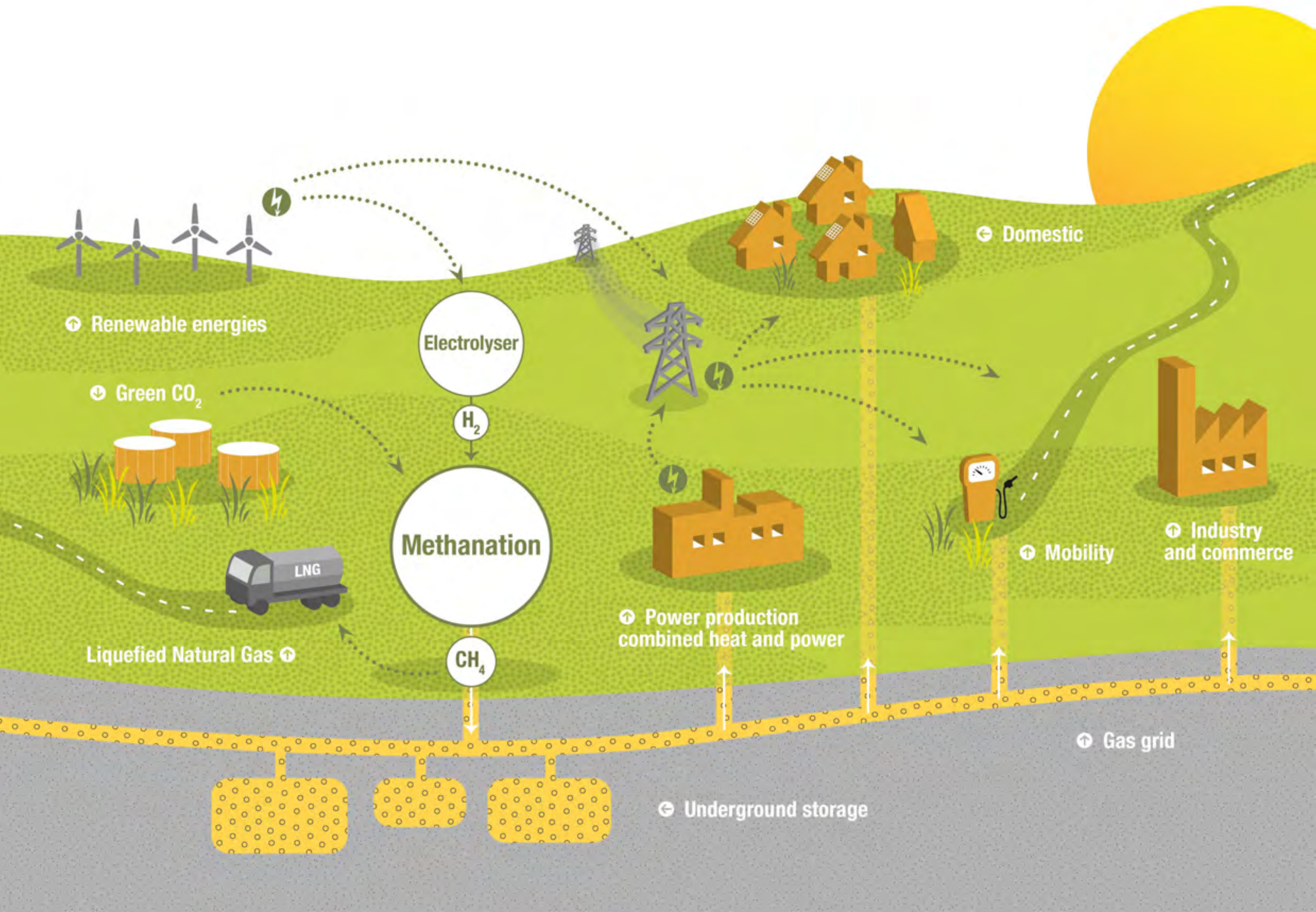
Power-to-gas: The key enabler for a CO_2-neutral energy system

