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STORE&GO

Innovative large-scale energy storage technologies and Power-to-Gas concepts after optimisation

D9.7

Report on the implementation of the various training programmes and their main results in terms of insights, knowledge and experiences.

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Executive Summary

At the moment of reporting, we successfully completed the first seven editions of the STORE&GO training. With the coming training in Karlsruhe (20th and 21st of February) we hope to have inspired and motivated over 200 experts in the energy field about the potential system solution power-to-gas offers. Next to that, by providing them the knowledge, expertise and a network we hope that with their newly acclaimed knowledge, they will contribute to overcoming the still existing barriers (technological, economic, legal, social and environmental). Almost 98% of the respondents of the survey perceived the content to be (strongly) relevant to their job, that it lived up to the expectations (96%) and they were well informed (86%). With the trainings we have hoped to make the impact necessary to take power-to-gas (PtG) forward.

The goal of the trainings was to discuss all the potential of PtG within the European energy system, to disseminate the expertise gained within STORE&GO, to showcase PtG technology at the demo sites, and to develop expert networks across Europe. Within this objective, Energy Delta Institute (EDI) prepared training series covering the development of an interdisciplinary skillset including regulatory, technical, economic, environmental and social aspects. The integration of energy systems (electric, molecules and heat) requires a multilateral understanding between the various stakeholders involved. By sharing knowledge about these various aspects the STORE&GO project aimed to contribute to a more effective and cost-efficient energy transition.

The main message of the training was:

1. Sector coupling is necessary to transform the EU into a carbon-neutral economy by 2050;
2. PtG is a mature technology enabling closer integration between power and end-use sectors;
3. PtG is not the only pathway to achieve carbon neutrality;
4. Any changes to the existing regulatory framework should be technology-neutral and should enable the market participants and investors to decide which technology could bring the greatest value for the end-users at the lowest cost.

Every training course included a social training in which participants and lecturers had a chance to further network and discuss and exchange knowledge in a less formal environment. This was highly valuated by participants. Next to the trainings, EDI prepared an online education platform on CrossKnowledge to support the training, and to offer a platform for information sharing between the participants of the various editions.

1 Introduction

The expertise developed in diverse fields of the STORE&GO project has been shared to students, (young) energy professionals and researchers, through a series of trainings on large-scale storage of energy modalities. The trainings had an interdisciplinary character, and the content has been strongly related to the testing and implementation activities in the industry. The participants of the programmes were informed about the various technical, economic, regulatory and social aspects that are relevant to this energy conversion/storage technology. As the STORE&GO project itself, the programme was set up to put the technology into the wider perspective of the energy system, and to analyse what constitutes to its business case and long-term perspective in contributing a future sustainable and reliable energy system in Europe. The training programmes have been developed and organised by the Energy Delta Institute (EDI) in close cooperation with the experts within the extensive network of lecturers of EDI, and in conjunction with experts from the various consortium partners of this research project. Lecturers and trainers in the programmes were equally from the research community and the industry.

This report summarizes the outcomes of the 3-day training programmes “Power to (the) molecules – from technology to market uptake”, which were executed as part of the dissemination activities of STORE&GO. The general objectives of the trainings are extensively discussed in chapter 2. The methodology and activities undertaken to come to the final programme, such as content development, lecturers’ selection, learning methods, material development, marketing and logistics, are discussed in chapter 3. Chapter 4 gives an overview of the evaluation of the various training editions, the follow-up plan for future trainings and potential barriers in market adoption, followed by a final conclusion in chapter 5.

2 General Aspects And Broad Objectives of The Trainings

Secure, long-term energy supplies that are economically viable, environmentally sustainable and socially responsible are a high priority on the European political agenda, as is reducing the continually growing dependency on energy imports. Power-to-Gas (PtG) could hold the key to large-scale seasonal storage of intermittent renewable electricity such as solar and wind, making renewable energy available around the clock.

The principle behind this new, environmentally friendly PtG technology could hardly be simpler. Solar and wind power is used to split water into oxygen and hydrogen by means of electrolysis. The hydrogen can then be stored for later use, for example as primary energy in fuel cells. But a step further is also possible: in methanation, the hydrogen is reacted with carbon dioxide (CO_2). The CO_2 can be drawn from the atmosphere, or it can come from a biogas or industrial plant. The final product of the process is renewable synthetic natural gas (SNG).

Methane is the main constituent of natural gas, making up as much as 98% of its content. It can be injected into the gas grid and used in the same way as conventional natural gas to fuel the built environment, for water heating and industrial processes, as a renewable fuel for gas-powered vehicles, or alternatively for gas-fired electricity generation. The process emits no emissions, apart from the oxygen released when the water is split. Today the efficiency of the conversion process is already at around 60%.This is a big step forward in view of the fact that surplus electricity is often not used at all, owing to the lack of storage capacity, and instead wind turbines are idled or whole wind farms are taken off the grid. If the hydrogen (and potentially the heat) can be used directly, the efficiency rate is even higher.

The PtG process solves some of the biggest problems posed by electricity storage – shortage of space and the speed of transition. The former means that we can simply turn to existing natural gas infrastructure, in the shape of the pipeline grid and large storage facilities. Instead of developing and rolling out an expensive and elaborate electricity grid, we could use PtG storage technologies, where the power would be transformed into synthetic natural gas and stored in depleted gas reservoirs. The second means that building new infrastructure requires time and time is very costly when it comes to reaching the objectives set by the Paris Agreement.

Within the STORE&GO project the strengths of PtG are assessed so that outcomes of the project can play a role to 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 the STORE&GO 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.

Within this approach Energy Delta Institute, part of New Energy Coalition, prepared training series covering the knowledge gathered within the STORE&GO project and disseminates this knowledge to ensure the development of an interdisciplinary skillset including regulatory, technical, economic and social aspects. The integration of energy systems (electric, molecules and heat) requires a bi-directional understanding between the various stakeholders involved. By sharing knowledge about

these various aspects the STORE&GO project aims to contribute to a more effective and cost-efficient energy transition.

The goal of the trainings is to discuss all emerging topics regarding PtG, and to showcase potential scenarios to implement PtG in Europe for the European energy transition. In addition the STORE&GO and other project results, with participants such as key stakeholders from politics, industry and the scientific community are discussed, so that the results can be channelled into a European PtG roadmap more efficiently.

To summarise, the developed training courses offer several benefits to the participants:

- Learning Something New: Participants learn about the different aspects of PtG technologies from experts which allows attendees to gain knowledge of the unknown and understand the concepts lying behind this new technology.
- Becoming an Expert: The trainings enable participants to gain more expertise in the PtG field and are also convenient for the participants who are not directly working in the PtG field. At the end of the courses participants leave with new ideas which can also be applied at their own company.
- Gaining Inspiration: Meeting new people and learning new things often leads to great feelings of inspiration. Inspired participants would want to share this new enthusiasm with colleagues and peers.
- Networking Opportunities: Within the training courses we enable participants to build new relationships with new contacts which allows them to personal and business growth, moreover the development of potential new projects and cooperation.
- Having fun: Attending trainings is fun as well, since it is a day away from the office to improve the self-development of the participants and most participants like connecting with others who share their interests and passions.

3 Training Methodology

3.1 Content: specific objectives and main message per theme

The STORE&GO trainings aim to improve the knowledge transfer and exchange at a holistic approach considering a wide range of aspects such as techno-economic feasibility of energy storage operations, integration of PtG concepts in the electricity grid management and power supply, reduction of regulatory barriers for PtG, as well as potential market uptake for PtG across Europe. Therefore, the contents of the trainings are specifically designed to give an overall insight from the project starting with the demonstration sites and the technologies deployed at these sites.

The road to a qualitative programme consisted of incremental steps and continuous reflection. The concept programmes have been developed some 6-10 months prior to the start of the training and discussed with the consortium during the General Assemblies in Berlin and Troia. In conjunction with the local partner in the training programme, the concept programme was fine-tuned to meet the expectations and the knowledge level of the target group. The programmes developed for each training can be found in the ANNEX: Course programs.

Day	Time Slot	Content
Day 1		**Introduction to PtG technologies and Store&Go Project**
	09.00 – 09.30	**Introduction and outline to the programme / EDI Funda C. Ertem-Kappler** - Official opening of the course and recap online material (European Energy outlook, gas developments and rise of renewables).
	09.30 – 10.30	**The rationale power-to-gas and methanation / EDI Catrinus JEPMA** - Challenges with power generation from volatile renewable sources - Limitations of power transmission and potential of natural gas grids - Potential applications for power-to-gas [e.g. large-scale energy storage, transport of energy, residential heating, mobility] - Aims and scope of STORE&GO
	10.30 – 10.45	Coffee break
	10.45 – 12.15	**Power-to-gas technologies** [include efficiencies, load profiles and performance indicators] / **DVGW - Felix Ortloff** - Electrolysis [alkaline, PEM, SOEC] - Supply of CO_2 [e.g. CO_2 capture, biogas plant] - Biological and catalytic methanation - Process concepts and integration [e.g. coupling of biogas plant] - Overview of existing studies related to power-to-gas [showing the bandwidth of forecasts] - Outlook for technological improvement in technologies
	12.15 – 13.15	Lunch time
	13.15 – 13.45	**STORE&GO demonstration sites / DVGW - Felix Ortloff** - New approaches in STORE&GO
	13.45 – 15.15	**Transport, storage and distribution of renewable gases in the existing natural gas infrastructure / DBI - Michael Wupperfeld** - Overview of existing natural gas infrastructure in Europe - Perspective: future use from the 10-year net development plan - Present state: injection of renewable gases - Blending of hydrogen into natural gas infrastructure - Comparison of hydrogen with methane and key issues w.r.t. centralized and decentralized infeed
	15.15 – 15.30	Coffee break

	15.30 – 17.00	**Power-to-gas as support for the electricity infrastructure / Polito - Andrea Mazza & Ettore Francesco Bompard** - Impact of electrification on electricity infrastructure - Options for power-to-gas in the transmission grid - Options for power-to-gas in the distribution grid
Day 2	**Business aspects and forecasts for Power to Methane**	
	09.00-10.45	**Economics and market potential for methanation/ LINZ - Robert Tichler** - Economies of the technologies (incl. learning curves) and the business case for methanation in Europe - Identification of business models and value drivers, as well as the willingness to pay. - Optimal location w.r.t. methane system integration (electricity grid integration, market offtake and co_2 source) - Macro-economic effects of power-to-gas
	10.45 – 11.00	Coffee break
	11.00-12.00	**Large scale energy storage in practice – a Dutch example / EnergyStock Jan Veijer** - The Hystock and the role of new gases for Gasunie
	12.00 – 13.00	Lunch time
	13.00 – 14.00	**Large scale energy storage in practice – a Dutch example / NEC - Patrick Cnubben** - TSO 2020 project and broad overview of H2 valley of north Netherlands
	14.00 – 15.15	**Legal and regulatory framework / RUG - Gijs Kreeft** - Applicable National and European legal regime, - Regulations regarding grid-infeed and recommendations for policy changes
	15.15-15.30	Break
	15.30 – 17.00	**Societal and environmental impact of power-to-gas / Xun Liao** - Environmental impact assessment of energy storage operation (e.g. risk analysis and LCA) - Public acceptance and engaging local population
Day 3	**Methanation in practice**	
	09.00 – 12.30	**Case Study** - Introduction of the casework **/ Funda C. Ertem-Kappler** - Working as groups on the case (inc. coffee break) – 2 hours - Presentation of the outcomes – 20 min. each groups
	12.30 – 14.00	**Lunch during certificate ceremony**
	14.00 – 15.00	**Visit to Entrance (Attendance is optional)**

The basis and content of the trainings were in general the same, but adjustments were made to align the local programmes with market developments and specific regional issues.

The participants gained a solid understanding of how technological, regulatory and other institutional concepts relate to PtG business cases and their implementation. The training programmes consisted of a fixed set of elements to cover the interdisciplinary set of skills required within PtG projects.

- Understand the technological process of demonstrated technology installed on one of the three demonstration sites;
- Assess the feasibility of business cases and discuss the energy system value of PtG;
- Understand the main regulatory, environmental and social aspects of methanation technology.

3.1.1 Demo sites

The demonstration sites played a key role in the training courses as they helped the participants to envision the technologies and process discussed during the project. Although it was not possible to visit a demo site during all trainings (due to distance), we intended to collaborate with other projects or local initiatives (see also Box 1). During the training in Linz a site visit to the underground sun storage project was arranged, a project that focuses on large scale seasonal storage in existing gas fields. During the training in Groningen we visited Entrance, an innovation centre dedicated to technological innovations for the energy transition. During the training in Amsterdam we visited Evantium Chemicals, a chemical technology company that focusses on renewable chemicals, and Photanol, a venture capital firm that invests in technological development.

