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THE IMPACT OF SUBSIDY MECHANISMS ON BIOMASS AND OIL SHALE BASED ELECTRICITY COST PRICES

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This paper provides electricity cost price estimates for biomass-based CHP plants and oil shale power plants to be constructed before 2013 and 2015 that can serve as references for more detailed case-specific studies. Calculation results give electricity costs prices under different CO_2 quota price levels (for oil shale energetics), different combined heat and power (CHP) plant scales (for biomass energetics), with and without subsidy mechanisms. The impact of subsidy mechanisms on biomass and oil-shale energetics to adoption of biomass energy sources and its move toward grid parity as well as reasonability of available subsidy mechanisms to avoid backing of projects which cover of expenditure without subsidies are discussed.

Introduction

Estonian energy sector is mainly based on oil shale, which is one of the main factors of the energetic independence of Estonia. About 87% of all electricity was produced from oil shale in the year 2009 [1].

The sustainability and maintenance of oil shale energy sector is a government priority, which is stated in National Development Plan of the Energy Sector until 2020 (referred to as DP) [2]. DP approved by the Government of the Republic defines the Government's strategy in one of the most important fields of energy policy – power engineering. Regarding DP the objective of the state is to ensure continuous, sustainable power supply at a justified price in Estonia [3].

However the old boilers of the power plants based on pulverized combustion of oil shale are nearly at the end of their working life, and they need to be replaced by new boilers using fluidised-bed combustion. The first two energy blocks (215 MW) with these kinds of boilers have shown their net efficiency in production (36.6% instead of the 30% achieved by the old

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boilers) and have reduced SO_2 emissions nearly to zero. By European Union (EU) directives all old pulverized combustion boilers have to be closed by 2015 [4].

The replacement of old oil shale boilers needs a lot of capital costs. Still, the time is already short for making a decision for investments.

Oil shale fuel can be partly replaced in Estonian energy sector by other local energy source: wood fuel. Wood can be used for electricity production in the combined heat and power (CHP) plants and in oil shale large-scale power plants, replacing not more than 10% of oil shale fuel.

CO_2 quota trade could be crucial to the competitiveness of the oil shale energy production sector in comparison with other fossil and renewable fuels. To ease the CO_2 quota trade risks to oil shale energetics, a new version of Energy Market Act, in addition to feed-in tariffs for renewable energy and energy produced in efficient cogeneration mode, includes a subsidy mechanism for oil shale energetics by the installed electrical capacity.

The suitability of the usage of feed-in tariffs as well as oil shale energetics subsidy mechanisms is widely discussed in Estonia. Some state institutions express the one opinion that subsidy of the projects which cover expenditure without subsidies by the electricity consumers mismatch their legal expectations. The rates of subsidies are very high; they impede free competition and are too burdensome for electricity consumers [5].

The goal of the paper is to estimate the impact of a policy mechanism on adoption of biomass energy sources and its move toward grid parity, the impact of subsidy mechanism on oil shale energetics by the installed electrical capacity to oil shale-based electricity cost price under different CO_2 quota price scenarios, and the impact on parity with biomass electricity cost price.

Methods

To estimate the impact of subsidy mechanisms on competitiveness of biomass and oil shale energetics, biomass and oil shale-based electricity cost prices with and without available subsidies are compared. The cost price is defined as the price of electricity that is sold for producer's price, without any profit for the producer.

Regarding Electricity Market Act, the subsidy will be given for oil shale power plants which will start operation between the years 2013 and 2015. It means that cost price should be estimated for new planned oil shale power plants [6].

The current version of Electricity Market Act defines that feed-in tariff for biomass electricity is available in the case of efficient cogeneration of a biomass plant. This condition means the necessity to consider heat sells as a part of cash flow for cost price calculation.

The principle scheme for calculation of electricity cost price without subsidy mechanisms is shown in Fig. 1.