STORE&GO

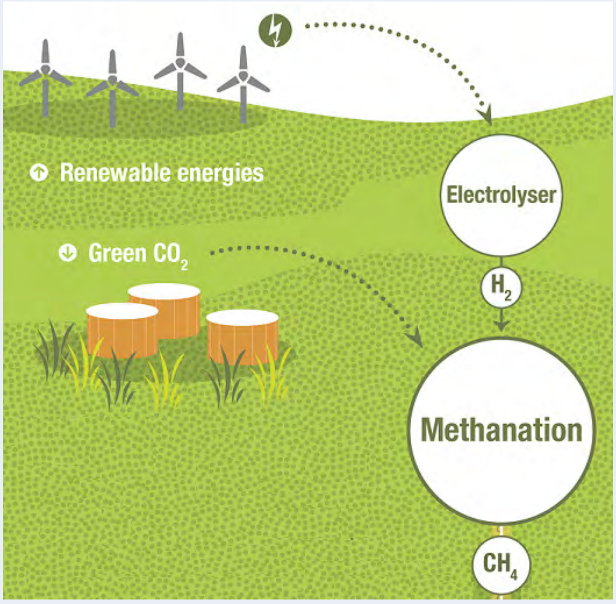


The project STORE&GO demonstrates how green methane provides a keystone for the cross-sector energy transition

In 2015, 195 countries have signed the Paris climate agreement that aims at reducing global warming to 2 °C or in a best case scenario to 1.5 °C. Greenhouse gas emissions have to be reduced dramatically. Therefore, the EU has set ambitious targets to reduce greenhouse gas emissions by at least 40 percent by 2030 compared to 1990 and by 80–95 percent by the year 2050. In order for the European Union to meet the assigned climate targets, energy production must come mainly from renewable sources. However, wind and solar power are volatile, intermittent due to their dependence on weather conditions and time of the day. At times renewable energy supply will surpass demand – for instance, during sunny summer days – and vice versa. Energy has therefore to be stored to be made available when needed.

Since March 1st 2016, 27 European partners have been investigating the potential of power-to-gas (PtG) applications in the European energy grid as an important step in the energy transition. STORE&GO assumes that Europe can reduce its carbon footprint and – at the same time – cover large parts of its future energy demand by making the most efficient use of renewable energies.

However, the integration of growing amounts of renewable sources poses technological difficulties. Even though battery arrays are becoming more powerful and price-efficient, and thus more relevant to store energy and to help stabilizing the electrical grid, they might not be able to handle the growing number of renewable energy sources. Long-term and large-scale storage demands for higher energy density, lower costs and less self-discharging. One option is PtG. PtG allows for storing power by producing synthetic natural gas (SNG). Generating gas from renewable electrical power using the PtG processes is by far the most promising way to store large amounts of energy. It also diminishes the need and costs for expanding the electricity grid.



INFOBOX: What is Power-to-Gas (PtG)?
Electricity from renewable sources is used to split water into hydrogen and oxygen via electrolysis. While the oxygen can simply be released into the atmosphere, the hydrogen is either used directly or can be combined with carbon dioxide (CO_2) and converted to methane (CH_4), also called synthetic natural gas (SNG). This can then easily be stored in the existing gas grid and transported to various applications, whenever and wherever needed: for the generation of electricity or heat, or as a fuel for vehicles or ships. PtG thereby facilitates the coupling of different energy sectors.

Funded under Horizon 2020 and coordinated by the DVGW Research Centre (German abbreviation for German Technical and Scientific Association for Gas and Water), STORE&GO is currently running three pilot plants with different innovative power-to-gas technologies: in Falkenhagen, Germany; in Solothurn, Switzerland; and in Troia, Italy. Details on the three demo sites are presented on the following pages.

STORE&GO demonstrates power-to-gas for large-scale energy storage

The spirit of STORE&GO is nurtured not only by multinational but also interdisciplinary collaboration, which is required to meet the need for a great variety of expertise. “We are convinced that it is not sufficient to simply serve the public a powerful new technology,” highlights Dr. Frank Graf (Head of department Gas Technology at DVGW Research Centre at Engler-Bunte-Institute of Karlsruhe Institute of Technology (KIT)). “Instead, we need to analyse the strengths of PtG so that we can give precise recommendations regarding how and where to roll out this technology. Policy makers and investors need to be consulted on how, when and where they can apply this technology to generate a business case, to safeguard the security of supply and to protect the environment.” For this reason, the STORE&GO consortium involves large industrial players, innovative small companies, and research institutes, which jointly focus on reactor concepts, electricity grids, techno-economic studies, business development and legal aspects.

