CLIMA 2016 - proceedings of the 12th REHVA World Congress

volume 3

Heiselberg, Per Kvols

Publication date:
2016

Document Version
Publisher's PDF, also known as Version of record

Link to publication from Aalborg University

Citation for published version (APA):
Heiselberg, P. K. (Ed.) (2016). *CLIMA 2016 - proceedings of the 12th REHVA World Congress: volume 3*. Department of Civil Engineering, Aalborg University.

GEMEN

Implementation of Power-to-Gas in the Building Sector

René L. Kobler[#1], Dott Ralf[#1], Steinke Gregor[#1] , Achim Geissler[#1]

[#1]Institute of Energy in Building

University of Applied Sciences and Arts Northwestern Switzerland

[1]rene.kobler @fhnw.ch

[2]ralf.dott @fhnw.ch

[3]gregor.steinke @fhnw.ch

[4]achim.geissler @fhnw.ch

Abstract

This is a project of initiation in which the application of the Power-to-Gas future technology is investigated on plausibility for generating renewable methane for space heating and hot water in buildings. The goals are to substitute the fossil methane by the use of self-produced renewable methane, the inception of seasonal storage and the dynamic convergence of the three grids: electrical power supply, gas infrastructure and district heating. The political goal is to fulfill exactly the specifications of the energy policy of the Swiss Government.

The impact of substituting around 11 TWh/a of fossil methane by renewable methane are considered for contemporary dwellings which are currently connected to the gas distribution system. It can be confirmed, that the implementation of Power-to-Gas in the building environment is feasible and in accordance with the guideline of the Swiss energy transition. For example, substituting the fossil methane by renewable methane a reduction of 1.0 - 2.3 Mio. t CO_2/a can be achieved compared to the current emission of 2.9 Mio. t CO_2/a. The implementation of Power-to-Gas in the building environment will reform the relations between the energy-grids. For this conversion there are still some drawbacks to be handled, which are kind of technical but especially social-economical hurdles. That regards upgrades like Power-to-Gas plants, seasonal energy storage for renewable methane and additional production of renewable electric power and new collaborations between different energy providers. For these issues various options till 2050 are illustrated. The options given are designed to open the discussion among the responsible groups of players.

Keywords - Power-to-Gas, renewable methane-gas, seasonal storage

1. Introduction GEMEN

The Swiss gas supply mainly consists of fossil methane. The final energy demand of fossil methane in Switzerland in 2013 was about 34 TWh/a [1]. This is equivalent to approx. 13.5% of the total fossile fuel consumption in Switzerland (Fig. 1). One third of these 34 TWh/a are delivered to the households currently connected to the grid (around 11 TWh/a). In addition to fossil methane also biogas is used (0.13 TWh/a), corresponding to approx. 0.4% of the supplied fossil methane. Gas consumption in Switzerland is increasing. Switzerland has no own natural gas production, however. 100% is imported from several countries.

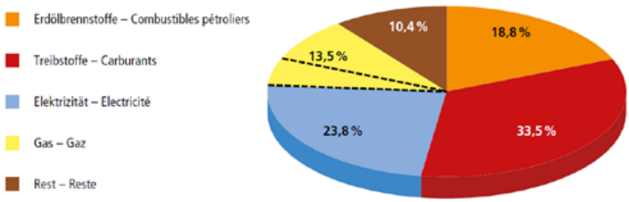

Fig. 1 Part of fossil fuel consumption in Switzerland in 2013, BFE 2014.

The energy reference area of households connected to the gas grid has increased by almost 70 % between 2000 and 2012. The amount in 2000 was 67.6 million m^2 and in 2012 114.1 million m^2 [2], representing approximately ¼ of the energy reference area of all dwellings in Switzerland (24.5%).

The estimated storage potential for methane in the Swiss gas grid will be around 0.1 TWh (end of 2014). In comparison, Germany has an estimated storage potential in the grid of around 200-220 TWh [4]. Taking into account the size difference of the countries which is a factor of ten, the storage potential per capita in Switzerland is still 200 times smaller than in Germany. The natural gas consumption per capita in Germany however, is on the other hand 2-3 times higher. The existing storage potential in Switzerland, especially in regard to seasonal potentials in the required range of several TWh, can be classified as very low.

