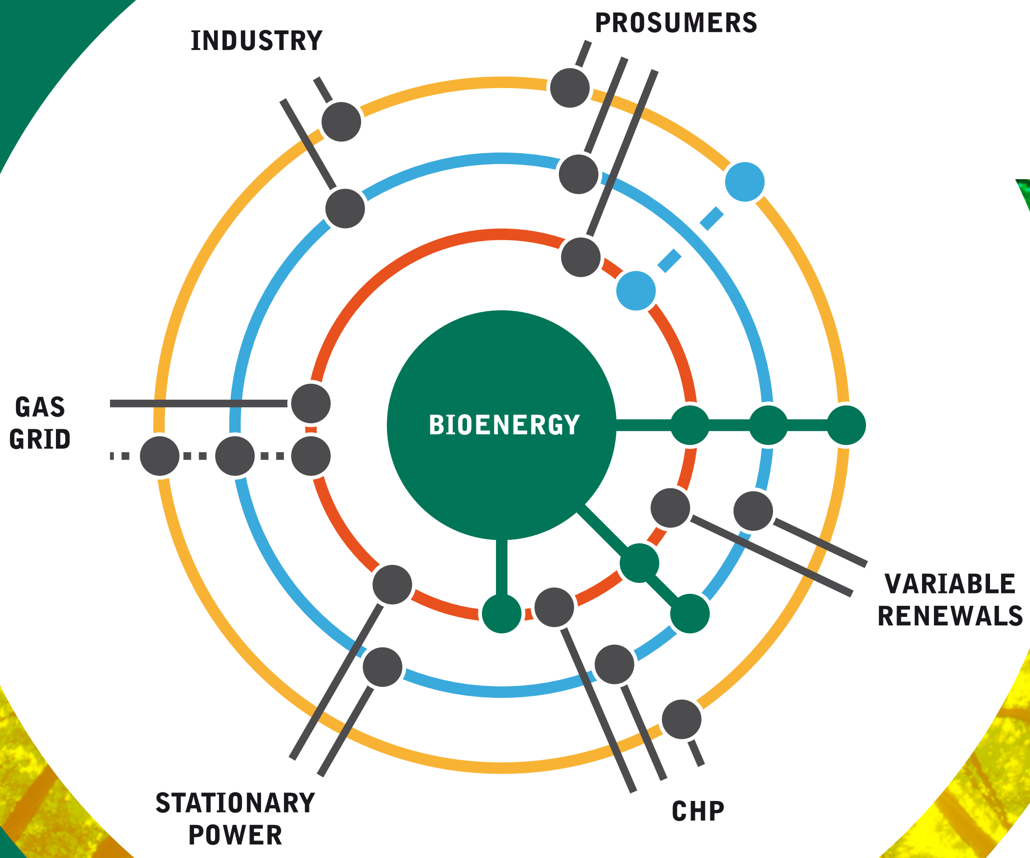
Bioenergy grid integration

Summary and conclusions from the IEA Bioenergy ExCo80 workshop



This publication provides the summary and conclusions for the workshop 'Bioenergy grid integration' held in conjunction with the meeting of the Executive Committee of IEA Bioenergy in Baden, Switzerland on 19 October 2017.

IEA Bioenergy

IEA Bioenergy: ExCo: 2018:01

Bioenergy grid integration

Summary and conclusions from the IEA Bioenergy ExCo80 workshop

Published by IEA Bioenergy

EXECUTIVE SUMMARY

Luc Pelkmans, Technical Coordinator, IEA Bioenergy

The IEA Bioenergy Technology Collaboration Programme (IEA Bioenergy TCP) held its biannual workshop in Baden, Switzerland on 19 October 2017 in conjunction with its Executive Committee meeting (ExCo80). The workshop on 'Bioenergy grid integration' was prepared in close collaboration with the Swiss Federal Office of Energy. The half day workshop consisted of two sessions: (1) connecting bioenergy systems to heat grids and (2) convergence of gas, heat and power grids, with a special focus on biogas. The workshop was concluded with a panel discussion on how bioenergy can play a role in the greening of existing grid systems.

Connecting with heat grids

Biomass can play an important role in the greening of heat provision through district heating networks. District heating provides flexibility to switch between energy sources, and enables the transition from fossil to renewable and waste heat utilisation. The centralised, larger scale installations facilitate lower emissions compared to individual biomass based heating systems. From a lifecycle cost perspective district heating energy is more cost effective than individual heating. Nevertheless, cost is a critical issue, with overall heat distribution costs being dominated by capital costs, typically representing two thirds of overall costs. Feed-in tariffs – for the co-produced electricity – and CO_2 certificates are often crucial for economic viability.

There are ways to optimise the use of heat grids. Energy losses through the heat distribution grid should be minimised by following existing quality management guidelines for district heating systems, particularly through a sufficiently high heat density (heat demand per km pipeline), the choice of pipe diameters, insulation level, the temperature spread (feed and return temperature) and the network layout. Heat storage within the district heating system increases flexibility and reduces the heat production capacity required. Demand side management to reduce peak loads can also be very effective in that sense. Additional flexibility can be incorporated, particularly when various producers are connected to the grid. There is also a trend to move to lower temperature levels in district heating grids, so that more use can be made of residual heat. Through combined heat and power (CHP), the different energy grids can be further synergised in the future ('hybrid networks').

A major barrier to district heating system deployment remains complexity related to identifying appropriate governance models. Some successful models have been public-private partnerships (PPPs), but the optimal approach is case and location specific, and also depends on regional policies and regulations.

Very long building permission processes have been a barrier for the realisation of biobased district heating projects, as was mentioned during the workshop for projects in Switzerland. In addition, financing, competition from other concepts and unexpected changes in regulation are challenges to be faced during the development of biomass plants.