The great variety of partners provides the experience and knowledge required for such an undertaking and ensures that STORE&GO’s activities result in real-world change. The researchers are working to improve technology, find business models and to define the legal framework for such new technology.

Innovative Technologies

Each of the concepts being demonstrated at the three STORE&GO pilot sites involves new methanation technologies, and each has been adapted to the respective demonstration site. The PtG plants are integrated into the existing power, heat and gas grids. This enables the researchers to feed renewable methane into the existing natural gas grid in a climate-neutral way without any restrictions. The synthetic gas can be made available for a wide range of customer applications. “The demo sites provide highly diverse testing environments, e.g. different climates and topologies; different grid types like transmission or distribution; different combination of solar, wind and hydro energy and different CO_2 sources, including bioethanol, wastewater and directly from air,” Graf elaborates. “In this way, we can analyse and compare the advantages of PtG in various environments.”

A European Roadmap

In addition, the project team is analysing the existing regulatory and legislative framework in order to identify where PtG fits in. As such, the researchers are involved in the BRIDGE initiative – a cooperation group involving to date 36 low carbon energy (LCE) smart-grid and energy storage projects funded under Horizon 2020. BRIDGE develops recommendations in the four working groups Customer Engagement, Business Models, Regulations and Data Management.

The researchers have also conducted a multi-country survey in order to identify public acceptance or resistance in relation to PtG, and they are creating a European PtG map displaying the most promising locations to install facilities.

Furthermore, as a central outcome the group is developing a European PtG roadmap that contains recommendations regarding which applications PtG may serve in the short-, mid- and long-term. So STORE&GO will benefit end users across Europe by ensuring a sustainable supply of energy. Furthermore, the renewable gas generated by PtG can gradually replace fossil gas in all gas applications, especially in heating and transport. It thus helps to free the heating and transport sector from CO_2 emissions. The team is pleased with the progress STORE&GO has made to date, and they are confident that they are on target to achieve project objectives.

The STORE&GO pilot sites

Falkenhagen – Where WindGas is produced

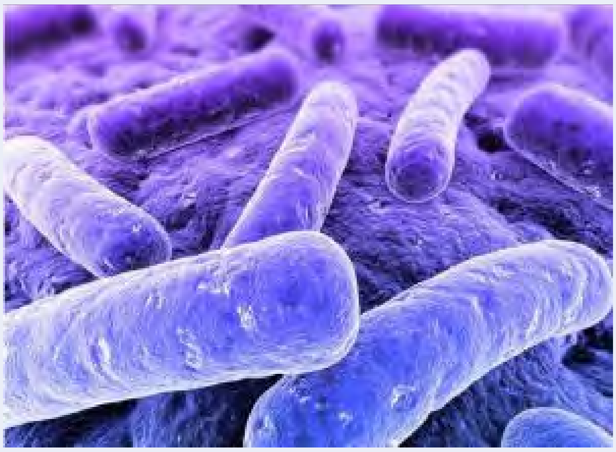
The overall objective in the German pilot project is the demonstration of operation of an integrated innovative PtG plant to produce SNG. The demonstration site Falkenhagen is located in the rural region of Prignitz in the German state Brandenburg in the North East of Germany. In this region, wind farms and photovoltaic systems generate large quantities of renewable power. The power needs to be transported across long distances to regions with high demand. As a result, grid bottlenecks have already occurred. The Falkenhagen site is therefore predestined for the application of PtG technology.

The pilot plant comprises an innovative methanation technology at 1 MW scale und uses CO_2 from biomass processes. The plant is connected to the high-pressure gas transport grid and to the electricity transmission grid. The thermal energy of the methanation plant is integrated into the heat supply of local industrial facilities. This allows for using the heat from the chemical reaction in other processes, and thus further increases the overall efficiency and cost effectiveness.

The involved partners are Uniper Energy Storage GmbH, Thyssenkrupp Industrial Solutions AG, the Karlsruhe Institute of Technology and the research center of DVGW, the German Association for Gas and Water. The methanation plant was publicly opened in May 2018 and will operate for two years.

