Dynamic Model of the Farm Producing Biogas from Agriculture Biomass

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ABSTRACT

As the technologies of the renewable energy production evolve, the sustainability aspects of the renewable energy production are topical at the moment. Dynamic modeling allows to design the whole production system and test the technological and economic aspects of this system for it`s efficiency and sustainability in a defined period of time. The Dynamic model, described in the article is set up for a farm that produces biogas from agriculture biomass. Dynamic model includes full cycle of agriculture production and consists of several mutually connected blocks: production (grain, biomass, milk, meat, biogas, heat, electricity), finance (investments, income, outcome, subsidies, loans), resources (arable land, farms, bioreactor, technical equipment, workforce), and risks (risk evaluation, risk reduction). The module is created within the Powersim Studio 7 software and tested with the data of the Latvia University of Agriculture (LUA) Study and Research farm ,,Vecauce'' biogas production plant.

Key words: Farm optimization, dynamic model, risk management

1. INTRODUCTION

Following the world tendencies the topicality of renewable energy production in Latvia is increasing. Currently, the most of the electricity from renewable resources is made from hydropower plants, but 1% of electricity in Latvia is produced by cogeneration of biomass [2], which is seen as a perspective source for increasing renewable energy production under the conditions of Latvia. The development of cogeneration plants is largely encouraged by funding from the EU structural funds, Cohesion fund and European Agriculture fund for rural development available from the government of Latvia and the EU in past few and the following years till 2013.

At the moment there are 23 biogas production plants working in the territory of Latvia with a total power capacity 29.92 MW, but till the year 2030 it is planned to increase the total production capacity till 90 MW (producing biogas from various biomasses) [2]. With the extending of biogas production from agriculture biomass sustainability aspects, risk assessment and risk management becomes topical in farms, that produce this kind of energy.

Currently in LUA biogas production technology studies, research on energy crop growing and biogas production economic assumptions are carried out. In this article the experience in setting up an all-embracing risk evaluation in farms that produce biogas and an attempt to create a dynamic module connected to the risk management mechanisms is reflected.

2. MATERIALS AND METHODS

A farm, that produces biogas is viewed from the system theory perspective [1]. Firstly the outside environment and it`s impact on the farm was determined: laws, regulations, subsidies, quotas, etc. The research was based on the data of a farm that is engaged both with crop production and dairy-farming and biogas production is an auxiliary sector. The crop production sector firstly serves to provide fodder for dairy cows – biomass for silage and heylage. Likewise crop production provides biogas reactor with maize or grass biomass [4]. The additional free arable land is fully used for grain production and growing of rape. The optimization of arable land is made by the following linear optimization task:

To find x_{ijt} values to maximize the income from crop-production.

$$z = \sum_{i=1}^{n} \sum_{j=1}^{m} \sum_{t=1}^{T} c_{ijt} \, a_{ijt} \, l_{ijt} \, x_{ijt} \rightarrow \max$$

By conditions

$\sum_{i=1}^{n}\sum_{j=1}^{m} a_{ijt} l_{ijt} x_{ijt} \geq A_{jt}, \quad t = 1,2,3,...,T$, the minimal demand for crop production is secured;

$\sum_{i=1}^{n} l_{it} x_{ijt} \leq L_t$, arable land constraint in t year;

$\sum_{t=1}^{T} x_{ijt} \leq 2*(T/3)$, constraint for crop production culture change in the field at least every 3 years;

$$x_{ijt} = \begin{cases} 1, if\ \ in\ \ t - year,\ i - \ field,\ j - culture\ \ is\ \ sowed \\ 0 - the\ \ oposite \end{cases}$$

The need for crop production A_{jt} is determined by the need for fodder and biogas production that is simulated in the dynamic model.

The dynamic model of the farm consists of several mutually connected modules: resources, production, finances and risks. Resources include 5 blocks (see Fig. 1): arable land, production premises, technical equipment and vehicles, personnel and optimization of crop production sector. The module *Resources* is located in the MS Excel software, including the optimization block. Information Exchange between MS Excel and Powersim Studio is done by using Studio Dataset. The second module – *Production* – includes the following blocks: grain production, rape production, biomass production, reproduction of milking cows, milk production, biogas production, heat and electricity production. All these blocks have Powersim Studio dynamic flow modules that, of course, are mutually connected. For example biogas production block includes biogas production flow module that accordingly is connected with the milking cow module, biomass production module and also heat and electricity production modules (see Fig. 2).

Finance module includes 3 blocks: income, costs and profit. Data for assumptions of income and costs are gathered form the production block modules.