EnTranCe
EnTranCe, the Energy Transition Centre, is the testing ground for applied research in the field of energy transition. The energy testing ground provides companies with the opportunity to work on developing innovations in the field of energy in collaboration with students. That collaboration means that new inventions and products are being developed in a way that is in keeping with the market. More information on this project can be found here.

Sun storage project
The sun storage project shares a similar objective as the STORE&GO demonstration sites. However, where the STORE&GO project focuses on the production technologies, the RAG-initiated project focuses more so on storing it in environmental friendly and naturally formed gas reservoirs, while using a carbon neutral process. More information on this project can be found here.

Avantium Chemicals BV
Avantium is a leading chemical technology company and a forerunner in renewable chemistry. Together with its partners, Avantium is a leading chemical technology company and a forerunner in renewable chemistry. Avantium develops efficient processes and sustainable products made from bio based materials. One of Avantium's success stories is YXY technology, with which it created PEF: a completely new, high-quality plastic made from plant-based industrial sugars.

Photanol BV
Photanol is a spin-off company of the University of Amsterdam. Since the start of the company in 2008, €15 million has been invested in technology development by shareholders and from grants (EU and NL). Photanol's objective is to bring new production routes for the production of bio-compounds with CO_2 as a feedstock to the market. The first focus is on the production of LLA to be followed by other valuable organic chemicals such as other organic acids, biofuels, essential oils, and sugars.

Box 1: Overview of other demo sites

The trainings in Solothurn, Berlin and Bari included a site visit to the STORE&GO demonstration plants (see also ANNEX: Course programs).). Although the technological processes installed on these sites differ, the concept of large-scale energy storage technologies and its solutions offered to the region can't be better explained than at the locations themselves.

Falkenhagen

Falkenhagen (Germany) was the first demonstration site that started operation. Its existing power-to-hydrogen process was expanded by a methanation stage in May 2018 and synthetic methane has been fed into the natural gas grid since January 2019. This allows the partners of the international research project STORE&GO to demonstrate the technical feasibility of the Power-to-Gas process for feeding "green" gas into the natural gas grid. At present, the plant produces up to 1,400 cubic meters of synthetic methane (SNG) per day, which corresponds to approximately 14,500 kWh of energy. For comparison purposes, with this amount of energy, 200 golf class CNG cars could drive about 150 km per day. The plant has already achieved over 700 operational hours with a methane purity reliably above 99%. The green methane is produced from hydrogen which, in turn, is generated with electricity from renewable sources and CO_2 from a bioethanol plant. The heat generated during the process is used by the nearby veneer mill, which increases the overall efficiency of the plant.

Photo 1: visit to the Falkenhagen demonstration site by participants of the Berlin training

Solothurn

The second STORE&GO demonstration site is located in Solothurn, Switzerland. It is the only one of the three STORE&GO plants that use biological methanation. Countless microorganisms, so-called Archaea, convert hydrogen and CO_2 to methane in the central vessel. After many busy months working with high intensity to finish the plant, the operators could finally animate the frugal microorganisms to spawn and to generate methane. The Solothurn plant has been producing methane since May 2019.

Photo 2: visit to the Solothurn demonstration site by participants of the Solothurn training

Troia

The community of Troia in Italy houses the third of the STORE&GO demo sites. This plant combines direct CO_2 capture from the air and a novel milli-structured methanation unit with an innovative micro-scale liquefaction unit for the produced methane. Such a sequence of new technologies displays possibly the most experimental one among the STORE&GO plants. The Troia process chain produced methane for the first time in April 2019. All three plants will use the remaining project duration to gather experience from the operation and to provide real data for further analysis within the project.

Photo 3: visit to the Troia demonstration plant by participants of the Troia training

Box 2: Overview of STORE&GO demo sites

3.1.2 Business case and system value

The main message and outcome of the techno-economic analysis is that PtG is not (yet) profitable in itself. Though, PtG increases energy security and lowers total costs of the energy system. The STORE&GO partners also performed a full cost-benefit analysis to assess the macro-economic value of having PtG in the year 2050. Results show that PtG lowers the total costs of the energy system and that it prevents more expensive investments or higher operational costs in other parts of the energy system. These results are also shown during the training sessions and discussed with the participants. PtG increases the energy security of the energy system by lowering the probability of shortages of energy, for example, during periods of low wind and solar energy production in Europe. PtG could ease bottlenecks in the electricity grids and allow for including renewable energy at lower costs than what would be required for extending electricity grids. The fact that PtG is not (yet) profitable in itself, but favourable for the energy system, makes it even more so important. The trainings bring stakeholders from various part of the energy system together (see Figure 1).

Figure 1: various stakeholders working together and discussing the potential of PtG (Groningen Training)

3.1.3 Environmental and social aspects

PtG technology has many system variations, and their environmental performances were also evaluated compared with conventional technologies before large-scale deployment. The results of system variations show that PtG can, depending on electricity supply and CO_2 source, significantly reduces GHG emissions compared to conventional gas production technologies, and that hydrogen production has higher potential of emission reduction than methane production. These environmental aspects are shown combined with the social aspects to the participants.

3.1.4 Legal aspects

In the last part of the trainings participants are given insights from regulatory and political barriers. From a technological point of view, renewable gases are ready to be integrated within the energy system. However, the current legal and regulatory framework and market conditions impede the installation of industrial-scale Power-to-Gas plants and the ramp-up of gas production.
STORE&GO partners found out that an optimized plant layout combined with proper market conditions would enhance the viability and offer opportunities in particular for seasonal storage of renewable energy. For the future legislation period in Europe, it will be necessary to find a legal category for PtG, to define who is allowed to operate it and to harmonize rules for operating gas networks. Due to a great knowledge demand on the juridical aspects of PtG, a specialized in-depth training has been developed in cooperation with the Florence school of Regulation in which a deep dive was provided on the various regulatory aspects (see also 6th training in Florence, Italy.

3.2 Online Learning Platform

3.2.1 CrossKnowledge

EDI has designed an online education platform on CrossKnowledge to allow individuals who do not have sufficient background in renewables and PtG to get an insight prior to the active training day and site visit. CrossKnowledge is an online environment, which gives room for individual assignments, discussion polls, quizzes and many more. Moreover, via the administration part of the programme we were able to track individual progress, total time spent as well as coaching opportunities and discussion sessions.

In addition to this, there were a number of additional benefits to the online learning:

- Flexibility: The participants are not tied down to a fixed schedule. In a traditional training setting, meeting times are set, and the participant has no power over this, forcing them to work their schedules around these dates. Most people who have other commitments choose online learning, and prefer this mode of learning, as it gives them power over how they will delegate their time towards their different projects.
- Reduced Costs: Online education costs are in most of the cases lower compared to the traditional trainings due to a variety of reasons. For example, there is no cost for commuting. Assorted costs that are related to transport, such as fuel, parking, car maintenance, and public transportation costs don't affect the online learner.
- Networking Opportunities: An online education platform also provides participants with the chance to network with peers across nations or even different continents, since all the participants of 7 trainings are registered on the same platform. This often leads to other opportunities in terms of collaboration with other individuals in the implementation of a project.
- Documentation: All the information that a participant will need is safely stored in an online database. This includes things like live discussion documents, training materials and emails. This means that if there's ever anything that needs to be clarified, the participant will be able to access these documents fast, saving valuable time. This is especially useful for individuals that need to carry out research for a project and submit their findings to a panel.
- Increased instructor time: Participants in traditional trainings may not get the personalized attention they need to have concepts clarified. This is not a problem for this type of education because online guided discussions and personal talk time with the moderators are a hallmark of online classes.

3.2.2 Development of the Platform Content

As discussed in Deliverable 9.4, a decision had to be taken on the design and structure of the online environment, on whether we would have single or multiple learning paths. We have decided to build multiple learning paths related to the various subtopics of PtG. The rational for this is to ease the use of the online modules for the variety of consumers. Hence, participants that have already gained expertise in one particular field of the PtG chain are not obliged to take all modules, but could instead focus their attention on the other fields. Moreover, it is easier to combine with other commitments if participants have to focus on a single module for half an hour, rather than forcing them to focus for half a day on a complete module.

The learning platform is divided into multiple learning modules dedicated to PtG value chain (see Figure 2). The following modules were considered:

- Module 1 - the PtG concept focuses on the production technology lying behind PtG;
- Module 2 - Details of electrolysers technology;
- Module 3 - Insight in the methanation process;

- Module 4 - Logistics, including the various aspects of storage and pipeline transport of PtG;
- Module 5 - Market adoption for PtG;
- Module 6 - System perspective of the complete PtG chain.

Each of the modules consist of a learning path of 30 minutes (30 points), starting with an introduction, a deep dive in the topic and quiz to test the knowledge gained within the module. The modules could, with minor adaptation, become available for a larger public as well[1]. In addition, we prepared background modules on: the **European Energy Landscape** – the essentials of the energy market, the basic concepts of energy, the global energy scene, with specific attention for the medium term developments in the global 'renewable energy arena'; **European Climate Policy** – climate change and the history of climate policy and how it developed in Europe; **Energy Transport & Distribution** – transport and distribution of gas; **Energy Consumers and Sectors** – Energy consumption across sectors, customer markets, energy use in industry; **CO2 reuse Regulation and Acceptance** – what carbon is, how EU trading systems are working, what a carbon capture technology is and how they might be beneficial to reduce global warming impact.

The online environment is available to the participants 1 month before the start of the course. Participants are expected to read the provided learning material and their knowledge will be tested through questionnaires and self-assessments. Practice has shown that 58 learners over seven trainings have registered for the online environment. This number is lower than the actual subscription (186) to the training. This can be easily explained by the fact that some of the participants had already developed a good understanding of PtG prior to the course.

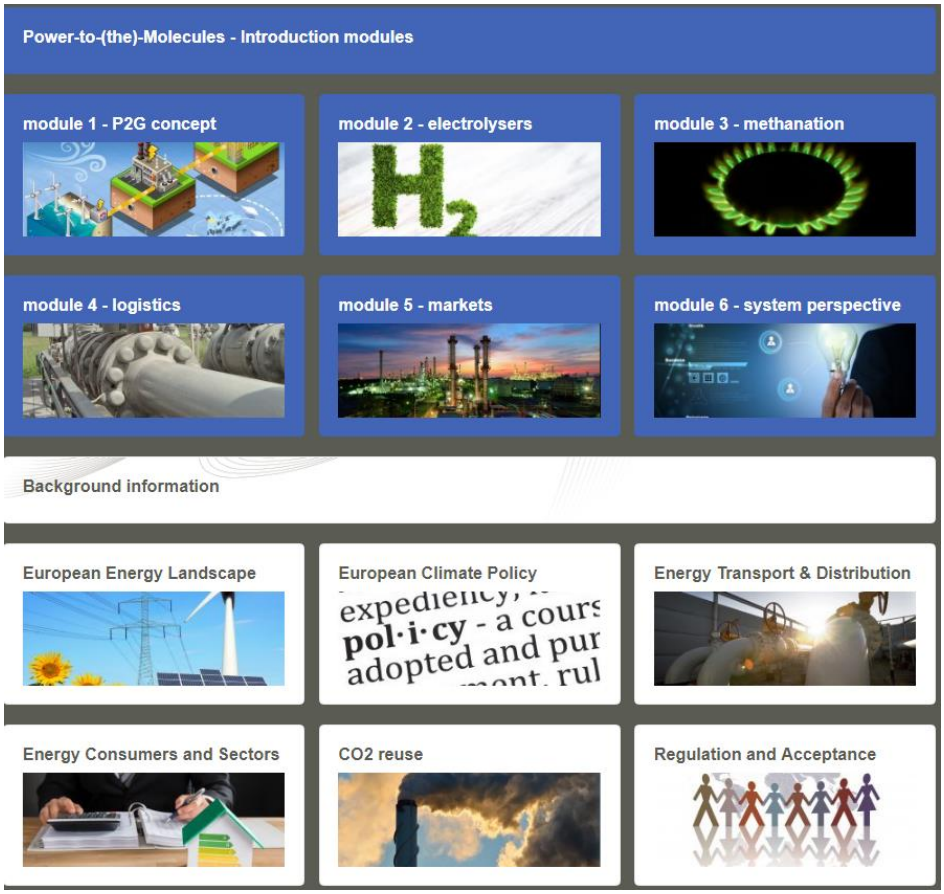


Figure 2: illustration of the online environment

[1] If you would like to have a subscription to the online environment please contact info@energydelta.nl

3.3 Case Study

We have developed a case study to be used at the end of the second day of a training. The study was used during the first training in Groningen. The participants have worked in small interdisciplinary groups (max. 5 persons) to implement the core concepts from the various perspectives. In doing so, the participants needed to apply theoretical concepts from the different fields.