Solothurn – Where millions of bacteria help the climate

Another demo site is located at Zuchwil/Solothurn in Switzerland. A special feature of this pilot project is that a biological methanation process is used for the conversion of the produced hydrogen to SNG. The hydrogen from the electrolyser is fed to a bioreactor containing Archaea microbes (see Infobox) along with CO_2 from a nearby wastewater treatment plant. The microscopic organisms transform the hydrogen and CO_2 into clean methane (CH_4), which can be fed directly into the gas network.



INFOBOX: How does biological methanation work?
Biological methanation makes use of single-celled microorganisms – the so-called Archaea. These microbes live in aqueous solution and produce methane at relatively low temperatures (50–60 °C). They can withstand extreme conditions and are very frugal. Archaea even occur in inhospitable places, like volcanic vents in the deep sea (black smokers). Some of the many subspecies are particularly suited for the methanation process. This technology is characterized by high robustness against contaminants such as sulphides or particulate matter, and by a high tolerance for variable hydrogen input (as is typical when powered by electricity from renewable sources).

Project partners for the Solothurn plant are Regio Energie Solothurn, Electroachaea GmbH, Empa (Swiss Federal Laboratories for Materials Science and Technology), Ecole Polytechnique Fédérale de Lausanne, Hochschule für Technik Rapperswil, and SVGW (Schweizer Verein des Gas- und Wasserfaches).

Troia – Exploiting the sun of Southern Italy

The Italian demonstration site has been realized in Troia, a municipality in the region of Puglia. This area is characterised by intense solar radiation and therefore by high PV production capacities. The renewable power is used in an existing electrolyser which was used in the EU supported INGRID project (www.ingridproject.eu) to generate hydrogen. The electrolyser is connected to the medium voltage power grid to provide a balancing service for the grid.

Within STORE&GO, this unit was extended by a methanation reactor. The implemented small-scale PtG solution (200 kW), developed by the French Alternative Energies and Atomic Energy Commission (Commissariat à l'énergie atomique et aux énergies alternatives, CEA) and Atmostat, converts renewable power to green gas. A special feature is a gas liquefaction unit developed by Hysytech, which converts the gas further into liquefied renewable gas (LRG), which is apt to directly substitute fossil LNG (Liquefied Natural Gas). The small-scale liquefaction unit chills the green gas to a temperature of –162 °C into a liquid state. LRG can be transported and distributed to customers by truck. This makes the plant independent from pipeline access. LRG is carbon neutral and can be used as green fuel for heavy duty trucks or ships.

