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Biomethane supply support policy: system dynamics approach

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Abstract

Support for renewable energy currently is revised in many countries due to the perception that the economic burden caused by the support exceeds the permissible limit. Decreased or suspended support creates instability in renewable energy production. There is a lack of research related to design of the sustainable renewable energy support policy, which considers the structure of the support policy system in detail leading to successful implementation of such support. The aim of the study was to create the model which helps to devise biomethane supply support policy providing controllable and stable growth of biomethane production over time avoiding relapsed "overshoots and oscillations" in the system. Due to the dynamic and complex character of energy supply system policy decisions, system dynamics was used as the method. The results show that the main parameters which have an impact on stability of the support policy are feedbacks linking the total biomethane support payments, the granted permits, the perceived limit of the support, willingness to invest in the production assets as well as time delays of the action resulting from the feedbacks. The results show that biomethane production can reach up to 610 GWh with the support of 66 EUR per MWh in 2030 without exceeding the perceived support limit and avoiding fluctuations in the system. The developed method-model can be used by the researchers and energy policy developers to study the dynamics of investments into biomethane supply systems and the resulting biomethane production volumes depending both on the sizes of the subsidies provided for the biomethane as well as the structure of the support system.

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Keywords: biomethane; energy dependency; energy strategy; renewable energy support policy; system dynamics

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1. Introduction

The most significant local energy resources in Latvia are wood biomass and hydro energy. In 2012 up to one third of the total primary energy consumption were provided by the local energy resources (int. al. 1.1 % by biogas). The rest of the part of the energy resources were imported from different states of the Baltic region, the European Union (EU) and also from third countries, including Russia [1]. Although the share of renewable energy sources (RES) in Latvia in the final energy consumption is quite high (35.8 %), Latvia is still heavily dependent on natural gas supplies from Russia [2, 3] providing 26.7 % of the total primary energy consumption[1].

Latvia has set a goal to increase the RES proportion in the gross final energy consumption by up to 40 % and 50 % in 2020 and 2030 accordingly, and to reduce energy import from current third country suppliers by 50 % compared with 2011 [4]. Several problems will have to be addressed in Latvia's energy policy in the future, i.e.:

- Requirements for biogas injection into the natural gas transmission system have not been established [4];
- No requirements for the gas quality have been defined;
- Current national support schemes create an additional burden on the end users.

According to the report of the European Biogas Association, the most common way to support RES in the EU was through a feed-in tariff FIT [5]. Along with Switzerland, Italy and Greece, Latvia was one of the EU states where biogas cogeneration plants received the highest support for the produced electricity – 251 EUR/MWh for plants with the electric capacity up to 80 kW with efficient CHP production [5]. FIT and the state-determined mandatory procurement system in Latvia was very successful in promoting RES, especially in the small hydro power sector, where the production increased from 2.5 to 30 GWh in the period from 1996 till 2001 [6] and also in the biogas sector. Yet, it should be noted that the technology cost for production of the energy from RES is expected to decrease with time and expansion of the technology. Therefore, it is planned to stop applying FIT in Latvia as it has proved to be suitable as a short term incentive only [4]. The waiver of FIT is also in line with the EC guidelines where the EU member states are encouraged to replace the FIT with a feed-in premium (FIP) to the market price. That is, Member States are suggested to create and initiate support mechanisms developed according to market-based principles [7]. In four EU countries, i.e. in the Netherlands, Denmark, Estonia and Finland, the FIP system is implemented to support producers of electricity from RES [5].