Future trends need to be incorporated, e.g. low-energy houses, and increased use of heat pumps by individual consumers. Nevertheless it was stated that the retrofitting rate of houses in Switzerland is quite low (less than 1% per year), while the living area per person increases. So heat demand will still be substantial in the coming decades. Providing baseload heat can still be an interesting business case.

Convergence of power, heat and gas grids

Biomass has an advantage in that it is storable, so bioenergy production can be better matched with demand. Particularly the use of biogas/renewable gas is very flexible and can play a substantial role in balancing the power grid, where intermittent renewables play an increasing role. With increased levels of individual power production through photovoltaic (PV) systems – with peak production in summer – and higher shares for heat pumps – with peak demand in winter – the imbalance between seasonal power production and demand will increase. The challenge for grid operators is how to make the most of various small renewable electricity production units while safeguarding the balancing of the power grid. Decentralised production units can be combined in a 'virtual power plant', which is marketed and controlled through a central stakeholder. Flexible production is delivered through the combination of many individual units. Biogas is very well suited to demand responsive energy production because it is controllable and contains gas storage within the process. The provision of flexibility is monetised through specific remunerations or bonuses. The system provides additional income to electricity producers, with limited impact on their daily operations, while their plants directly support the stability of the grid. For the transmission system operator a large number of small units is now accessible through a single point of contact. This also provides a testing ground for the control infrastructure of the future energy system, which will have higher levels of intermittent renewable energy sources.

One should remember that biogas is more than electricity production, and its role in closing loops (e.g. in waste management) should also be emphasised. To reach optimal efficiencies, heat demand is a central issue for biogas energy conversion. Nevertheless, due to specific incentives for renewable power, a large part of the biogas is today focused on producing electricity. Typically only one third of the energy is converted to electrical power. The remaining amount is available as heat, which is often not fully used, especially in the summer months. Converting biogas to biomethane and injecting into the grid is more and more applied, particularly when there is no year-round local heat demand. Using the gas grid provides a large buffer for biomethane, even at base load in summer time. The gas grid then provides the flexibility to use the gas for CHP, heat or as transport fuel. Through capturing the CO_2 which is separated during the process of biomethane production from raw biogas, and converting it into additional methane by the addition of hydrogen (H_2) from renewable electricity, it is possible to increase the biomethane production by 60% – using the same amount of biomass as before. This is one example of power-to-gas (PtG), but there are also others, which are more focused on balancing power grids (producing methane in times of oversupply of renewable electricity). Biomethane and PtG concepts will contribute to maintaining the existing large European infrastructure for gas distribution, and to improving its environmental footprint by increasing the share of renewable gas.

Conclusions and recommendations

Biomass can play an important role in the greening of heat provision through district heating networks. Existing district heating systems provide ideal platforms to transition from fossil to renewable and residual heat. New district heating systems have major challenges related to (capital) costs and governance. There are ways to optimise the use of heat grids, by following quality management guidelines (to limit energy losses), introducing heat storage in the system, and through demand side management. It is also important to incorporate flexibility so that various producers can be connected to the grid. Appropriate governance models (such as public-private partnerships) need to be developed, which are case and location specific, and also depend on regional policies and regulations.

It is clear that synergies between different energy grids – particularly power, heat and gas – are increasing. Biogas is very well suited to demand responsive energy production. An effective approach to stabilise the power grid (with an increasing share of variable renewable energy) is to combine decentralised renewable energy production units in a 'virtual power plant', which is marketed and controlled through a central stakeholder. Providing flexibility to the power grid should be monetised through specific remunerations or bonuses. The concurrent provision of heat in CHP systems should be taken into account. Testing grounds need to be implemented for the control infrastructure of the future energy system, which will have higher levels of intermittent renewable energy sources.

While renewable energy incentives have so far focused mostly on power production, this should be opened up to renewable heat and renewable gas provision. Biomethane and power-to-gas concepts can improve the environmental footprint of gas used by various customers. Moreover, connecting biogas/biomethane to the gas grid provides a large buffer, providing the flexibility to use the gas for CHP, heat or as transport fuel. The renewable nature of this gas should be recognised in the gas grid (e.g. through guarantees of origin). New concepts and business cases for power-to-gas, capturing CO_2 (particularly CO_2 separated during the process of biomethane production) and converting it into additional biomethane through hydrogen from renewable power should be further explored, while also accounting for their role in balancing power grids.

The PowerPoint presentations can be downloaded from IEA Bioenergy's website http://www.ieabioenergy.com/publications/ws23-bioenergy-grid-integration/.

WORKSHOP

Welcome speeches

Sandra Hermle of the **Swiss Federal Office of Energy** welcomed the participants to Baden. As an introduction to the workshop theme, she presented a number of background figures on the role of biomass in renewable energy, particularly for electricity and heat production. Biomass represents over 95% of renewable heat provision globally. While its role in renewable electricity is smaller, bioenergy has the potential to play a focal role as a stabilising element in the renewable power supply system. Seasonality, i.e. fluctuations in renewable energy supply and energy demand in the winter and summer seasons, is one of the key challenges for future smart energy system management.

Kees Kwant, the chair of **IEA Bioenergy**, welcomed all participants on behalf of the IEA Bioenergy TCP. Integrating bioenergy in existing and future grids – electricity, heat or gas grids – can provide major opportunities. Of course there are also hurdles to further deployment. It is important to pinpoint such hurdles and discuss how they can be handled. The workshop provides a platform to discuss cases and strategies for bioenergy grid integration.

Session 1: Connecting bioenergy systems to heat grids

This session was moderated by Jaap Koppejan, Procede Biomass, The Netherlands, leader of IEA Bioenergy Task 32.

