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EXTERNAL COSTS OF ELECTRICAL POWER GENERATION FROM RENEWABLE RESOURCES

ĀRĒJĀS IZMAKSAS ELEKTROENERĢIJAS RAŽOŠANAI AR ATJAUNOJAMAJIEM ENERGORESURSIEM

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Introduction

An electrical power production is examined from Solar energy and cogeneration, using biomass. In the framework of this work the following are described: the charts of two kinds of electrical power generation; advantages and disadvantages of use; and main aspects, that link to long-term development, that is, economic, social and environmental aspects. The costs of the power generation include operation and maintenance as well as external costs. The last ones have to be calculated to cover impact to environment from power generation. Two types of electrical power production (biomass and Solar energy resources) are analyzed from the viewpoint of the external costs.

Methodology used

There were considered the external costs of cogeneration, which uses wood as a fuel, and the external costs of the system of Solar batteries. An effect on the environment and humans from electricity generation is analyzed by use the numerical experiment, which includes processing and selection of initial data. Results of numerical experiment presents environmental and economical parameters and give answers about absolute values of external costs which sooner or later could be added to todays electricity prices. Data and results concerned to particular places in Latvia and for a certain cogeneration units or a system of Solar batteries, the external costs were calculated for one cogeneration and one system of Solar batteries. Later to compare both electrical power production kinds, the obtained costs were divided on 1 kWh of generated electricity.

Two methods were used to calculate the external costs of electrical power cogeneration plants.

As the first method data were used from the project „ExternE" in Finland. Finland was chosen because it is one of the nearest countries to Latvia in which the climate conditions can be very similar. This method included 2 different approaches.

First case describes the analysis was based on the best practice project in Finland for 1 kW generated electricity, Research includes calculation of emissions per unit and the absolute values of the external costs by the mathematical calculations

As the second method there were chosen program „RiskPoll", which uses the same emission rates, which already have been calculated for the first method. Output data present only effect on human health, therefore later, comparing these methods, only measurements for effect on human health were compared. This program presents also the effect on materials and crops, but, taking into account this, the effect is insignificant; at least it is evident from the first method.

2 methods were used also for calculation of external costs of the system of Solar batteries. In the first case there were used the data of the project „ExternE" in Germany. Germany was selected because of availability of data for the calculations of the external costs for Solar electrical power generation. However difference in the climate conditions brings additional calculations and they were corrected by use of standard climate conditions. The assumption that Solar batteries are made in Germany was done in the analysis. So as the emissions in the air proceed direct from generation process, it was supposed, that it is correct to use the results of this project also for the climate conditions of Latvia.

In the second case includes the same German project with additional calculations to correct the transport of Solar batteries. This German project included also transport costs, but it was assumed, that they are too little, because the distance from the producer to user of Solar batteries is small. So as the transportation distance is approximately 1000 km, there were used data for external costs from the heavy transport, depending on the transportation distance. In this method the previous results were used and the measurements obtained were added for correction of the transport costs.

Calculations of the cogeneration

Using the data of the project "ExternE" in Finland

To calculate the external costs of the electricity generation in cogeneration, there were found the data about cogeneration, which are shown in table 1.

Table 1.

Most important main characteristics of the cogeneration

	Power, MW	Annual energy, GWh
Fuel consumption	19.6	70.4
Total delivered energy	16.0	57.5
Electricity (net)	4.0	14.4
District heat (net enthalpy)	12.0	43.2
Temperature of outgoing water		100 °C
Temperature of ingoing water		50 °C

Energy needed for production of wood chips with the shipset-system is 1.08 l diesel fuel/m3 chips (1.35 l/MWh woods fuel) and electricity needed in the sawmill chain 2.56 kWh/MWh wood fuel. In the example, the general diesel fuel consumption is 9936l/year and electricity consumption is 61MWhe/year. The diesel fuel consumption is needed for transportation is 51 l/100 km. The diesel fuel in the example is 28152l/year.
The air emissions of the power generation stage are shown in table 2 and the total emissions from production and transportation for the estimated fuel is shown in table 3.

Table 2.

The air emissions of the power generation stage

	Emissions g/kWh$_e$	Emissions mg/MJ	Emissions t/gadā	% of the whole biomass fuel cycle
SO_2	0.43	40	6.87	97
NO_x	1.67	150	25.75	93
TSP	0.21	20	3.43	96

Table 3.