During the assignment participants have worked on a given location and applied the overall knowledge they gathered during the training. They have created four PtG production scenarios under the consideration of different electrical input, gas storage possibilities, different gas infrastructure and CO_2 sources.

In order to help with the calculations we have created an Excel file with the CAPEX and OPEX for methanation and electrolyser technologies depending on the plant size. The file consists of different costs for H2 storage, feedstock such as electricity, water, CO_2, grid injection costs, pipelines and revenues. A business case was developed, considering the following main elements:

- **Technological characteristics**
  The technologies available for methanation do not fit in all situations and technological improvements might quickly change the business case. Therefore, participants should argue the scenario taken by their team.

- **Location and market decisions**
  Given the characteristics of the central/decentral location, one should decide the offtake markets (e.g. feed-in or mobility sector). Moreover, the potential offtake price depends on the willingness of the offtake to pay an add-on price.

- **Risk factors**
  Identification of potential risks associated with the investment decision. Part of the risks would be associated with regulatory aspects and social acceptance.

In the end participants discussed their overall outcomes. Although the discussions were very fruitful, due to time constrains we were not encouraged by collaborators to use the case study in the other trainings. Another concern was the fact that having a profitable business case was only possible with hydrogen production, and we did not want to create a negative impression on methanation technologies. The case study is attached in ANNEX: Case study. The model that has been developed for this case study remains available upon request.

4 Training execution

4.1 Marketing and logistics

The main objective of “Power to (the) molecules – from technology to market uptake” is to disseminate the knowledge and experience gained on large-scale energy storage technologies during the project STORE&GO. EDI has developed marketing materials, such as a brochure (see ANNEX: Marketing material), which has been distributed within the partners of STORE&GO and also within the network of EDI, to ensure that the training reaches out to a wide public.

The marketing materials have been customised for each of the trainings to ensure the right target groups have been reached. The brochure includes detailed information about the content of the programme, the target group, and site visit. Besides a brochure, EDI markets the training programme on its webpage, including the programme and practical details for subscription. A link towards the digital brochure was put on this webpage too. Moreover, the website includes an option for potential participants to show their interest in the programme and to put them on the short-list for one of the course editions. This short list can be used to select the participants on the basis of their experience, skills and affiliations and to compose groups on an international basis to the extent feasible.

In some cases due to ongoing organizations and adaptations in the programme and changes in the lecturer’s schedules, the registration for the participants was opened late, which resulted in fewer numbers of registrations. We, and the consortium have tried to send invitations to a larger audience, however, in some cases (for instance Solothurn) it was not possible to engage more participants.

EDI was responsible to arrange suitable training locations as well as transport to the site visits. Additional logistics such as transport and accommodation for lecturers and participants needed to be arranged after the Go-decision was taken. Fortunately, there was always sufficient market interest to reach a Go-decision. Unfortunately, though, was that most of the demo-sites did not have suitable training facilities, hence, EDI saw itself obliged to arrange training locations in hotels located in nearby cities. These locations should at least offer sufficient accommodations, as all participants had to stay for at least one night. Venues and catering were selected and mostly arranged by the co-organizers of the training.

Prior to the trainings, all participants have received a welcome email from the moderator (Dr. F.C. Ertem-Kappler) including a short introduction from the moderator itself and detailed course program and information on STORE&GO project and site visit, and if necessary security details about the site visit.

Later on participants received more information on the bios of lecturers, who would be involved within the training. The participants were asked to define their learning objectives prior to the start of the training, and together with the background information of the participants, this information was shared with the lectures. This latter step is important to make sure that the lectures could adapt their presentations based on the expectations of the participants.

The welcome email also includes practical information, such as information on the venue and how to reach the location. About four weeks prior the trainings have started, the participants received an invitation to the online learning platform with their specific usernames and passwords, so that they could use the opportunity to inform themselves about the Power-to-Gas technologies in advance. Every training course included a social training at the end of the first day, in which

participants and lecturers had a chance to further network, discuss and exchange knowledge in a less formal setting. Locations of the social dinner were selected based on the availability of each city, which resulted in a variety in prices, ambience and choices of the food and beverages.

4.2 The training programme

The various editions of the training have been developed in close collaboration with the co-organizers (see also ANNEX: Overview of training editions). On behalf of EDI, Dr. F.C. Ertem-Kappler moderated all training sessions.

The courses were in principle held in English. An exception is made for the training in Bari, for which interpreter services were used. To guarantee a good level of interaction between the lecturers and the participants, the training programmes are organised for groups of 25 to 30 participants at most. Again, an exception was made for the training in Bari.

4.3 Participants

The training was especially developed for professionals working in or related to the energy industry. Participants came from different fields (e.g. regulators, policy makers, engineers, and/or business developers) as well as from different sectors (gas industry, electricity suppliers, government and industry suppliers). The intention was to bring forward an interdisciplinary group to ensure discussions covering the different aspects of the methanation value chain and such that each of them could contribute in their field of work.

A total of 186 individuals attended seven learning trainings in five countries during a one-year period from November 2018 to September 2019. Of these 186 participants, 39% were senior managers and engineers, 19% were scientists and researchers, 21% were consultants and policy advisors, 15% were business developers and 6% were students (see Figure 3). The energy professionals from various fields (academic, local government and industry) have actively participated in the trainings. About 25.3% of the participants were women from the energy sector. A complete participant overview is given in ANNEX: Participant affiliation list.

4.4 Overview of training editions

Edition	Duration (days)	Number of participants	Co-organizers	Site visit
Groningen	3	25	-	EnTranCe
Solothurn	2	14	Solothurn Regio energie and Bundesamt für Energie	Demo site Solothurn
Linz	2	31	Energy Institute Linz	Underground sun storage
Berlin	2	24	ThyssenKrupp	Demo site in Falkenhagen
Bari	3	46	Chamber of Engineers	Demo site in Troia
Florence	2	26	Florence School of regulation	Focus on the regulatory issues
Amsterdam	3	20	University of Amsterdam	Avantium chemicals bv. Or photanol bv

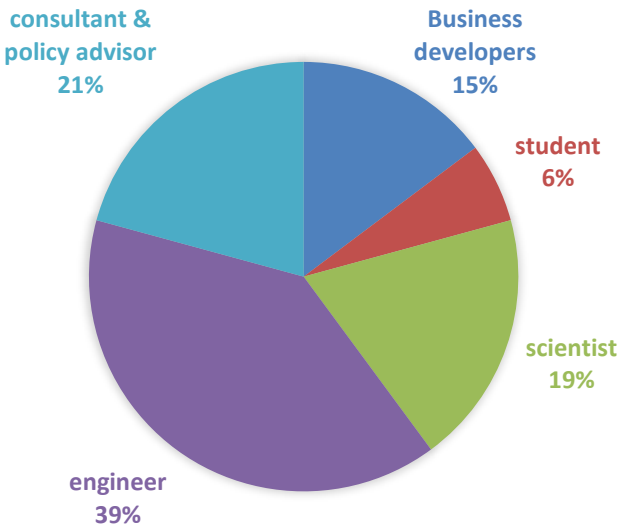


Figure 3: overview of participants by background

4.5 Lectures and material

Choosing the right expert for the trainings is of vital importance because it makes or breaks the success of the overall training. Lectures create value for the organization and for the STORE&GO project by increasing the buzz you need when building the exploitation campaign. The entire tone surrounding the training and the success of the training is set by who we choose for our speaker. Therefore, for the trainings speakers from the STORE&GO consortium were given a priority, since they are the hands on expert who could tell about their experiences from the first mouth. STORE&GO partners, and more intensively the co-organisers, were involved in the development of course material and in the organisation of the site visits. Ultimately, the lecturers were selected for each edition separately based on their availability and expertise, to ensure that the lecture profile

fits the regional markets. Therefore, in some cases suggested experts outside the consortium were invited as external speakers, as well.

There were difficulties in the engagement of consortium to become a speaker due to their budget limitations or other commitments in their agenda. Therefore, we tried to combine the trainings with the project meetings to overcome this, whenever this was possible. Another barrier we faced was the difficulty to involve external speakers who could cover the intended content of the training programme. Because some of the content, especially learning curves and business models were specific to the STORE&GO project deliverables. This also resulted in higher budget spending for external speakers than initially expected.

Once an 'go' moment is given to the course, an important role of EDI starts. EDI reaches out to all the lecturers of that specific edition to coordinate the content of the lectures and make sure the content aligned with the objective of STORE&GO. It is important to keep a clear structure in the programme, common thread between lectures and therefore a training overlap between the lecturers.

This has been a repetitive exercise since all programmes were fine-tuned to the regional market. ANNEX: Presentation list provides an overview of all presentations. These presentations are available upon request[2].

A couple of times we experienced delays caused by airline strikes, our speakers could not make it on time or could not show at all. We overcame this by arranging online webinars.

Photo 4: training material

4.6 Networking and certificate

Social dining at a restaurant was chosen as a philosophy of using meals specifically as a means to connect with others: eat to socialize. The social dinner provided opportunities to network with lecturers and participants in an informal setting. The social dinners have been highly valuated by all participants and have been fruitful to identify common business interests in PtG.

All participants received a certificate of completion if, and only if, they complete 80% of the training programme, this includes the exercises from the online environment. ANNEX: Certificate shows an example of such a certificate.

[2] Please send a request to info@energydelta.nl

5 Training Evaluation

During the trainings the focus was placed on technological, economic and regulatory aspects related to Power-to-Gas (PtG). The technology is considered to be a key enabler of sector coupling as it allows to produce hydrogen and renewable methane from electricity.

During the first session, the participants investigated the available PtG technologies, their scale-up potential, and future economic viability. The participants were also introduced to early-stage PtG projects across Europe. Even though robust business cases based on PtG are yet to emerge, the above mentioned projects show that PtG is a mature technology. However, for it to scale-up, further policy and regulatory interventions are required.

The potential policy and regulatory interventions needed to incentivize the investment in PtG facilities and possible market design implications were discussed in further detail in the second session of our training. One of the most frequently asked questions was related to the relationship between ownership and operation of PtG facilities. Would the TSOs lose their neutrality, if they were allowed to operate it? Does the urgency of decarbonisation justify the changes to a regulatory framework aimed at loosening unbundling rules? Are renewable gas targets necessary to scale up the PtG technology?

Four main takeaways emerged from the discussions:

- Due to the rising share of variable renewable energy and the increasing demand for greater temporal and geographical flexibility, it seems that sector coupling is necessary to transform the EU into a carbon-neutral economy by 2050.
- The experience gathered with demonstration projects shows that PtG is a mature technology enabling closer integration between power and end-use sectors. Yet, it is not economically viable due to the several factors such as high technology cost and energy losses; slow progress in scale-up; unfavourable taxation schemes; the lack of regulatory and legal framework governing the ownership and operation of PtG facilities, the harmonized gas quality standards and the taxonomy.
- PtG is not the only pathway to achieve carbon neutrality. Other options such as biogas/bio methane, bio-SNG via gasification, and methane reforming with CCS could bring similar results. All the identified pathways bring with them some challenges, e.g. the availability of organic feedstock for biogas/bio methane production, high technology costs.
- Any changes to the existing regulatory framework should be technology-neutral and should enable the market participants and investors to decide which technology could bring the greatest value for the end-users at the lowest cost.

5.1 Survey

This first measure is about determining participants' general level of satisfaction with the learning training. Senior Managers were asked to complete a ***Brief Evaluation Form*** at the end of the day, while Focal Points were asked to complete a similar form called the ***Daily Evaluation Form.*** The intention in obtaining this type of feedback is to ensure that the program is revised in a spirit of "continuous improvement" to better reflect the needs of the participants on an ongoing basis.

Various evaluations were carried out during the course, including a specific evaluation for each part of the course. Here we present an overview of the final evaluation. Issues considered were the

methodology of the course, content of the presentations, the applicability of the knowledge gained, as well as general suggestions for improvements. 50 participants completed the survey.

Regarding the methodology, most of participants qualified it as very good (48%) and good (30%), 17% evaluated it as excellent. Participants expressed their interest in giving more opportunity to open discussions and practical exercises. Taking into account the topic of the course, 70% of the participants considered that the number of participants was adequate, 26% considered it too low, and only one participant considered it too high. Some of them commented that the varying experiences among participants were good, and that it would have been useful to get the experiences of local data users in terms of type of data required and challenges in accessing quality data. The organization of the course was well perceived in general. 39% qualified it as excellent, 35% very good and 22% good. One recommendation was that evaluations for the course should be done electronically. An example of the survey can be found in ANNEX: Survey.

5.2 Survey outcomes

In this chapter you will find the survey outcomes of the first seven trainings of the programme. It is expected that this will most likely be in line with the final survey outcomes from all eight trainings.

The content of the trainings has been perceived as very relevant. Almost 98% of the participants perceived the content to be (strongly) relevant to their job, that it lived up to the expectations (96%) and they were well informed (86%). There were almost no participants that did not agree with the statements below.