Today's natural gas infrastructure is not involved in an interacting energy exchange process with other energy grids, as it would be the case with an implementation of Power-to-Gas. The gas grid is only an energy distribution system. The value of the gas infrastructure amounts to 13-20 billion Sfr. [3]. It is an accepted goal on a medium time scale to dispense with fossil energy sources for space heating. This of course is relevant for the future of the existing gas infrastructure. Future maintenance and possible expansion requirements are unclear due to uncertainties in regard to continuing support of the energy transition to 2050 by the government.

To properly understand GEMEN (GEbäudepark und MEthangasNetz), a rough introduction of the Power-to-Gas system (P2G) (Fig. 2) is indispensable. It was invented by Michael Sterner [4]. The Power-to-gas method was originally developed in the context of non-usable electrical power from wind turbines. The surplus power is used to generate hydrogen by hydrolysis. Subsequently, the hydrogen is converted to methane gas by adding CO_2. Basically, a sustainable, closed CO_2-cycle is achieved, which is one of the most significant differences to fossil methane. If renewable electricity and atmospheric CO_2 are used, renewable methane gas (EE-gas, CH_4) is produced. This renewable methane gas can be transported in the existing gas grid. The fossil methane gas is thus substituted by the renewable one. The efficiency of the conversion of electricity to renewable methane is around 60% [5] (Fig. 2). The process of P2G itself is not studied in GEMEN. Relevant data was received from the company ETOGAS (5).

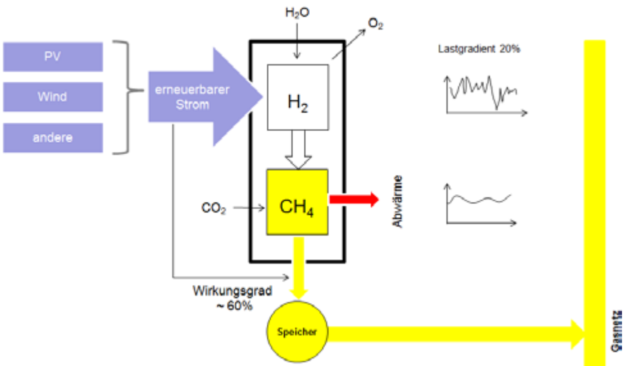

Fig. 2 Power-to-Gas, roughly illustrated

Due to an efficiency increasing through the convergence of the three energy grids gas/electricity/district heating, it is worthwhile also having a look at an implemantation of P2G in the building sector (besides the reconversion to electricity or the use in mobility). The implementation of P2G in the building sector immediately shows large potential for sustainable development. This is for instance the big question of *seasonal* storage of renewable energy, the impact of the replacement of fossil methane by renewable methane itself, and an ongoing usage of the existing gas infrastructure. Above all, the four-base strategies and their three goals of the Swiss energy policy are fulfilled (Table 1). What quantities of renewable methane should be used in a long term view, can not be answered seriously at the present time. However, by utilizing the waste heat in the methanization-process (Fig. 2) an increase in overall efficiency of up to about 80 % is possible.

2. Approach

The plausibility of implementation of P2G in the building sector is checked from the perspective of the Swiss building stock. The project focus is on building-specific concerns. General P2G "questions not answered" are to be treated in following projects. It needs to be examined and assessed whether the use of renewable methane for heating and hot water in the building sector is reasonable and whether the gas infrastructure could be completed into an interacting energy system with the buildings. Hereby, the objectives of the energy transition are to be met (Table 1). The conditions for this fulfillment are always to be seen from the perspective of a total substitution of fossil methane by renewable methane. For this purpose, the following questions are examined:

- Is a total substitution of fossil methane by renewable methane possible for today's gas grid with its connected buildings?
- Is the potential for seasonal energy storage for space heating and hot water worthwhile?
- Does the implementation of P2G in the building sector support the four-base strategy with their three goals for the energy policy of the Swiss Federal Council?
- What are the requirements for the future infrastructure upgrade of the methane gas grid to promote the renewable methane?

Under these aspects, the elements within the system boundary, as illustrated in Fig. 3, will be considered in more detail.