Heat grid – District heating with biomass in Switzerland and internationally

Thomas Nussbaumer, Verenum, Switzerland, Swiss national Task leader of IEA Bioenergy Task 32

District heating (DH) enables the use of biomass as renewable energy to substitute decentralised fossil heating with low (air) pollution and high comfort. On the other hand, district heating causes additional costs and energy losses. Capital costs dominate the heat distribution costs. To minimise capital costs, pipe diameters should be as small as possible, taking into account pumping losses. Heat storage increases flexibility for CHP and power production. A two to three hour capacity heat storage would reduce the boiler capacity by 20% and the total capital costs by 2.5%. Reducing peak loads through demand side management (e.g. phasing the start of floor heating systems) can also reduce the required heat production capacity.

Heat losses strongly depend on linear heat density, i.e. the amount of overall heat demand over the year, per meter of heat pipeline (expressed in MWh/a.m). A survey of IEA Bioenergy Task 32 provided data from over 800 district heating systems in Austria, Denmark, Finland, Germany and Switzerland[1]. In these systems heat density varied from below 0.5 MWh/a.m up to above 5 MWh/a.m, while QM Holzheizwerke[2] in Switzerland proposes a minimum value of 1.8 MWh/a.m. At this scale typical heat losses of 13 % are achieved. For smaller heat density systems, heat losses are typically much higher.

1 Full study available at: http://task32.ieabioenergy.com/wp-content/uploads/2017/03/IEA_Task32_DHS_Status_Report.pdf

2 QM Holzheizwerke® is a quality management system for wood heating plants, for the production and distribution of domestic heating, sanitary hot water and process heat, see http://www.qmholzheizwerke.ch

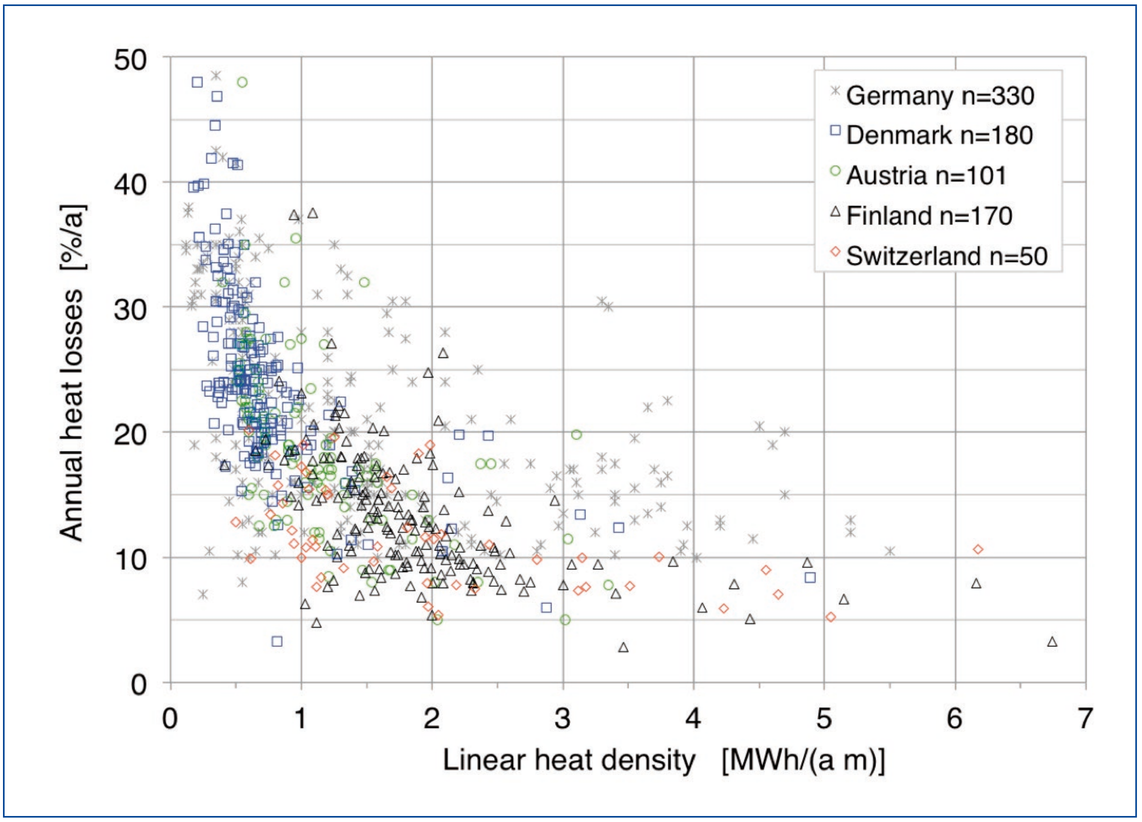


Figure 1: Heat losses as a function of linear heat density of the district heating network – results from the IEA Bioenergy Task 32 survey

Next to the linear heat density, other parameters also strongly influence losses and cost, including pipe diameter, temperature spread (feed and return temperature) and network layout. To deploy the potential of district heating, plant planning and operation are crucial. Experiences are available and need to be implemented by training and education, e.g. through the Swiss Handbook on District Heating Planning[3].

3 available at www.qmfernwaerme.ch

How to build and integrate a district heating network – success story with hurdles

Urs Rhyner, Agro Energie Schwyz AG, Switzerland

AGRO Energie Schwyz AG operates a biomass power plant in Schwyz, in the heart of Switzerland. Heat and power are provided to the region of Schwyz by using renewable and local resources. A 9.9 MW_{th} wood-fired power station with a 1.5 MW_{el} Organic Rankine Cycle (ORC) is operated using urban waste wood. Two wood boilers of 3.2 and 6.5 MW_{th} are operated using wood chips. A biogas fermentation plant is operated with manure and organic wastes. The biogas is used in a CHP of 526 kW_{el}. The following figure shows the demand profile of each of these units over the year. Renewable energy production in 2016 amounted to 80 GWh heat and 13 GWh electricity.

