The importance of Modelling the Environmental Impacts of a Biomass Based Electric Power Generation for public safety

ROBERT BAŤA, PAVLA PŮLKRÁBKOVÁ
Faculty of Economics and Administration
University of Pardubice
Studentská 95, 532 10 Pardubice
CZECH REPUBLIC
robert.bata@upce.cz, PulkrabkovaPavla@seznam.cz, www.upce.cz

Abstract: This paper deals with the issues of the impacts of renewable energy sources utilization. It focuses on a biomass based electric power generation and modeling possibilities of its environmental impacts. It also includes a case study with analysis of individual processes, which take place in chosen biogas plant. For the process analyses modeling methods were used. For model implementation were used Petri nets.

Key-Words: renewable energy resources, emissions, biomass, biogas plant, Petri nets, air pollution, public safety.

1 Energy Resources

The current development is characterized by continuous growth of requirements for the amount of consumed fuels and energy. As Šatera writes “The significant worldwide growth in renewable energy capacity is recent and has been observed mainly since the end of 2004 when it grew at rates of 10% to 60% annually for many technologies” [22]. This problem is also amplified by the current developments in world population growth. The result is a rapid decline of fossil fuels and negative environmental impacts associated with their use [2,20]. In the 20th century, energy was obtained mainly from non-renewable sources. Those are resources depletion of which is expected within hundreds of years latest, but their eventual recovery would take much longer [19].

The decisive share of strategic raw materials such as crude oil and natural gas is located in the Middle East, a politically unstable region. In contrast, the largest economic centers such as the U.S., European Union and Japan don’t have such big fossil energy sources available in their area. Under such circumstances the risk of energetic dependency on politically unstable mining areas brings the risk of an outbreak of regional energy crisis caused by increasing energy costs, which could escalate into a global economic crisis. This seems to be real and likely to happen sooner or later [11,23].

For these reasons, the emphasis is on finding new, in places of consumption available, energy sources. Because these areas of consumption do not have enough fossil fuels available, it will be focused on renewable energy sources. Another advantage of renewable energy sources is their environmental friendliness. But even these have their limits, especially geographic and climatic conditions [1,11]. Likewise, the use of renewable energy sources, though it is presented as environmentally friendly, induces environmental burden too. The Czech Republic achieved 10% share of electricity generation from renewable sources in gross electricity consumption during 2012. This requirement is met mainly through the development of large solar power plants, which, however, due to purchase price subsidies system setting appear to be highly unprofitable. Great potential for recovery, however, is offered by still unused resources in the form of biomass. In this context, it should be added that the characteristics of renewable energy sources forbids the approach to focus on a single source, which will then be preferred. The use of renewable energy sources must always be based on an analysis of demanded forms and the appropriate combination of different renewable sources. It is necessary to take into account especially the available potential of selected sources in the particular area.

Current trends of corporate performance evaluation have to take into account their environmental, social, economic performance [6]. This paper aims to design a model for quantifying the energy potential and environmental impacts of energy use of biomass in the form of biogas and all areas affected.

In the case of biomass in relation to energy, this term is usually used for wood and wooden waste, straw and other agricultural products. This energy source is considered very promising and is expected to be able in future to replace a substantial portion of non-renewable energy sources - coal, petroleum products and natural gas [1,11].

The question is to what extent the potential of biomass is sufficient to cover the total energy consumption and to what extent it will be necessary to combine with other sources. Due to the limited amount of available inputs for sustainable energy production, it would certainly be wasteful not to use available resources.

2 Use of Biomass

Biomass can be used for several different purposes, the oldest of which includes its use as food for humans and animals. Furthermore, it can be used as a heat source for heating, cooking and water heating as a source of raw materials for industry, can also serve as a source of energy for transport or electricity generation. In addition to positive environmental impacts this has a great political significance because it helps to reduce dependence on energy imports from abroad.

It should be borne in mind that the possibility of the use of renewable resources is very broad.