The procedure consists of two main branches. These are the application of a hypothesis testing and the exploration. The hypothesis is based on the above-derived outcomes. It simply is:

> *"The households currently connected to the methane gas supply can be operated with pure renewable gas and thus around 2 million tons of CO_2 will be saved per year."*

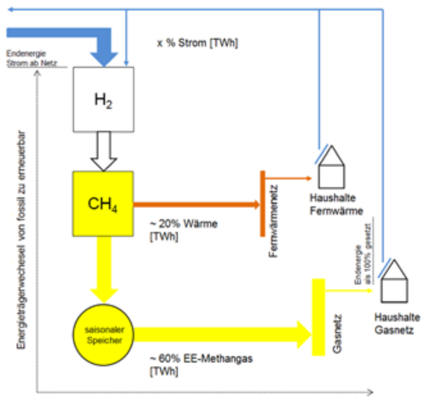

Fig. 3: System boundary in GEMEN

In the exploration phase, the principle of applied research and inter-disciplinary cooperation with stakeholders is used. A systematic search for possible solutions addressed to the above mentioned objectives and key questions is done. The main criteria for assessing the results are based on the four-base strategy and their three objectives of the Swiss energy policy (Table 1). It is assumed that the still ongoing development of the P2G technology obtains economic level, that the required storage quantities for methane is to be supplemented in the existing gas infrastructure and that sufficient renewable electricity for the production of renewable gas will be available in the future. The exploration phase also has to document experienced knowledge. Unclear relationships concerning the combination of energy grids and the building park are to be expected.

3. Results

A total substitution of fossil methane of around 11 TWh/a for households currently connected to the gas grid by renewable methane is possible from a technical point of view. The technologies are feasible and mostly available on the market. This is true in particular, if the required infrastructure for storing renewable methane will be complemented in the existing gas grid, the demand for enough renewable electric power for the production of renewable methane will be fulfilled and the efficiency of the building park will strongly be optimized till 2050.

The existing gas supply infrastructure can be continued. The development and realization of the essential infrastructure can be done evolutionarily (Fig. 4).

The hypothesis is confirmed also with respect to the CO_2 reduction potential. If the production processes for renewable methane is applied correctly, the CO_2 cycle between the production and the later combustion is largely closed. The electrical power must be from renewable sources and itself having a correspondingly low CO_2 load for a targeted maximum CO_2 reduction. The same applies to the required CO_2 for the methanization, probably obtained atmospherically in the long term.

The possible CO_2 reductions by only substituting fossil for renewable methane (calculated for constant methane gas demand in future) are:

- for electricity from PV: 1.0 million tons CO_2 /a
- for electricity from wind power: 2.3 million tons CO_2 /a

Compared to today's CO_2 emissions of 2.9 million tons/a, this corresponds to savings of 34 % resp. 79 %. Based on the annual total national CO_2 emissions of around 40 million tons, it corresponds to 2.5 % and 5.7 %, respectively. The reduction by improved efficiency of a good thermal insulation of buildings is not included in these figures. This would further reduce the CO_2 emissions.

Furthermore, the use of renewable methane for space heating would immediately lower CO_2 emissions (indirectly comprehensable in Fig. 4). This is favorable, because the current renovation rate of older buildings in Switzerland is only approx. 1 %/a and residential buildings from the middle of the last century show heating demands of up to 800 MJ/(m^2 a).

The classification of the results according to the four-base strategy and their three goals of the Swiss energy policy leads to following results (Table 1):

Table 1

Bases and Goals	**Fulfilling**
Base 1 *Energy Efficiency*	The need to increase energy efficiency in the building stock (based on space heating and hot water) is confirmed, because renewable energy is not "infinite" in the sense of endless availability per time. Reduced energy demand through efficiency measures (taking into account embodied energy) reduces the required amount

	of renewable energy and thus the pressure on the environment (e.g. wind turbines). The target standard for energy efficiency in buildings should be in the range of passive house standard.
Base 2 *Promotion Renewable Energy*	This is fully complied with, striving for a total substitution. The substitution of fossil by renewable methane is very direct (CH_4 to CH_4). Much of the existing infrastructure can be used, meaning the grid itself but also the established technology like gas boilers or combined heat and power.
Base 3 *Replacement and Expansion of big Power Plants*	The development of plants for renewable H_2 and CH_4 production corresponds to the intention of needed infrastructure. The infrastructure for seasonal storage of renewable methane allows the inclusion of energy harvest in summer for use in winter. In that order the Base 2 and Goal 1 supported.
Base 4 *Energy Foreign Policy*	Domestically harvested and stored energy yields a different position with other countries. The purchase of fluctuating electricity (low cost) can be maximized.
Goal 1 *Security of Supply of Energy*	This will be increased by the accessibility of stored energy. First mainly for space heating and hot water, but also with regard to additional use for other sectors.
Goal 2 *Reducing Greenhouse Gas*	The CO_2 reduction is guaranteed by inputs with low load of CO_2.
Goal 3 *Reducing Dependence of fossil Energy*	The independence increases with the substitution of the renewable methane.