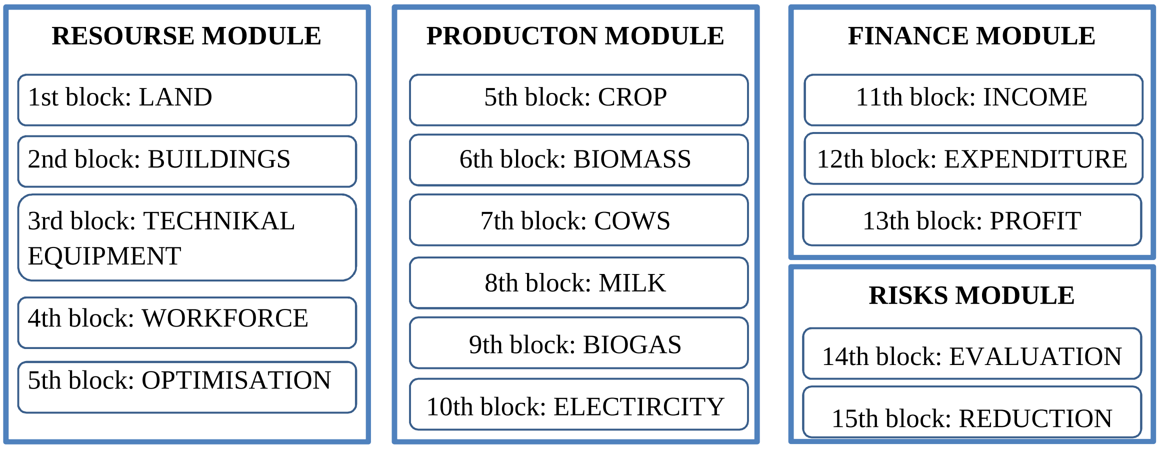

Figure 1. **Structural scheme of the farm dynamic module**

Risk module consists of two blocks: risk assessment and risk reduction. To define risk assessment variables expert interviews were used and the variables with the highest significance and likelihood of occurrence where chosen [3]. For risk reduction the Powersim Studio tool Risk Management was used, that allows reducing and diversifying biogas production risks.

As the basis for biogas production module, the LUA study and research farm ,,Vecauce'' biogas plant was used. It is built using *WEL tec BioPower GmbH* technology [5]. This technology is characteristic with biogas production in mezofil fermentation process, the brutto capacity of the fermenter is 2 006 m³.

As a substrate in fermenter cattle manure, maize silage, grain and other substrates can be used, for the post-fermentate a 4 100 m³ tank is built. A container-type TES with the electric power capacity of 260 kWel (for the production of electricity) and a heat production capacity of 310 kWter (for production of heat) is used for biogas procession into electric energy and heat. The nominal power capacity in the reactor is achieved within a year.

Gas engine is produced by a company *Libherr* [6], but the generator by *Marelli* [7]. Gas consumption is 140 Nm³/h and temperature of the hot water is 70/90 ºC. The forecasted annual production of electricity is 2 184 MWh. For the technological use in the plant 110 – 120 kW of heat are required or about 30% from the total amount of produced heat in the plant.

The production of biogas is limited by the maximal capacity of the bioreactor and the amount of manure form the dairy cow farm. The amount of manure is determined by the number of dairy cows in the farm, in the MPS ,,Vecauce'' there are 500 dairy cows. The amount of biomass for the biogas production can be supplied according to the necessity by increasing the production fields of maize or grass jet the priority of the simulation is to secure dairy cows with the fodder from the agriculture production of the farm.