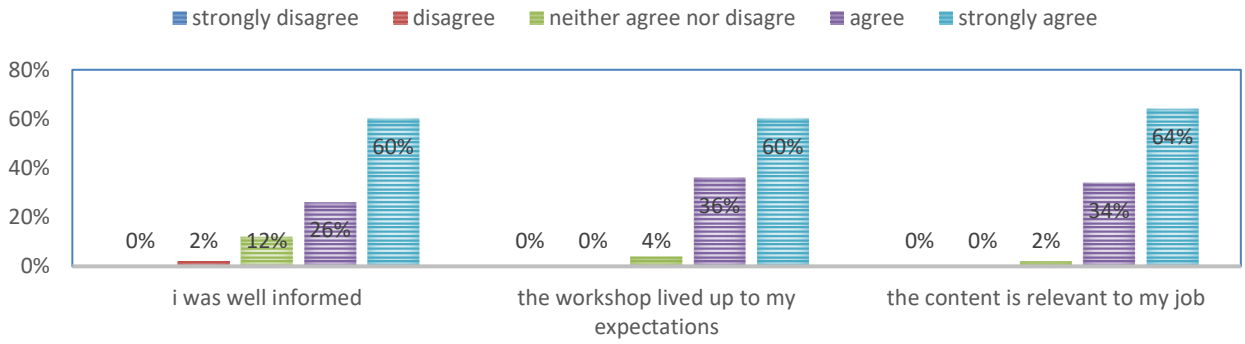


Figure 4: overview outcomes training content

The participants did mostly agree that the design of the trainings were clear, stimulating and difficult enough (Figure 5). Almost all participants (strongly) agreed that they learned from the training, and that they will be able to use what they learned (Figure 6). In addition to these scorings, a number of open-recommendations have been given to us as well, such as:

- During training there should be longer coffee breaks in the morning and afternoon to refresh participants.
- There is need to modify training literature and adapt it more frequently based on the learning objectives of the participants.
- There is need for various games, online quizzes and activities to encourage and stimulate the learning and involvement of the participants.
- The learning content should be available to the participants prior to the training.
- There is a need to develop an opportunity to join the trainings online and live, so that anyone who is interested in joining but does not have the travel budget can join, as well.

- There is a need to stimulate the online learning of the participants, since it is currently the only online Power-to-Gas learning platform available.
- Although the content which is covered by the programme is technical and broad, there is a need to apply pre and after tests to measure the what the participants have learnt.

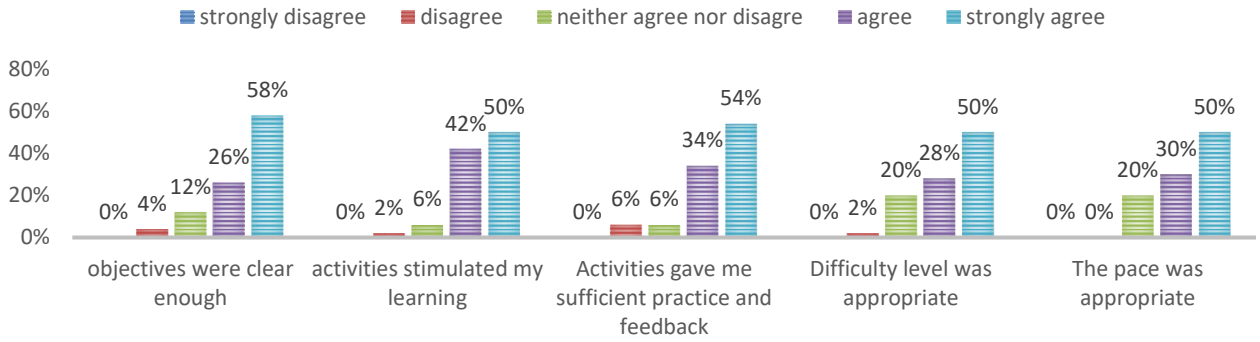


Figure 5: overview outcomes training design

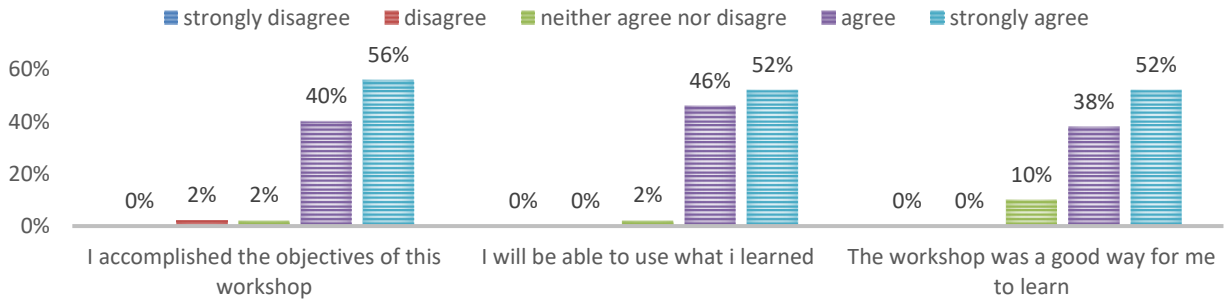


Figure 6: overview outcomes training results

6 Conclusions

At the moment of reporting, we successfully completed the first seven editions of the STORE&GO training. With the coming training in Karlsruhe (20th and 21st of February) we hope to have inspired and motivated over 200 experts in the energy field about the potential system solution power-to-gas offers. Next to that, by providing them the knowledge, expertise and a network we hope that with their newly acclaimed knowledge, they will contribute to overcoming the still existing barriers (technological, economic, legal, social and environmental). Almost 98% of the respondents of the survey perceived the content to be (strongly) relevant to their job, that it lived up to the expectations (96%) and they were well informed (86%). With we have hoped to make the impact necessary to take PtG forward.

In the end we are happy with the success of the STORE&GO trainings, although, we encounter some areas for improvement. During the execution of the programme, we noticed that it would be impossible to organise all trainings at the three demo sites. First of all, there was a demand for knowledge in the non-demo sites. Second, the geographical spread has reduced and/or spread the time commitment of each individual STORE&GO partner. However, this led to an increase in expenditure for training facilities and external speakers. Although these costs are offset by lower costs from internal speakers of EDI.

Upcoming activities

The preparation for the last edition (Karlsruhe – 20th and 21st February 2020) is going according to plan. The edition will be co-organized by the Karlsruhe Institute of Technology (KIT) and a site-visit is planned to the “Energylab 2.0”. All training material will remain available after the closure of STORE&GO programme.

Florence school of regulation is interested in offering the training on a commercial level together with EDI after the completion of the programme. The realisation of this depends on a number of factors: the knowledge demand, the availability of experts and the inclusion of STORE&GO member organisations. Although the development costs of the training have already been covered (reducing cost price of the training), the training should be continuously updated with regard to new development.

The online learning environment will remain available for at least one year after completion of the programme. This implies that the participants of the final training have the same opportunities for using the content provided on this platform and to interact with previous participant.

7 Annexes

7.1 ANNEX: Course programs

7.1.1 1st training in Groningen, The Netherlands

Day	Time Slot	Content
Day 1		**Introduction to PtG technologies and Store&Go Project**
	09.00 – 09.30	**Introduction and outline to the programme / EDI Funda C. Ertem-Kappler** - Official opening of the course and recap online material (European Energy outlook, gas developments and rise of renewables).
	09.30 – 10.30	**The rationale power-to-gas and methanation / EDI Catrinus JEPMA** - Challenges with power generation from volatile renewable sources - Limitations of power transmission and potential of natural gas grids - Potential applications for power-to-gas [e.g. large-scale energy storage, transport of energy, residential heating, mobility] - Aims and scope of STORE&GO
	10.30 – 10.45	Coffee break
	10.45 – 12.15	**Power-to-gas technologies** [include efficiencies, load profiles and performance indicators] / **DVGW - Felix Ortloff** - Electrolysis [alkaline, PEM, SOEC] - Supply of CO_2 [e.g. CO_2 capture, biogas plant] - Biological and catalytic methanation - Process concepts and integration [e.g. coupling of biogas plant] - Overview of existing studies related to power-to-gas [showing the bandwidth of forecasts] - Outlook for technological improvement in technologies
	12.15 – 13.15	Lunch time
	13.15 – 13.45	**STORE&GO demonstration sites / DVGW - Felix Ortloff** - New approaches in STORE&GO
	13.45 – 15.15	**Transport, storage and distribution of renewable gases in the existing natural gas infrastructure / DBI - Michael Wupperfeld** - Overview of existing natural gas infrastructure in Europe - Perspective: future use from the 10-year net development plan - Present state: injection of renewable gases - Blending of hydrogen into natural gas infrastructure - Comparison of hydrogen with methane and key issues w.r.t. centralized and decentralized infeed
	15.15 – 15.30	Coffee break
	15.30 – 17.00	**Power-to-gas as support for the electricity infrastructure / Polito - Andrea Mazza & Ettore Francesco Bompard** - Impact of electrification on electricity infrastructure - Options for power-to-gas in the transmission grid - Options for power-to-gas in the distribution grid
Day 2		**Business aspects and forecasts for Power to Methane**
	09.00-10.45	**Economics and market potential for methanation/ LINZ - Robert Tichler** - Economies of the technologies (incl. learning curves) and the business case for methanation in Europe - Identification of business models and value drivers, as well as the willingness to pay. - Optimal location w.r.t. methane system integration (electricity grid integration, market offtake and co_2 source)

		- Macro-economic effects of power-to-gas
	10.45 – 11.00	Coffee break
	11.00-12.00	**Large scale energy storage in practice – a Dutch example / EnergyStock Jan Veijer** - The Hystock and the role of new gases for Gasunie
	12.00 – 13.00	Lunch time
	13.00 – 14.00	**Large scale energy storage in practice – a Dutch example / NEC - Patrick Cnubben** - TSO 2020 project and broad overview of H2 valley of north Netherlands
	14.00 – 15.15	**Legal and regulatory framework / RUG - Gijs Kreeft** - Applicable National and European legal regime, - Regulations regarding grid-infeed and recommendations for policy changes
	15.15-15.30	Break
	15.30 – 17.00	**Societal and environmental impact of power-to-gas / Xun Liao** - Environmental impact assessment of energy storage operation (e.g. risk analysis and LCA) - Public acceptance and engaging local population
Day 3	**Methanation in practice**	
	09.00 – 12.30	**Case Study** - Introduction of the casework **/ Funda C. Ertem-Kappler** - Working as groups on the case (inc. coffee break) – 2 hours - Presentation of the outcomes – 20 min. each groups
	12.30 – 14.00	**Lunch during certificate ceremony**
	14.00 – 15.00	**Visit to Entrance (Attendance is optional)**

7.1.2 2nd training in Solothurn, Switzerland

Day	Time	Content
Day 1		***Introduction to PtG technologies and Store&Go Project***
	16.00 – 16.30	**Opening / EDI - Funda Cansu Ertem-Kappler** - Store&Go project –scope, goals, structure, status - Role of EDI - Aim of the workshop and the detailed program description **Welcome / BFE - Stefan Oberholzer** - Switzerland and the Energy Strategy 2050, the national context. - Pathways to meet the renewable targets
	16.30 – 17.30	**The rationale power-to-gas and methanation / IET Rapperswil HSR - J. Gorre** - Energy system Switzerland. - Long term storage - Store&Go project targets - Demonstration sites from the project - Project structure & key advantages
	18.00 – 19.00	**Social time with snacks & beverages**
Day 2		**Business aspects and forecasts for Power to Methane**
	9.15 – 10.15	**Power-to-gas technologies** [include efficiencies, load profiles and performance indicators] / **DVGW - Felix Ortloff** - Electrolysis [alkaline, PEM, SOEC] - Supply of CO2 [e.g. CO2 capture, biogas plant] - Biological and catalytic methanation **Feature : Direct Mathanation of Biogas / PSI - Serge Biollaz** - General introduction to biogas production plants and biogas injection. - Biogas upgrading VS. Direct methanization
	10.15 – 10.30	Coffee Break
	10.30 – 11.00	**Power-to-gas technologies & Store&Go / SVGW - Andrew Lochbrunner** - Store&Go project part at the Solothurn site. - Plant description. - System integration. - Expected results - Summary and outlook
	11.00 -.12.30	**Economics and market potential for methanation/ LINZ - Andreas Zauner** - PtG and economics : the general framework; - system components and costs; - CAPEX-considerations. - Main business drivers and business cases. - Learning curve considerations. - Products of PtG plants and production costs. - Business models for operation of PtG plants. - Macro-economic effects influencing PtG **Direct Mathanization / Energie360 - Andreas Kunz** - Plant and costs (CAPEX-consideration). - Comparison to gas upgrading and injection as base case. - Cost factors. OPEX assumptions - SNG production costs. - Business case direct methanization.
	12.30 -13.30	Lunch

