THESIS ON ECONOMICS H20

Economic Instruments as Tools for Environmental Regulation of Electricity Production in Estonia

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Declaration:

Hereby I declare that this doctoral thesis, my original investigation and achievement, submitted for the doctoral degree at Tallinn University of Technology has not been submitted for any academic degree.

/Jüri Kleesmaa/

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MAJANDUS H20

Keskkonnaregulatsioonide majanduslikud meetmed elektri tootmisel Eestis

JÜRI KLEESMAA

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CONTENTS

INTRODUCTION

90% of Estonian electricity is produced from the local fuel oil shale. The use of oil shale for electricity production puts pressure on the environment. The European Union (EU), with its environmental regulations, has set a complicated task for Estonia – the substitution of oil shale-based electricity with other energy sources, which require the necessary skills for making technically and economically reasonable decisions.

Current electricity production in Estonia does not meet the environmental requirements established by the EU legislation, and Estonia is presently introducing different regulations that should ensure the respective compliance, thus electricity production is expected to undergo great changes in the near future.

The goal of this Doctoral Thesis is to study the effects of the forthcoming environmental regulations on Estonian electricity production, specifically during the 2020 timeframe. The Doctoral Thesis embraces four measures: EU-ETS – the European Union Emission Trading System, FITs – Feed-in-Tariffs, costs originating from environmental charges (including ash handling and emission-related costs) and the impact of industrial emission limit values on electricity production.

So far, the effects of environmental regulations on the electricity production in Estonia have been studied very little on an academic level[1]. A part from academic research the government of Estonia has commission studies about impacts from environmental regulations on electricity market. Previous researches does not cover such topics as Feed-in-Tariffs, competitions between fuel producing firms, SO_2 control cost with primary method and at the same time CO_2 generation, electricity production forecast vision up to 2020, which therefore will be analysed in this thesis. This Doctoral Thesis, based on five different research works, contributes to the field of activity under observation. Every research work presented in this Doctoral Thesis focuses on a certain case study; where the effects of regulations on the electricity production in Estonia form a connecting theme between these research works.

The European Union (EU), to the membership of which Estonia also belongs since 1 May 2004, has set the development of common energy and environmental policy as its main task in the field of energy use for the coming decades. The envisaged common energy and environmental policy is to be grounded on clear-cut aspirations and a time schedule towards transition to a low-carbon sector, i.e. green energy, and energy saving.

A need for a more reasonable use of energy is also conditioned by increased environmental impacts arising from the use of fossil energy sources compared to

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[1] The research completed at the Estonian Institute of Economics in 2004 assessed the effect of environmental regulations on the development of Estonian electricity sector until 2015, and by taking these regulations into account, projected an electricity production price.

bioenergy[2]. Combustion of fossil fuels adds stored carbon to the natural carbon cycle in the biosphere; but the combustion of biofuels does not, since biofuels form a part of the biosphere's carbon cycle.

In order to reach the goals listed above, the European Commission (EC) issued communication COM(2007) 1 (Brussels 2007) on an energy policy for Europe for the purpose of enhancing sustainability, security of energy supply at competitive prices in the European Union and for the combating of climate change[3]. The plan of the European Parliament to reduce greenhouse gas[4] emissions and increase the share of renewable energy[5] in energy consumption became known as the "20-20-20 targets"[6]. On the basis of these targets, EU's leaders committed to a reduction of greenhouse gas emissions by at least 20% below 1990 levels; 20% of EU energy consumption to come from renewable sources[7]; and a 20% reduction in primary energy[8] use from higher energy efficiency[9] – all by the year 2020.

In 2009 the European Commission passed important legal acts to implement the planned targets. These regulations revised and expanded the Emissions Trading System (EU-ETS)[10] of the European Communities and concentrate on the efforts of Member States to reduce their greenhouse gas emissions to meet the Commission's greenhouse gas emission reduction commitments up to 2020[11] and promote the use of energy from renewable sources by the year 2020[12].

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[2] Bioenergy includes the biodegradable fraction of products, waste and residues from agriculture (including vegetal and animal substances), forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste (Directive 2003/30/EC of the European Parliament and of the Council).

[3] Based on contemporary knowledge, CO_2 is regarded one of the main factors causing climate change and creating greenhouse effects, as a result of which the average temperature of the earth is rising.

[4] Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), fluorinated greenhouse gases (HFC, SF_6, PFC).

[5] Renewable energy embraces water, wind, solar energy, waves, tides, geothermal heat, landfill gas, gas discharged in the process of waste water treatment and bioenergy.

[6] The European Union Climate and Energy Package.

[7] The following topic was not discussed in this Doctoral Thesis.

[8] Primary Energy derived from a natural source and used by not converting it into another kind of energy. Estonian primary energy sources are oil shale, peat, firewood, wood waste and biogas. Imported primary energy sources are coal, natural gas, liquefied gas, light oil and heavy fuel oil, diesel fuel, motor vehicle petrol and aviation kerosene are included.

[9] Ratio of final energy consumption to primary energy.

[10] Directive 2009/29/EC of the European Parliament and of the Council of 23 April 2009.

[11] Decision No 406/2009/EC of the European Parliament and of the Council of 23 April 2009.

[12] Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009.