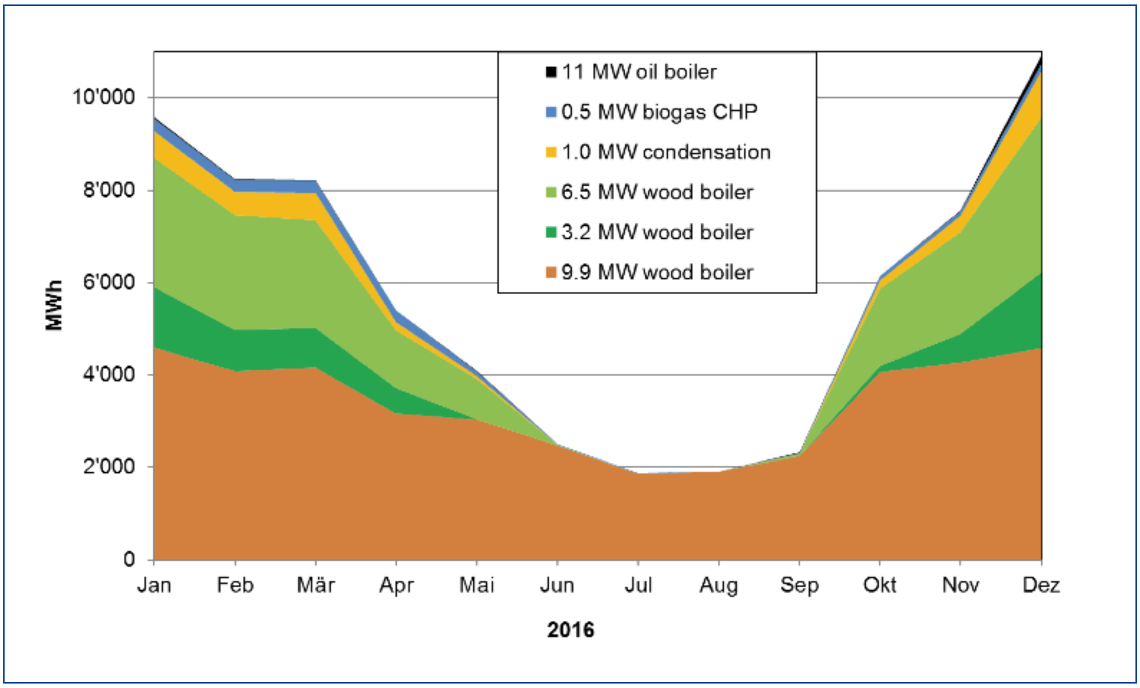


Figure 2: Evolution of monthly heat demand in 2016 of the Schwyz district heating grid (source: Agro Energie Schwyz)

The 26 MW district heating grid is over 80 km long and provides heat to more than 960 private and public buildings. The district heating is operated throughout the year with a supply temperature of 95 °C and a return temperature of 50 °C. The system includes leak monitoring and category 3 pipe insulation. Customer demand optimisation is achieved by time shifting and interruption of floor heatings to reduce peak demand. A heat accumulator of 1300 MWh operated with water at atmospheric pressure with a volume of 28,000 m³ is planned to be commissioned by 2020.

In terms of economics, the operating costs are dominated by capital costs, of which the district heating network represents two thirds. Electricity feed-in tariffs and CO_2 certificates are crucial for economic viability.

Similar district heating projects with wood-fired power stations are under development. The production site in Küssnacht SZ, adjacent to the biggest saw mill in Switzerland, can take advantage of several synergies such as wood resources, heat and power demand, saw dust for wood pellets and an optimised transportation of wood.

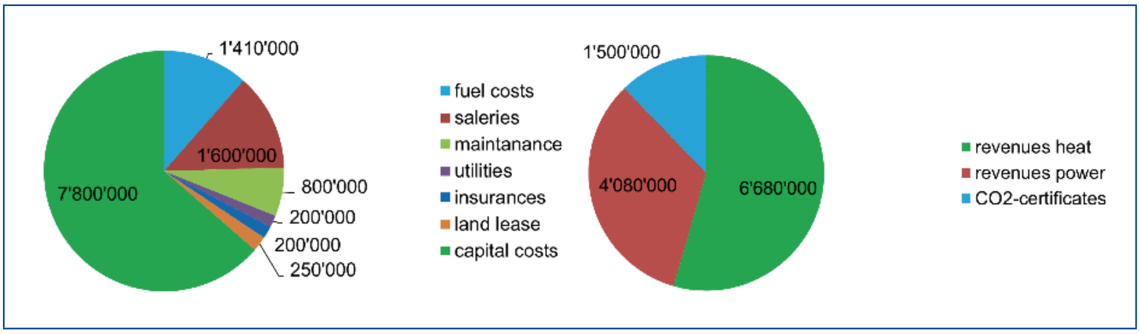


Figure 3: Operating costs (left) and revenues (right) of the Schwyz district heating (expressed in CHF; 1 EUR = 1.15 CHF) (source: Agro Energie Schwyz)

Very long building permission processes are a barrier to the realisation of such projects in Switzerland. In addition, financing, competition from other concepts and unexpected changes in regulation are challenges to be faced during the development of biomass power plants.

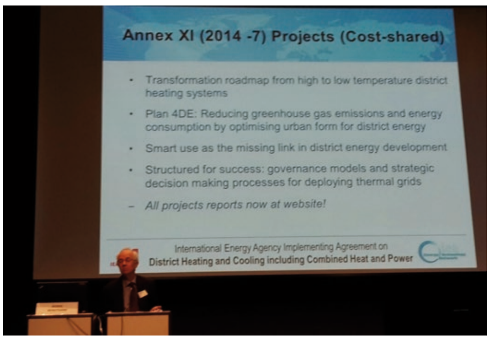
District heating and cooling: environmental technology for the 21st century

Robin Wiltshire,
BRE Building Research Establishment,
United Kingdom, Chair IEA DHC/CHP

The presentation outlined the work of the IEA Technology Collaboration Programme on District Heating and Cooling including Combined Heat and Power (IEA DHC/CHP), which was established in 1983 and is currently rapidly expanding. [4] This TCP works by both cost and task sharing, carrying out research projects in three-year 'annexes', which comprise 4 to 6 projects. Research topics cover all aspects of DHC technology focusing on reducing cost and improving performance: e.g. pipe materials, installation techniques, system optimisation, pro-active maintenance, thermal storage or integrating renewables.