	13.30 – 14.30	**Transport, storage and distribution of renewable gases in the existing natural gas infrastructure / DBI - Michael Wupperfeld** - Introduction to gas transportation : transport and distribution. - Grid structure, pressures, gas quality. - Operation of gas grids. Injection of gases into the transport or distribution grid. - The European gas transport grid. Grid codes. **The Swiss national grid / Gasverbund Mittelland AG - Othmar Naef** - The Swiss gas transport and distribution grid. - The overall pipeline network. - The regional transport concept and their companies. - Codes and standards for grid operations and gas injection. - Gas quality requirements.
	14.30 – 14.45	**Coffee Break**
	14.45 – 15.45	**Production costs and ecologic benefit of green gases / EMPA - Urs Cabalzar** - Costs of (green gas) SNG in mobility sector
	15.45-17.00	**Societal and environmental impact of power-to-gas / EPFL - Xun Liao** - Introduction into environmental impact assessment; LCA-Methodology. - PtG-LCA based on component inventory and ecoinvent database. - General results for PtM-installations. - LCA for storage operations. - The Solothurn case study.
Day 3		***Biological methanation in detail – training at Solothurn***
	09.15 - 10.30	**Legal and regulatory framework / Universität Luzern - Markus Schreiber** - General legal frameworks for PtG/Energy Storage systems. - The European approach and context. - Swiss national legal framework. - Standards and codes for grid access and injection of renewable gases.
	10.30 – 10.45	**Coffee Break**
	10.45 – 13.00	**Transfer to site visit inc. coffee service at the location** **Biological methanation in detail / Doris Hafenbradl - Electrochea** - Biological methanation with the the Electrochaea process. - The microbiological bases : Achea microorganisms. - Process and plant design. The main component. Design parameters. Dimensioning. - Plant start up and operation. Operational states of the plant. Plant control. - Gas quality, gas cleaning. Examples: Avedoer Plant, Solothurn plant. Indication of plant costs. **Plant tour, regioenergie, tbc** **Certificates and survey**
	13.00 – 14.00	Lunch

7.1.3 3rd training in Linz, Austria

Day	Time Slot	Content
Day 1 04.03.19		**Introduction to PtG technologies and Store&Go Project, business aspects and forecasts**
	09.00 – 09.30	**Introduction and outline to the programme / NEC - Funda C. Ertem-Kappler** - Welcome and opening - Scope of Store&Go workshops, program description - Role of Energy Delta Institute
	09.30 – 10.30	**The rationale power-to-gas and methanation / Energieinstitut an der JKU – Robert Tichler** - Energy system Austria, national RE production target - Need for Long term storage - Store&Go project structure, partners - Project targets - Overview of demonstration sites
	10.30 – 10.45	Coffee break
	10.45 – 12.30	**Power-to-gas technologies** [include efficiencies, load profiles and performance indicators] / **Universita di Pisa - AnnaLewandowska-Bernat** - Electrolysis [alkaline, PEM, SOEC] - Supply of CO_2 [e.g. CO_2 capture, biogas plant] - Biological and catalytic methanation - Power-to-gas as long term energy storage - Role of PtG in different energy systems - Overview of existing studies related to power-to-gas [showing the bandwidth of forecasts]
	12.30 – 13.30	Lunch
	13.30 – 14.00	**Store&go demonstration sites / Energieinstitut an der JKU - Andreas Zauner** - Closer look on the technological structure of 3 demonstrators
	14.00 – 15.30	**Economics and market potential for methanation/ Energieinstitut an der JKU - Robert Tichler & Andreas Zauner** - Economies of the technologies (incl. learning curves) and the business case for methanation in Europe - Identification of business models and value drivers, as well as the willingness to pay. - Optimal location w.r.t. methane system integration (electricity grid integration, market offtake and co_2 source) - Macro-economic effects of power-to-gas
	15.30– 15.45	Coffee break
	15.45 – 17.00	**Legal and regulatory framework / Universität Luzern - Markus Schreiber** - General legal frameworks for PtG/Energy Storage systems. - The European approach and context. - Austrian national legal framework. - Standards and codes for grid access and injection of renewable gases
	19.00	**Dinner at PÖSTLINGBERG SCHLÖSSL**
Day 2 05.03.19		**Gas & electricity grid, LCA of P2G technologies and site visit**
	08.00-09.00	**Travel to Underground sun storage site**
	09.00-09.45 09.45-10.30	**Underground sun storage site** Introduction of the project / **RAG, Stefan Bauer** Site visit
	10.30-11.30	**travel back**
	11.30-12.30	Lunch

	12.30-13.30	**Smart energy solutions with hydrogen options / Bahcesehir University – Canan Acar** - Hydrogen's role for a sustainable future - Sustainable hydrogen production methods - Recommendations for hydrogen energy systems - Hydrogen VS. methane
	13.30 – 14.45	**Power-to-gas as support for the electricity infrastructure / Polito - Andrea Mazza** - Impact of electrification on electricity infrastructure - Options for power-to-gas in the transmission grid - Options for power-to-gas in the distribution grid
	14.45 – 15.00	Coffee Break
	15.00 – 16.15	**Environmental impacts of power-to-gas systems / Fraunhofer Ins. - Andre Sternberg** - Introduction into environmental impact assessment; LCA-Methodology. - PtG-LCA based on component inventory and ecoinvent database. - General results for PtG-installations. - LCA for storage operations.
	16.15 – 17.00	**Closing & Survey - certificate ceremony**

7.1.4 4th training in Berlin, Germany

Day	Time Slot	Content
Day 1 03.04.19	**Introduction to PtG technologies and Store&Go Project, business aspects and forecasts**	
	09.00 – 09.30	**Introduction and outline to the programme / NEC, Funda C. Ertem-Kappler** - Welcome and opening - Scope of Store&Go workshops, program description - Role of EDI
	09.30 – 10.30	**The rationale power-to-gas and methanation / Uniper, Helge Föcker** - Energy system Gerrmany, national RE production target - Need for Long term storage - Store&Go project structure, partners - Project targets - Overview of demonstration sites
	10.30 – 10.45	Coffee break
	10.45 – 12.15	**Power-to-gas technologies** [include efficiencies, load profiles and performance indicators] / **Hanze University**, **Andras Perl** - Electrolysis [alkaline, PEM, SOEC] - Supply of CO_2 [e.g. CO_2 capture, biogas plant] - Biological and catalytic methanation - Power-to-gas as long term energy storage - Role of PtG in different energy systems - Overview of existing studies related to power-to-gas [showing the bandwidth of forecasts]
	12.15 – 13.15	Lunch time
	13.15 – 13.45	**Store&go demonstration sites / Thyssenkrupp, Steffen Schirrmeister** - Closer look on the technological structure of 3 demonstrators
	13.45 – 15.15	**Economics and market potential for methanation/ Energieinstute LINZ - Andreas Zauner** - Economies of the technologies (incl. learning curves) and the business case for methanation in Europe - Identification of business models and value drivers, as well as the willingness to pay. - Optimal location w.r.t. methane system integration (electricity grid integration, market offtake and co_2 source) - Macro-economic effects of power-to-gas
	15.15– 15.30	Coffee break
	15.30 – 17.00	**Legal and regulatory framework / University of Luzern, Markus Schreiber** - General legal frameworks for PtG/Energy Storage systems - The European approach and context - German national legal framework - Standards and codes for grid access and injection of renewable gases
	19.00 – 22.00	**Dinner at Restaurant Nolle**
Day 2 04.04.19	**LCA of P2G technologies & Windgas Falkenhagen Plant**	
	08.30 – 10.30	**Transfer to Falkenhagen by bus / meeting point in front of Neue Mälzerei**
	10.30 – 10.45	Coffee break
	10.45-12.00	**Societal and environmental impacts of power-to-gas / PSI, Zhang Xiaojin** - Introduction into environmental impact assessment; LCA-Methodology - PtG-LCA based on component inventory and ecoinvent database - General results for PtM-installations - LCA for storage operations

	12.00 – 13. 00	Lunch time – Transfer to Windgas Plant
	13.00 – 15.30	**Falkenhagen Windgas plant / Thyssenkrupp, Steffen Schirrmeister** - Store&Go project part at the Falkenhagen site - Plant description - System integration - Expected results - Summary and outlook **Coffee break incl. plant tour** **Certificate ceremony & survey**
	15.30 – 17.30	**travel back to Berlin**

7.1.5 5th training in Bari, Italy

MONDAY 20 MAY– OVERVIEW OF THE PROJECT AND THE WORKSHOP	
13:45 – 14:00	Welcome coffee
14:00 – 14:15	Introduction to the event G. Cafaro (AEIT) F. C. Ertem-Kappler (Energy Delta Institute part of New Energy Coalition) D. Arnone (Engineering I.I.)
14:15 – 15:00	Enabling new flexibility resources to support the power grid of the future M. La Scala, S. Bruno (Politecnico di Bari)
15:00 - 15:45	The hydrogen as an additional fuel for gas turbines S. Camporeale, M. Torresi, A. Saponaro (Politecnico di Bari)
15:45 - 16:30	From INGRID to the STORE&GO D. Arnone (Engineering I.I.)
16:30 - 17:15	STORE&GO methanation plant: the design of the overall process S. Bensaid (Politecnico di Torino)
17:15 - 17:50	Layout of the plant - civil works and authorization procedures D. Pomponio (Studio BFP)
17:50 - 18:00	Recap of the first day D. Arnone (Engineering I.I.)
TUESDAY 21 MAY – INSIDE THE TECHNOLOGY	
8:45 – 9:00	Welcome coffee
9:00 - 9:45	Design of a millistructured reactor for methanation G. Geffraye (Commissariat à l'énergie atomique - CEA)
9:45 – 10:30	CO2 capturing module L. Kaufman (Climeworks)
10:30 – 11:15	Methanation unit P. Bucci (Atmostat Alcen)
11:15 – 12:00	Liquefaction unit A. Saldivia (Hysytech)
12:00 –12:45	Monitoring, Security and Control infrastructure A. Rossi (Engineering I.I.)
12:45 –14:00	Lunch break
14:00 –14:45	Impact of the plant on the power grid A. Mazza (Politecnico di Torino)
14:45 –15:30	Regulatory Framework A. Saldivia (Hysystech)
15:30 –16:15	Techno-economics and regulation of power-to-gas D. Parra Mendoza (Université De Genéve). P. Bucci (Atmostat Alcen)
16:15 –16:30	Coffee break
16:30 –17:50	Open discussion and feedback collection Moderator: D. Arnone (Engineering I. I.)
17:50 –18:00	Recap of the second day D. Arnone (Engineering I.I.)
WEDNESDAY 22 MAY– VISIT OF THE TROIA PLANT	
8:45 – 9:00	Briefing of the visit D. Arnone (Engineering I.I.)
9:00 -10:30	Trip from Bari to the pilot site in Troia by bus
10:30 –11:00	Welcome brunch on site
11:00 –12:30	Visit of the plant and closing of the event
12:30 –14:00	Trip from the pilot site in Troia to Bari by bus

7.1.6 6th training in Florence, Italy

Day	Time Slot	Content
Day 1 11.07.19	**Introduction to PtG technologies and Store&Go Project, business aspects and Life Cycle Assessment**	
	09.00 – 09.20	**Introduction and outline of the programme / Ilaria Conti, FSR; NEC, Funda C. Ertem-Kappler** - Welcome and opening - Scope of Store&Go workshops, program description - Role of EDI
	09.20 – 10.15	**The rationale power-to-gas and methanation / NEC, Machiel van Steenis confirmed** - Overall energy systems - Need for Long term storage - Store&Go project structure, partners - Project targets - Overview of demonstration sites Q&A
	10.15 – 10.30	Coffee break
	10.30 – 12.00	**Power-to-gas technologies** [include efficiencies, load profiles and performance indicators] / **Hanze University**, **Andras Perl confirmed** - Electrolysis [alkaline, PEM, SOEC] - Supply of CO_2 [e.g. CO_2 capture, biogas plant] - Biological and catalytic methanation - Power-to-gas as long term energy storage - Role of PtG in different energy systems - Overview of existing studies related to power-to-gas [showing the bandwidth of forecasts] Q&A
	12.00 – 13.00	**Smart energy solutions with hydrogen options / Bahcesehir University – Canan Acar confirmed** - Hydrogen's role for a sustainable future - Sustainable hydrogen production methods - Recommendations for hydrogen energy systems - Hydrogen VS. methane Q&A
	13.00 – 14.00	Lunch time
	14.00 – 15.30	**Economics and market potential for methanation/ University of Geneve - David Parra confirmed** - Economies of the technologies (incl. learning curves) and the business case for methanation in Europe - Identification of business models and value drivers, as well as the willingness to pay. - Optimal location w.r.t. methane system integration (electricity grid integration, market offtake and co_2 source) - Macro-economic effects of power-to-gas Q&A
	15.30– 15.45	Coffee break
	15.45 – 17.00	**Environmental impacts of power-to-gas / PSI, Zhang Xiaojin confirmed** - Introduction into environmental impact assessment; LCA-Methodology - PtG-LCA based on component inventory and ecoinvent database - General results for PtM-installations - LCA for storage operations Q&A
	19.00 – 22.00	**Dinner**
Day 2	**Regulatory aspects of P2G technologies**	