Apart from wood, which could be used to produce products like from crude oil, there are many other possibilities and their combinations that can be used. Tab. 1 shows a quick overview of commercially available and used renewable energy sources

Tab. 1: A quick overview of commercially available and used renewable energy sources

Source	**Technical device or process for the conversion of**	**Usable form of energy / energy carrier generated**
1 Sun energy	Photovoltaic solar collectors	Electrical energy
	Photothermic solar collectors	Heat
	Heat pump	Heat
2 Energy of flowing water	Hydroelectric power station	Electrical energy
	Water wheels (usually mill, sawmill, etc.)	Use of mechanical power
3 Wind Energy	Wind power plant	Electrical energy
	Equipment with blades (windmill)	Use of mechanical power
4 Geothermal energy	Pumping hot water from a borehole	Heat
	Geothermal power plant	Electrical energy, heat
	Heat pump	Heat
5 Tidal energy (gravitational system of the Sun, Earth and Moon)	Tidal power plant	Electrical energy
6 Biomass		
6.1 Wood, fast-growing trees	Direct combustion	Heat
	Direct combustion - steam turbine.	Electrical energy, heat
	Thermal gasification - gas engine.	Electrical energy, heat
	Thermal gasification - fuel cell.	Electrical energy, heat
	Thermal gasification - methanization	Synthetic natural gas
	Thermal gasification – Fischer tropsch	Synthetic diesel, gasoline (called II generation biofuels)
6.2 Biowaste from agriculture (grass, residue production)	Biogas plant	Electrical energy, heat
	Biogas plant	Synthetic diesel, gasoline (called II generation biofuels)
	Hydrothermal carbonization	Outputs usable such as coal and crude oil.

6.3 Oily waste from the food industry (eg oil and fats from restaurants)	Modified diesel engine (direct use in transport)	Liquid biofuel.
	Diesel engine	Biodiesel I. generation.
6.4 Purposely grown energy crops	Diesel engine	Biodiesel I. generation.
	Petrol engine	Bioethanol (biofuel I. generation).

Source: [own according [3]]

Various forms of use of these resources may, if management methods are applied in broader context, help to solve the negative impacts on the environment associated with tourism [5][4].

2.1 Generating Electricity Using Biogas in Biogas Plants

The outline presented in Tab. 1 includes many different sources of renewable energy. Resources that do not use biomass are given as a complement to the overall context, and as a potential additional source to biomass sources which are analyzed here.

Electricity from biomass can be produced in several ways. As shown in tab 1, these processes are different in technologies used, fuel utilized as well as in capital costs of electricity produced. [7,15,21].

One possibility is the production of electrical energy through combustion of biogas. As visible from Tab. 1, except for the primary output, which in this case is electrical energy, there could be other related useful outputs as well, as heat energy in this case.

The biogas is considered to be a mixture of methane, which occupies the largest share of in the mixture, and other gases such as carbon dioxide, water vapor, nitrogen, oxygen, hydrogen, ammonia and sulphide [10]. The source of raw materials are biodegradable materials. Generally speaking, any organic material with a high content of volatile substances, and dry mass of less than 50% can be used.

The basis for the creation of biogas is methane fermentation, which occurs in anaerobic environment by the action of methanogenic bacteria in a closed fermenter [18]. The final product is a biologically stable substrate with high fertilizing effect (digestate) and biogas containing 55-70% methane and with calorific value of about 18 to 26 $MJ.m^{-3}$. The gas is then usually diverted over the gas tank to the cogeneration unit, where burning takes place to produce electricity and heat.

For completeness, some material outputs of the process should be mentioned. As stated above, the output is solid digestate, which is characterized as a fertilizer. It should be noted that the properties of the digestate as fertilizer are not, due to the high rate of decomposition of organic substances, comparable with organic fertilizers such as compost. The process produces organic fertilizer, similarly like composting, however, it needs to be said that the output material is not fully comparable with composting.

The digestate, if it does not meet relatively strict regulations, is considered a waste and requires treatment methods which correspond to the requirements established by the law on waste management.

Another output of the process of anaerobic digestion is the liquid waste. Its use in agriculture is somewhat problematic for its chemical composition, even though it is a waste created by using organic materials.

