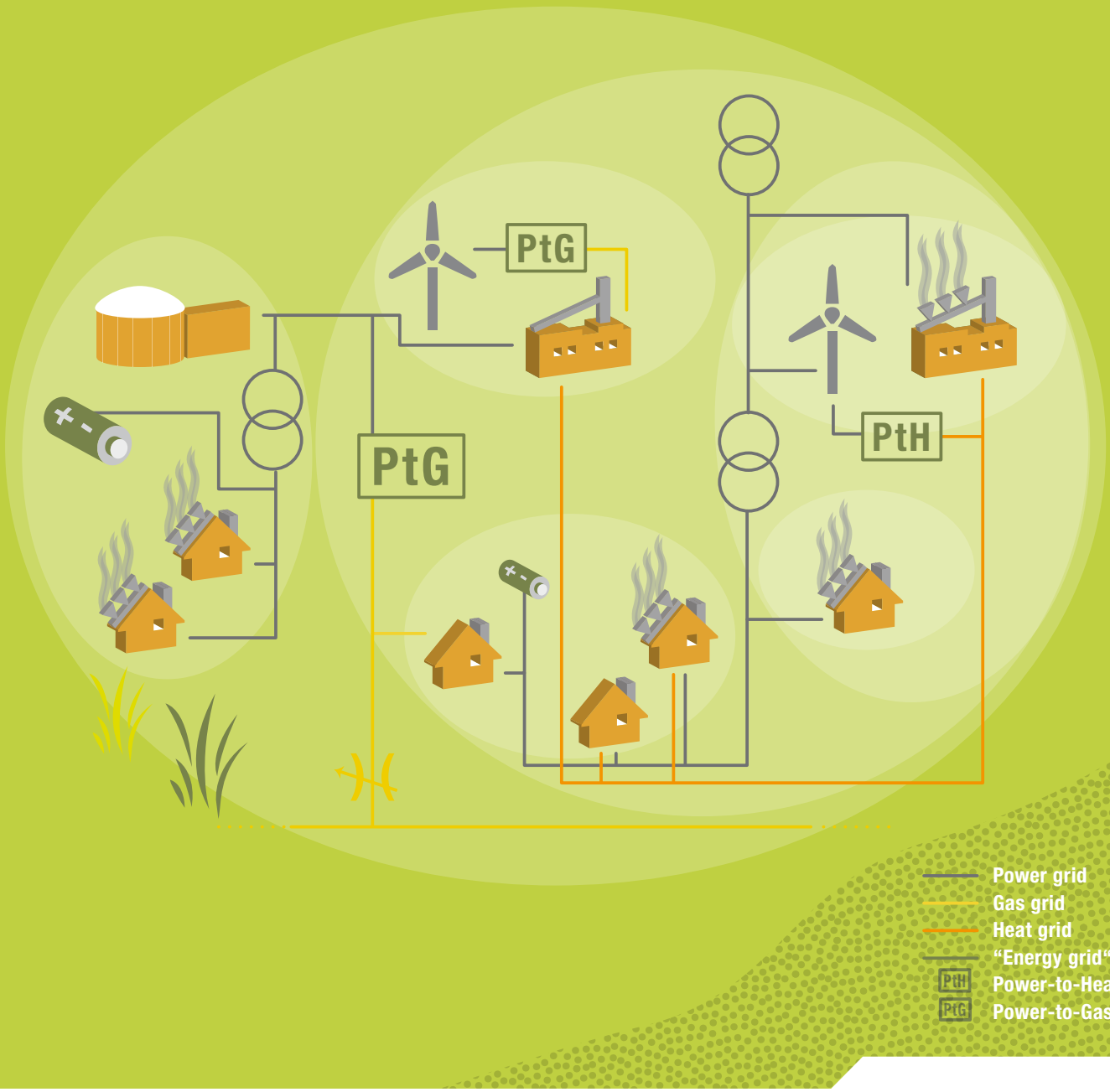
This applies both to the path from power to gas system by means of electrolysis and to the reverse path via combined heat and power generation in form of virtual power stations. In cellular grid structures, so-called agent-based control systems ensure a high degree of automation and operational reliability. The ICT concepts must be enhanced so they can be used in the power supply under the aspect of grid coupling. A high level of information exchange across sector boundaries will render grid control considerably more flexible.