4. Outlook

There is further research to be done in several projects for this future technology and its implementation, which have to accompany an appropriate overall development until 2050. That could be impetus for the development of methane terminals, the creation of guideline documents for infrastructure investments and also for the realization of demonstration projects. When the plants for the production of renewable methane will be realized (including those for renewable electricity) the public permit process will also be one of the big challenges. This is not a technical problem but a socio-economical one.

Furthermore, it is foreseeable that the energy contained in fossil sources must be replaced by renewable sources (minus the savings by increasing efficiency of the buildings). In this case, the access via the electricity sector is being called. This in a situation, where other scopes, such as the replacement of nuclear power plants or electrification of mobility, are upcoming. With excellent thermal insulation standard in the building stock, an electricity demand of around 7 TWh/a can be expected for the dwellings within the system boundary of GEMEN.

The alignment and the fulfillment of the four-base strategy and their three goals of the Swiss energy policy can be shown with simplified conditions (Fig. 4). The differently greyed triangles represent efficiency of the building stock, the dependence on imported fossil methane and the necessary promotion of renewable energy. The three subjects are described in Table 1.

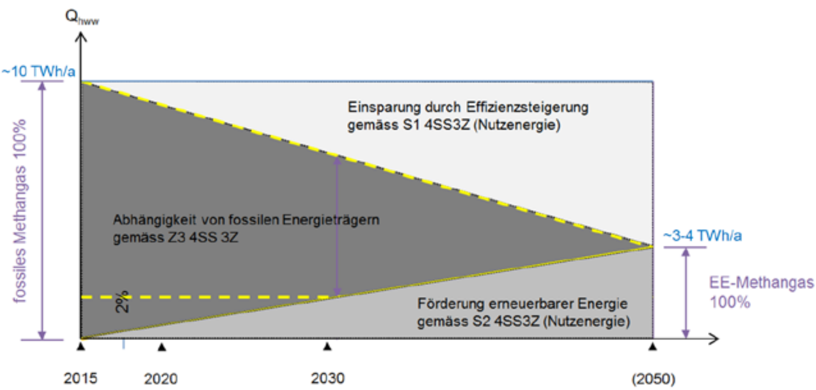

Fig. 4 Supposable approach till 2050 and the relations between efficiency/dependence on fossil energy/promotion of renewable energy.

In step with actual practice into a realization of P2G in the building park, questions remain still to be answered at the moment. In the project GEMEN, the implementation of P2G in the Swiss building stock was examined and its plausibility confirmed. The merging of electricity, gas and district heating on the basis of such an implementation is absolutely new territory with economical risks attached. Expected obstacles are less of a technical, but more of a socio-economic nature. In order to address these obstacles, GEMEN 2 is in preparation. Sequences to be captured practically, based on a theoretical building permit process of a P2G project in a district, can explore such obstacles. The case made relevant findings will be analyzed, evaluated in the context of the four-base strategy and their three goals. This essay intends to expand solutions for a successful implementation. Further technical research projects are also planned.

5. Acknowledgment

The research project was funded by the Swiss Federal Office of Energy (SFOE). We thank a lot for this opportunity, to be able to clarify this important question. We also thank FOGA (Forschungs-, Entwicklungs- und Förderungsfonds der Schweizerischen Gasindustrie) for supporting the research. Our gratitude is also adressed to all the professionals, coming from Industry and public authority. Without their help, knowledge and engagement, such projects would not be feasible.

6. References

[1] BFE; "Schweizerische Gesamtenergiestatistik 2013"; 2014.
[2] Prognos AG; "Der Energieverbrauch der Privaten Haushalte 2000-2012"; BFE; 2013.
[3] NFP 54, "Was kostet das Bauwerk Schweiz und wer zahlt dafür"?; 2011.
[4] Sterner Michael; "Bioenergy and renewable power methane in integrated 100% renewable energy systems"; Fraunhofer IWES; 2009.
[5] ETOGAS (Stuttgart); "Entwicklung, Herstellung, Vertrieb von Power-to-Gas Anlagen"; www.etogas.com (21.01.2015).