2.2 Emissions from Burning of Biomass

The burning of biomass creates additional pollutants, some very dangerous, such as polyaromatic hydrocarbons or dioxins. But measurements showed that the amount of harmful emissions is determined primarily by the way of incineration [13].

The amount of these pollutants can be very small and thus harmless for the environment and public health.

A concentration of carbon monoxide (CO) shows the quality of combustion process - poor adjustment of combustion parameters or improper design of the incinerator.

NOx emissions are most affected by nitrogen content in the fuel and temperature in the combustion chamber. Sulfur is contained in the biomass in a minimum amount, the sulfur dioxide (SO2) from its combustion are low. [9,16].

The amount of polyaromatic hydrocarbons can also be affected by setting of the combustion process. Dioxins need specific conditions to be created. They are present only in trace amounts in the waste gases. But it also does not mean that there cannot be other and better sources of renewable energy than just a biogas plants. Given the significant limitations of renewable energy sources, it is necessary to consider all options and analyze their advantages and disadvantages.

A model of a biogas plant can be designed for the quantification of emissions induced by the process of biogas preparation, electricity and heat in a cogeneration unit

Application of the model allows simulating amount of emissions produced by a particular biogas plant but also produced in order to obtain specified amount of energy.

Alternatively, the input can also be the amount of available biomass and different limit values for emissions of pollutants or waste heat. To this purpose one of the best suited tools could be a tool for modeling material and energy flows. The general model design is shown in Fig.1.

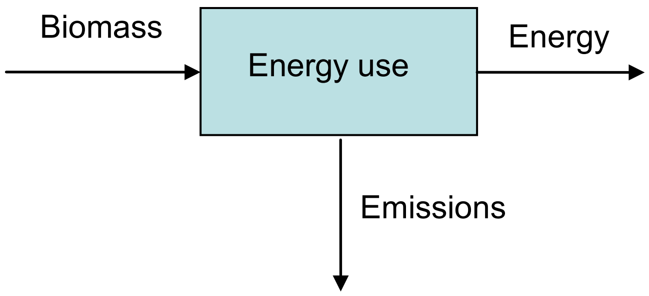

Fig. 1. Model design of biomass energy use.
Source: own

The proposed model should provide a generalized overview, so the environment in which they will be implemented should allow partial changes in the parameters of individual processes to ensure easy portability of all types of biogas plants using anaerobic digestion method. For this purpose we chose the model using colored Petri nets, which meets the requirements defined above. For the calculation of model parameters empirically observed data from chosen biogas plant was used.

2.3 Biogas Plant in city of Litomyšl

The chosen biogas plant is located on the northern side of the city of Litomysl in the Pardubice Region in Czech Republic, and his operator is an agricultural cooperative of breeders and growers (ZDCHP). The main object of their activity is agricultural production and the construction of biogas plants led the team to further develop.

The advantage is not only treatment of previously unused material, but also the raising funds from the sales of energy produced.

2.4 Energy Production

For energy production biogas is used here. For the production of biogas mainly corn silage, grass silage, corn meal, corn, manure and slurry are used. The volumes of biogas which can be obtained from these materials are listed in Table 1.

Table 1: The volume of biogas in materials

Material	m^3 biogas /1 t material
corn silage	200 – 220
grass silage	140 – 160
grain	580 – 600
hominy	580 – 600
manure and slurry	80

Source: [8]

Raw material is fed into the digester, where it is heated to the temperature of 45 ° C and passed through a process of fermentation. The resulting biogas is discharged through the gas tank to the cogeneration unit, where it is combusted and the generated electrical energy is discharged into the network. Every month in this way 650-700 thousand kWh of power is produced. For continuous operation about 11,000 cubic meters of biogas per day is required, which represents about 60 tons of biomass. Used fuel (Digest) has a high nutritional value and is, therefore, used as a fertilizer.

The cogeneration station is classified in terms of legislation between the central sources of air pollution. They must meet specified emission limits. In early 2009, when the three cogeneration units (performance parameters are listed in Table 2) were brought into operation, measurements of emissions produced were carried out. Later the fourth unit was put into operation, but its measurement is not available. Cogeneration units are equipped with diesel engines with jet ignition of additional fuel, which is extra light heating oil. Its share is 4% of the total electricity generated.