12.07.19	09.00 – 10.15	**European Energy and Climate Ambitions | Maria Olczak, FSR** **Classification of Power-to-Gas within the Energy Supply Chain** - Power-to-Gas as Storage - Power-to-Gas as Final Consumer - Power-to-Gas as Producer **Sector Coupling and Power-to-Gas in 2020 Gas Package** Q&A
	10.15 – 10.30	Coffee break
	10.30 – 11.45	**Unbundling Rules in the Context of Power-to-Gas | Markus Schreiber – University of Lucerne** - Operation of a Power-to-Gas Installation by System Operators - Combined Ownership of a Power-to-Gas Installation and a Gas Storage Facility **Authorisation Procedures for Power-to-Gas Installations | Studiobfp - Danilo Pomponio** Q&A
	11.45 – 13.00	**Legal Framework for Accommodating SNG in the Gas Network (and future network development) | ENTSOG Cihan Sönmez and Jos Dehaeseleer | Marcogaz** - Classification of SNG under Natural Gas Legislation - Connection to the Natural Gas Network and Cost Distribution - Technical Specifications for the Injection of SNG (Marcogaz) - Remedies for Capacity Constrains at the Distribution level - Privileges for Shippers of SNG as Biogas - TYNDP process and interlinked electricity and gas model Q&A
	13.00 – 14.00	**Lunch break**
	14.00 – 15.15	**Network Tariffs, Taxes and other Surcharges | Cristiano Francese, independent expert former DNGVL** - Network Tariffs - Electricity Tax - General System Charges - Surcharge for the Financing of Support Schemes Q&A
	15.15 – 15.30	Coffee break
	15.30 – 16. 45	**Support Schemes for the Use of SNG | Attila Kovacs – European Renewable Gas Registry (ERGaR)** - Support for Electricity Generation from SNG - System of Mass Balancing and Guarantees of Origin - Support for Use of SNG in Transportation - Use of SNG for Heating - Payments for Avoided Network Costs Q&A
	16.45 – 17.00	**Certificate ceremony & survey**

7.1.7 7th training in Amsterdam, The Netherlands

Day	Time Slot	Content
Day 1 04.09.19		**Introduction to PtG technologies and Store&Go Project, business aspects and LCA**
	09.00 – 09.15	**Introduction and outline to the programme / NEC, Funda C. Ertem-Kappler** - Welcome and opening - Scope of Store&Go workshops, program description - Role of EDI
	09.15 – 09.45	**The rationale power-to-gas and methanation / NEC, Machiel van Steenis** - Need for Long term storage - Store&Go project structure, partners - Project targets - Overview of demonstration sites
	09.45 – 10.00	**Coffee break**
	10.00 – 11.30	**Power-to-gas technologies** [include efficiencies, load profiles and performance indicators] / **Hanze University**, **Andras Perl** - Electrolysis [alkaline, PEM, SOEC] - Supply of CO_2 [e.g. CO_2 capture, biogas plant] - Biological and catalytic methanation - Power-to-gas as long term energy storage - Role of PtG in different energy systems
	11.30 – 12.30	**Smart energy solutions with hydrogen options / Bahcesehir University, Canan Acar** - Hydrogen's role for a sustainable future - Sustainable hydrogen production methods - Recommendations for hydrogen energy systems - Hydrogen VS. methane
	12.30 – 13.30	Lunch time
	13.30 – 15.00	**Techno-economic assessment of powertogas technologies/ University of Amsterdam-ECN part of TNO, Remko Detz** - Economies of the powertogas technologies; hydrogen, syngas, methanol, diesel and methane - Identification of business models and value drivers - Macro-economic effects of power-to-gas - A circular carbon economy and its contribution to limit global warming
	15.00– 15.15	Coffee break
	15.15 – 16.30	**Environmental impacts of power-to-gas / PSI, Zhang Xiaojin** - Introduction into environmental impact assessment; LCA-Methodology - PtG-LCA based on component inventory and ecoinvent database - General results for PtM-installations - LCA for storage operations
	16.30 – 17.45	**Legal and regulatory framework / RUG, Ruven Fleming** - General legal frameworks for PtG/Energy Storage systems. - The European approach and context. - Dutch national legal framework. - Standards and codes for grid access and injection of renewable gases
	17.45 -18.00	**Certificate ceremony & survey**

	18.30 – 21.00	**Dinner at Brasserie Ambassade**
CO_2OLING THE EARTH SUMMER SCHOOL		
Day 2 05.09.19	**Morning Session**	
	08.30 – 09.00	**Registration**
	09.00 - 09.30	**Welcome**
	09.30 – 10.00	**EU environmental policy explained**
	10.00- 10.30	**Plenary Lecture**
	10.30 – 11.10	**Circular Economy and CO_2**
	11.10 - 11.30	**Coffee Break**
	11.30 – 13.00	**Floor to the Companies: how CO2 conversion can be exploited in industry?**
	13.00 – 14.20	**Lunch**
	Project Presentations	
	14.20 – 14.40	**RECODE:** Recycling carbon dioxide in cement industry to produce added-value additives
	14.40 – 15.00	**ENGICOIN:** Engineered microbial factories for CO2 exploitation in an integrated waste treatment platform
	15.00 – 15.20	**Celbicon:** Cost-effective CO2 conversion into chemicals via combination of Capture, ELectrochemical and BIochemical CONversion technologies
	15.20 – 15.40	**Coffee Break**
	15.40 – 16.00	**Carbon4Pur:** Turning industrial waste gases (mixed CO/CO2 streams) into intermediates for polyurethane plastics for rigid foams/ building insulation and coatings
	16.00 – 16.20	**Store&Go:** Innovative large-scale energy STORagE technologies AND Power-to-Gas concepts after Optimisation
	16.20 – 16.40	**BIOCON-CO_2:** BIOtechnological processes based on microbial platforms for the CONversion of CO_2 from the iron and steel industry into commodities for chemicals and plastics
	16.40 – 17.00	**CONCLUSIONS**
	SPINNING TABLES: NOT JUST SCIENCE	
	18.00 – 20.00	**All the participant are invited to join some experts to talk about transversal topics in an "informal talk":** **"How can we "speak" science?"** **"SSH &RRI what these are and why their importance is increasing"**
Day 3 06.09.19	**Morning Session**	
	08.30 -09.00	**Welcome**
	09.00 – 10.00	**RECODE Catalysis**
	10.00 – 11.00	**ENGICOIN Microbes**
	11.00 – 11.30	**Coffee Break**
	11.30 – 12.00	**CELBICON**
	12.00 – 13.00	**BIOCO2-NCO**
	POSTER SESSION	
	14.00 -16.00	**PhD and Post Docs participating to the selected EU project will present posters regarding their work**
	SITE VISITS	
	16.00 - ….	**Participants who have applied for the site visits will be gathering to proceed to the site visits**

7.2 ANNEX: Case study

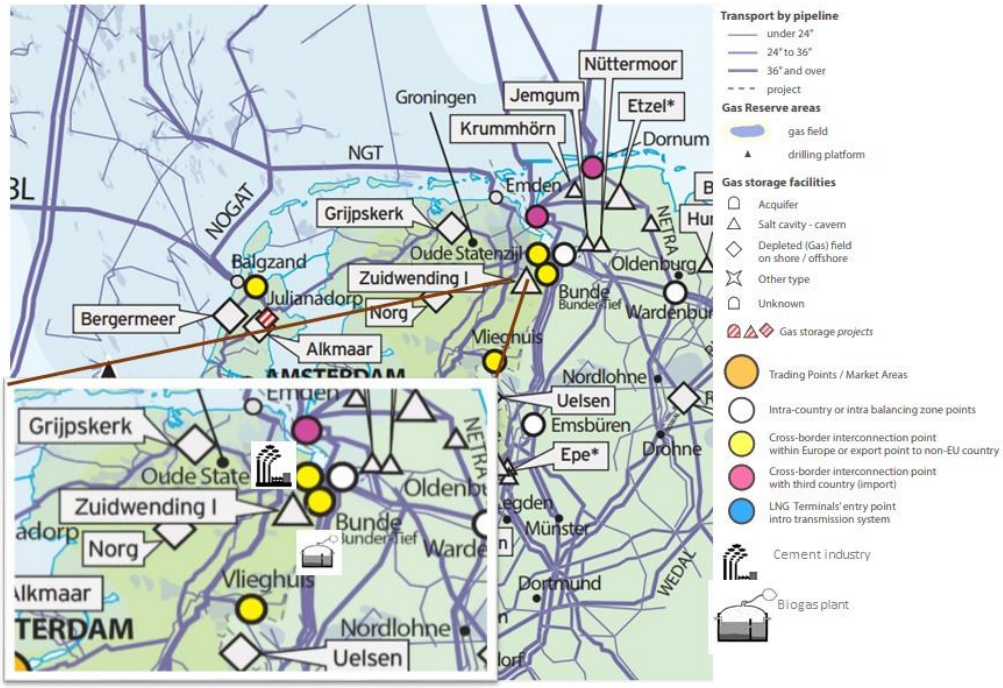
Background story

Due to incentives and support provided by the European governments the amount of energy produced from renewable sources has rapidly increased in the last years. There is, however, a certain challenge to overcome: **balance of the grid**!

A shortcoming of many renewables is their production uncertainty by means of instabilities in time (especially for wind and solar). There are a variety of flexibility solutions to balance these fluctuations and meet the required demand at all times, where storage is one of them. Storage can play a great role in providing flexibility; one can simply store the energy, when there is a generation surplus and discharge the stored energy, during the times when there is a generation shortage. Depending on the time scale (hours up to several months), there are different storage technologies available.

Presently, seasonal storage of electricity is not applied on a large scale. The closest one is pumped hydro storage, which is restricted to certain geographical locations and can only offer a storage time of less than one week. A technology that is emerging as an alternative is the Power to Gas (P2G). In P2G, electricity is used to split water into hydrogen (H_2) and oxygen (O_2) through hydrolysis, whereby the electric energy is stored into the hydrogen. Optionally hydrogen can be further converted into methane (CH_4) by combining it with CO_2. The technology is currently at its early stages and has a high specific cost and low efficiency as limitations. In order to achieve 100% renewable energy scenarios P2G will become compulsory in the near future. This option complements the common application of storage for short-term applications and balancing of grid fluctuations with a long-term function.

Case Description



- In this session you are expected to create **four P2G production scenarios**! End of the session you are expected to compare your own scenarios and discuss the pros&cons of each cases with the others.

- You have learnt about the demonstration site of Gasunie that subsidiaries EnergyStock and New Energy. The plant aims to convert sustainable electricity into hydrogen for mobility and industry. Your given location is – **Zuidwending!**

- **The electricity produced by solar panels** will be delivered from TenneT's high-voltage electricity grid for your planned facility.
- In your scenarios you can choose between the electrical input either 5 MW, 10 MW or 20 MW.
- **Underground Gas Storage** (in salt caverns) in Zuidwending is an ideal location for large-scale storage of methane and within this business case you are expected to store the methane at the caverns.
- There is a great connection with main **infrastructure for gas**: transmission grid is 9.6 km and distribution grid is 6 km away from the planned facility.
- In the vicinity of the planned facility there are 2 **CO_2 sources**: 10 km south a **biogas plant** and 30 km north a **cement factory**.