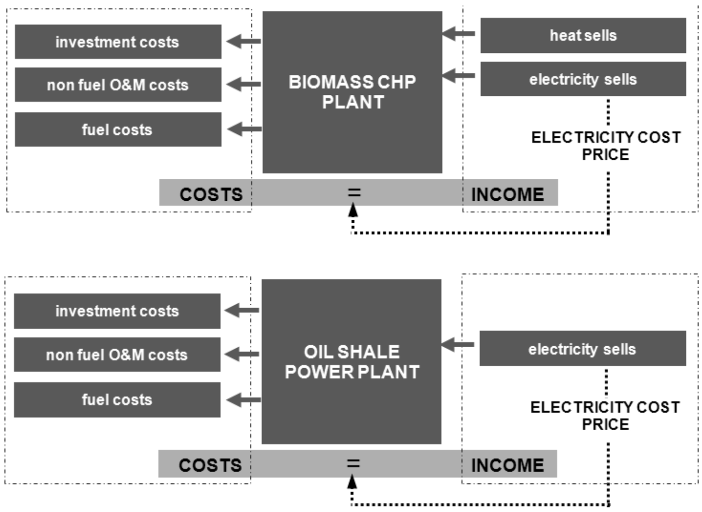

Fig. 1. Electricity cost price calculation principle for biomass CHP plant and oil shale power plant without subsidy mechanisms.

Subsidy is a part of an income. Subsidy decreases the income from electricity sells which is necessary to balance electricity production costs. Electricity production costs consist of investment costs, fuel costs and non-fuel operation and maintenance (hereinafter O&M) costs.

The principle scheme for calculation of electricity cost price with subsidy mechanisms for biomass CHP plant and oil shale power plant is shown in Fig. 2.

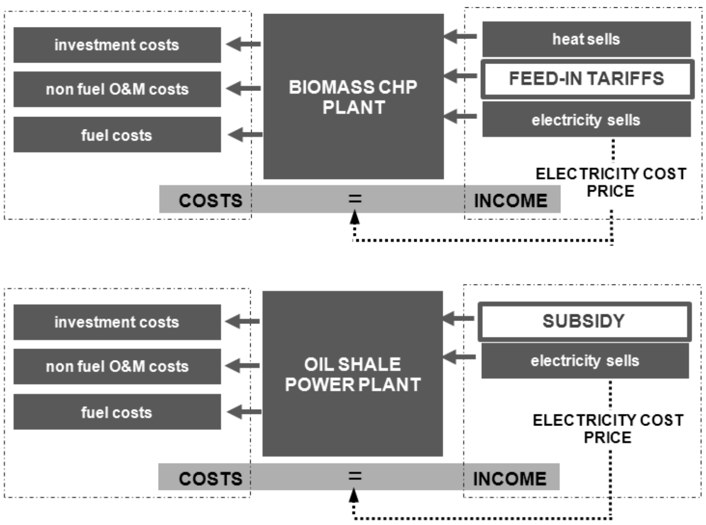

Fig. 2. Electricity cost price calculation principle for biomass CHP plant and oil shale power plant with subsidy mechanisms.

The electricity cost price estimations and subsidy mechanisms for oil shale and biomass energetics are provided below.

Electricity cost price

Oil shale electricity cost price

Analysis of oil shale electricity cost price is based on “Strategic Environmental Assessment of the National Development Plan of the Energy Sector until 2020” (hereinafter SEIADP). The Environmental Board approved the strategic environmental assessment by letter No 6-8/3061 dated 26 February 2009, and the corresponding report has been annexed to the Development Plan [7].

SEIADP includes values for electricity production costs for oil shale energetics. Investment costs, fuel costs and non-fuel O&M costs are estimated basing on data used for international project NEED (*New Energy Externalities Developments for Sustainability*) partners. Additional information regarding provided data is available in SEIADP.

Composition of oil shale electricity cost price used in further estimations is shown in Table 1. Regarding SEIADP, the values correspond to new oil shale power plants to be constructed before the year 2016.

Table 1. **Oil shale cost price composition**

Costs	€/MWh_{el}
Investment costs	15
Fuel costs	8
Non-fuel O&M costs	6
Electricity cost price	**29**

The cost values in Table 1 do not include CO_2 quota cost price. SEIADP compilers estimate an additional 15.3 €/MWh_{el} carbon dioxide quota related costs at the CO_2 quota price level 19 €/tCO_2. Assumed estimations make an increase in electricity cost price for 0.8 €/MWh_{el} per every €/tCO_2 quota price.

Biomass electricity cost price

Regarding SEIADP, the oil shale cost price is valid for large-scale 300–400 MW_{el} power plants foreseen in DP. The electricity cost price for biomass is also provided in the SEIADP report. The estimated price is 52 €/MWh_{el}, but there is no explanation regarding correspondence of cost price value to plant capacities.