Table 2: Cogeneration units properties

	Power (kw)	Share of (%)
Electric power	250	43
Usable heat power	232	40
Losses	x	17

Source: [8]

The values of emissions into the atmosphere were measured for each of the three engines separately. There have been several measurements; the values for the various engines are listed in Table 3. Concentrations of substances are taken as an average for each measurement, related to normal conditions in dry burning and are converted to 5% O_2.

Table 3: Summary of emission results for engines

Measured component	Unit	Concentration [M1; M2; M3]	Specific production emissions [mg/m^3 biogas] [M1; M2; M3]
SPS	mg/m^3	5; 5,3; 4,6	46; 49; 43
SO_2	mg/m^3	112; 107; 114	940; 867; 912
Σ NO_x	mg/m^3	405; 378; 354	3 400; 3 062; 2 829
CO	mg/m^3	592; 511; 547	4 963; 4140; 4 367

Source: [17]

There is also available information on the average consumption of biogas - approx. 124.4 m3/hr. Concentrations of individual pollution components resulting from the biogas plant were compared with the emission limits and it is clear that all three cogeneration units in this area meet the standards.

3 Characteristics of the Modeling Tool

The process of electricity generation from biomass includes many inputs and outputs. For the model construction was, therefore, used a colored Petri net implemented in Umberto environment where inputs are different types of biomass and the most widely watched output is the generated electricity [24].

The Petri net could be in general defined like a 5-tuple GPN = <P,T,QP,QT, QE>,

Where P is a finite set of places represented by circles, T is a finite set o transitions represented by lines or rectangles.

$P \cap T = 0$

QP is an ordered 4-tuple QP=<C,IC,M_0C,UP>, which defines the qualities of k places of the set P.

QT is an ordered 5-tuple QT=<QC,τ,PR,IF,UT>, which defines the qualities of r transtitions of the set T.

QE is an ordered 3-tuple QE=<IE,EE,LE>, which defines the qualities of edges and is given by forward and backward incidence function.

An ordered 4-tuple, that defines the qualities of k places of the set P can be defined: C is a finite set of the colors used, IC:P*T→R*C, R ist the set of real numbers, IC((n,c)m,i,j), where mϵ<1,h>, iϵ<1,k>, jϵ<1,r>, is the forward incidence function.

M_0C:P*R→C is an initial marking andUP is a finite set of qualities of tokens in the places piϵP, UP={up1,up2, … ,upk}.

An ordered 5-tuple, that defines the qualities of r transitions of the set T can be defined: QC:T*P→R*C, R is set of real numbers, QC((n,c)m,i,j), where mϵ<1,h>, iϵ<1,k>, jϵ<1,r>, is the backward incidence function. T is a finite set of times of firings of r transitionsT. τ = {τ1,τ2, … ,τr}.

PR is a finite set of predicates, PR = {pr1,pr2, … ,pr3}, where for each lϵ<l,q>, then prlϵ{TRUE, FALSE} holds true. Each predicate prlϵPR can be conected with arbitrarz transition tjϵT bz normal or inhibit arc. This conection is given bz incidence function IF.

IF> T*PR→{1, -1,0} is an incidence function and mens

IF(tj,prl)=1 and exist connection between transition tjϵT and predicate prlϵPR, is the transition tjϵT enabled if the value of predicate prlϵPR is TRUE.

IF(tj,prl)=-1 and exist connection between transition tjϵT and predicate prlϵPR, is the transition tjϵT enabled if the value of predicate prlϵPR is FALSE.

IF(tj,prl)= and connection between transition tjϵT and predicate prlϵPR, dont exist, is the firing of transition tjϵT not determined by predicate prlϵPR.

UT is a finite set of qualities of transitions tjϵT, UT={ut1,ut2, … ,utr}, which can be deterministic, stochastic or fuzzy.

The finite set of qualities of edges, which is given by forward and backward incidence function, can be defined as QE=<IE,EE.LE>

Where IE is a finite set of inhibit arcs (ie), IE={ie1,ie2, … ,ieie}.