The Directive of the European Parliament and of the Council on industrial emissions[13] also plays an essential role. According to the Directive the integrated air pollution prevention and control is implemented. As a part of this, the Directive limits the amounts of air emissions allowed to be discharged by large combustion plants (over 50 MW) into the surrounding environment.

In compliance with environmental regulations of the EU, Estonia has created a judicial area in its republic for promoting the use of green energy sector and for energy conservation. National legislative acts recently passed in this field are targeted at regulating the greenhouse gas emission allowance trading procedure[14] and on meeting the limit and target values of ambient air pollution levels, other maximum permitted contents of pollutants and dates set for achieving them[15]. The regulation on greenhouse gas emission allowance trading establishes procedures and requirements for application and granting of emission allowances and guidelines for allocation of emission allowances for free. In addition, the referred regulation lays down a procedure for the surveillance and certification of greenhouse gas emissions and for the return of emission allowances.

Emissions of SO_2, NO_x and solid particles are regulated by the legislation on environmental charges. The objective of applying pollution charges[16] is to prevent or reduce possible damage caused by the release of pollutants or waste into the environment.

In addition to legislative acts, the Estonian Government has adopted several important development plans, such as the Development Plan of the Estonian Electricity Sector until 2018[17] and the Estonian Renewable Energy Development Plan until 2020[18]. The Development Plan of the Estonian Electricity Sector for 2008–2018 has been approved by the Government of the Republic lays out the Government's strategy in one of the most important fields of energy policy – power generation.

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[13] Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010.

[14] The Minister of the Environment Regulation No. 44 of 08.07.2011 „Kasvuhoonegaaside heitkoguste ühikutega kauplemise kord" (procedure for greenhouse gas (GHG) emission allowance trading) took effect on 15.07.2011.

[15] The Minister of the Environment Regulation No. 43 „Välisõhu saastatuse taseme piir- ja sihtväärtused, saasteaine sisalduse muud piirnormid ning nende saavutamise tähtajad" (the limit and target values of ambient air pollution level, other maximum permitted contents of pollutants and dates for achieving these targets) of 08.07.2011 took effect on 15 July 2011.

[16] Environmental Charges Act, State Gazette I, 14.03.2011. Statistical Office of the European Communities i.e. Eurostat uses the concept 'environmental tax' that includes all environment-related taxes, fees, excise duties and state fees. In this research the term 'pollution charge' is used instead of 'pollution tax'.

[17] Ministry of Economic Affairs and Communications, passed by the Government of the Republic of Estonia Order No. 74 of 26.02.2009.

[18] Ministry of Economic Affairs and Communications, approved by the Government of the Republic Order No. 452 of 26.11.2010.

The Electricity Market Act plays a vital role in the organisation of Estonian electricity production.[19] This act regulates the generation, transmission, sale, export, import and transit of electricity and the economic and technical management of the power system. The act prescribes the principles for the operation of the electricity market based on the need to ensure an effective supply of electricity at reasonable prices and meeting environmental requirements and along with the needs of consumers, and on the balanced use of, environmentally clean and long-term sustainable energy sources. The Electricity Market Act also sets out a procedure for electricity producers from renewable energy sources on acquisition of feed-in-tariffs (FIT) and the tariff amounts.

Estonian electricity production is mainly based on oil shale. 92.5% (Statistics Estonia, 2011) of the total electric power output of Estonia is generated from the local fuel – oil shale. By structure, oil shale exerts a significant impact on the environment – the emission factor[20] of CO_2 in electricity generation is 1,156 kg/MWh_e, which is up to two times higher than the emission factor of natural gas 573 kg/MWh_e (Kleesmaa 2010 and Kleesmaa et al. 2011). In addition, oil shale fuel has a very high ash content which is 47%[21] of fuel weight (for example, the ash content of wood as a biofuel is ca. 1%). In order to comply with environmental requirements, the high ash content requires specific ash handling techniques for ash depositing.

The Development Plan of the Estonian Electricity Sector until 2018 determines the installation and use of capacities and technologies planned for the energy sector. According to the best future scenario set out in the Development Plan of the Estonian Electricity Sector, the capacity of co-generation plants[22] should be increased to 300 MW_e by 2014; 2x300 MW_e oil shale fluidised bed combustion units[23] should be erected by the end of 2015; by 2012, desulphurisation and denitrification systems must be installed in four of the existing old 200 MW_e oil shale units; by 2013, the capacity of on-shore wind turbines must be increased to 400 MW_e. Investment decisions grounded on the best scenario of the Development Plan have in some cases already been carried out and further activities are under way.

In the first research paper the aggregate table setting out the capacities planned in the best electricity production scenario of the Development Plan of Estonian Electricity Sector has been supplemented with the indicators of the previous periods' actual operation hours and CO_2 emissions found by the official

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[19] Electricity Market Act, 11.02.2003 State Gazette I 2003, 25, 153.

[20] Emmission of unit mass (kg) per primary energy unit (MWh – megawatt-hour).

[21] Ash is a fireproof residue from combustion. It is formed of the mineral particles of fuel in the process of burning.

[22] Generation of electric energy on the basis of heat and power cogeneration mode.

[23] A fluidised bed unit consists of two fluidised bed boilers, a turbine and an electric generator.