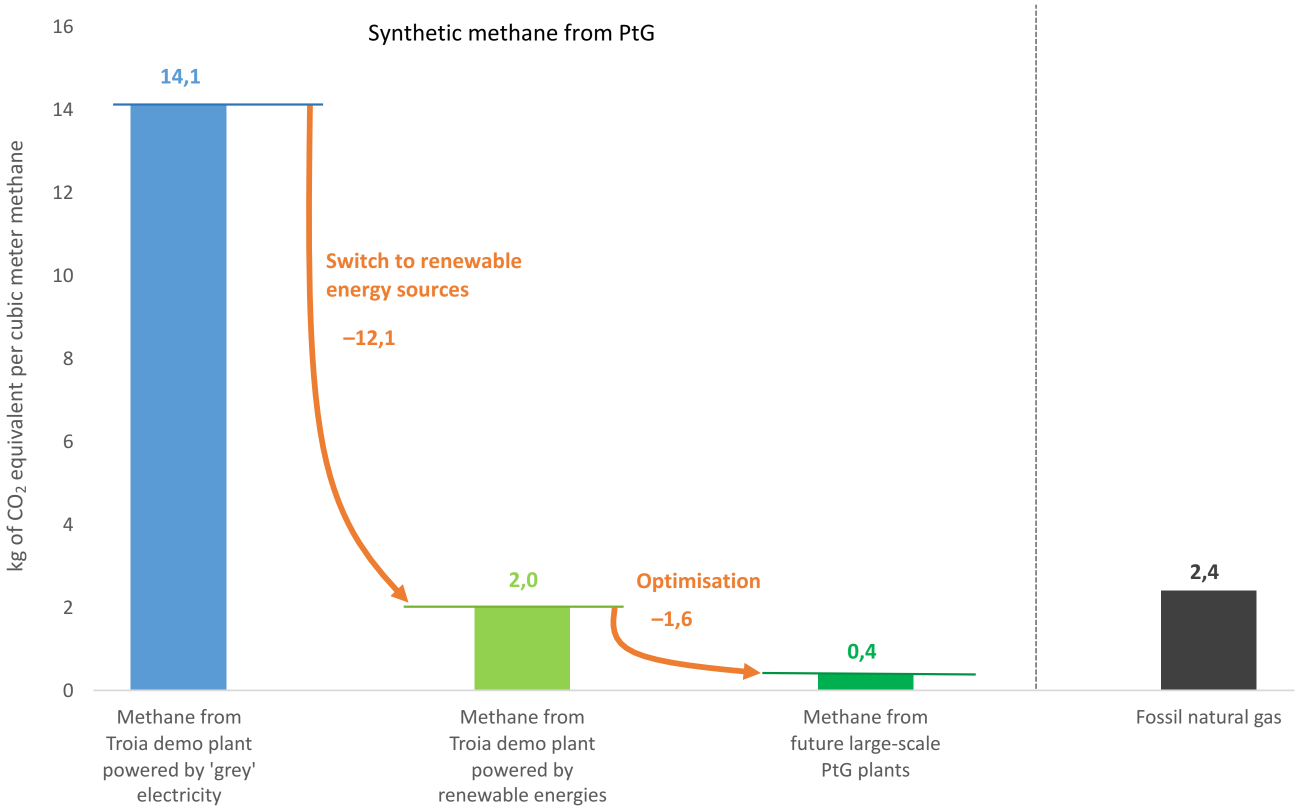
Another special feature of the pilot methanation plant is the CO_2 capture technology delivered by Climeworks, which is based on a cyclic adsorption/desorption process with an innovative filter material. This absorbs and captures the required CO_2 directly from the atmosphere, thereby closing the carbon cycle.

First Results

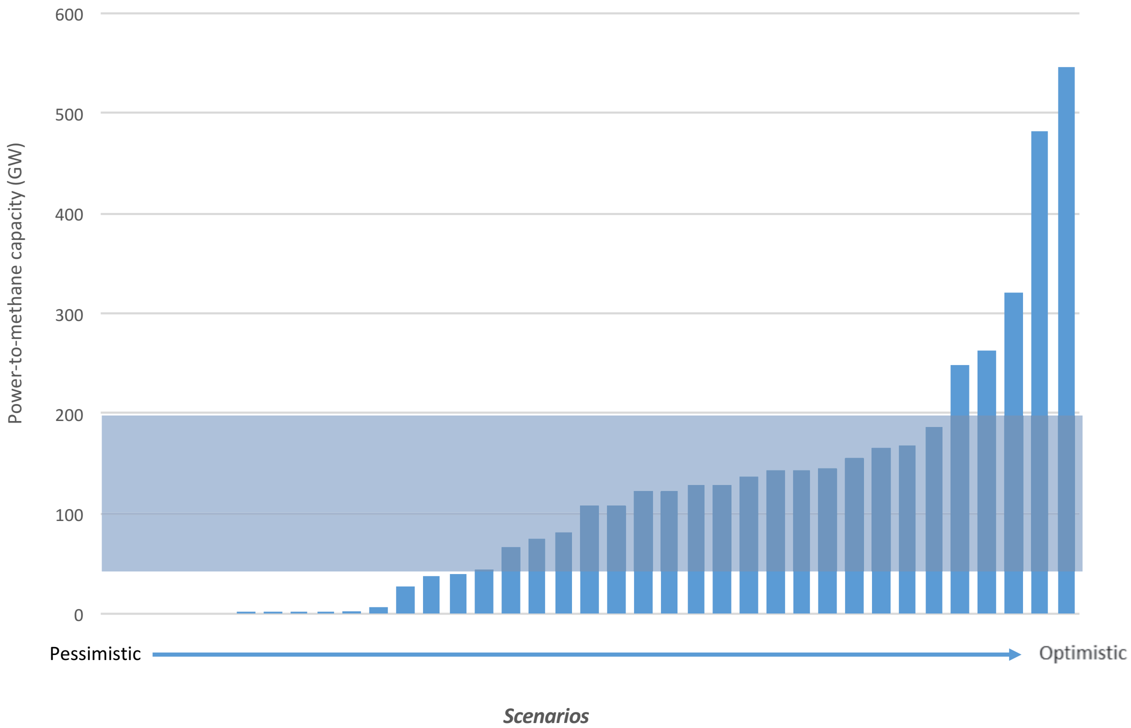
Life cycle environmental impact assessment model for power-to-gas systems