The total emissions from production and transportation for the estimated fuel

Total emissions		CO t	NO_x t	TSP t	SO_2 t	CO_2 1000 t
Production total		0.20	0.54	0.06	0.08	0.05
Transportation total		0.25	1.46	0.08	0.11	0.08

Apparently, the largest part of emissions in the air is during production and transportation of the biomass fuel (CO_2 emissions).

Using the program "RiskPoll"
The data for the program "RiskPoll" are shown in table 4.

Table 4.

Data for the program "RiskPoll"

	Emissions t/year during power generation	Emissions t/year during fuel	Total emissions t/year
SO_2	6.87	0.19	7.06
NO_x	25.75	2.00	27.75
TSP	3.43	0.14	3.57
CO_2	0.00	0.13	0.13

Location: longitude – 57°; latitude – 24°; source location: 3 (large city); stack height: 60 m; stack diameter: 1.6 m; exhaust gas velocity: 1.4 m/s; exhaust gas temperature: 403 K; regional Receptor Density: 2855 pers./km^2; emissions: shown in table 4; results: shown in table 5.

Table 5.

Results of the program "RiskPoll"

Method	Category	External costs, USD
Chronic Bronchitis [Abbey 1995]	TSP	21 500.00
Restricted activity days [Ostro 1987]	TSP	7 040.00
Respiratory hospitalization [Dab 1996]	TSP	28.90
Chronic cough, children [Dockery 1989]	TSP	321.00
Congestive heart failure, elderly [Schwartz/Morris 1995]	TSP	27.30
Cough, adult asthmatics [Dusseldorp 1995]	TSP	1 370.00
Bronchodilator use, adult asthmatics [Dusseldorp 1995]	TSP	590.00
Lower respiratory symptoms, adult asthmatics [Dusseldorp 1995]	TSP	44.00
Cough, children asthmatics [Pope/Dockery 1992]	TSP	272.00
Bronchodilator use, children asthmatics [Roemer 1993]	TSP	70.20
Lower respiratory symptoms [Roemer 1993]	TSP	18.60
Mortality YOLL [Anderson/Toulomi 1996]	SO_2	171.00
Respiratory hospitalization [Ponce de Leon 1996]	SO_2	66.30
Total:		31 519.30
For 1 kWh electricity generated:		0.0022

Taking into account that the data are for the year of 2004 and currency, it is assumed that 0.59 USD_{2004} = 1 LVL_{2007}. The external costs using the program „RiskPoll" are 18596.39LVL/year, but 0.0013LVL/year/kWh for 1 kWh electricity generated.

Results using the data of the project "ExternE" in Finland

Total damages of biomass fuel cycle by impact category are shown in figure 1. Comparison of different global warming (GW) damage estimates and health damage estimates for the biomass fuel cycle are show in figure 2.

Total external costs for the power generation in cogeneration are:

- GW low – 78781LVL;
- GW mid (3%) – 94331LVL;
- GW mid (1%) – 129181LVL;
- GW high – 238041LVL.

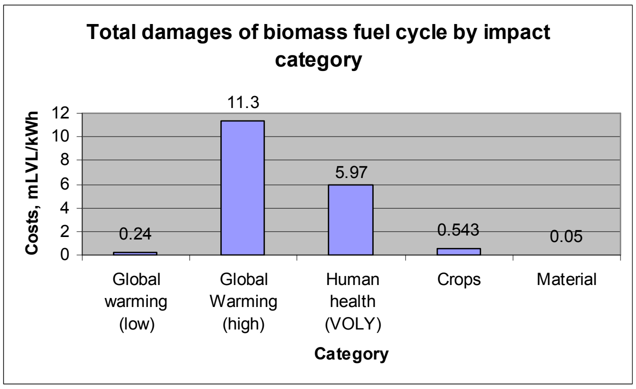

Figure 1. Total damages of biomass fuel cycle by impact category

Results using the program "RiskPoll"

To make different calculations the program „RiskPoll" was used. Using the program „RiskPoll" total external costs are 18596.39LVL/year, but 0.0013LVL/year/kWh for 1 kWh electricity generated. The program shows only the effects on human health. The largest costs are for chronic bronchitis and other respiratory diseases.