CO_2 calculation method[24]. The referred supplementary calculations enable assessing the new situation developed by the year 2020 in quantitative terms. On the basis of the forecasts Estonian electricity production will change fundamentally, i.e. the share of oil shale-based electricity generation will decrease to ca. 40%, whereas the share of renewable energy will increase to ca. 31%.

Realisation of the best future scenario depends largely on the effect of the CO_2 trade, which, via the price and quantity of emission allowances, regulates and motivates the diversification of the electricity production portfolio through cost-effectiveness, which in turn would facilitate technological development. The Minister of the Environment delegated out, through Regulation No. 44, the application process for free allowances and on the procedure for certification of emissions to an independent accredited verifier during 2011–2012 and 2013–2020, which so far had been carried out by a solely competent authority – the Ministry of the Environment, is an indication of the Government's efforts to understand the possibilities for regulating the EU greenhouse gas emissions trading. It is relevant to mention that, in March–August 2011, the author of this Doctoral Thesis has himself participated in the free CO_2 emission allowance certification process of several enterprises, carried out in accordance with the requirements established by EU Regulation 2009/29/EC. Practical experience acquired in the course of certification confirms once again the hypothesis that a well-functioning regulation motivates enterprises' activities. Carrying out of the certification process gives enterprises a chance to analyse their day-to-day business in detail. On the basis of relevant results, enterprises can make decisions for optimisation of their business (and enhancement of competitiveness) in new conditions as well as to find the best ways to protect the surrounding environment (Porter 1995, Thompson 2004, Neary 2006).

The following articles have been published in the course of research:

Kleesmaa, Jüri. Impact of CO_2 trade on electricity producers depending on the use of different energy sources in Estonia. In: Estonian Economic Policy Debate XVIII: XVIII Economics Policy Conference, Värska, 1.–3.07.2010. Berlin*Tallinn: Berliner Wissenchafts-Verlag, Mattimar, 121−139, 2010.

Latõšov, E., Kleesmaa, J., Siirde, A. The impact of pollution charges, ash handling and carbon dioxide to cost competitiveness of fuel sources for energy production in Estonia. Scientific proceedings of Riga Technical University. Environmental and Climate Technologies, 4(13), 58–63, 2010.

Kleesmaa, J., Pädam, S., Ehrlich, Ü. Subsidising renewable electricity in Estonia. In: Energy and Sustainability III: Energy and sustainability 2011, Alicante, Spain, 2011. (Editorial Board) Mammoli, A. A., Brebbia, C. A., Villacampa Esteve, Y. WIT Press, 2011, (Ecology and the Environment; 143), 229–241.

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[24] The Minister of the Environment regulation no 94 "Välisõhku eralduva süsinikdioksiidi heitkoguse määramismeetod" (method for determination of carbon dioxide emission discharged into ambient air) of 16.07.2004.

Kleesmaa, J., Latõšov, E., Karolin, R. Primary method for reduction of SO_2 and its impact for CO_2 in pulverized oil shale fired boilers at Narva Power Plant. Oil Shale 2011, vol 28-2, p 321–336.

Kleesmaa, J., Viiding, M., Latõšov, E. Implication for competitiveness of Estonian energy-intensive industry after establishment of CO_2 pricing from year 2013 onwards. Baltic Journal of Economics, autumn 2011. [Forthcoming]

The main research tasks of the Doctoral Thesis are as follows.

1. Assuming that the best scenario of the Development Plan of the Estonian Electricity Sector will be implemented, give a quantitative assessment of the impact on CO_2 emissions by taking into account actual operation hours, and compare the result with the objective set out in the European Union Emission Trading System (EU-ETS).
2. Assess the impact of additional costs arising from environmental charges, ash handling fees and the price of CO_2 quota on the cost-competitiveness of oil shale, wood, peat and natural gas in the Estonian fuel market in 2015.
3. On the basis of the economic activities of two power plants (heat and power cogeneration plants), assess the effect of Feed-in-Tariffs (FIT), and explain whether the current tariff is justified from the perspectives of effectiveness, economic efficiency and how it influences consumer prices.
4. Analyse the possibilities of using the primary method BLW (Brennschiefer–Luft–Wasser) for the purpose of achieving the permitted SO_2 emission level established in the EU environmental regulations. Although the primary method potentially achieves the desired reduction of SO_2 emissions, other emissions (due to fuel consumption increase) might increase. The main contribution of the author's research is the development of an algorithm that calculates the per ton cost of the SO_2 air emissions in different modes of the primary method, taking into consideration investment costs, the increased costs of other emissions and increased fuel consumption costs.
5. Analyse on the basis of the CO_2 emission allowance prices (15, 25 and 50 euros per ton, respectively) the impact on the competitiveness of 21 companies that participate in the EU Emission Trading System, provided that all carbon dioxide emission allowances were bought at auction contrary to the free allowances distributed during 2008–2012.

The object of the Doctoral Thesis research is Estonian electricity production and the effect of legislative acts on the formation of its structure until 2020. In addition, other energy-intensive enterprises not related to electricity production are observed in a new environment created due to the application of legislative acts.

In the methods parts of the Doctoral Thesis, the knowledge acquired in the course of various research works has been used. Being continuously involved in the field of energy, which is presently so closely connected with economic issues, enables to directly perceive sensitive points and also the impacts of change and the indifference that enterprises come across in their usual activities.