The number of biogas plants in Latvia has increased slowly since 2004. To a certain extent this was urged by the EU and global trends to shift to RES, to some extent also in the context of the Kyoto Protocol, as well as the fact that EU funds supporting such projects became available (Latvia joined EU in 2004). It should be noted that several ministries are involved with RES issues in Latvia. Each of them develops their own guidelines, rules and regulations and besides ministries have weak mutual communication. Wherewithal, but mainly due to the notable financial support that became available (e.g. EU-Program for Agriculture is available in Latvia – it covers about 40 % of investments costs) and also due to the regulatory changes in 2007, the willingness to invest in biogas CHP's increased rapidly and it created a situation that all the quotas within the mandatory procurement scheme were reached in a very short time. Since 2008, installed net electric capacities of power plants using RES (including biogas plants) have rapidly increased. Until 2006 only a few biogas plants were in operation, five years later there were already 27 biogas plants, ten more plants started to operate in 2012 [5] and 56 biogas plants sold the produced electricity in accordance with the mandatory procurement in 2014 [8].

Since the FIT in Latvia is bound to the price of natural gas, which has rapidly risen, the overall electricity price has also increased. This situation led to strong dissatisfaction in the industrial sector. The government decided to take measures to stabilize the situation. In 2011 the quotas (the granting right to sell the produced electricity as the amount of electricity to be mandatorily procured and the right to receive a guaranteed fee for the electric capacity installed in a power plant) was suspended and this decision most likely will remain in force until 2017. Complex, unclear and unstable RES-related legislation led to the situation that the willingness to invest decreased rapidly and the development of the RES energy sector in Latvia in recent years has come to a standstill. In addition, a number of problems were identified and a number of conclusions were drawn. The main conclusions include: there is a need to change the pricing formula; selection of the quota acquirer should be carried by the price offered; and a well-defined control mechanism should be initiated. For the latter suggestion, in the case of a new biogas plant, the electricity production had to begin within 24 months of issuance of the license (the quota was valid for 2 years).

Upgraded biogas (biomethane) is a well manageable energy source. It can be injected directly into the natural gas grid, stored, distributed and used in the same way as natural gas and it does not depend on seasonality. Therefore, biomethane is known as one of the most important renewable substitutes for natural gas. But the main barrier for biomethane injection is the cost of biogas production, upgrading and development of infrastructure. In addition, there is no legal framework for the biomethane grid injection in Latvia.

As a tool for the conceptualization of energy systems, the system dynamics (SD) approach is successfully used to address various energy policy issues both worldwide and in Latvia. For instance, structural validity of a SD model to assess the energy policy of Pakistan was carried out by [9]; SD approach in combination with the quality function deployment was used to create the energy security management model in developing economies, with the Korean gas sector as an example [10]; to understand the dynamics of electricity generation capacity in Canada [11] as well as to assess the role of renewable energy policies in energy dependency in Finland [12] and to analyze the dynamics of the biomethane production chain [13]. SD modeling was also applied for renewable energy and CO_2 emissions in Ecuador [14] and to see how China might achieve its 2020 emissions target [15]. The SD approach also has been used in several studies of the Latvian energy issues before: on wood energy market development [16] and to promote the use of wood fuel in the Latvian district heating system [17], as well as to design the future biodiesel policy and consumption patterns [18], to investigate the conceptual system that uses intermitted renewable energy resources to produce hydrogen and fuel [19], and to outline the dynamics under the market of energy efficiency in both municipality and state owned buildings [20].

Nomenclature

CHP	combined heat and power plants
CLD	Causal loop diagram
FIP	feed-in premium
FIT	feed-in tariff
LHV	lower heating value
MPC	mandatory procurement component
RES	renewable energy sources

2. Methods

The aim of the study was to create a model which helps to devise biomethane production support policy providing controllable and stable growth of the biomethane production over time avoiding relapsed “overshoots and oscillations” in the system. Due to the dynamic and complex character of energy supply system policy decisions, the basic, interdisciplinary SD [21–23] approach was used.

The scope of the model includes the parts representing a policy for granting biomethane production permits and dynamics of construction of the physical assets for the biomethane production. These parts are modeled as co-flows and stocks of permits and physical biomethane production assets. The model was validated using data about historic dynamics of increase of the capacity of the biogas cogeneration plants in Latvia. Historical data were gathered from the registers of the Ministry of Economics and Central Statistical Bureau of Latvia [2].