EE is a finite set of emptz arcs (ee), EE={ee1,ee2, … ,eeee}.

LE is a finite set of logical arcs (le), LE={le1,le2, … ,lele} [14].

This definition allows a mathematical description of any type of Petri nets with which should be worked.

Given that the Umberto environment makes it possible to use decimal values for marking in places as well, it was necessary to modify the IC and QC, which in the former definition allows only marking indicated in the natural numbers. Modified definition then allows a full description of the model already implemented in the Umberto environment.

Using colored Petri nets the process of electricity production from biomass was modeled based on available data, but it was necessary to calculate some unavailable data for parameter setting. The whole process requires a model with two transitions of which the first represents the production of biogas from biomass and the second represents the co-generation process. Negative final outputs are emissions and waste heat, positive output is the generated energy. The model implemented in Umberto 5.0.1 environment is shown in Fig. 2

$P=\{p_1, p_2, p_3, p_4, p_5\}$;
$T=\{t_1, t_2\}$;
C={biomass, biogas, CO, digestate, electricity produced, NOx, waste heat, SO2, heat produced, SPS};
IC: $\{((p_1 * t_1)$biomass), $((p_2 * t_2)$biogas)};
QC: $\{((t_1 * p_2)$biogas), $((t_1 * p_5)$digestate), $((t_2 * p_4)CO_2$, NOx, SO_2, SPS, waste heat), $((t_2 * p_3)$electricity produced, heat produced)}.

Because the Umberto environment uses for marking upper case, further individual net vertices are labeled in accordance with the graphical output of this environment shown in Figure 2.

Place P1 represents the input, which is biomass. This material consumption a day is approximately 60 tones (60,000 kg)

Place P2 connects the process of biogas production and energy use represented by transitions T1 and T2. The volume of daily produced biogas is approx 11,000 cubic meters = 11,000 m^3 * 1.2 $kg.m^3$ = 13 200 kg for biogas with 60% CH_4 and 40% CO_2, with density of 1.2 $kg.m^{-3}$. [12] The average hourly consumption of produced biogas is 124.4 m^3/hr. 124.4 m^3/hr . 1.2 $kg.m^{-3}$ = 149.28 kg/hr

Place P3 shows the desired outputs, thermal and electrical performance. The data obtained from biogas plant Litomysl show electric power of 250 kWh and thermal power of 232 kWh.

Place P4 shows the emissions and waste heat.

Place P5 represents the output of digestate.

The transition T1 represents production of biogas. Biomass enters here, the outputs are

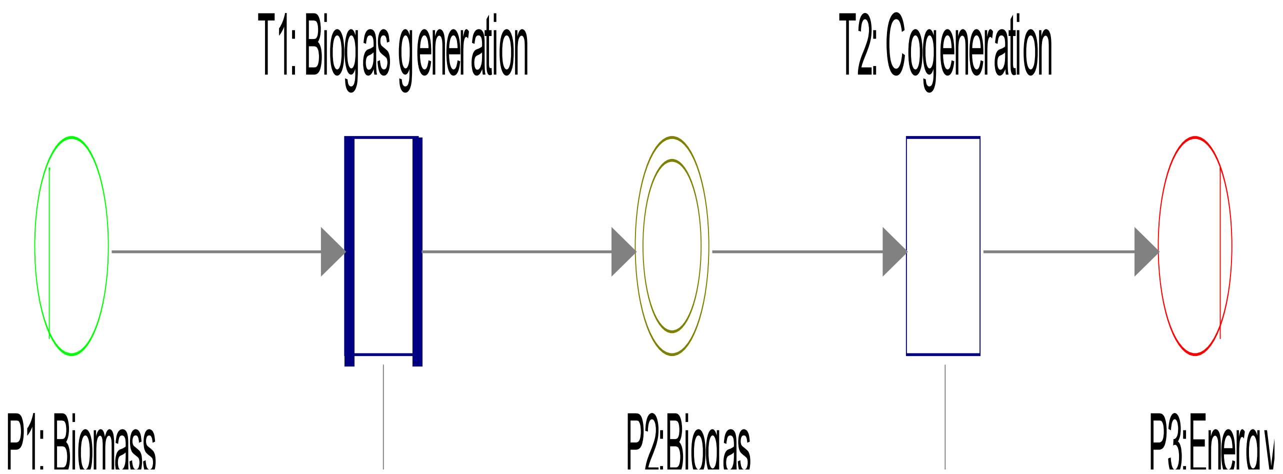

Fig. 2: The process modeled in Umberto 5.0.1 environment Source: own

biogas and digestate. Related energy flows are not included for simplification, they are added as a part of the 17% of the waste heat in cogeneration process, modeled by transition T2.