One of the specific issues that have been analysed within STORE&GO is the expected carbon footprint of synthetic methane (SNG) from the project demo sites. Xun Liao and Victor Godina, both members of Prof. François Maréchal's research group at the EPFL (École Polytechnique Fédérale de Lausanne), calculated the life cycle carbon footprint of SNG from the STORE&GO demo plants and compared it with the footprint of fossil gas. The calculations take into account the whole PtG process: from plant construction and operation to combustion of the product.

The study shows that the carbon footprint of SNG from PtG has high variability depending on geographical location, system configurations, electricity generation mix and CO_2 sourcing. Other influencing factors are opportunities for heat integration and surplus heat valorisation, maturity and efficiency of the technology, and scale of production. For the specific case that the small-scale demo plant in Troia is powered by the regular Italian electricity mix – which includes high-carbon energy sources – the production and combustion of one cubic meter of such SNG generates CO_2 emissions of 14.1 $kgCO_2eq/m^3$ (blue bar in the graph). If, however, electricity for the Troia plant comes exclusively from the nearby wind and solar installations, the carbon footprint is reduced by 85% to



CO_2 footprint of synthetic methane from different PtG processes. Blue: Footprint of methane from the Troia demo plant with the current Italian 'grey' electricity mix. Light green: Footprint of methane from the Troia demo plant when completely powered by the renewable energy sources near the plant. Dark green: Footprint of methane from future large-scale PtG plants. For reference, rightmost the CO_2 footprint of fossil gas. Data source: Xun Liao and Victor Godina / EPFL École Polytechnique Fédérale de Lausanne, Switzerland.



Power-to-methane capacity in the European energy system in the year 2050, according to cost optimization simulations. The capacity varies strongly depending on the chosen scenario (labelled from PtG-'pessimistic' to -'optimistic'), with a large number of realistic scenarios yielding significant PtG capacities (marked area). Data source: Herib Blanco / Center for Energy and Environmental Sciences, University of Groningen, Netherlands.

a low number of 2 kgCO_2eq/m^3 (light green bar). Future large-scale PtG plants will benefit from further optimization measures, such as economies of scale, heat valorisation, improved materials sourcing and improved efficiency of the electrolysis. With these measures, the carbon footprint of future SNG can be reduced even further to only 0.4 kgCO_2eq/m^3 (dark green bar). For comparison, the production and combustion of one cubic meter of fossil natural gas emits six times more greenhouse gases.

PtG's role in the future energy system

As one of the scientists involved in STORE&GO, Herib Blanco from the Center for Energy and Environmental Sciences at the University of Groningen modelled the European energy system in the year 2050 using a tool developed at the Joint Research Centre based on cost optimization. Given the large uncertainty on how the future can unfold, an extensive sensitivity analysis was done to cover the wide range of possibilities. The objective was to identify the role PtG can play in the future and to identify the drivers and barriers for the technology. Modelling parameters included CO_2 emission target, availability of carbon capture and storage, biomass potential and technology performance, among others.

21 out of the 55 low carbon scenarios show that a synthetic methane capacity within a range from 40 to 200 GW might fit in the future energy systems, which corresponds to 5% and 30% of the future overall gas demand, respectively. This means that there is a multitude of scenarios where PtG can play a crucial role. Therefore, research and development has to be continued so that the technology will be available in coming years to support the transition of the energy system to a world free of fossil carbon.