Each research paper is based on calculation models developed by the authors for the specific purpose of the paper. The mentioned models enable the analysis of basic data by changing different input values.

The cost-competitiveness of fuels producers has been assessed depending on the implications of environmental charges and CO_2 trade. Taking economic indicators and the financial result on enterprise level, into consideration the impact of FIT is assessed from the enterprise's as well as social-economic perspectives.

Basic data used in the Doctoral Thesis include the European Union directives, national development plans, annual reports of enterprises, legal acts of Estonia, results of pulverised oil shale combustion tests, results of various research works, articles published in scientific journals and other sources of literature.

The contribution of this Doctoral Thesis in theoretical and practical terms lies in the following.

1. The cost-competitiveness of fuels is handled from the perspective of supplementary costs arising from various regulations that are added to fixed fuel prices. Supplementary cost involves costs related to ash handling.
2. According to the author's knowledge, no assessments have so far been carried out with respect to FITs granted to cogeneration plants on enterprise level – at least no relevant public information is available. The implications of FITs have been studied on the basis of power plants' annual reports by analysing financial-economic indicators.
3. Modelling of the tests carried out in the pulverised oil shale-fired boilers with the aim of introducing the primary method is unique at the global level, since no such oil shale-related models have been previously compiled. Another aspect is the use of the test results for calculating emission reduction costs.

Overview of the approval of research results

1. Results of the research about the impacts of CO_2 trade on electricity producers in Estonia were presented by the author at the Scientific− Conference on Economic Policy at Värska in 2010.
2. Conclusions drawn from the results of the research paper on the impact of pollution charges, ash handling and the prices of CO_2 emission allowances on the costs of different fuels were presented by correspondent author Eduard Latõšov at the Riga Technical University conference in 2010.
3. The results of the research paper on the implications of FITs on Estonian electricity production and the case study of cogeneration plants were presented by the author at the scientific conference "Energy and Sustainability 2011" in Alicante, Spain, April 2011, on the recommendation of the team of authors involved.
4. The research paper about implications of the tradable CO_2 emission allowances on Estonian energy−intensive enterprises was presented by one of the authors of the paper – Marko Viiding (Doctoral candidate at the University of Tartu) – at the Scientific Conference on Economic Policy in Värska conference in 2011.

Abbreviations

AVC – Average Variable Cost
B – fuel consumption
BLW – Brennschiefer-Luft-Wasser (fuel-air-water)
B-LW – optimal capacity – air-water
bLW – minimum capacity – air-water
C – carbon content
$Ca(OH)_2$ – slaked lime
$CaCO_3$ – limestone
Ca/S – calcium and sulphur ratio
CEO – Chief Executive Officer
CHP – Cogeneration Heat and Power
CO_2 – carbon dioxide
COM – Commission of the European Communities
CaO – calcium oxide
C_{var} – variable costs magnitude
C_{const} – investment cost
EC – European Commission
EU – European Union
EU-ETS – the European Union Emission Trading System
EUR – euro
FIT – Feed in Tariff
G – quantity
GHG – Green House Gas
GWh, MWh, kWh – energy content
H_2O – water chemical conglomerate
IRR – Internal Rate of Return
Kc – part of oxidize carbon
K_2O – potassium oxide
LIFAC – flue gas cleaning method
LRMC – Long Run Marginal Cost
LW – Luf-Wasser (air-water)
Mc – carbon emission value
MgO – magnesium oxide
MW – capacity
NAP – National Allocation Plan
Nm^3 – normal cubic meter
NO_x – nitrogen oxide
OK – equity share
O_2 – oxygen
PM – solid particuls
P_{CO2} – cost of CO_2 emission
Q – fuel calorific value

RO_x – fuel fine crushing
S – sulphur
SO_2 – sulphur dioxide
SRMC – Short Run Marginal Cost
VC – Variable Cost
VK – loan capital share
VKG – Viru Keemia Grupp
WACC – Weighted Average Cost of Capital
k – equity cost
mg – milligram
q – specific emission
β – emissions relative reduction
η – absorption factor
η – energy unit efficiency

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I would like to thank my family – my wife Tiina Kleesmaa and my son Alo Kleesmaa. I appreciate their profound understanding and support that helped me to reach the goal set.

1. EFFECT OF ENVIRONMENTAL REGULATIONS ON ELECTRICITY PRODUCTION IN ESTONIA UNTIL 2020

Business executives (including electricity producers) traditionally think that environmental regulations such as permitted maximum levels of air emissions, pollution charges and greenhouse gas trading allowances, affect the competitiveness of companies, restrict business activity and are inhibiting and non-productive from the perspective of business operations. The permitted maximum levels imposed on air emissions impacts the use of technologies. Pollution charges and emission trading allowances make the parties involved consider air emissions and these measures also have an effect on by-products that were earlier untouched by regulation.

On the basis of different case studies, this thesis analyses the implications of EU directives, greenhouse gas trading, maximum permitted levels of air emissions as well as the environmental charges arising from Estonian legislation and the feed-in-tariff (FIT) specified in the Electricity Market Act. In addition, the overall aim of the thesis is to analyse the impacts that environmental regulations have on electricity production. This is done from the perspective of Estonian electricity producers' business activities, as well as from the point of view of the impact of regulations on a wider societal perspective.