The parameters of transition T1 are then set for the material flows, the input is presented by

3.1 Characteristics of the Model and Computing Utility

The Petri net shown in Fig. 2 is, as defined above, characterized as follows:

biomass, biogas and digestate are the outputs. Digestate total weight is equal to the difference between input (biomass) and second output (biogas)

60 000 kg – 13 200 kg = 46 800 kg

The second transition T2 shows the process of cogeneration. Default values of the average specific emissions of the engines were used, which are shown in Table 4. These substances have been converted for the purpose of modeling on 1 kg biogas produced. A calculation was made where, in the first step, measured production emissions in $kg.m^{-3}$ after multiplying by biogas volume in m^3 were calculated. This whole process is done in detail for CO, for other emissions the same formula is used. The calculations for particular pollutants are:

The average of the monitored engines can be calculated by averaging of the empirical data obtained from the measurement, by the general formula:

$$\overline{x} = \sum_{i=1}^{n} xi \qquad (1)$$

substituting

(4963+4140+4367)/3=4490 $mg.m^{-3}$

In kg (1 mg = $kg.10^{-6}$)

4490 $mg.m^{-3}$ 10^{-6} = 0,00449 $kg.m^{-3}$

The amount of 0,00449 kg $CO.m^{-3}$ created on average every hour during the operation of the motor is

0,00449 $kg.m^{-3}$.124,4 $m^3.h^{-1}$ = 0,558556 $kg.h^{-1}$

Analogically for other monitored pollutants:

NO_x:

0,003096 $kg.m^{-3}$. 124,4 $m^3.h^{-1}$ = 0,3851424 $kg.h^{-1}$

SO_2:

0,0009063$kg.m^{-3}$. 124,4 $m^3.h^{-1}$ = 0,11274745 $kg.h^{-1}$

SPS:

0,000046 $kg.m^{-3}$. 124,4 $m^3.h^{-1}$ = 0,0057224 $kg.h^{-1}$

The heat that cannot be further utilized represents about 17% of the engine output. Remaining 83% represent mechanical and heat output. Available data show only electrical power. In order to calculate the total power, it is necessary to take into account electric generator efficiency as well. Therefore, mechanical power of the engine needs to be calculated. Mechanical power of the engine can be calculated as the rate of electrical power and efficiency of transition to electric energy, which fluctuated between 90-93% in ZDCHP. Let us use 91.5% for the calculation

The total usable power P_{usable} of the engine (83%) is calculated according to formula:

$$P_{usable} = \frac{P_{el}}{\eta} + P_{th} \qquad (2)$$

where P_{el} represents electrical power of the whole device and P_{th} thermal power. After substitution to (2)

P_{usable} = (250 kw/0,915) + 232 kw

P_{usable} = 505,22 kW.

This power represents 83% of energy in the fuel, loss P_l represents the remainder to 100%:

P_l = (505,22 kw/83).17 = 103,5 kW.

Now it is possible to calculate mechanical efficiency of one engine, in other words the efficiency of transition from gas to mechanical energy. This is gained by multiplication of mechanical power, which is the electrical power ($P_{el.}$) divided by efficiency of mechanical energy transition to electrical energy ($\eta_{transition}$), and inverse value of total power ($P_{total.}$).

For efficiency of transition, value 91.5% was used, as described above. The total power of the combustion engine is calculated as sum of:

mechanical power	Pmech. = 273,22 kW
thermal power	Pth. = 232 kW
loss power	Pl. = 103,5 kW

The total power of the combustion engine P (tot), will be calculated according to formula:

$$P_{tot} = P_{mech} + P_{th} + P_l \qquad (3)$$

after substitution:

P_{tot} = 273,22 kw + 232 kw + 103,5 kw = 608,72 kw.