If the results of both methods have to be compared, human health (VOLY) costs 5.97mLVL/kWh, but using program „RiskPoll" output data human health costs 1.30mLVL/year/kWh. It is supposed, that the difference is not substantial, because the program „RiskPoll" did not show many output data, for example, for NOx effect on health. However lack of detailed information could cause increase the obtained external costs up to 2 or even 3 times, that is, 3.90mLVL/year/kWh.

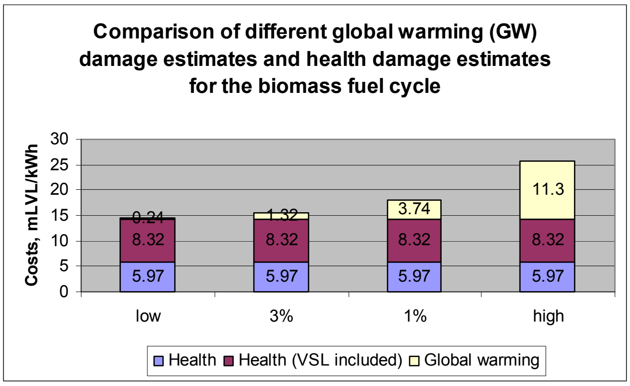

Figure 2. Comparison of different global warming (GW) damage estimates and health damage estimates for the biomass fuel cycle

Calculations of the PV

The modules of Solar batteries are taken from http://www.photovoltaik-shop.com with 1,92 kWp (BP Solar 3160S module). The system consists of modules of 12 Solar batteries BP 3160S (W). The Solar battery module is about 160 Wp and consists of 72 elements.

Module sizes are 1593 mm length x 790 mm width x 50 mm height, that is, 1 module area is 1.26 m^2, but an area of all system is 15m^2. 1 module weight is 25 kg, but the weight of the entire system is 300kg.

It was assumed that the Solar batteries are transported from Germany with a load transport (about 1000 km, 4 t). Diesel fuel consumption is 210 l. So as 1 system of the Solar batteries weight is 300 kg, the diesel fuel consumption for 1 system of Solar batteries is 15.75 l.

2 kWp are typically used for houses, they occupy approximately 20 m^2 and in a year make 1500 kWh. Emissions from the PV life cycle are shown in table 6.

Table 6.

Emissions from the PV life cycle

	PV home application		PV facade application	
	for kW_p	for MWh	for kW_p	for MWh
SO_2	1894.6 g	104.1 g	1793.0 g	113.7 g
NO_x	1801.3 g	99.0 g	1287.7 g	81.7 g
TSP	110.3 g	6.1 g	-	-
CO_2	970.8 kg	53.3 kg	777.2 kg	49.3 kg

The system of the Solar batteries in example is used with 2 kWp and laid on the roof of house, see in table 7.

Table 7.

Emissions from the PV in example

1.92 kW_p	
SO_2	3.64 kg
NO_x	3.46 kg
TSP	0.21 kg
CO_2	1860.00 kg

Emissions from the PV transportation are shown in Table 8.

Table 8.

Emissions from the PV transportation

Total emissions	CO, kg	NO_x, kg	TSP, kg	SO_2, kg	CO_2, 1000 kg
For 1 system	0.14	0.82	0.05	0.06	0.04

Using socio-economic results of the European commission researches harm from electrical power and transport data for external costs for the transport of the heavy load 100 km, the transportation external costs of the Solar batteries can be calculated. The external costs for 100 km are show in table 9.

Table 9.

The external costs for 100 km

Damage on environment	EUR/100 km
Noise	0.70
Global warming	1.00
Congestion	0.40
Air pollution	2.70
Accidents	4.30

For 1 system of Solar batteries the transport drives 1000 km, so the external costs for the transportation are shown in table 10. Taking into account that the data are for the year 2003 and currency changes are significant in the period from 2003 till today, it is assumed that 0.85 EUR_{2003} = 1 $LVL_{2007.}$

Table 10.

The external costs for the PV transportation

Damage on environment	EUR 1000 km	LVL (with inflation)
Noise	7.00	5.95
Global warming	10.00	8.50
Congestion	4.00	3.40
Air pollution	27.00	22.95
Accidents	43.00	36.55

Total damages of PV cycle by impact category are shown in figure 3. Comparison of different global warming (GW) damage estimates and health damage estimates for the PV cycle are show in figure 4. PV external costs are shown in figure 5.