The first research paper "Impact of CO_2 trade on electricity producers depending on the use of different energy sources in Estonia" analyses the structural impact of the Development Plan of the Estonian Electricity Sector until 2018 in light of EU greenhouse gas allowance trade. The best future scenario proposed in the mentioned Development Plan serves as background information for the study that focuses on finding the implicators of electricity production technologies pursuant to the emission trading directive and its consequences to the fuel market. The Development Plan of the Estonian Electricity Sector is given a quantitative assessment as a result of the research.

The second research paper analyses the usage of different fuels in electricity production by taking into account the requirements of the CO_2 emission trading directive as well as the impact of the environmental costs of fuels from other legislation. Thereby the impact of environmental charges until 2015 in the case of fixed prices of different fuels, CO_2 allowance trading, and supplementary costs related to ash handling have been taken into account as relevant determinants.

In the third research paper dealing with the impact of FITs on renewable electricity production, two 25 MW_{el} cogeneration plants that started operation in 2009 serve as case studies. In the case studies assessment of the cogeneration plants' investment decisions and profitability are based on their annual reports (Annual Reports 2010). In order to assess profitability without FITs, the rules of the Estonian Competition Authority were applied and the revenue per MWh (megawatt-hour) without FIT was calculated. Then, the results were compared with the marginal cost and the cost price of electricity. Since a gradual transition from oil shale-based electricity to electricity based on renewable resources has a positive effect on the environment we calculated the external costs depending on whether electricity is being produced from oil shale, wood chips or peat.

In order to meet the SO_2 specific emission limit value (400 mg/Nm^3) set as a target for 2016 by the European Union, in the fourth research paper is analysed that it is advisable to apply flue gas circulation, finer crushing of oil shale dust and water injection first to one of the pulverized oil shale-fired boilers for the purpose of studying the impacts of these factors on the SO_2 emission.

The last research paper studies the competitiveness of the 47 enterprises that participate in the EU-ETS, i.e. EU's CO_2 emissions trading system after 2013 assuming that all CO_2 allowances have to be bought at auction. The research paper includes both electricity producers and other energy intensive companies that switched into the given trade system. The research paper centred on the impact that an increasing variable costs has on the competitiveness of the studied energy intense companies (including electricity producers) depending on their CO_2 emission intensity. The research also observed how the energy intense companies manage to shift additional costs to the fixed sales price; as well as the measures taken to reduce the CO_2 emission in their production.

1.1. Setting of theses, literature and methods

In the view of environmental regulations, Estonian electricity production is on the threshold of a new era – the use of fuels needs to be changed, combustion technologies need to be improved, new technologies need to be introduced for the purpose of meeting the environmental requirements that tend to become ever stricter, otherwise electricity producers will face fines and a threat of a shutdown.

The CO_2 emission allowance trading system (EU-ETS), environmental charges on fuels and ash handling fees, the FIT arising from the Electricity Market Act – all these measures have an impact on electricity production.

1.1.1. Implementation of the best scenario described in the Development Plan of the Estonian Electricity Sector until 2018 will cause a sharp reduction of CO_2 emissions

An objective arising from the best scenario proposed by the government in the Estonian Electricity Sector Development Plan until 2018 involves diversification of electricity production to be achieved due to the introduction of different technologies. The government assessed the scenarios from three aspects – economy, security and environment. The aim the of research paper was to assess the best possible scenario of the electricity sector from the perspective of CO_2, (i.e. how much the quantity of CO_2 will decrease) in the case that the best future scenario of the Development Plan is implemented and in which way it is in line with the target set for greenhouse gas emission trading.

The first introductory trading period under Directive 2003/87/EC establishing a scheme for greenhouse gas emission allowance trading within the Community lasted from 2005 to 2007 when the main CO_2 emission allowance trading took place only between the EU Member States. The second period started on 01.01.2008 and lasts until 31.12.2012. The third emission allowance trading period will cover the period 2013–2020 and is tied to the EU Climate and Energy Package (20%+20%+20) which was adopted in 2008. The aim of the package is to reduce greenhouse gas emissions by at least 20% below the 1990 level by the year 2020. At the same time, by 2020 the number of emission allowances will be reduced by 21% compared to the cap of 2005, with an annual reduction of 1.74%. A target was also set for the energy sector – all emission allowances shall be bought on the market.

For the trading period which started in 2008, the European Commission (EC) directives took extremely radical cut-down decisions with respect to the total sum of allowances to be allocated to Member States (the so-called national Allocation Plan – NAP) in order to stabilise the situation prevalent during the previous trading period. The purpose of the CO_2 market is to allow demand and supply set the price and value of one ton of CO_2.

For the 2008–2012 trading period, Estonia made an allocation proposal of 24.4 million tons of CO_2 quotas for free per year (122 million t / 5 y.) to the EC. The EC reduced the proposed quota amount to 12.7 million tons (63.5 million t / 5 y.), i.e. ca. by 52%. In Estonia, 47 installations, including 39 in the energy production sector, 6 in the mineral industry and 2 in the paper and pulp industry, participate in allowances trading. Greenhouse gas permits are issued by the Minister of the Environment under Regulation No. 257 which provides for the permitted quantity of emissions discharged by stationary sources of pollution for the period from 1 January 2008 until 31 December 2012. Every year 11,678,257 tons are distributed to installations and the annual reserve comprises 1,038,801 tons meant for new installations entering the trading system.