Among the model parameters that showed a strong impact on the deployment of PtG, these are the main drivers:

- Ambitious (+95%) CO_2 reduction targets
- Limited availability of CO_2 underground storage
- Limited biomass potential
- High process efficiency and low technology cost
- Use of liquefied methane for navigation and heavy-duty transport
- Costly, difficult or heavily delayed expansion of the electricity grid

Analyses on PtG licensing and regulatory regimes

An interview with Gijs Kreeft, Faculty of Law, University of Groningen

Gijs Kreeft is a researcher within STORE&GO and staff of the Groningen Centre of Energy Law. His research focuses on legal and regulatory developments regarding Power-to-Gas, systems integration, and energy storage.

One of the main objectives of the STORE&GO project is to identify legal and regulatory challenges for the deployment of power-to-gas and production of synthetic methane, both at the level of the European Union (EU) as well as at a national level for the host countries of the STORE&GO pilot plants. Studies also focus on legal measures facilitating the injection of synthetic, or substitute, natural gas (SNG) into the gas network. We asked Gijs Kreeft from the RUG University of Groningen about his work, and the challenges and possible solutions he has identified so far.

What are the challenges when it comes to licensing and regulatory regimes?

Kreeft: PtG is associated with various new concepts which are not yet (sufficiently) considered under EU and national legislation. For example, energy storage as an asset, and hydrogen and SNG as renewable energy carriers, have only recently gained attention from legislators. These new technical developments lead to various fundamental legal issues which need to be resolved. For instance, the question whether network system operators or gas storage system operators are allowed to run a PtG facility. Or whether authorisation procedures should consider PtG plants as chemicals-producing installations rather than installations that produce energy commodities. It is also necessary for legislators to define if, and under which circumstances, PtG is a gas producing activity instead of an energy or gas storage technology. Finally, due to the often fragmented and sectoral nature of energy legislation, the technical trend towards the coupling of energy sectors is not reflected in the legal framework.

Why do you think is there so much left open?

Kreeft: PtG is a relatively new technology and is still in the development phase. As is often the case: law follows innovation. Another issue is awareness. As policy-makers do not yet fully comprehend the PtG process and its potential for the transition towards a low-carbon energy system, they tend to adopt a 'wait and see' attitude. Consequently, PtG and SNG are not sufficiently considered in renewable energy promotion policies. We observed, for example, that electricity and heat from SNG is generally not considered as 'renewable'. At a more structural level, policy-makers are still struggling with the question how to integrate technologies which connect energy systems through conversion. This leads to the current situation that in some cases, PtG plant operators and the actual final consumers both pay network tariffs and surcharges, leading to double taxation.

What can politics and lawmakers do to improve the framework?

Kreeft: Most important, we need a structural and fundamental shift in the political mind-set, through which we start to see the energy system not as being fragmented between electricity, gas, and heat, but instead as one single integrated system. The legal field is just starting to adapt to this new way of thinking. At the 'issue-level', we identified various issues. Among which are the necessity to develop harmonised rules on guarantees of origin, which take into account the need for seasonal storage, an evaluation of permit procedures, an end to double-taxation practices, and updated support schemes. Another efficient measure could be the introduction of a carbon tax, which should make renewable gases more competitive. Last but not least, R&D has to be further supported to strengthen the advantages of PtG further.

INFOBOX: Steps to bring PtG forward

1. Harmonise the rules for electricity and gas networks, and define the regulatory framework for PtG installations.

2. Liberate PtG plants from end-user fees.

3. Support R&D to increase the efficiency of PtG technologies further, and to improve the cost efficiency for a market introduction of the PtG technology.

4. Establish an overall pricing system on greenhouse gas emissions in order to benefit any low-carbon technology.

STORE&GO key facts:

Full title:
Innovative Large Scale Energy STORagE Technologies & Power-to-Gas Concepts after Optimisation

Consortium:
27 partners from six European countries

Runtime:
March 2016 – February 2020

Budget:
28 million Euro

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Establishing a European Energy Union

Maroš Šefčovič, Vice-President, Energy Union at European Commission speaks to Open Access Government about establishing a European Energy Union and the importance of all Europeans having access to secure, affordable and climate-friendly energy

Establishing a European Energy Union happens by connecting infrastructures, enforcing legislation and increasing competition to help drive down costs for citizens and businesses and boost growth, Maroš Šefčovič, Vice-President of Energy Union underlines. In this interview with Open Access Government, he reveals that this is one of the top priorities of the European Commission today and he believes that this important mission has been accomplished.