Electricity cost prices for biomass CHP plants are very sensitive to plant capacities and could differ significantly. To estimate the impact of biomass CHP plant scale factor on electricity cost price, the following assumptions are taken into account at estimating cost price of electricity produced in biomass-based CHP plants:

– Calculations are provided for biomass-based CHP plants with nominal net electrical capacity of 1, 10 and 25 MW_{el};
– Annual working hours divided to nominal capacity – 5000 hours [7];
– Project life time – 25 years;
– Assumed self-financing is 50%. Loan part is 50%. No grant payments are taken into account;
– Loan term – 25 years; interest rate – 4.5% [8]. Loan type – annuity loan;
– Heat losses in district heating network make 20% [9].
– Fuel price is 18 €/MWh_{fuel} [10];
– Heat price is 35 €/MWh_{fuel} (does not include expected profit). The CHP heat price indicative value is estimated basing on heat cost prices of biomass fuelled boiler houses [11];
– Efficiencies, investment costs, O&M costs and some other parameters are obtained and systemized on the basis of information regarding CHP plants collected from different information sources [12–16];
– A cost price calculation does not take into account available feed-in tariff.

The initial data for calculation of electricity cost price, intermediate calculation results and calculated electricity cost prices for 1, 10 and 25 MW_{el} biomass based CHP plants are shown in Table 2.

Calculation results show that electricity cost prices estimated for biomass-based CHP plants vary significantly. The CHP plant scale factor has a significant influence on cost price formation. Construction of CHP plants in places with higher annual heat consumption is more preferable. Their electrical efficiency is higher, specific investment and maintenance costs are lower. An overview of places where CHP plants based on biomass are constructed in Estonia shows their correspondence to above-mentioned principles [17].

The calculation results show that cost price in the case of a 25 MW_{el} CHP plant is very close to values provided in SEIADP (53 €/MWh_{el} versus 52 €/MWh_{el} in SEIADP). At the same time the estimated electricity cost price in the case of a 1 MW_{el} CHP plant is practically three times higher.

It is important to mention that calculated values are indicative and may significantly differ from the values for real-life projects.

Table 2. **Estimation of electricity cost price for biomass-based CHP plants**

Electrical capacity	MW_{el}	1	10	25
Specific investment	M€/MW_{el}	7.5	3.7	3
Annual working hours divided to nominal capacity	hours	5000	5000	5000
Project life time	years	25	25	25
Interest rate	%	4.5%	4.5%	4.5%
Investment	M€	7.5	37	75
Electrical efficiency	%	15	25	30
Heat efficiency	%	70	62	60
Total efficiency	%	85	87	90
Heat capacity	MW_{heat}	4.7	24.8	50
Fuel capacity	MW_{fuel}	6.7	40	83.3
Annual electricity production	MWh_{el}	5000	50000	125000
Annual heat production	MWh_{heat}	23333	124000	250000
Annual fuel consumption	MWh_{fuel}	33333	200000	416667
Fuel price	€/MWh	18	18	18
Fuel costs	M€	0.6	3.6	7.5
Non fuel O&M costs	% from total investment annually	5	4	3
Non fuel O&M costs	M€	0.375	1.48	2.25
Investment part	M€	0.3	1.48	3
Interest	M€	0.10	0.51	1.03
Total costs	M€	1.38	7.07	13.78
Heat price	€/MWh	35	35	35
Heat loses in DH network	%	20	20	20
Heat sells	M€	0.65	3.5	7.0
Electricity sells	M€	0.72	3.6	6.8
Electricity price	**€/MWh**	**144.9**	**71.9**	**54.2**

Subsidy mechanisms in Estonia

The history of state subsidy mechanisms

Policy in the field of electricity production is influenced by the European Union and local Estonian legislation.

According to the EC Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources in the internal electricity market, an indicative target of 21 percent was established for renewable energy sources' share in the total energy consumption of EU members by 2010. After the Commission's re-assessment in 2008, however, the existing policies and measures were estimated to lead to a 19 percent share of renewable energy in the EU's electricity production by 2010. The directive also defines indicative targets for each member state; the figure for Estonia was 5.1% by 2010.

The EU has also adopted measures to promote combined heat and power generation, which are mainly based on the EC Directive 2004/8/EC on the promotion of cogeneration based on a useful heat demand in the internal energy market.

To fulfil the requirements of EU directives, numerous changes have been made in The Electricity Market Act. This legislation act contains the support scheme for both renewable energy and cogeneration [6].