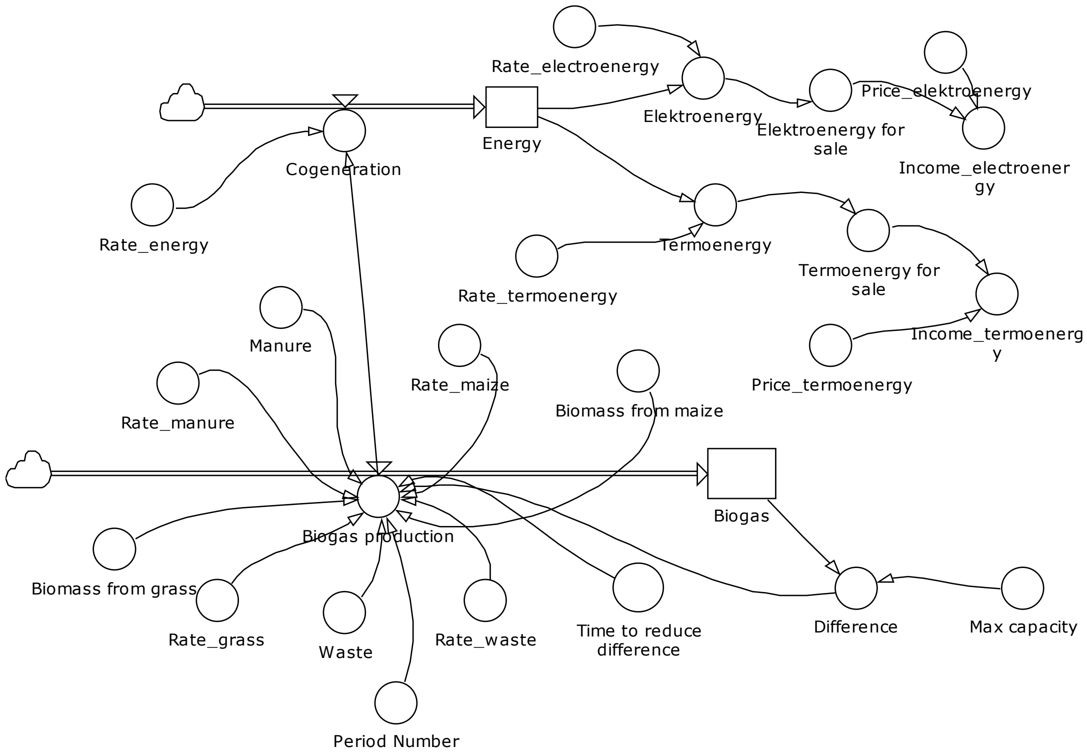

Figure 2. **Flow diagram of the biogas production dynamic module**

In the flow diagram the variables that determine biogas production are shown. These variables are modulated in other blocks of Production module, for example, biomass form maize and biomass from grass are modulated in the block – Biomass. Biogas outcome id assumed as a probable variable with a normal distribution, that is determined by an average value and a standard deviation.

3. RESULTS AND DISCUSSION

Each of the blocks of the Production module gives an outcome in the process of simulation: grain yield, biomass yield, number of dairy cows and an amount of milk produced, etc., as well as income and costs of the production in the farm. All production costs and income of the farm is summarized in the Finance module and it gives a possibility to estimate the profit of the farm. For example, production of electricity from biogas is characterized by the following charts: produced electricity and income from sale of the produced electricity.

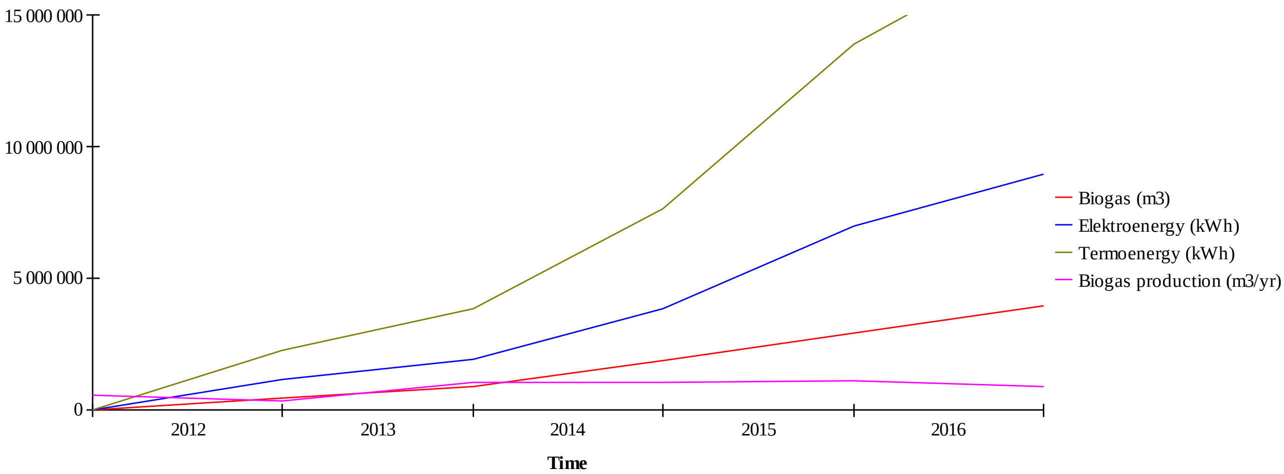

Figure 3. **Biogas production result chart**

4. CONCLUSIONS

Biogas production from agriculture biomass is a new type of economic activity for farms in Latvia that is currently supported from the state through purchase tariffs and from the EU in the form of co-funding for investments.

Dynamic module allows to cover the whole cycle of biogas production, procession and distribution of the produced energy, by including agriculture and dairy production, biogas production itself and the subsequent cogeneration of heat and energy. Thus it allows improving the whole production cycle of the farm and testing the sustainability and economic efficiency of the renewable energy production in a defined period of time.

Dynamic simulation also provides an opportunity to evaluate production risks and plan possible risk management alternatives as risk transfer, risk reduction, etc.

After creation of the conceptual module it needs to be calibrated carefully according to the parameters of the specific farm with an aim to increase the reliability and applicability of the simulation results.

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