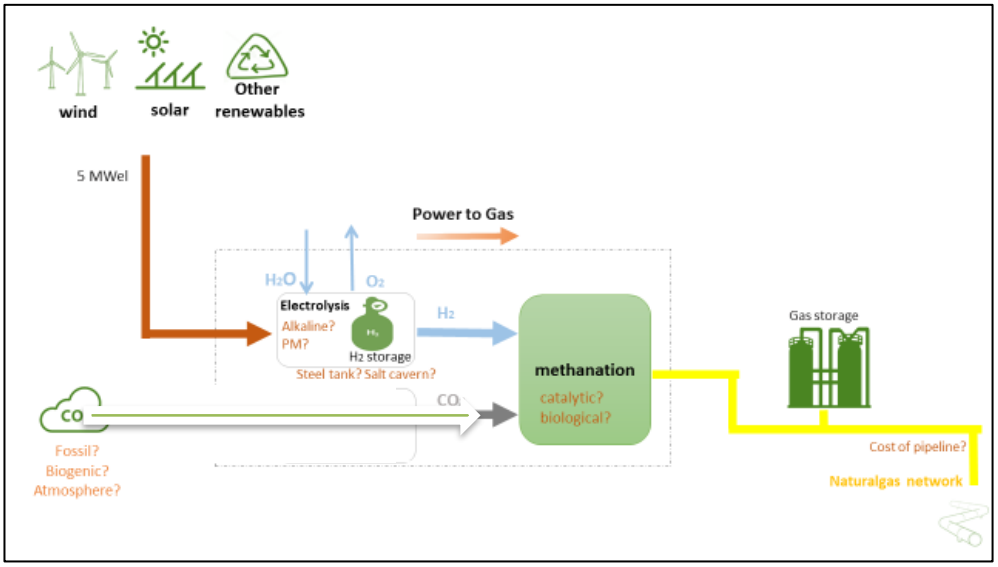


Figure 7. System configuration

Investment costs (CAPEX) and operational costs (OPEX) are given in the excel sheet, **CAPEX for methanation and electrolyser change depending on the plant size!**

1) **Electrolyser**
   The core of the planned P2G plant is the electrolyser, in which water is split into the O_2 and H_2. Please **analyse the two electrolyser technology**:
   - Alkaline (AEL)
   - PEM

   Produced O_2 and low temperature heat from the electrolysis will be released into the air. Therefore **no O_2 revenues** should be expected.
2) **H_2 storage**
   Produced H_2 is then stored for 4 hours in a steel tank before it is used further for methane generation. Size of the storage depends on the size of the plant but also on the chosen electrolyser technology. The storage of hydrogen is 5 bars.
   - high-pressure steel tanks: the higher the pressure is, the more gas can be stored.

3) **Methanation process**
   Conversion of hydrogen into methane is realized in a reactor through either catalytic or biological methanation. In this next step your duty **is to decide on the methanation process**. The efficiency

of both catalytic and biological methanation processes are limited by the Sabatier reaction to a maximum of 80 %. One of the main differences between two methanation is the heat that is released, which is high-temperature for chemical methanation and low-temperature heat for biological methanation.

- Catalytic methanation occurs in fixed bed reactors packed with catalysts that lower the energy of activation for the Sabatier reaction.
- Biological methanation takes place in reactors filled with archea-culture that extracts some of the energy released from the Sabatier reaction and use it for growth.

4) Feedstock

Water is relatively cheap in the Netherlands, therefore it is considered irrelevant for the development of the case. Electricity prices show differences based on the country and for the Netherlands you are expected to use **the average price of 32,24€** (2016).

Within the project you have to decide from which **source** you would like to capture **the CO_2**:
Fossil sources, biogenic or atmosphere. Relevant data is provided in the excel sheet and you should use the data to make your decision!

Potential CO_2 could be supplied through fossil or biogenic sources depending on the existing industry on the chosen location. Another way is to supply the CO_2 from the ambient air. You should consider which source you would like to use! Seized CO_2 will be delivered continuously, therefore a storage tank is not necessary.

5) Pipelines

The costs of methane pipeline depend on the distance of the grid in the given location.
The costs of hydrogen pipeline should be no concern of yours, since the H_2 will be directed into the methanation process from the pressurized steel tank after 4h storage time, not into the grid.

6) Gas grid injection station

After its storage in the salt cavern (cavern will be used by several other P2G plants in the future), methane will be injected into the natural gas grid. An injection point in the transmission grid will be more costly than an injection point in the distribution grid. You should consider this criteria when you are working on the given location.
Revenue for the methane is 0.25€/m^3.
It is important to note that the gas grid injection station do not depend on the size of the plant in the model. Also costs for pipelines do not depend on the plant size: they only depend on the **length of the methane pipeline**.

7.3 ANNEX: Marketing material

7.3.1 Example brochure

Co-funded by the European Union's Horizon 2020 research and innovation programme under Grant Agreement no. 691797

Supported by Schweizerische Eidgenossenschaft Confédération suisse Confederazione Svizzera Confederaziun svizra

STORE&GO

MASTERCLASS IN POWER TO (THE) MOLECULES

- FROM TECHNOLOGY TO MARKET UPTAKE

By 2050, the EU aims to cut CO_2 emissions by 80 to 95 percent, which can only be realised by turning the vast majority of energy sources from fossil into renewable ones. The integration of such large amounts of renewable energy sources poses technological difficulties, as those sources are volatile and generate electricity intermittently. Storing large amounts of electric energy will enable countries to deal with long periods of shortage. Power-to-Gas (PtG) technology allows for storing the surplus of renewable energies on sunny or windy days by the creation of synthetic natural gas (SNG). The produced gas can be stored in the existing gas infrastructure. The existing gas grid allows for the transportation of the gas to various applications whenever and wherever it is needed, e.g. for the generation of electricity, the generation of heat, or mobility. PtG and SNG thereby facilitates the coupling of different energy sectors. During the course we will go beyond the state of the art of PtG and especially SNG, and focus on its integration into the daily operation of European energy grids.

Target audience

The programme is especially developed for young professionals and researchers working in or related to the energy industry, such as:

- Policy makers from regional, national and European level;
- Business developers in the field of energy storage;
- Technological engineers in the field of electrolysers, methanation and/or CO_2 capture;
- Transmission system operators of both the gas and the electric grid;
- Gas and electricity traders;
- Large industrial consumers;
- Financial and knowledge institutes as well as university lecturers.

Certification

Participants in the training will receive a participation certificate on behalf of the Energy Delta Institute.

CHECK OUT WWW.ENERGYDELTA.ORG TO FIND OUT THE LATEST DETAILS

7.3.2 Example website (subscription and news)

home > energy delta institute > events > past events > 2019 - masterclasses in power to (the) molecules - from technology to market uptake (store & go) ii

2019 - Masterclasses in Power to (the) molecules - from technology to market uptake (Store & Go) II

STORE&GO

Various editions will take place in 2019. Send an email-request to Funda Ertem Kappler to find out more about the upcoming dates and locations.

Climate change, renewable energy, low-carbon economy: For some, these are key themes and arguments, for others, they stand for a business sector that combines environmentally friendly technologies with a clear image to guarantee that we can leave a world worth living in for future generations.

The large-scale deployment of renewable energy sources (RES) is a key feature of de-fossilizing the energy supply. However, rapidly growing the share of fluctuating renewable power sources (like wind and solar) in the energy mix requires coping with the intermittency. Therefore, the conversion of renewable electricity (RES-E) into the more convenient form of a gas could help offset fluctuating RES while providing a diverse mix of energy carriers. The Power-to-Gas (PtG) technology is one promising option in the context of these challenges. It enables a combined temporal and spatial balancing solution for a time when renewable energy will supply the major part of the electrical demand. Compared to other storage technologies like batteries or compressed air, PtG could offer long term seasonal storage solutions without any necessary alterations on the existing infrastructure. Therefore, the PtG process chain is expected to play a significant role in the future energy system. By this technology RES-E can be transformed into storable methane – synthetic natural gas (SNG) – via electrolysis and subsequent methanation.

In light of the HORIZON 2020, STORE&GO is proving the technical feasibility of methanation, and extensive research has been dedicated to the economic, juridical and social aspects of PtG. This event will provide you with a comprehensive overview on PtG process chains and technologies, their possible integration in European gas grids, and their system value for the European energy system.

***This event (incl. the online platform) can be attended without any cost. Note that accommodation and travel costs for participants won't be covered by the event.**

Next editions
3 & 4 April 2019 at Berlin, Germany. Includes a site visit to Falkenhagen.

For more information, please contact Funda Ertem Kappler.

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more contact details ▶

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News Detail

2018-11-05 Masterclass in Power to (the) molecules – from technology to market uptake

07/Jan/2019 News

The kick-off masterclass "Power-to-(the)-molecules" took place in the beginning of November in Groningen, 2018. The masterclass was the first edition of a series of eight workshops that are organized by the Energy Delta Institute (EDI) in Groningen under the flagship of the Horizon 2020 project STORE&GO.

The kick-off masterclass "Power-to-(the)-molecules" took place in the beginning of November in Groningen, 2018. The masterclass was the first edition of a series of eight workshops that are organized by the Energy Delta Institute (EDI) in Groningen under the flagship of the Horizon 2020 project STORE&GO.

The energy professionals from various fields (academic, local government and industry) have actively participated in the event, in which the participants were introduced to the basics of power-to-gas technologies and were tutored to focus on an economical case study. Overall, it was a fruitful learning activity and a great networking event. The participants had the chance to exchange their own experiences with each other and were very glad to learn more about the STORE&GO project and the technologies at their three demonstration sites in Germany, Switzerland and in Italy.

The power-to-gas process chain is expected to play a significant role in the future energy system. With the power-to-gas technology, flexible renewable energy resources can be transformed into storable methane – synthetic natural gas (SNG) – via electrolysis and subsequent methanation.

The training series covers the knowledge gathered within the STORE&GO program and disseminates this knowledge to ensure the development of an interdisciplinary skillset – including regulatory, technical, economic and social aspects. The integration of energy systems (electric, molecules and heat) requires bi-directional understanding between the various stakeholders involved. By sharing knowledge about these various aspects the STORE&GO project aims to contribute to this and ultimately to a more effective and cost-efficient energy transition.

A few impressions and notes from the masterclass can be seen below, which were taken by one of the participants.

(Visual notes are from Tineke von der Meij, EnergyGardenNL, www.energygarden.info)

If you are interested in participating in one of the upcoming masterclasses, please contact EDI about the possibilities and find out where the next masterclass will take place. More information about the masterclass and the upcoming editions can be found here.










STORE&GO

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News Detail

04. October 2019 Introduction to PtG technologies and STORE&GO

02/Oct/2019 News

From the 4th of September until the 6th, the latest edition of the STORE&GO masterclass "Power to (the) molecules – from technology to market uptake" took place in Amsterdam followed up by organized site visits by the University of Amsterdam as part of the summer school.

About 19 people attended the training course in Amsterdam, which had the chance to get valuable insights about the power-to-gas technology. The focus of the first day was to introduce the participants to the basics of Power-to-Gas technology as well as to present various innovative plant concepts. Afterwards smart energy solutions with hydrogen options presented, followed by techno-economic assessment of power-to-gas technologies. In the afternoon Xiaojin introduced the participants to the environmental impacts of power-to-gas and the legal and regulatory framework regarding power-to-gas and energy storage systems by Ruven Flamming from the Rijksuniversiteit Groningen.

The second day was introduced by further short presentations on economic and regulatory topics and questions. Afterwards, six projects had the opportunity to present themselves within the framework of the Summer School programme, including the STORE&GO project. Day three ended with the start of the site visits and travles to two of the three STORE&GO demosites. The participants visited Falkenhagen (Germany) and Solothurn (Switzerland) and received comprehensive guided tours by the STORE&GO project managers of the demosites.

In summary, it can be said once again that the masterclass was a complete success and was very well received by all participants.