A scheme, which includes the obligation for the network operators to purchase electricity generated from renewable energy sources, has been in use since 1998. Up to May 2007, the rate of the obligatory feed-in tariff was 51.77 EUR/MWh. For a long period Estonia provided a level of support in the form of feed-in tariffs, which was quite close to the range of electricity generation costs. The main idea of such a policy is to offer a moderate profit for the most cost-efficient plants [18]. This policy would work efficiently in the case of high interest in installing new plants, but, as a result, no new plants were erected before changes were made in the support schemes [19].

In 2007 several important changes were made in the support schemes for electricity production from renewable sources and in cogeneration production plants. Earlier, cogeneration had not been supported in Estonia, and the new provisions of the Act stimulated high efficiency cogeneration by electricity purchase obligation and a certain feed-in tariff.

Two alternatives were introduced as options for cogeneration: either to select a combination of purchase obligation with the feed-in tariff; or to apply only for a subsidized feed-in tariff. However, the subsidy system changed again on July 1, 2010.

Current subsidy mechanisms

There are several subsidy mechanisms for biomass and oil shale energetics. The main mechanisms marked in the valid Electricity Market Act are summarized in Table 3. The main difference in biomass energy subsidizing is that only the feed-in tariff is used. The purchase obligation is not available.

Table 3. **Current subsidy mechanisms for biomass and oil shale energetics**

	Fuel	
	Oil shale	Biomass
Subsidy mechanism	Net capacity usage	Feed-in tariff
	If CO_2 quota price is above 20 €/tCO_2, then 16.0 €/MW_{el} per hour If CO_2 quota price is 15–20 €/tCO_2, then 14.7 €/MW_{el} per hour If CO_2 quota price is 10–14.99 €/tCO_2, then 14.1 €/MW_{el} per hour	53.7 €/MWh_{el}
Subsidy description	Subsidy is valid for oil shale plants which starts operation between 1 January 2013 and 1 January 2016. Subsidy is valid for 20 years. Subsidy should not exceed 83.3 M€ annually.	Electricity is produced under efficient cogeneration regime. Feed-in tariff is valid for 12 years.

Electricity produced in the efficient cogeneration mode from biomass is subsidized by feed-in tariff, which is given per MWh of electricity delivered to grid. Oil shale energetics is subsidized by net capacity usage of oil shale plants and does not depend on electricity production level. Regarding SEIADP annual working time of new oil shale boilers is estimated to be 7500 hours reduced to nominal electrical capacity. It makes the following values for oil shale electricity subsidies per MWh_{el}:

– 16.4 €/MWh_{el} , in case of CO_2 quota price 10-14.99 €/tCO_2;
– 17.2 €/MWh_{el} , in case of CO_2 quota price 15-20 €/tCO_2;
– 18.7 €/MWh_{el} , in case of CO_2 quota price is above 20 €/tCO_2.

Oil shale subsidy restriction at the level of 83.3 M€ is equal to subsidizing of an approximately 600 MW_{el} net capacities of oil shale electricity production at maximum subsidy level 16 €/MW_{el}.

It is also important to mention a regulation which assumes grant payments for under 2 MW_{el} biomass CHP plants for up to 50% from expenses eligible for assistance [20]. Enactment of this regulation is extremely important for expansion of small-scale CHP plants. At the same time application of this regulation is limited by availability of funds. They depend on amount of CO_2 quota sold and terms of sale. The impossibility to expect a guaranteed utilization of above-mentioned grant payments makes it unreasonable to take them into account during plant planning. The grant payments under [20] are not considered in this paper.

Influence of subsidies on oil shale and biomass electricity cost price

To describe the influence of feed-in tariffs on biomass and net capacity usage subsidy on oil shale electricity cost price, the following graph is provided (Fig. 3).