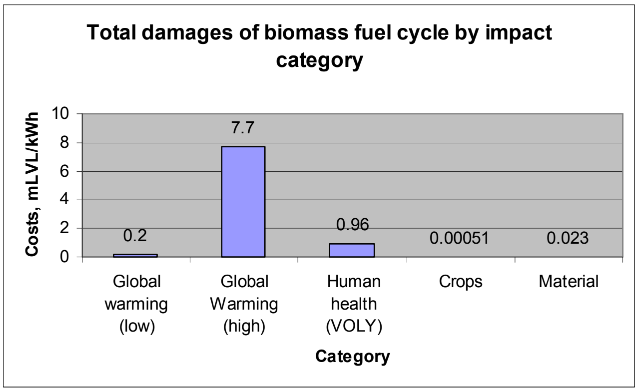

Figure 3. Total damages of PV cycle by impact category

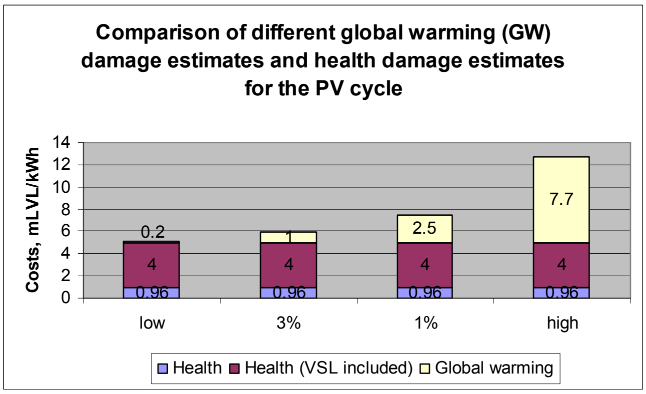

Figure 4. Comparison of different global warming (GW) damage estimates and health damage estimates for the PV cycle

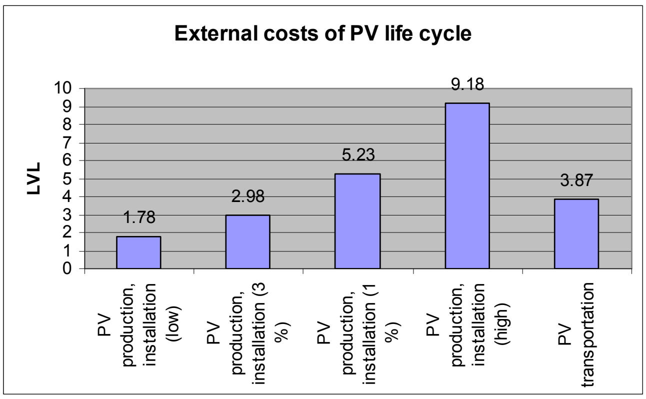

Figure 5. PV external costs compared to PV transportation external costs

Comparison of all methods

External costs of all methods are shown in figure 6.