Mr. Wiltshire outlined recent and ongoing work, with key themes including the transformation of heat grids to lower temperatures in order to enable transition from fossil to renewable and waste heat utilisation, and the future synergising of energy grids ('hybrid networks').

A recent project concluded that district heating energy is more cost effective than individual heating when considered from a lifecycle cost perspective... in neighbourhoods where we would not have expected this to be the case. A major barrier to DH system deployment remains complexity related to identifying appropriate governance models. Some successful models have been public-private partnerships (PPPs), but the optimal approach is case and location specific. A strategic view is required for the coming decades to suit countries with 2050 visions for low/zero carbon futures.



4 More information available at: http://www.iea-dhc.org/

Session 2: Convergence of gas, heat and power grids, with a special focus on biogas

This session was moderated by *Urs Baier, Zürcher Hochschule für Angewandte Wissenschaften, Swiss national task leader in IEA Bioenergy Task 37.*

Convergence of the grid – taking all different grids into account: "Hybridwerk Aarmatt" – At the interface of the electricity, gas and district heating grid

Andrew Lochbrunner, Regio Energie Solothurn, Switzerland

Regio Energie Solothurn operates a hybrid plant in Solothurn, in the Northwest of Switzerland, the main components being a gas boiler, three hot water storage tanks, a gas-fired CHP plant and two electrolysers. Depending on the actual grid situation, the plant can produce or consume electricity and/or gas. Operating the CHP plant and the gas boiler supplies electricity and heat to the local grids. During times of excesss production of electricity, operation of the two electrolysers helps to stabilise the grid, while at the same time producing hydrogen, which is fed into the local grid.

Nevertheless there are limitations to feeding hydrogen into the grid, and there are issues related to security, costs and energy density.

As part of the Horizon 2020 Project "STORE&GO"[5] financed by the EU and the SERI (State Secretariat for Education, Research and Innovation), a biological methanation plant, supplied by Electrochaea, will be added to the existing hybrid plant, transforming hydrogen and captured CO_2 from a water purification plant into methane which will be fed into the natural gas grid.

The project consists of three different sites demonstrating "innovative Power to Gas (PtG) storage concepts" at locations in Germany, Switzerland and Italy. The project goal is to overcome technical, economic, social and legal barriers, considering the integration of PtG storage into flexible energy supply and distribution systems with a high share of renewable energy. It also aims to solve some of the main problems of renewable energies such as wind and solar: fluctuating production, suboptimal power grid infrastructure, and a lack of storage solutions for renewable power at the local, national and European level.

At the same time PtG concepts will contribute to maintaining the existing large European infrastructure for gas distribution, and improving its environmental footprint by increasing the share of renewable gas.

5 More information at: www.storeandgo.info

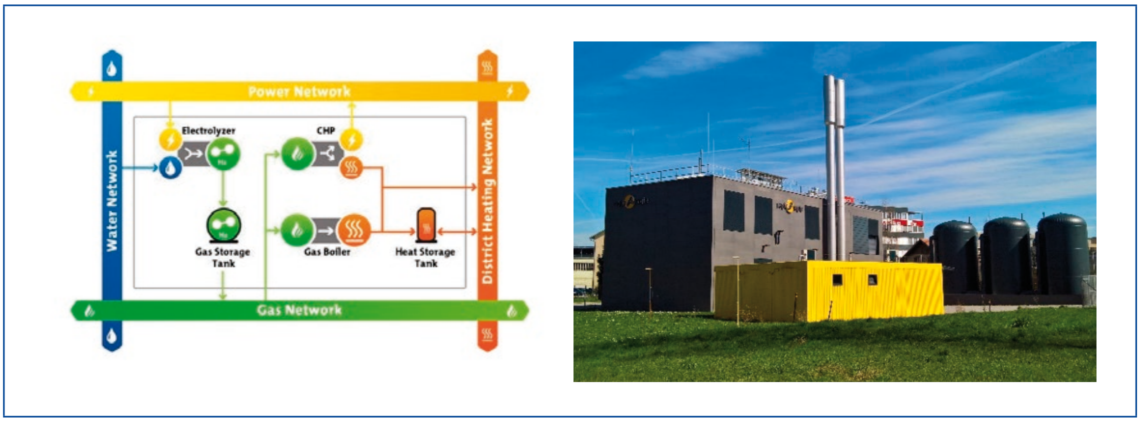


Figure 4: Grid convergence, to be implemented at the hybrid plant Aarmatt (source: Regio Energie Solothurn)

The strategic integration of biomethane in the gas grid

Andreas Kunz, Energie 360° AG, Switzerland

The production of biomethane has grown strongly in the last decade. Renewable gas has been fed into the natural gas network for 20 years. Biomethane marketed in Switzerland originates exclusively from residual material and waste such as kitchen and garden waste, sewage sludge or manure.

Over the past decade, the production and injection into the gas grid in Switzerland has increased more than tenfold to 308 GWh biomethane (in 2016). This still represents only 1% of total gas demand. The Swiss gas industry wants to increase the share of renewable gas in the residential thermal energy sector to 30% by 2030. In this market, Energie 360° already supplies gas with a content of 10% biogas to its customers. To achieve this goal, Switzerland needs to build new biomethane production capacities as well as to import a considerable amount of renewable gas.