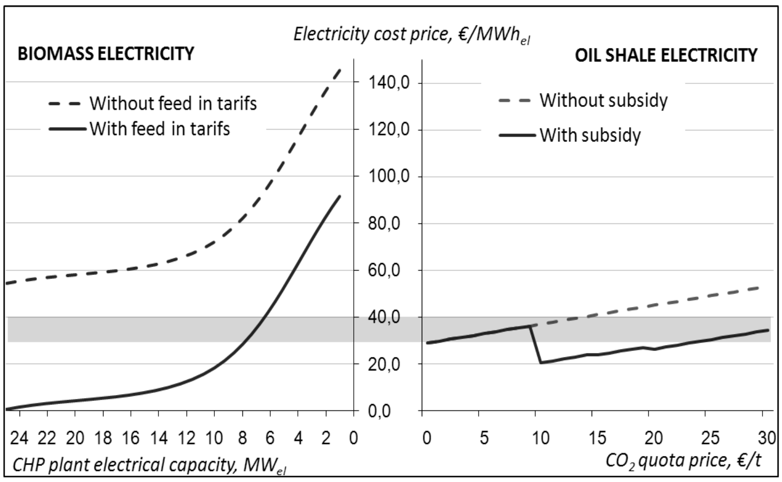

Fig. 3. Dependence of biomass and oil shale electricity cost price on subsidies available in Estonia.

The graph is constructed based on calculation performed in sections *Electricity cost price* and *Subsidy mechanisms in Estonia*. Located in the centre of the graph, vertical axis describes electricity cost price. The graph on the left of the vertical axis specifies cost price of electricity produced in biomass-based CHP plants depending on nominal electrical capacity of the plant. The graph on the right of the vertical axis shows the cost price of oil shale based electricity depending on CO_2 quota price.

Both graphs consist of two data series, which show the electricity cost prices with and without subsidies.

Oil shale electricity cost price without CO_2 quota trade is about 30 €/MWh_{el}. The CO_2 share in electricity production costs increases cost price for a 0.36 €/MWh_{el} per every €/tCO_2. Thus at 20 €/tCO_2 the oil shale electricity cost price will increase 1.5 times.

The subsidy for oil shale energetics will enable to soften the impact of CO_2 quota trade. The implementation of subsidy mechanisms will keep electricity costs in the range of –25 to +35% for CO_2 quota prices 0 to 30 €/tCO_2. The maximum effect of subsidy mechanisms becomes marked at slightly more than 10 €/tCO_2, which allows to decrease cost price by a quarter.

The estimated electricity cost price for biomass CHP plants without feed-in tariffs is roughly 2–5 times higher than for oil shale energetics. Fixed feed-in tariff enables to decrease electricity cost price below oil shale electricity level. A significant decrease is achievable for large-scale CHP plants where biomass-based electricity cost price could near 0 €/MWh_{el}. At the same time fixed feed-in tariff for small-scale biomass CHP plants could be not enough to reach grid parity with oil shale electricity.

The impact of subsidy mechanisms for biomass and oil shale based electricity cost prices is discussed in the next section.

Discussion

Oil shale electricity

Estonia is in a situation where by the year 2015 old oil shale pulverized combustion boilers will be shut down because of high SO_2 emission which does not fulfil the EU requirements. To avoid the influence of CO_2 quota trade on electricity cost price for new planned oil shale energy blocks, subsidy mechanisms have been passed considering CO_2 quota price. The subsidy for oil shale energetics will keep electricity cost price at the competitive range. In spite of that it is assumed that subsidy level for oil shale industry should be revised at least after receiving tenders with technical and economical proposals from the potential contractors for construction of new oil shale power plants. The purpose of that is to avoid the impact of graded tariff system on superfluous fluctuation in oil shale electricity cost price.

It is important to mention that subsidy for new oil shale boilers is intended to improve energetic independence of Estonia. At the same time the specifics of subsidy mechanism does not take into account the amount of electricity produced and does not depend on sells to the internal/external markets.

Biomass electricity

For the time being the feed-in tariff is fixed for all renewable fuels, including biomass in Estonia. Feed-in tariff does not take into account special features of electricity production technologies, plant capacity factor, fuel types, available operation time, etc. The consideration of previously mentioned factors in feed-in tariff formation could significantly increase the reasonability of distributed funds, in other words to avoid subsidy of the projects which cover expenditure without subsidies and to support the projects which need them at the optimum level (to minimize risk of over-compensating of economically efficient plants).

At the same time the implementation and evaluation of a stepped tariff design can lead to high administrative complexity. Many different tariff levels within the same technology may lead to less transparency and uncertainty for the investors.

The trial calculations presented in this paper as well as comparison with feed-in tariffs designs in other EU countries [21] show the necessity to improve the feed-in tariff design in Estonia. To make it more efficient it could be reasonable to look for cooperation with other countries and organisations, as an example of the *International Feed-In Cooperation* [22].

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