Due to the number of factors which have an effect on energy policy, as well as the complexity of such system, the SD approach was used to review the consequences of policies and scenarios. Fig. 1 shows the main elements and the feedback loops which explain the existing structure of biogas CHP support system and the problems it created.

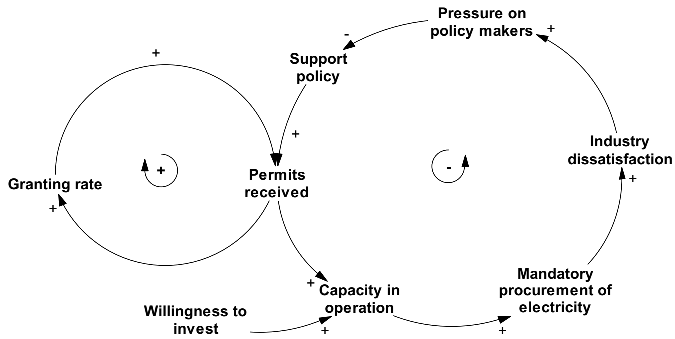

Fig. 1. Causal loop diagram (CLD) defined in a research to assess the biogas CHP support system.

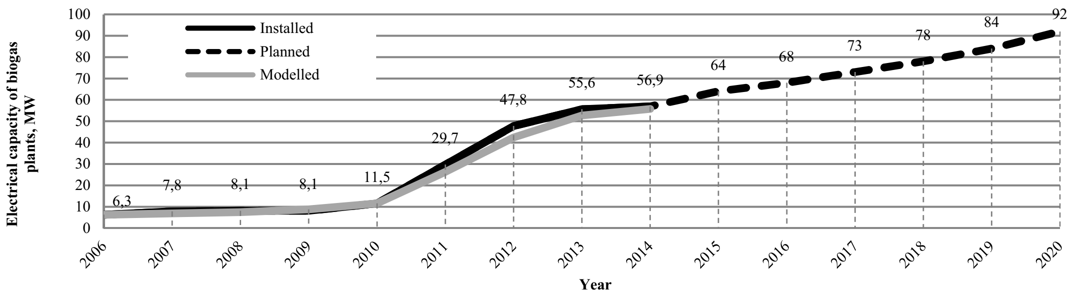

Fig. 2. Comparison of the actual (till 2014), simulated and planned [24] total installed electric capacities of biogas CHP plants.

According to Fig. 1 and 2, it is a typical S-shaped growth system. Support policy positively affects the number of permits received (+). This in turn increases a granting rate and plant capacity in operation, and also sequentially capacity in operation is increased by the willingness to invest. The capacity in operation increases mandatory procurement of electricity that causes industry dissatisfaction and creates pressure on policy makers and hence causes negative effect on support policy (-). The problem from the policy point of view was such that policy makers started to react only when pressure of industry reached a certain level, and the reaction was sudden the termination of permit granting.

Using the structure, which is presented by the above CLD, a SD model is constructed to develop biomethane supply support policy. According to Latvia's national action plan for promoting renewable energy, Latvia should have a total installed electric capacity of biogas plants equal to 92 MW by 2020 [24]. Fig. 2 illustrates the historical pace and future trend required to achieve this goal, and if it is chosen to continue support of the electricity produced by the biogas CHP plants.

The SD model, which represents the historical growth of the total installed electric capacity of biogas CHP plants was created and verified with historic data about the dynamics of increase of the capacity of the biogas cogeneration plants in Latvia. The verified model, after some modifications of the structure (additional auxiliary parameters were introduced and they are described further), was used to develop future scenarios for biomethane support policy.

Bio-methane support policy is modeled almost the same as the existing biogas CHP support system (Fig. 3). The structure of the model includes the parts representing a policy for granting biomethane production permits and dynamics of construction of the physical assets for the biomethane production. These parts are modeled as co-flows and stocks of permits and physical biomethane production assets (Fig. 4).

The SD model was developed using the Powersim Studio 8 software platform, and the simulation period was selected to be 2017 – 2030.