Further elements of the so-called smart grids are ICT-assisted intelligent measuring devices – smart meters – as well as a cost-efficient and comprehensive exchange of information between the coupling elements in the power and gas system. The technical integration of these components into a joint smart grid concept will be another focal point of the cooperation with the power grid.

Innovative grid operation and demonstration

The range of gas qualities in the gas grid is increasingly becoming broader, for

Transformation process



example with LNG of high energy density and, as a perspective, hydrogen from power-to-gas plants. For safety, operational and billing reasons, special attention needs to be given to this. In the Smart Grid cluster, the subject of gas quality tracking is therefore treated with high priority.
In addition to this, numerical methods of adequate accuracy must be developed for dispatching supplementary to the use of complex measurement technologies.

A further need for research arises from the development of methods for an active or bi-directional operating mode of the gas grids. An intelligent gas grid of the future also includes an increased capacity for a decentralised intake of renewable gas. One approach in this regard is the active operating mode of the gas grid, for example by means of bi-directionality between pressure levels that is for instance achieved by biogas backfeed.

After the successful development of smart grid concepts with power-to-gas and ICT technologies, these must also be demonstrated in practical application. In this area too, the DVGW sees its task in scientifically accompanying demonstration projects in combined gas and power grid automation – the smart grids. So as to satisfy the DVGW's mandate, standardisation and regulation are to be closely associated with research in this connection.

Efficient use of gas

The lasting increase of energy efficiency is a central topic within the scope of DVGW innovation research. For this purpose, the gas industry has at its disposal highly efficient and mature technologies for a variety of applications in the domestic, commercial and industrial sector. A research requirement of overriding importance becomes apparent in the compilation of potential analyses and in the development of processes and technologies, but also in the accompanying scientific research undertaken to define basic legal and political conditions. Modern methods used by geoinformation systems play an increasing role in this connection in order to identify regions where modern gas utilisation technologies are able to achieve particularly high effects for the energy transition.

Power-optimised operating methods of combined heat and power generation

A great potential in helping to achieve the objectives of the energy transition is ascribed to highly efficient gas application technologies, as these lead to distinct CO_2 reductions. In this connection, the combined heat and power generation in power-optimised or power-controlled plants is of special importance, for instance to use it in virtual power plants. Apart from system and technology research, for example in the course of the market launch of linked CHP systems based on ICT technology, accompanying scientific research in the field of emission improvements of motor-driven combined heat and power plants and their behaviour in case of more strongly fluctuating gas qualities is also necessary to that end.

Basic requirement for a power-optimised or power-controlled CHP plant operation is a heat management that is optimised for this purpose. Because this is the only manner in which an operation that is temporarily decoupled from the building's heat requirement can be implemented. Novel storage concepts and operating strategies have to be developed, including the research work on novel storage materials exhibiting clearly higher intake capacities.

Low energy buildings place high requirements on the power supply because, as a rule they exhibit low and continuous load profiles, but nevertheless also require high peaks of demand, for example for hot water generation, to be covered. Further questions arise with regard to the technical-economical role of gas technologies in this sector. Similar research requirements arise with regard to the use and approval of regenerative gases on the heat market and for rehabilitations, for instance as accompanying research with the purpose of transferring country regulations to a federal level.

Fuel cells

Fuel cells convert energy that is chemically bound in natural gas into power and heat by electrochemical means. With this direct conversion step, very high electrical efficiencies can be achieved. In recent years, extensive research and development work has been done. Two fuel cell system principles – polymer electrolyte membrane fuel cells (PEMFC), solid oxide fuel cells (SOFC) – have turned out to be sustainable. These essentially differ in the required gas processing methods at respectively different operating temperatures. Although the SOFC technology works with very high operating temperatures of up to 750 °C, it achieves electrical efficiencies of up to 60 percent. This demonstrates the considerable potential of this type of fuel cell in an impressive manner.

A need for technological research lies in the improvement of the range of functions such as long-term stability and operational reliability, but also in system integration in the building energy sector. Attendant accompanying scientific research on the market launch is necessary to spread this climate-friendly and system-stabilising application technology. The enhancement of fuel cell technology in particular in the power range up to 50 kW for the district power supply is essential to achieve a market penetration also in superordinate sectors.