Estonia filed an action to the European Court of Justice against the European Commission claiming that the European Commission made serious errors and exceeded its authority in making the relevant decision. The European Court agreed to Estonia's opinions and noted that the Commission had no right to replace Estonia's data by its own ones during the assessment of the National Allocation Plan. In addition, the Commission's data had not taken Estonian energy policy sufficiently into account and were not based on accurate GDP growth forecasts. Besides, the European Court confirmed that the principle of good administration had been violated[25].

The court judgement entailed new decisions to be taken on Estonian emission quotas by the EC. In 2009, the EC provided justifications for its decision previously taken on the quantity of emission quotas and refused to amend it. Negotiations between the EC and Estonia continue at present. In July 2011,

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[25] Eurpean Commission Decision of 11.12.2009 concerning the national allocation plan for the allocation of greenhouse gas emission allowances notified by Estonia in accordance with Directive 2003/87/EC of the European, Parliament and of the Council.

Estonia made a new proposal to the EC asking for the rate of 13.3 million tons of emission allowances[26].

Assuming that the CO_2 allowances basic value for Estonia will be 12.7 million tons. The EU energy policy measure foresees reduction of greenhouse gas emission allowances by 1.74% per year compared to the reference year 2005. Proceeding from these values at the referred minimal CO_2 reduction rate, the respective CO_2 amount is estimated to be no more than 11.2 million tons in 2020. To compare goals of EU-ETS to our best scenarios CO_2 quantity of this scenario will be calculated and benchmarked to EU-ETS minimum CO_2 reduction requirements.

The Minister of the Environment Regulations No. 94 of 16.07.2004 and No. 99 of 02.08.2004 serve as the bases for calculations of the CO_2 emission released into the ambient air during combustion of different fuels (in the 1st, 2nd and 5th articles). The mentioned regulations provide for a method of determining the amount of CO_2 released into the ambient air. The author has compiled an Excel program-based calculation model for determining the discharged CO_2 amount in the case of the best future scenario of electricity production. The input of the calculation program is comprised of CO_2 emission factors, capacity of the power plant, operational efficiency and duration of operation period, whereas, the relevant calculations were made by using the determination method established by the referred Regulation of the Minister of the Environment. Electricity production in 2020 and the CO_2 emission released in the course of electricity production are the results gained due to the calculation process.

1.1.2. The cost-competitiveness of oil shale, wood, peat and natural gas will face a change in 2015 due to increases in environmental charges, ash handling fees and the CO_2 emission allowance price

In Estonia, environmental charges have been applied since 1991. In the course of 20 years, these charges have been revised and amended and the respective rates have been increased step by step. The rates of the environmental charges that took effect in 1991 were low, because the economic level and the solvency of the population were also low. In terms of environmental protection, their impact was symbolic, in order to ‘drawing attention’ nature. As a result of the gradual increase in the charge rates over a long period of time with a larger ‘leap’ made in 2006, the charge rates have by now grown to the level that to some extent already encourages environmental protection activities. (Kraav 2008).

Pollution charges serve as an economic instrument functioning by ‘the polluter pays’ principle. The goal is to let an undertaking choose whether to invest in the reduction of pollution and pay less pollution charge in the future or to continue its production process and polluting and pay compensation to the state for the environmental pollution caused.

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[26] http://majandus.delfi.ee/news/uudised/eesti-vahendab-uues-kavas-soovitavat-co2-kvooti-miljoni-tonni-vorra.d?id=50691217 (in Estonian). Retrived 22.09.2011.

The aim of the research paper is to assess the impact of monetary measures on the cost competitiveness of oil shale, peat, wood and natural gas. Cost competitiveness of a fuel has been determined on the basis of the change in fuel-related environmental costs for the period 2010–2015. While the pre-charge prices of various fuels were fixed, the costs were added of ash handling fees, environmental charges and the price of CO_2 emission allowances per one megawatt-hour of energy content of respective fuel.

Quantities of emissions released into the environment in the course of fuel combustion and ash formation have been calculated according to the Environmental Charges Act of 15 June 2010.

1.1.3. FITs are effective for introducing renewable energy, but the costs may not be justified

FITs entail a guaranteed price for those undertakings that produce electricity from renewable sources whereas the network operator is obliged to purchase their production (del Rio & Gual 2007). There are two possibilities for covering the costs of FITs: this is done on account of consumer's electricity bill or through the public sector budget. An important reason, why the electricity produced form renewable sources is subsidised is that the production costs are bigger than in case of electricity from other sources (del Rio & Gual 2007).

Relying on German and Danish experience, Sijm (Sijm 2002) has assessed the sustainability of FITs and he concludes that FITs are effective for encouraging production of electricity from renewable sources, but costly, inefficient and distorts the market.