Due to the cost-covering feed-in remuneration (KEV) for renewable electrical power, a large part of the biomass is today used to produce electricity. Typically only one third of the energy is converted to electrical power. The remaining amount is available as heat, which is often not fully used, especially in the summer months. With injection into the gas grid the entire amount of energy is stored and can be used later on a case by case basis for heat, electricity or fuel for mobility at the time of use during the year. Moreover, the Swiss electrical energy mix already has a low CO_2 footprint and therefore the impact of the additional renewable electrical power is low, or could in time of excess power in the electricity grid even worsen the situation. Biomethane injection into the gas grid could have a much higher impact as it substitutes natural gas, or petrol if it is used in the transport sector.

Using more biomass for the production of gas is only the first step. It is of equal importance to optimise the yield of existing biogas injection plants. Energie360° and the Paul Scherrer Instituts (PSI) have proven, during a one thousand hours test run in the Zurich-Werdhölzli sewage treatment plant, that it is possible to increase the biomethane production by 60% - using the same amount of raw biogas as before. This is due to a power-to-gas process: instead of releasing the CO_2, which is separated during the process of biomethane production, to the atmosphere, it is converted into additional methane by the addition of hydrogen (H_2). The benefit is that the quantity of renewable gas from the same amount of biomass can be increased significantly.

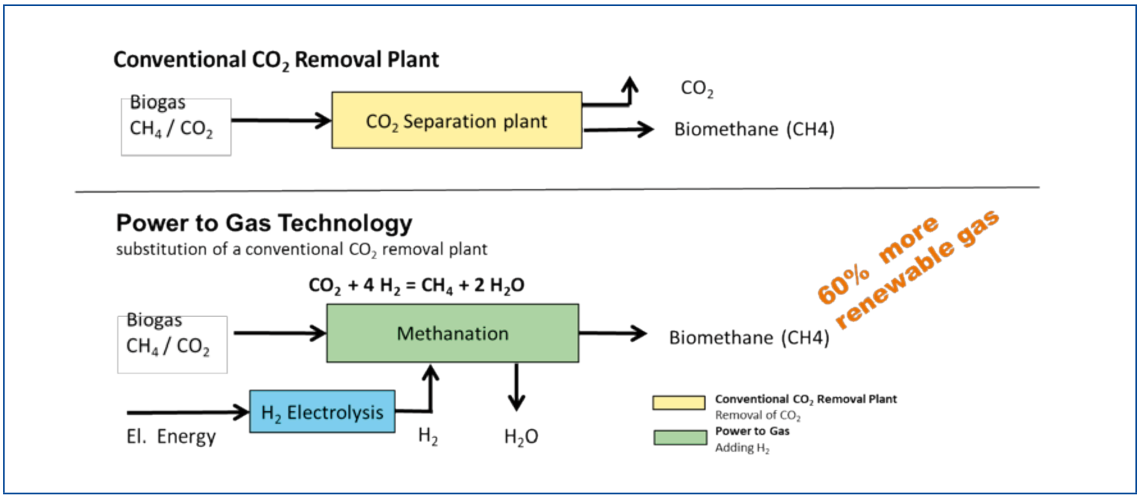


Figure 5: Increasing the output of renewable gas of a biogas plant through power-to-gas technology (source: Energie360°)

Through transformation of biogas plants in the vicinity of a gas grid from electrical power production to gas injection, and through the application of the power-to-gas technology instead of CO_2 separation for existing and new biogas plants, renewable gas production in Switzerland could be increased fivefold, i.e. from 308 GWh now to 1.5 TWh.

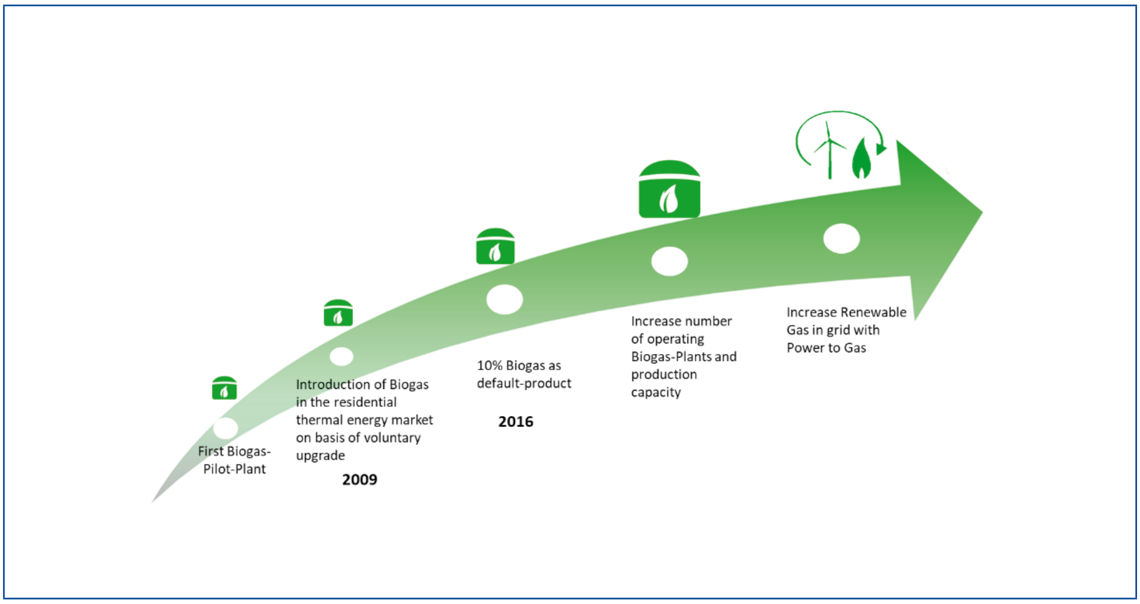


Figure 6: Strategy of Energie360° to increase the content of renewable gas in the gas grid (source: Energie360°)

Potential of biogenic combined heat and power generation in Switzerland: Project CHPswarm for power-on-demand

Gil Georges, Aerothermochemistry and Combustion Systems Laboratory, ETH Zürich, Switzerland

The project *CHPswarm* investigated the role decentralised combined heat and power (CHP) may play in the future Swiss energy system, relying on fuels from sustainable biomass through the gas grid. In principle, any energy converter could form the heart of a CHP system while gas-fired internal combustion engines offer fast response time in minutes coupled with a high overall efficiency.