There are three stocks with the respective flows:

- Permits received and granted, cancellation rate of permits, as well as the flow of annual permits leading to investment;

- Capacity under construction;
- Capacity in operation with capacity order rate, commissioning and de-commissioning rate.

The ‘Granting rate’ in the model of biomethane support policy is influenced by two newly introduced delayed parameters: ‘Granting rate of de-commissioned permits’ and ‘Effect of the fraction on the granting rate’. The latter is the main instrument of the support policy, i.e. the pre-determined relation between the ratio of actual and limit (set by policymakers) values of the support and annually granted permits of biomethane production capacity. The ‘Cancellation rate’ represents the permits which are cancelled if not realized during the two year period. It is assumed that willingness to invest will rapidly increase for the first 3 years since 2017 when the trust to the support policy will be re-established, and then will remain stable at a level of 75 %. Willingness to invest determines the number of permits leading to investment, i.e. ‘Capacity order rate’. The ‘Commissioning rate’ is designated by the average construction time (18 months) of the plant and by the ‘Capacity under construction’. The ‘De-commissioning rate’ is determined by the period of support (10 years) and ‘Capacity in operation’.

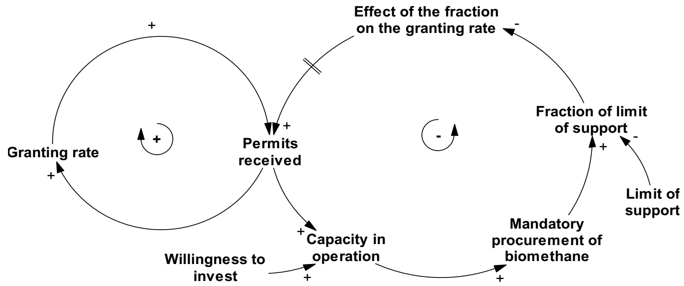

Fig. 3. Causal loop diagram representing the structure of the biomethane support policy.

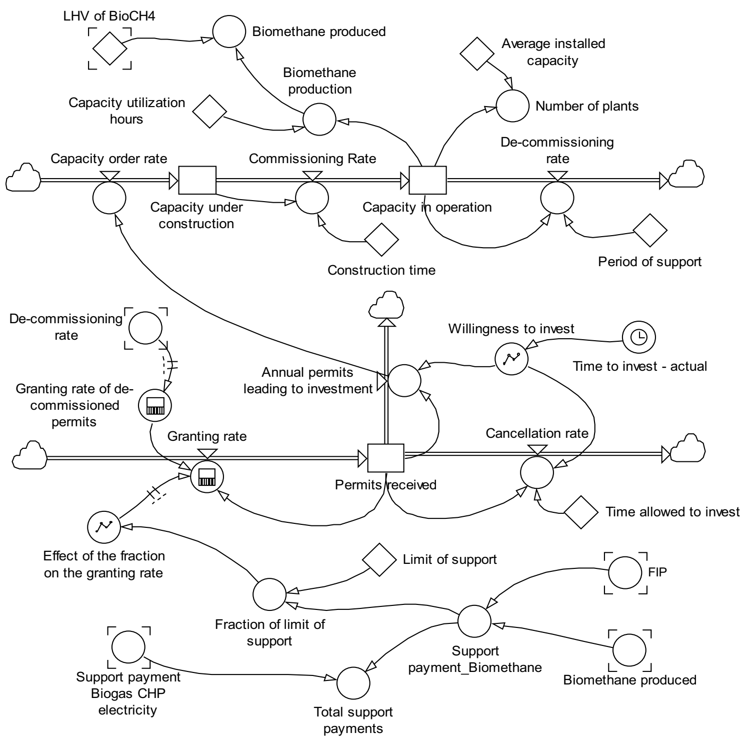

Fig. 4. System dynamics model of biomethane supply support policy.