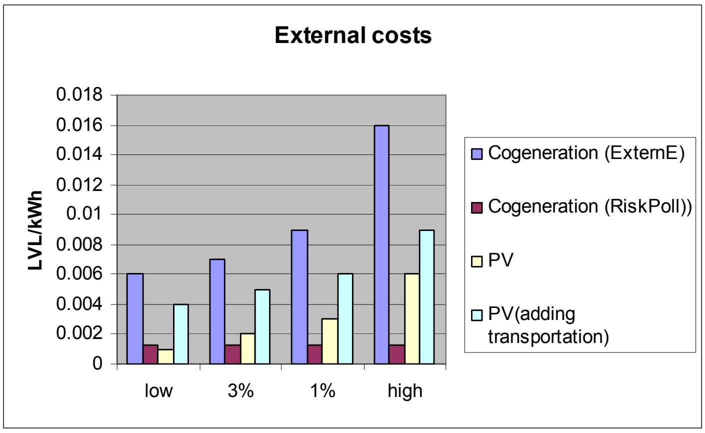

Figure 6. External costs of all methods

Conclusions

1. External costs for 1 kWh electricity generated:
   - cogeneration, using the project „ExternE" 6 LVL/MWh – 16 LVL/MWh;
   - cogeneration, using the program „RiskPoll" 1.3 LVL/MWh;
   - PV, using the project „ExternE" 1 LVL/MWh – 6 LVL/MWh;
   - PV, adding transportation 4 LVL/MWh – 9 LVL/MWh.
2. If the results are compared of both electrical power production methods in categories, in both cases the external costs for a crops and materials are minimum, but the largest external costs are direct for the global warming and middle costs are for human health.
3. Payback time of Solar batteries in the Latvia is large because the PVs are expensive and today's prices of the electrical power is comparatively low. The payback time of cogeneration units is lower because of costs of technologies are lower and therefore the price of electrical power from the PVs has to be much larger than from cogeneration. For example, the electrical power of the PV can cost 0.30 LVL/kWh and the cogeneration electrical power price can cost 0.051 LVL/kWh. Electrical energy costs together with the external costs are forming total price, which is following: for cogeneration 0.067 LVL/kWh and for PV 0.309 LVL/kWh. It means that the external costs are comparatively small. However they could influenced selection of an electrical power generation scheme in future when green energy conception will become more significant and prices of biomass will increase in Latvia.
4. According to latest researches the electricity external costs are larger in case of use of fossil fuels: for coal is 1.4 – 10.5 santim/kWh, for natural gas – 0.7 – 2.1 santim/kWh. The electrical power external costs (calculated) for the cogeneration by use of biomass are 1.6 santim/kWh. External costs of electricity produced by Solar PV are low - 0.9 santim/kWh. It means that Solar energy use is environmentally friendly and at the moment when they will be taken into account during economical calculations Solar electricity will become more popular in Latvia too.

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Svetļicka K., Sarma U., Blumberga D. Ārējās izmaksas elektroenerģijas ražošanai no atjaunojamajiem energoresursiem.
Darba tēma ir elektroenerģijas ražošanas no atjaunojamajiem energoresursiem ārējās izmaksas. Šī darba ietvaros tiek aprakstītas koģenerācijas, kas kā kurināmo izmanto koksni un saules bateriju sistēmu shēmas. Tiek analizētas to izmantošanas priekšrocības un trūkumi un galvenie aspekti, kas saistīti ar ilgtspējīgu attīstību, tas ir, ekonomiskie, sociālie un vides aspekti. Ietekme uz vidi un cilvēku tiek atspoguļota skaitliski. Tiek salīdzināti abu elektroenerģijas ražošanas veidu rezultāti. Salīdzinot abas elektroenerģijas ražošanas metodes, jāsecina, ka abos gadījumos ārējās materiālu izmaksas ir minimālas, bet vislielākās ārējās izmaksas ir vērstas uz globālo sasilšanu, un vidējās izmaksas vērstas uz cilvēka veselību. Ir jāuzsver, ka fosilo kurināmo ārējās izmaksas ir lielākas.

Svetļicka K., Sarma U., Blumberga D., External costs of electrical power generation from renewable resources.
The theme of this thesis is external costs of electrical power generation from renewable resources. There are described cogeneration, which uses wood fuel as a fuel, PV system charts, advantages and disadvantages of use and main aspects, that links with long-term development, that is, economic, social and environment aspects. Damage on an environment and human is found numeral. Results are compared both electrical power production kinds. If compare the results of both electrical power production methods in categories, in both cases the external costs for a crops and materials are minimum, but the largest external costs are direct for the global warming and middle costs are for the human health. external costs for the fossil fuel are larger, that had to be proven.

Светлицка К., Сарма У., Блумберга Д., Внешние затраты на производство электроэнергии применяя возобновляемые энергоресурсы.
Тема работы это расчет внешних затрат при производстве электроэнергии из возобновляемых энергоресурсов. В рамках данной работы описаны главные достоинства и недостатки когенерациии, где используется топливо в виде древесины, системы солнечных батарей. Описаны главные аспекты, которые связаны с долговременным развитием, т.е. экономические, социальные и экологические аспекты. Влияние на среду и на здоровье человека отражается численно. Сравнены результаты для обоих видов производства электроэнергии. Если сравнивать оба вида производства электроэнергии, то в обоих случаях внешние затраты на материалы минимальны, но наибольшие затраты направлены на глобальное потепление и средние затраты направлены на здоровье человека. Особое внимание нужно направить на применение схем механизмов Киото.