The primary interest in the project was the energy systemic potential of a whole swarm of distributed biomass-CHP plants. Regional case studies were combined with energy-economic modelling at the national level.
The case studies investigated the biomethane production potentials within the boundaries of the study region. Then, softly coupled simulations of the swarm, the buildings and industrial processes they provide with heat and the electric grid were run to explore the technical feasibility and the potential to compensate fluctuating photovoltaic generation.

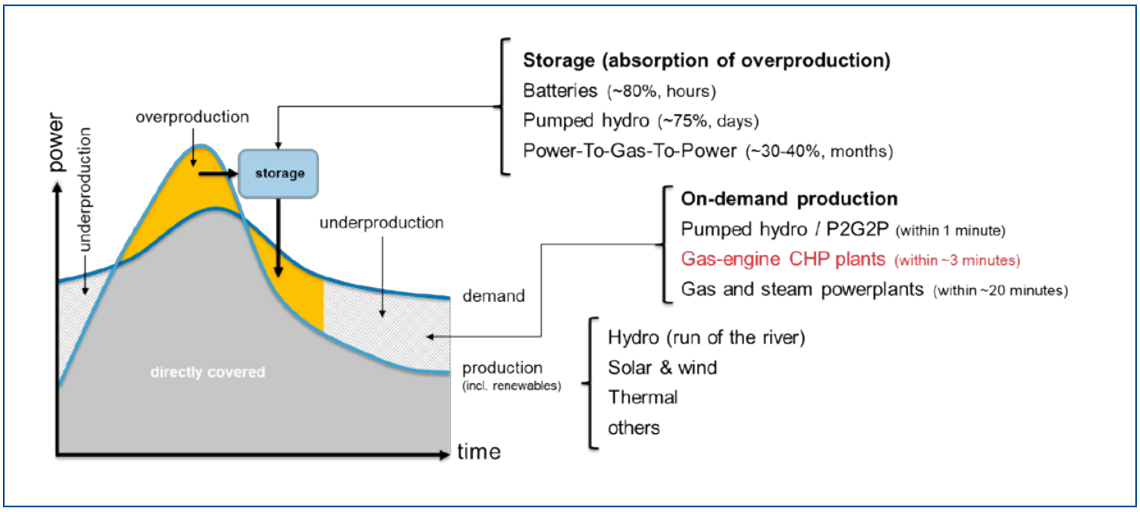


Figure 7: Compensation of fluctuating renewables in the power grid – need for fast-switchable storage and on-demand production (source: ETH Zürich)

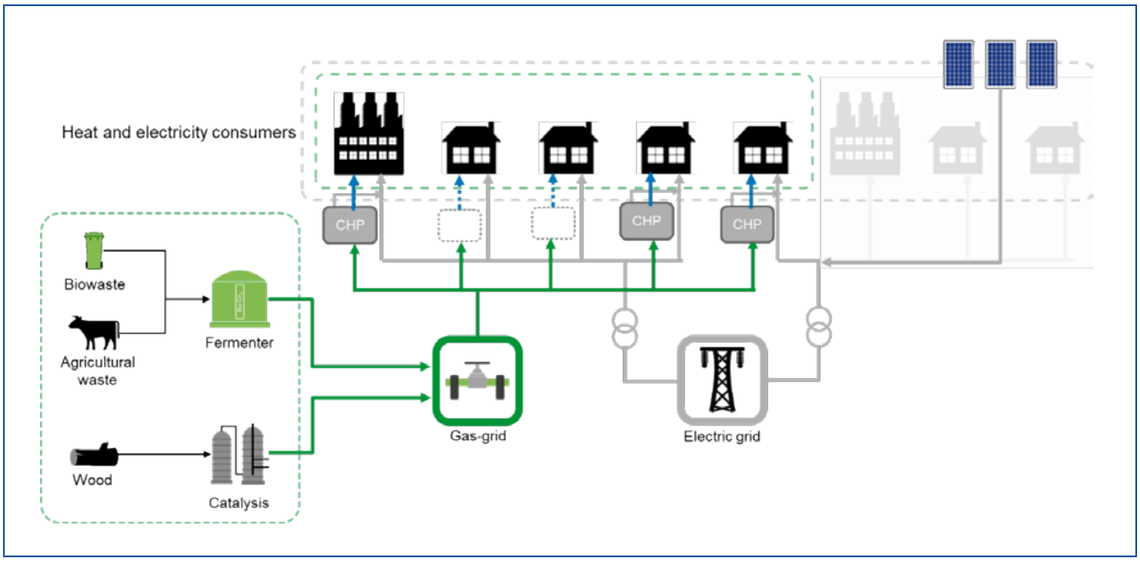


Figure 8: Schematic representation of a swarm of individual CHP plants, relying on biomethane through the gas grid (source: ETH Zürich)

In the example of the case-study of Lucerne, it was shown that a swarm consuming all the biogenic resources in the canton can provide about 100 MW of electrical power covering 20% of the heat and 10% of the electricity demand.

Some specific conclusions:

- The CHPs have an anticyclic correlation with PV and run-of-the-river hydro production, so they have an important role in winter time.
- The operation of small CHPs is highly dynamic (minute based); their business case depends on peaks in electricity prices induced by fluctuating renewables.
- Limiting factors to the size of the swarm (and hence its production) are the available biomethane/biomass, bottlenecks in the electricity grid, and heat demand (availability of heat sinks, also decades into the future).
- Depending on the economic and political boundary conditions, CHP plants can achieve a non-negligible market penetration. CHPs are to play an important role if natural gas prices become high, or climate policies become stringent.