The model also takes into account installed electric capacity of the existing biogas CHP plants, electricity produced from biogas CHP plants and also support payments – FIT for biogas CHP electricity (an average FIT paid during the last years is 136 EUR per MWh). Spatial lay-out of the biogas production and upgrading infrastructure was not considered in the study, but construction of gas pipelines in average distance of 16 km (for one plant) for injection into the natural gas grid was included in the investments. Limit of support is set at 40 million EUR per year, which was the average payment during last years to support electricity produced at the biogas CHP plants.

Due to lack of heat loads for the existing biogas CHP plants, biomethane production instead of electricity production may be supported in the future. Therefore, two different support policies were considered and simulated using the model:

- Feed-In Tariff (FIT) – the constant previously calculated tariff which is quoted in the long-term contract between biomethane producer and government;
- Feed-In Premium (FIP) – more market-oriented FIT design when a premium payment on top of natural gas market price is paid. It is assumed that the fixed revenue is guaranteed and the premium varies as a function of natural gas market price. Both, FIT and FIP are affected by decreasing specific investment in the biomethane production facilities due to learning effect.

3. Results and discussion

At present, the amount, which is paid as a support for electricity produced at biogas CHP plants, is about 36 million EUR. Results show that if the constant FIT is initiated, for the first three years, while the biomethane industry is in the development stage, the amount of support to be paid would decrease along with the reduction of the amount of electricity produced from biogas (Fig. 5a). However, in the coming three years, due to development of the sector, the support limit (i.e. 40 million EUR per year) would be achieved and an overshoot would be caused for both the support payment for biomethane and the total support payment and it would remain high (Fig. 5a). Besides, the support would be sufficient to produce approximately 375 GWh per year in the end of 2030 (Fig. 5b). According to estimates, the most rapid development of the biomethane sector would begin in the third year (it is assumed that two years are necessary for plant construction) and would cease in the tenth year. The volume of produced biomethane would even start to decline at the end of 12th year (Fig. 5b).

On the contrary, if FIP support policy would be initiated, biomethane industry would develop a little bit slower initially, but support payment for biomethane would not exceed the limit (Fig. 6a). In case of the FIP support policy, the payable amount of support would decrease for the first four years, but then it would gradually increase, reaching the limit during the next eight years (Fig. 6a). Moreover, with the FIP support policy 610 GWh of biomethane could be produced annually at the end of 2030 (Fig. 6b). Like in the case of FIT support policy, the amount of biomethane produced would start to increase in the 3rd year. However, unlike the FIT incentive, development of the biomethane sector would not stop or reduce in the coming ten-eleven years in case of FIT (Fig. 6b). On the contrary, in total nearly, by 8.000 GWh more of biomethane would be produced with FIP than with FIT support policy. It is calculated that the FIP payment for one MWh of biomethane would decrease by 19 EUR during the period from 2017 to 2030 and the FIP in 2030 would be 66 EUR per MWh of biomethane.

Analyzing the total amount of support payments that have been disbursed to 2030, it can be concluded that according to the FIT support policy, the amount to be paid for the produced biomethane would be 1.223 million EUR higher that would be paid with the FIP support policy. This difference is explained by the different policy approaches. FIT could be defined as a constant previously calculated tariff which is paid for a long period (for example 10 years), but policymakers can also design it decreasing over time. Whereas, FIP is a market-oriented tariff with a premium payment on top of the natural gas market price. Therefore, when the natural gas prices rise, then the payable FIP amount decreases. In addition, the payable FIP amount also is influenced and decreased due to the learning effect when specific investment in the biomethane production facilities decreases. Regardless of the chosen policy, the share of the support for electricity from biogas CHP in the total support gradually declines, because the support period for the existing biogas CHP plants ends.