Hybrid systems

The combination of fossil gas with natural gas to lastingly reduce CO_2 emissions does not only constitute a cost-efficient solution for the heat market. Large potentials are also available both in the industry, trade and services sector (ITS-sector). Owing to the flexibility of the energy source gas, it can be ideally combined with regenerative energies, in particular in view of EEC-subsidised plants. Hybrid systems, for example consisting of biomass base load plants and natural gas peak load plants, lend themselves for commercial but also for industrial heat production. In this field there are identifiable development needs as far as system integration and standardisation are concerned. As these are as a rule case-related solutions, such research projects must be developed and implemented together with the partners involved, where necessary within the scope of regional or local programmes.

Basic conditions for energy saving

The requirements on the saving of energy are laid down in different regulations and standards. They encompass a large scope with partly differing conditions at regional and federal level. Their joint denominator is the fact that increasingly more stringent parameters and indicators for energy efficiency and emission reduction are defined.

Within the scope of energy conservation legislation, the Energy Conservation Ordinance has evolved into the central control element. It is based on primary energy factors as far as the climate protection-relevant assessment of energy sources is concerned. These in turn flow into other rules and regulations and constitute a guide parameter. Current research has revealed that the basis of calculation for primary energy factors has over the years developed such that there is no steering effect with regard to climate protection and other increasingly more important factors such as system and grid stability, resource consumption, life cycle considerations, etc. The research cluster CHP / application technology therefore is to enhance the existing systematics of primary energy factors and supplement these with new indicators. At the same time, experience gained in other European countries outside Germany is to be taken into account. Here, advanced approaches, for instance with regard to the incorporation of CO_2 emissions or biomass sustainability indicators, were developed.

Consequences of fluctuating gas qualities

The diversification of gas procurement, in particular due to high-calorific LNG and the integration of renewable gases into our gas system, may increasingly lead to fluctuations in gas quality. This has repercussions for different application technologies, for example for special combustion and production processes. Adaptation strategies for standard application technologies, for example on the heat or mobility market, are available but in particular in the commercial and industrial sector a research requirement continues to exist.

Research aims at increasing the robustness of application technologies with respect to fluctuating gas qualities by means of the dynamic combustion control approach. At the same time, the focus is on broad areas of application, not on individual technologies. Research also comprises novel control concepts, which are based on the external provision of information, for example by a grid-side gas procurement information system, but with a rather medium-term focus.

Mobility with gas

With roughly 200 million tons of CO_2 per year, the traffic sector causes one quarter of the CO_2 emissions in Germany. Decarbonisation strategies are multifaceted, because special requirements have to be met as far as mobility is concerned. High ranges are indispensable in long-distance and heavy goods transport. Noise emissions are increasingly relevant for the supply of urban spaces, as is the reduction of local emissions to improve the local air quality, in particular with regard to nitrogen oxide, particle and particulate emissions. Here the use of liquefied natural gas (LNG) offers considerable opportunities. In the private transport sector, gas mobility has for many years already been implemented through the use of CNG (compressed natural gas). World-wide, roughly 17 million natural gas vehicles are travelling the roads. In addition, reductions of specific CO_2 emission can be realised by the substitution of fossil natural gas with gases from regenerative sources such as biogas.

Mobility concepts with liquid natural gas (LNG)

In the diversification of the natural gas supply, LNG is increasingly gaining in importance as an alternative to conventional fuels in the mobility sector (heavy goods traffic, marine transport, inland water transport). In maritime and inland water transport and notably in heavy goods traffic on the road, LNG is a clean alternative to drive concepts that are based on heavy fuel oil, marine gas oil or diesel. With its emission reduction potential, LNG is able to considerably contribute towards the achievement of climate targets. Positive climate effects achieved through the use of LNG in the field of mobility can be further improved with the admixture of bio-LNG .

In order to provide early active support for this gas technology and its introduction into practical use, the DVGW is scientifically accompanying this topic with the research cluster LNG / mobility. The research work mainly comprises the compilation of a LNG roadmap as well as the development of processes and technologies.

A comprehensive overview will be generated by means of a potential analysis in view of LNG quantities, logistics chains, potentials of bio-LNG and greenhouse gas reductions and from this a roadmap for LNG will then be developed.