Gained values will be substituted into the formula for total efficiency of the engine:

$$\eta_{engine} = \frac{P_{el}}{\eta_{transf}} \text{ x } \frac{1}{P_{tot}} \qquad (4)$$

after substitution:

η_{engine} = (250/0,915) x (1/608,72)

η_{engine} = 0,448 843 = 44,88%

From the calculation it is obvious tat engine efficiency is around 45%. Based on the calculations, it is possible to specify processes by setting up parameters of transitions T1 and T2. The values are listed in Table 4.

Table 4 Result of the model after entering particular input

Transition T1			
Inputs		Outputs	
Biomass	1 000 kg	Biogas	220 kg
		Digestate	780 kg
Transition T2			
Biogas	149,28 kg	Heat	232 kWh
		El. energy	250 kWh
		Waste heat	103,5 kWh
		CO	0,558556 kg
		NO_x	0,3851424 kg
		SO_2	0,1127474 kg
		SPS	0,0057224 kg

Source: own

Outputs of the model are listed further.

3.2 Results of Modeling

All empirically obtained as well as calculated values were entered into the Umberto 5.0.1 environment where the whole model was implemented. The outputs calculated by the model are summarized in Table 5. An input of 1000 kg of biomass was selected for the model calculation.

Table 5 Outputs of the model

Output	Place	Value	Unit
Heat	P3	341,9	kWh
El. energy	P3	368,4	kWh
Waste heat	P4	152,5	kWh
CO	P4	0,823	$kg.h^{-1}$
NO_x	P4	0,568	$kg.h^{-1}$
SO_2	P4	0,166	$kg.h^{-1}$
SPS	P4	0,008	$kg.h^{-1}$
Digestate	P5	750	kg

Source: Output of the model in Umberto 5.0.1 environment

The amount of produced digestate from 1000 kg of biomass is rather high and ZDCHP Litomyšl uses it high nutritional value as a fertilizer.

3.3 Further research direction

The performed analysis is a part of a larger whole, which should result, after appropriate comparative analysis, in determination of the preference sequence in selecting the optimal mix of renewable sources use. The resulting hierarchy would work the same way as existing waste management hierarchy, as set out in the EU Waste Directive. The mapped process described above may then serve as a usable part of the basis for developing a comparative analysis to determine the preferred order of renewable energy sources use.

4. Conclusion

The output of the model shows that using cogeneration process it is possible, from inputs considered, to utilize one ton of input biomass to produce 341,9 kWh of heat energy and 368,4 kWh of electric energy, which are understood as positive outputs in presented model. The further, significant contribution of the model is quantification of environmental burden by means of negative outputs, indirectly in the form of 152,5 kWh loss heat, 0,823 kg/hour emissions of CO, 0,568 kg/hour emissions of NO_x, 0,166 kg/hour emissions of SO_2 a 0,008 kg/hour emissions of solid polluting substances.

Because the model is based on empirical data, it can be applied to any similar device, so it can be used for prediction of air pollution in the processing of any amount of biomass. Therefore, qualified estimation of the environmental burden can be created and can be used to evaluate the possible risks for the population from the operation of biogas plants in relevant situation e.g. close to residential areas.

The advantage of using Petri nets is the ability to model a process for any number of input and output substances and energies. In this case the values of outputs are in accordance with the requirement for air protection requirements. In the evaluation of the results of these models, it is also necessary to consider not only the composition of the gas discharged, but its total volume.

The advantages of the production process of electric energy from biomass in biogas plants at agricultural facilities, which is also the case of the Litomysl biogas plant, are mainly in utilizing such input resources that could not be used otherwise, e.g. manure and sewage. The combustion engine efficiency at this process is high, approximately 45%.

From the environmental viewpoint the results of this modeling suggest that production of electricity from biomass does not have a significant negative impact on the environment, but if cleaner technologies were available, such as the use of water power plants, it would be necessary to carefully analyze the energy needs and possible sources in terms of their performance.

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