Spain has achieved notable results in the development of electricity production from renewable sources. Del Rio and Gual (2007) find evidence similar to Sijm in their assessment. The Spanish system has proved effective in stimulating wind energy, but has not showed the same success in the case of other energy sources. Consumer prices rose during the time period 1999–2003 from 0.14 euro cents to 0.26 euro cents per kWh. However, the costs of FITs are large in comparison with the avoided external costs.

The goal of the research paper about subsidizing renewable electricity in Estonia is to assess the application of FITs to heat and power cogeneration plants and, to explore whether the current tariff is effective, justified from the perspective of efficiency and what effect it has on the consumer price. Another goal of the research paper is to determine the value of avoiding external costs. So far, we have no information about previous assessments of the application of FITs to cogeneration plants. Thus, the relevant article can be regarded as the first one in this field.

The 2008 and 2009 annual reports submitted by two power plants serve as a basis for assessing the efficiency of FIT. The financial indicators of these enterprises are used as benchmarks and as inputs to the analysis. Since information of the annual reports do not directly reveal the power plant dependence on FIT, the following formula was compiled by the authors. The formula reflects the dependence of operating profit on the size of FIT:

$$\pi_{el} = \pi_{el}^{excl\,FIT} + (Q_{el} \times FIT_i)$$

where

π_{el} is operating profit from electricity sales expressed in euros, $\pi_{el}^{excl\,FIT}$ – operating profit without FIT in euros, Q_{el} – produced electric energy in megawatt-hours and, FIT_i denotes the size of support given in case of different fuels in euros per megawatt-hour; i=1,2 (1=wood and 2=peat).

The operation of power plants without FITs was analysed by using the regulator method established by the Estonian Competition Authority – a price formula of WACC i.e. the Weighted Average Capital Cost:

$$WACC = k_e \times \frac{OK}{(VK + OK)} + k_d \times \frac{VK}{(VK + OK)}$$

where

k_e – cost of equity capital (%), k_d – cost of borrowed capital or external liabilities (%), OK – proportion of equity capital determined by the regulator (%), and VK – proportion of borrowed capital determined by the regulator (%).

According to the support rates provided for in the Electricity Market Act, the size of FIT if electricity is generated from a renewable energy source (including wood in a cogeneration regime) and from peat in an efficient cogeneration regime[27] is 54 euros per megawatt-hour in the case of wood fuel and 32 euros per megawatt-hour in the case of peat.

1.1.4. The use of primary energy method has great advantages in SO_2 capturing costs in pulverised oil shale-fired boilers

Reduction of the SO_2 emissions released in the pulverised oil shale combustion process is one of the most important and complicated environmental issues faced by Narva Power Plants. The EU accession agreement sets out an obligation to restrict the SO_2 emissions to 25,000 tons per year from 2012 onwards source. The directive on industrial emissions establishes an obligation to substantially reduce the discharge of specific emissions SO_2, NO_x and fly ash starting from 2016. These requirements will significantly limit electricity production capacity in Estonia. In order to ensure compliance with the EU requirements, several flue gas cleaning methods (dry, semi-dry, wet, plasma and photochemical methods) targeted at reducing the SO_2 emissions have been studied and tested (Ots 2006). However, the experience gained from the referred tests shows that the listed methods do not fully take the specific mineral properties of oil shale into

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[27] „Elektrienergia tootmine elektri- ja soojusenergia koostootmise režiimil, lähtuvalt soojusenergia nõudlusest ja tagades energiasäästu vastavalt tõhusa koostootmise nõuetele“ (production of electric energy in the heat and power cogeneration mode depending on the demand for heat energy and by ensuring the saving of energy in compliance with the requirements set for efficient cogeneration); State Gazette I 2007, 23, 120 – in force since 01.05.2007.

account. Furthermore, the possibility of their application and assurance of their efficiency is questionable. To increase the SO_2 capture in pulverised oil shale-fired boilers by primary methods comprises a large reserve in the reduction of SO_2 emission. Its own nature offers a solution to this problem as oil shale has been supplied with a neutralizing mineral ballast that contains up to ten times more SO_2-binding components (CaO, MgO, K_2O, etc.) than stoichiometrically needed. Nevertheless, by the currently applied pulverised oil shale combustion methods, the capture of SO_2 varies to a large extent in a pulverised oil shale-fired boiler by 70–80%. The specific emission of SO_2 in leaving flue gases is 1,800–2,700 mg/Nm^3 (Aunela 1995). This indicates that the specific emission of SO_2 in flue gases changes to a large extent during the boiler operation period, because the regime and technological parameters change, too. This suggests that application of primary methods for capturing SO_2 in pulverised oil shale-fired boilers involves large reserves and this potential is not fully made use of as of yet. The main difficulty in taking into use of the mentioned reserves while capturing SO_2 is that there is lack of experience in the combustion of a fuel of similar structure and in the capture of SO_2 by primary methods.

The application of primary methods in pulverised oil shale combustion reduces the emissions of NO_x and SO_2. The decrease in SO_2 emissions is proved by the results of earlier tests carried out on the Eesti Power Plant boiler walls by the Power Plant staff source. The tests were based on water injection tests after a finer crushing of oil shale dust and heating of steam in the superheater. The mentioned tests had earlier been carried out in a boiler of the Balti Power Plant and resulted in an enlarged fly ash chemisorption surface.