The classification of LNG into power supply concepts is also important in this connection. Viewed form a global point of view, the use of LNG for the supply of regions or companies in isolated operation is highly relevant. For Germany with its high gas grid density, this will be limited to individual regions, for instance to the commercial or industrial sector. Despite the regional character of these projects, which are supported within the scope of local or regional programmes, the results are relevant because of their transferability. Another topic is the revision of the bodies of rules and regulations and standards for LNG technology. There is need for action in this regard to facilitate the market launch of LNG as fuel. Specific technology developments such as the enhancement of motor technology will be accompanied by the DVGW.

Mobility concepts with compressed gas (CNG)

CNG (compressed natural gas) is a mature and established decarbonisation technology for the traffic sector. Further solutions must be identified to achieve a consolidation and sustainable growth of CNG applications in the mobility sector. To this end, integration potentials of renewable gases via novel paths, for example as power-based fuels, must be investigated. Such options considerably improve the integration of renewable energies into our energy systems, as they permit a spatially and temporally shifted use of RE-power with a clearly higher added value.

In addition, CNG technologies must be enhanced with the help of local and regional programmes in terms of a reduction of local emissions and dust loads. Questions relating to the increasingly broad gas quality range and its repercussions for CNG technologies and components will also continue to entail further research requirements.

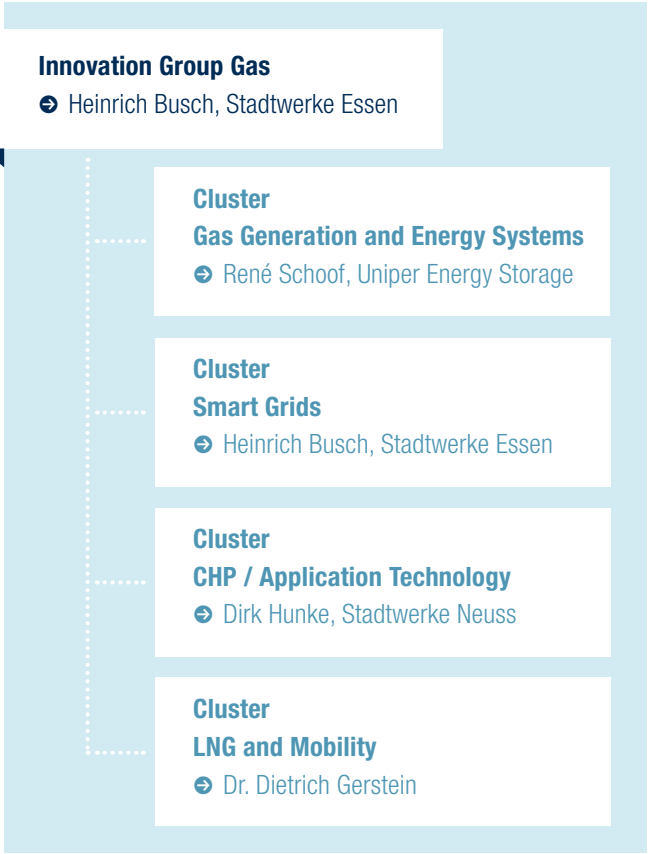
Hydrogen mobility, based on the power-to-gas principle, also possesses a high decarbonisation potential. Accompanying cross-sector scientific research projects in conjunction with the organisations involved will be necessary, in particular with regard to questions involving the infrastructure.

Structure of innovation research in the DVGW

Innovation research in the DVGW is steered by the Innovation Group Gas. Its task is the initiation, assessment and prioritisation of research topics. The Innovation Group further ensures the communication with regard to these topics, including the communication into the political space, as well as the communication with regard to the results adopted on completion of the projects. With that, communication with the member companies is ensured.

Four research clusters have been set up to accompany the projects:

- Gas generation and energy systems
- Smart grids
- CHP / Application technology
- LNG and mobility



List of abbreviations

CNG	Compressed Natural Gas
RE	Renewable energies
REA	Renewable Energies Act
RE-gas	Gas from renewable energies
RE-power	Power from renewable energies
ITS-sector	Industry, trade and services sector
ICT	Information and communication technology
CHP	Combined heat and power generation
LNG	Liquefied Natural Gas
PEMFC	Polymeric Electrolyte Membrane Fuel Cell
PtG	Power-to-Gas
PtH	Power-to-Heat
SNG	Synthetic Natural Gas
SOFC	Solid Oxide Fuel Cell

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