Power grid – Virtual Power Plant for demand responsive energy production from biogas plants

Martin Schröcker, Fleco Power AG, Switzerland

Decentralised production units can be combined in a 'virtual power plant', which is marketed and controlled through a central stakeholder. Flexible production is delivered through the combination of many individual units. Controllable generation is necessary to keep electricity consumption and production in balance – decentralised generation can make an important contribution. Biogas is very well suited to demand responsive energy production because it is controllable and contains gas storage within the process at no extra cost. Local boundary conditions such as minimum power levels, heat delivery contracts or limits in gas storage can lead to constraints on the available flexibility.

Fleco Power AG manages a Virtual Power Plant in Switzerland by using IT based services to optimise economic returns and integration into the energy system for decentralised renewable generation. The platform controls the output of connected decentralsed renewable generation assets and forwards control commands to the individual systems. Nevertheless, the system gives precedence to local operations (e.g. storage capacity/heat demand) and control signals are 'suggestions' that will be executed only if circumstances allow. This strengthens the operators' trust that their processes will not be adversely impacted.

The main application at the moment is the provision of tertiary (within 15 minutes balancing) negative balancing power for the Swiss Transmission Grid Operator Swissgrid. The system has a lot of redundancy. Operators receive a call to reduce power a few times per month, impacting operations up to a few hours. The Virtual Power Plant currently comprises more than 100 units, with an overall capacity of several dozen MW.

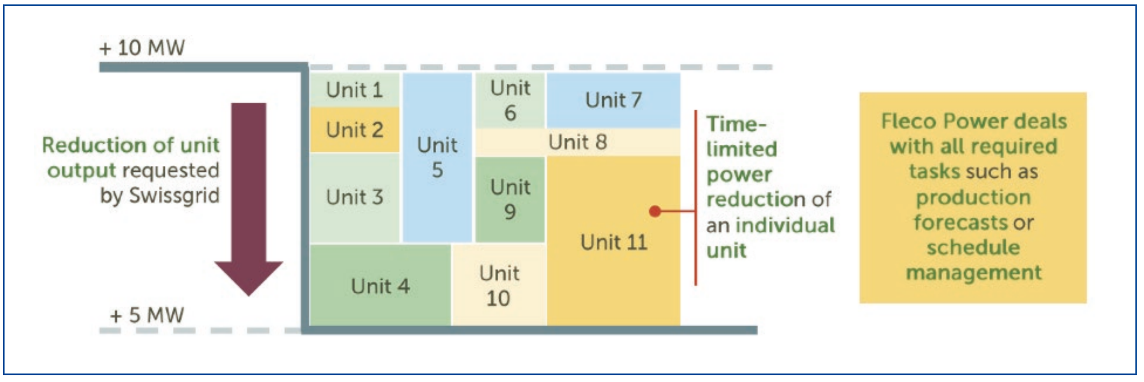


Figure 9: illustration of how tertiary negative ancillary services can be applied (source: Fleco Power)

The provision of flexibility is monetised through specific remunerations or bonuses. The system provides additional income to electricity producers, with minimum impact on their daily operations, while their plants directly support the stability of the grid. For the transmission system operator a large number of small units is now accessible through a single point of contact.

This also provides a testing ground for the control infrastructure of the future energy system, which will have higher levels of intermittent renewable energy sources.

In future, flexibility can be given an even higher value, e.g. through the avoidance of network extensions.

Panel discussion

All speakers were asked to take part in a final closing panel discussion, moderated by Jaap Koppejan and Urs Baier.

Some of the conclusions of the panel discussion (in addition to clarifying questions related to the presentations):

With increased levels of individual power production through PVs (with peak production in summer) and higher shares of heat pumps (with peak demand in winter), the imbalance between seasonal power production and demand will increase. The challenge for grid operators is how to make the most of PV while safeguarding the balancing of the power grid.

Biomass has an advantage in that it is storable, so that bioenergy production can be better matched with demand. In particular, the use of biogas is very flexible and can play a substantial role in balancing of the power grid, where intermittent renewables play an increasing role. One should remember that biogas is more than electricity production, and its role in closing loops (e.g. in waste management) should also be emphasised. To reach optimal efficiencies, heat demand is a central issue for biogas energy conversion.

Converting biogas to biomethane and injecting into the grid should be prioritised, unless there is year-round local heat demand. Using the gas grid provides a large buffer for biomethane, even at base load in summer time. The gas grid then provides flexibility to use the gas for CHP, heat or as transport fuel. There is also room for a smooth introduction of power-to-gas, which links grid balancing with gas production.

There are ways to optimise the use of heat grids. Additional flexibility can be incorporated, particularly when various producers are connected to the grid. There is also a trend to move to lower temperature levels in district heating grids, so that more use can be made of residual heat. Future trends need to be incorporated, e.g. low-energy houses, and increased use of heat pumps by individual consumers. Nevertheless it was stated that the retrofitting rate of houses in Switzerland is quite low (less than 1% per year), while the living area per person increases. So heat demand will still be substantial in the coming decades. Providing baseload heat can still be an interesting business case.

Acknowledgements

A special thanks goes to Sandra Hermle of the Swiss Federal Office of Energy for contacting potential speakers and setting up most of the workshop programme, as well as for hosting the event, and for taking care of all practical issues before and during the workshop. Thanks also to all speakers and the session moderators Jaap Koppejan and Urs Baier. Their contributions are gratefully acknowledged.

Luc Pelkmans, the Technical Coordinator of IEA Bioenergy, prepared the text with input from the different speakers. Pearse Buckley, the IEA Bioenergy Secretary, facilitated the editorial process and arranged the final design and production.

IEA Bioenergy

Further Information

IEA Bioenergy Website
www.ieabioenergy.com

Contact us:
www.ieabioenergy.com/contact-us/