7.4 ANNEX: Overview of training editions

Edition	Duration (days)	Number of participants	Co-organizers	Site visit
Groningen	3	25	-	EnTranCe
Solothurn	2	14	Solothurn Regio energie and Bundesamt für Energie	Demo site Solothurn
Linz	2	31	Energy Institute Linz	Underground sun storage
Berlin	2	24	ThyssenKrupp	Demo site in Falkenhagen
Bari	3	46	Chamber of Engineers	Demo site in Troia
Florence	2	26	Florence School of regulation	Focus on the regulatory issues
Amsterdam	3	20	University of Amsterdam	Avantium chemicals bv. Or photanol bv

7.5 ANNEX: Participant affiliation list

Affiliation	Count
1to3 Capital B.V.	1
aggreko	1
Alpiq	1
Attiki Gas Supply Company – Hellenic Company of Energy SA	1
Austrian Energy Agency	1
AVL List GmbH	2
Baker Hughes, General Electric	1
Bayernwerk AG	1
CCS	1
Center for vedvarende energi / Centre for Renewables	1
Central Europe Energy Partners	2
Centre de Recherches Energétiques et Municipales / CREM	1
Chalmers	1
Clariant	3
Clausthal University of Technology	1
Denmarks Technical University	1
Dow	1
EBN	2
Enagas	1
ENDESA, S.A.	1
Enel spa	1
Energie Steiermark	2
Energieinstitut	2
Energy Community	3

Energy Delta EMBA EMFC-EI	1
Energy Delta Institute	2
Energy Garden	1
Energy Institute Hrvoje Pozar	1
ENGIE SA	1
Eni	1
Enpuls	1
ENTSO-E	1
ETHZ	1
European Commission	1
European Network of Transmission System Operators	1
European University Institute	1
EVN Wärmekraftwerke GmbH	1
FEN Systems	1
Fondazione Eni Enrico Mattei	1
Friedrich-Alexander-Universität Erlangen-Nürnberg	1
Gas Infrastructure Europe	2
GasTerra	2
Gasunie	1
GroenLeven B.V.	1
Groningen seaports	3
GRTgaz	1
Hanze University of Applied Sciences	3
HEIG-VD	1
Hera Group S.p.A.	1
HSR Hochschule für Technik Rapperswil	1
HyCentA Research GmbH	2
Hydrogen Energy	2
Independant Originator	1
ING	23
ING Attestato	1
Innogy	3
K1 MET GmbH	1
Kompetenzzentrum Wasser Berlin gGmbH	2
Liander N.V	1
Lifetec	1
Linz AG	1
Lynnplanet	1
microbEnergy	3
MicroPyros GmbH	2
NAM	1
Natural & bio Gas Vehicle Association	1
Naturgy	1
NEC	3
Net4gas	5
No affiliation	16

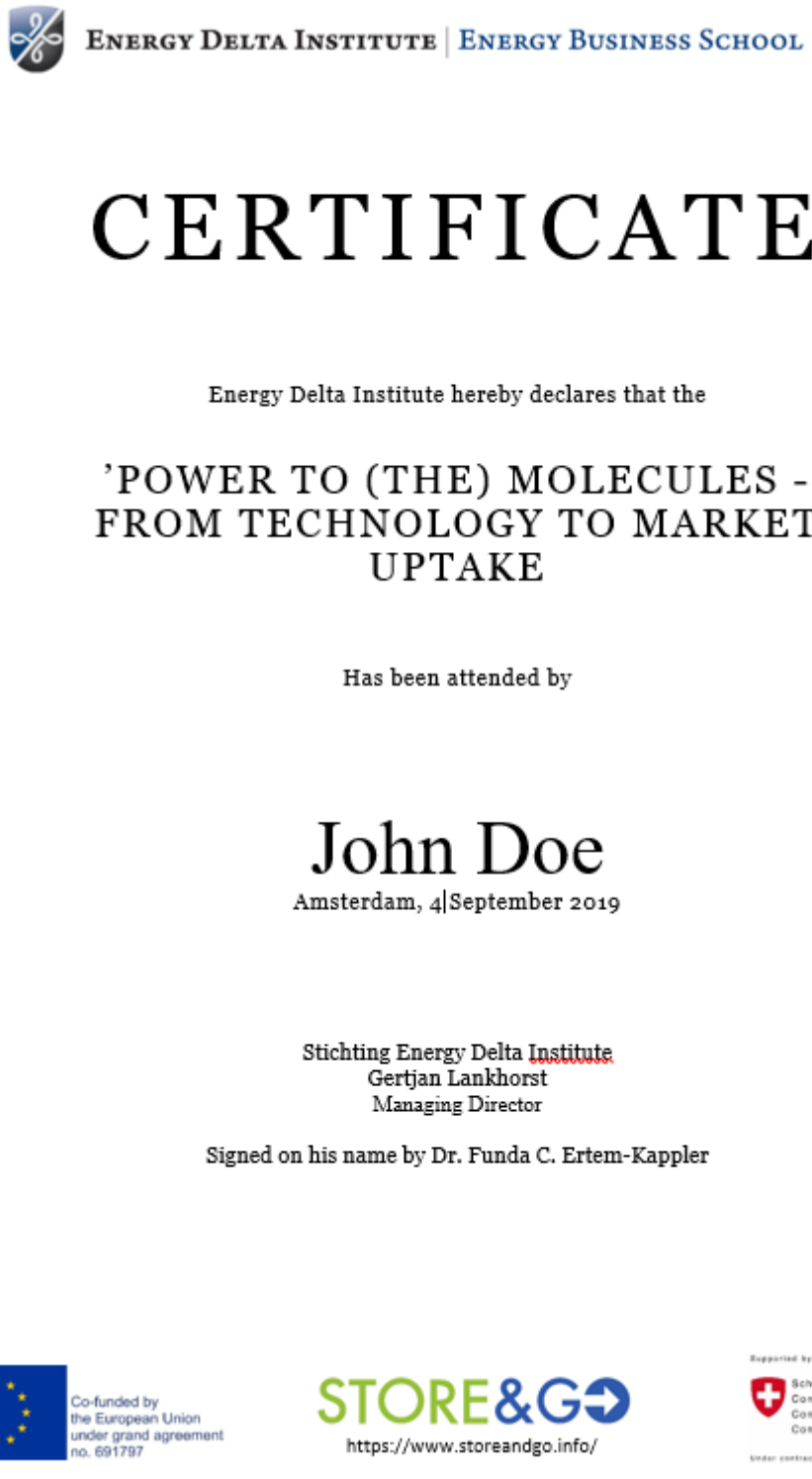
NOGEPA	1
OMV Gas Marketing & Trading GmbH	1
Open Grid Europe	1
OTH Regensburg	1
POLIBA	1
POLITO	1
Provincie Drenthe	1
PSI	2
RAG Austria AG	1
Research Center on Animal Production	1
RUG	5
Schneider Electric GmbH	1
SET e.V.	1
Shell	1
Società Gasdotti Italia SpA	1
ST	10
Stork	1
Summitengineering	1
SVGW	1
Technische Universität Chemnitz	2
TenneT TSO	1
TERNA	1
thyssenkrupp	1
TU München	1
Univ. of Erlangen-Nuernberg	1
University of Lorraine - National University of Colombia	1
Vattenfal	1
VDMA	1
Verbund Solutions Gmbh	1
Verein Deutscher Ingenieure	1
Voestalpine	3
WIVA P&G	1

7.6 ANNEX: Presentation list

Presentation	Lecturer	Times given
The rationale power-to-gas and methanation	EDI Catrinus Jepma IET Rapperswil HSR - J. Gorre Energieinstitut an der JKU – Robert Tichler Uniper - Helge Föcker NEC - Machiel van Steenis	6
Power-to-gas technologies	DVGW - Felix Ortloff Universita di Pisa - AnnaLewandowska-Bernat Hanze University, Andras Perl	6
STORE&GO demonstration sites	DVGW - Felix Ortloff Thyssenkrupp, Steffen Schirrmeister	2
Transport, storage and distribution of renewable gases in the existing natural gas infrastructure	DBI - Michael Wupperfeld Energieinstitut an der JKU - Andreas Zauner	3
Power-to-gas as support for the electricity infrastructure	Polito - Andrea Mazza & Ettore Francesco Bompard Polito - Andrea Mazza	2
Economics and market potential for methanation	LINZ - Robert Tichler Energieinstitut an der JKU - Robert Tichler & Andreas Zauner Energieinstute LINZ - Andreas Zauner University of Geneve - David Parra	5
Large scale energy storage in practice – a Dutch example	EnergyStock - Jan Veijer NEC - Patrick Cnubben	1
Legal and regulatory framework	RUG - Gijs Kreeft Universität Luzern - Markus Schreiber RUG, Ruven Fleming	5
Societal and environmental impact of power-to-gas	Xun Liao PSI, Zhang Xiaojin	3
Power-to-gas technologies & STORE&GO	SVGW - Andrew Lochbrunner	1
Production costs and ecologic benefit of green gases	EMPA - Urs Cabalzar	1
Biological methanation in detail	Electrochea - Doris Hafenbradl	1
Smart energy solutions with hydrogen options	Bahcesehir University – Canan Acar	3
Environmental impacts of power-to-gas systems	Fraunhofer Ins. - Andre Sternberg PSI, Zhang Xiaojin	3
Falkenhagen Windgas plant	Thyssenkrupp, Steffen Schirrmeister	1
Enabling new flexibility resources to support the power grid of the future	Politecnico di Bari - M. La Scala, S. Bruno	1
The hydrogen as an additional fuel for gas turbines	Politecnico di Bari - S. Camporeale, M. Torresi, A. Saponaro	1
From INGRID to the STORE&GO	Engineering I.I. - D. Arnone	1
STORE&GO methanation plant: the design of the overall process	Studio BFP - D. Pomponio	1
Design of a millistructured reactor for methanation	Commissariat à l'énergie atomique - CEA - G. Geffraye	1

CO2 capturing module	Climeworks - L. Kaufman	1
Methanation unit	Atmostat Alcen - P. Bucci	1
Liquefaction unit	Hysytech - A. Saldivia	1
Monitoring, Security and Control infrastructure	Engineering I.I. - A. Rossi	1
Impact of the plant on the power grid	Politecnico di Torino - A. Mazza	1
Regulatory Framework	Hysystech - A. Saldivia	1
European Energy and Climate Ambitions	FSR - Maria Olczak	1
Unbundling Rules in the Context of Power-to-Gas	University of Lucerne - Markus Schreiber	1
Legal Framework for Accommodating SNG in the Gas Network (and future network development)	ENTSOG - Cihan Sönmez and Jos Dehaeseleer	1
Network Tariffs, Taxes and other Surcharges	Cristiano Francese	1
Support Schemes for the Use of SNG	European Renewable Gas Registry (ERGaR) - Attila Kovacs	1
Techno-economic assessment of powertogas technologies	University of Amsterdam-ECN part of TNO, Remko Detz	1

7.7 ANNEX: Certificate



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CERTIFICATE

Energy Delta Institute hereby declares that the

'POWER TO (THE) MOLECULES - FROM TECHNOLOGY TO MARKET UPTAKE

Has been attended by

John Doe

Amsterdam, 4|September 2019

Stichting Energy Delta Institute
Gertjan Lankhorst
Managing Director

Signed on his name by Dr. Funda C. Ertem-Kappler

Co-funded by the European Union under grand agreement no. 691797

STORE&GO
https://www.storeandgo.info/

Supported by Schweizerische Eidgenossenschaft Confédération suisse Confederazione Svizzera Confederaziun svizra

7.8 ANNEX: Survey

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STORE&GO WORKSHOP EVALUATION QUESTIONNAIRE- Amsterdam

Workshop Name: _____

Training Location: Amsterdam

Participant Name (optional): _____

Date: _____

Job Title: _____

Years in present position? **<1** **1-3** **3-5** **5+**

INSTRUCTIONS

Please circle your response to the items. Rate aspects of the workshop on a 1 to 5 scale:

1 = "Strongly disagree," or the lowest, most negative impression

3 = "Neither agree nor disagree," or an adequate impression

5 = "strongly agree," or the highest, most positive impression

Choose N/A if the item is not appropriate or not applicable to this workshop. Your feedback is sincerely appreciated. Thank you.

WORKSHOP CONTENT (Circle your response to each item.)

1=Strongly disagree 2=Disagree 3=Neither agree nor disagree 4=Agree 5=Strongly agree N/A=Not applicable

1. I was well informed about the objectives of this workshop. 1 2 3 4 5 N/A

2. This workshop lived up to my expectations. 1 2 3 4 5 N/A

3. The content is relevant to my job. 1 2 3 4 5 N/A

WORKSHOP DESIGN (Circle your response to each item.)

4. The workshop objectives were clear to me. 1 2 3 4 5 N/A

5. The workshop activities stimulated my learning. 1 2 3 4 5 N/A

6. The activities in this workshop gave me sufficient practice and feedback. 1 2 3 4 5 N/A

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7. The difficulty level of this workshop was 1 2 3 4 5 N/A

appropriate.

8. The pace of this workshop was appropriate. 1 2 3 4 5 N/A

9. What topic would you like to have heard in more depth?

10. About what additional topic would you like to have heard?

11. What topic could have been more to the point? Why?

WORKSHOP RESULTS (Circle your response to each item.)

12. I accomplished the objectives of this workshop. 1 2 3 4 5 N/A

13. I will be able to use what I learned in this 1 2 3 4 5 N/A

workshop.

SELF-PACED DELIVERY (Circle your response to each item.)

14. The workshop was a good way for me to 1 2 3 4 5 N/A

learn this content.

15. How would you improve this workshop? (Check all that apply.)

___Provide better information before the workshop.

___Clarify the workshop objectives.

___Reduce the content covered in the workshop.

___Increase the content covered in the workshop.

___Update the content covered in the workshop.

___Improve the instructional methods.

___Make workshop activities more stimulating.

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___Improve workshop organization.

___Make the workshop less difficult.

___Make the workshop more difficult.

16. How would you improve this workshop (cont'd)

___Slow down the pace of the workshop.

___Speed up the pace of the workshop.

___Allot more time for the workshop.

___Shorten the time for the workshop.

___Improve the tests used in the workshop.

___Add more video to the workshop.

17. What other improvements would you recommend in this workshop?

18. What is least valuable about this workshop?

19. What is most valuable about this workshop?

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20. Are you interested in receiving other educational materials/workshops from EDI or e-mail updates about Store&Go project?

Yes No

If so, please write your name, address, e-mail, phone number, and the subject(s) and

grade level(s) you work with most.