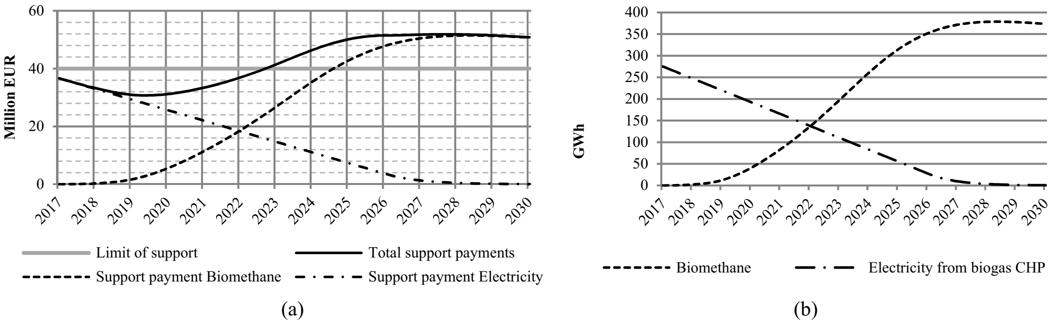

Fig. 5. (a) Costs of FIT support policy; (b) Biomethane and biogas CHP produced electricity.

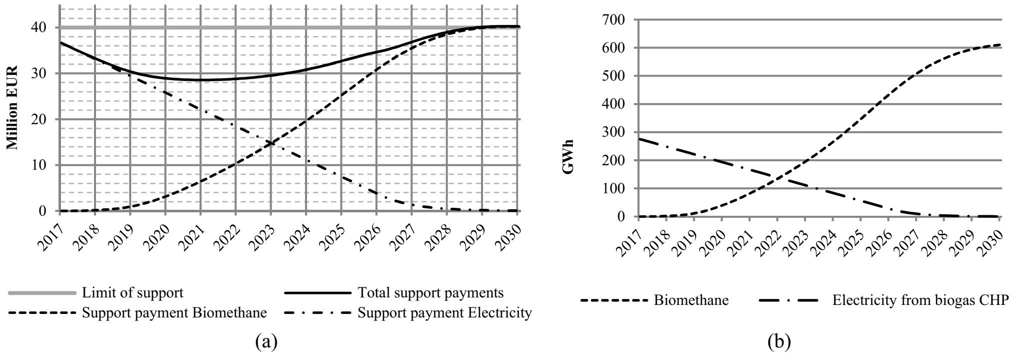

Fig. 6. (a) Costs of FIP support policy; (b) Biomethane and biogas CHP produced electricity.

According to the Proposal for a European Biomethane Roadmap [25], two years ago biomethane was produced in 14 European countries and the biomethane sector is evolving quite rapidly [5]. In 11 European countries mostly (100 % of cases in the Netherlands and United Kingdom and ~98 % of cases in Germany [26]) biomethane is fed into local natural gas grids. These facts agree with assumptions about development of biomethane sector in Latvia and the scenario that also in Latvia biomethane would be injected into the natural gas grid. It is clear that under the current market conditions, biomethane production should be supported to compete with natural gas sales price. The report's [25] authors admit that the biomethane production rate would increase, if a support mechanism for biomethane grid injection were introduced to make the production economically comparable with the price of electricity produced at biogas CHP plants. Currently France and United Kingdom have introduced FIT for biomethane injection into the natural gas grid [25]. In France FIT is dependent on the capacity of biomethane plant and the type of feedstock used.

In addition, preference is given to smaller size units processing organic waste materials [25]. In other EU countries different incentives are introduced, such as 'technology bonus' for generating renewable electricity (in Germany and Austria), tax reliefs (in Sweden) and others [5, 25]. Nonetheless, the European Commission suggests replacing FIT with incentives to make producers respond to market developments [27] and these recommendations are in line with conclusions of this research. There is no need to carry out a comparison of the amount of payable support in different countries, since labor costs, feedstock and natural gas prices, etc. differ in each country, which affects the FIP amount.

Although the FIP support policy seems to provide more controllable and stable growth of the biomethane production over time, further research and calculations of investment support policy should be carried out. As well as sensitivity of different parameters in the system of support policy such as time delays of the action resulting from the feedbacks, time allowed to invest, as well as changes in the limit (annual growth of the support limit, for example) or period of support (15 instead of 10 years) should be considered. It also would be important to assess the changes caused in the system if capacity of biogas plants would be adjusted to ensure economic feasibility of the plant.

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