As the interview begins, Maroš explains that all the legislative proposals to be included in the Energy Union were put on the table. Important aims here concerns energy security, which means hardware in terms of connection and how we can help each other to prevent any interruptions in the supply of energy. He also tells us that software is required in this respect, to deal with European energy markets and modernise the way in which energy is both produced and consumed. For that, well-interconnected networks are needed, and these can be combined with the European Commission's ambitious climate agenda, he adds.

Maroš then stresses that the European Commission has found a unique way to include climate risk into the modernisation of industry, which consists of 9 million European workers, so while the legislation is now approved, the finishing touches have yet to be applied. In terms of clean mobility, the legislation includes new emission standards for cars and trucks which will increase a country's Gross Domestic Product (GDP) over the next year. Concerning this important energy legislation Maroš underlines that the European Commission has had very strong support from the public for it.

The conversation then turns to Maroš's thoughts on all Europeans having access to secure, affordable and climate-friendly energy. Firstly, it is vital that Europeans have clean and affordable energy to benefit their daily lives in terms of their wellbeing, Maroš tell us before offering his own thoughts on this.

"It is also important from the point of view of health because every year we are receiving more information about the impact of air pollution of our citizens. With higher levels of pollution in our cities, we now have more evidence that air pollution has negative consequences, such as on the mental state of our people.

"Also, the price of energy is very important for the competitiveness of our industry, so energy needs to be both affordable and clean.

"I am also encouraged by the proactive approach of our citizens, in terms of them turning into active consumers of energy so they are becoming readier to generate energy on their own. If you talk to those in the construction industry today, they will tell you that they have hardly built any houses or high rise buildings without a smart system in the building."

Looking at the EU's 2030 energy and climate targets, a part of this is a proposed reduction of 40% of greenhouse gas emissions, a minimum of 32% renewables in the EU energy mix and a 32.5% goal of energy efficiency savings. Maroš reveals that this was presented as the European Commission's commitment to the people of Europe but also to the global community in terms of the Paris Agreement in 2015 where it was agreed that by 2030 greenhouse gas emissions must be reduced by at least

Maroš Šefčovič

40%. It was also agreed there that at least 27% of renewables would be generated by that time and that the level of energy efficiency would be 27%.

"What happened, was that the industry, the politicians, the mayors and the consumers agreed that we can become more ambitious when it comes to such targets. In the discussion between the EU Member States and the European Parliament, we ended up with a higher target, so by 2030, we want to have at least 32% of renewables in the energy mix.

"We also want to achieve a level of energy efficiency in terms of saving 32.5%, so I am sure that these two targets set for the EU Member States will be translated into the reduction of greenhouse gas emissions. I think we will overshoot our emissions reductions target of 40%. This is very important because we wanted to show that for example, in terms of climate change we are the global leader and the first major economy which has transformed our commitment to law.

"This is also very important for industry and I am glad to say that this has had strong support from the public, including the mayors of our European cities who have become the closest allies we have. They are the first ones who deal with air pollution, traffic jams and access to clean water and are helping us a lot in achieving this target."

In closing, we move to a challenge around energy policy and ask Vice-President Šefčovič about the trilateral ministerial talks with Russia and Ukraine, that concern the long-term transit of gas to Europe. He says that this is the most complicated issue he has on his desk, one reason for which is that Europeans have a fresh memory of gas interruptions in 2009. Here, most Central European Eastern countries were put into a situation where the whole of the industry was put on hold and the last remaining energy was channelled to hospitals and households.

"Of course, another factor is the complex question in Ukraine and Russia where a delicate discussion is needed. This is coming at a time when we all had to assess how much gas is needed in Europe. However, the good news is that in a recent discussion we had with Russian and Ukrainian ministers and company leaders, was that we will negotiate a way to ensure transit to Ukraine is secured on a basis of a commercially viable volume. That will help with their heating infrastructure, but also connect them with highly reputable energy operators externally to help them in managing the transmission of gas. I believe that this will make it easier for the European Commission, The World Bank and the European Bank for Reconstruction and Development (EBRD) who gave out a lot of money for the refurbishment of this gas pipeline and we aim to push these talks forward in the future."

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