Water injection after the superheater activates fly ash (i.e. it enlarges the fly ash chemisorption surface). The water injection technology is a simplified high-temperature technology developed on the basis of the LIFAC gas cleaning method. For a long time, the LIFAC gas cleaning method has been successfully and widely applied to coal-firing power plants for the reduction of SO_2 emissions (Hämälä 1986 and Ryyppö 2000).

Circulation of flue gases lowers the combustion flame temperature, which in turn reduces a high-temperature agglomeration process. Finer-fraction crushing of oil shale reduces mechanical separation and enlarges the fly ash chemisorption surface. Both primary technologies have for a long time been successfully and widely applied to coal-firing power plants for the reduction of NO_x emission (Kotler 1987, Leikert 1986, Jaborski 1995, Weber 1986, Macphail 1999 and Sidorkin 1991).

The advantage of primary technologies lies in considerably smaller investments and operational costs compared to those of gas cleaning equipment such as SO_2 scrubbers and catalytic NO_x reactors (Nolan 1995, overview of the methods 1993, Beljaikin 2000, Šmigol 2006 and Šmigol 2007).

The cost calculations of the fourth research paper are based on the technological and economic-analytical algorithm of the primary method BLW (Brennschiefer–Luft–Wasser) technology, which was compiled by the team of authors (Appendix B).

1.1.5. Additional costs of the CO_2 emission allowances influence the variable costs and might thereby affect the competitiveness of enterprises participating in the trade with emission allowances

Researchers of economics regard that, in principle, competitiveness can be affected by environmental regulations in two ways: the first approach states that environmental regulation is harmful to competitiveness (Oates, Palmer & Portney, Simpson 1993) – a) there is a fixed opportunity cost, b) and is therefore harmful to other innovations; and the second approach suggests that a reasonably implemented environmental regulation improves competitiveness (Porter & van der Linde 1995). Michael Porter presents six aims of environmental regulation that all foster the competitiveness of firms: a) signals to firms an efficient use of resources, b) focuses on the collection of information, c) reduces uncertainty, d) creates certain pressure, e) ensures a transitional buffer stock, and f) improves the quality of the environment. Empirical results support neither the first nor the second approach (Lanoie 2008).

In this research paper 21 of the largest energy-intensive enterprises in Estonia were analysed. Six of these enterprises have more than one subsidiary. Subsidiaries included, we have 47 Estonian production units registered in the European Commission's National Allocation Plan for the Community Emissions Trading Scheme (European Commission 2008).

The referred Allocation Plan provides an overview of some of the principles according to which these production units have been classified. Several production units produce electricity, or heat or cogenerate both. Some enterprise groups own several subsidiaries, but only a certain number of them deal with energy production (e.g. Eesti Energia AS, Viru Keemia Grupp AS (VKG) and Kiviõli Keemiatööstuse OÜ). Some enterprises do not produce energy, but rather emit large amounts of CO_2 as part of their production process. Such enterprises are, for example, manufacturers of cement – Kunda Nordic Tsement and cellulose and pulp producers – AS Estonian Cell and Horizon Tselluloosi ja Paberi AS, manufacturers of bricks – Wienerberger and glass producer O-I Production Estonia.

In the research paper, the authors observe the variable costs of these companies in 2008 and 2009, and assume that changes in variable costs have a direct impact on the total costs. In the structure of costs of energy-producing companies, variable costs – also including fuel costs – comprise 85–90% of total costs. Thus, variable costs constitute a good indicator that shows how the establishment of the carbon dioxide emission allowance price brings about a change in total costs.

The aim of using the CO_2 emission allowance prices (15, 25 and 50 euros per ton) is to compare a scenario with free allocation of allowances to another scenario where allowances are to be bought at auction to their different market prices. Data on the variable costs of the 21 companies observed here have been derived from the 2008 and 2009 annual reports. Data on the fuels used have been collected from annual reports, if available, or from public sources and in some cases via personal contacts between the corresponding author and the companies concerned.

Changes in variable costs that depend on the CO_2 emission allowance price can be expressed through the formula compiled by the authors:

$$\Delta VC_{i,j,n,e} = \frac{p_{CO2_e} \times CO2_j \times G_{i,j,n} \times Q_j}{VC_{i,j,n,e}} \times 100, \%$$

where

$VC_{i,j,n}$ – is variable cost in euros, P_{CO2_e} – cost of CO_2 emission in euros, $CO2_j$ – the emission factor in ton per megawatt-hours, $G_{i,j,n}$ – corresponds to the amount of fuel used in tons, Q_j – calorific value in megawatt-hours per ton.

Every value of variable costs of observed enterprises ($VC_{i,j,n}$) is unique: i stands for an individual enterprise ($i = 1 \dots 22$); n marks the accounting year of variable cost ($n = 1,2$), so that $n=1$ stands for the accounting year 2008, and $n=2$ for the accounting year 2009; e represents the price of CO_2 emission where $e=1$ means 0 euros per ton, $e=2$ stands for 15, $e=3$ stands for 25 and $e=4$ represents 50 euros per ton; j represents the type of fuel used ($j = 1 \dots 5$), where $j=1$ stands for oil shale, $j=2$ is generator gas, $j=3$ is shale oil, $j=4$ is natural gas and $j=5$ represents peat.

2. RESULTS

2.1. Realisation of the best future scenario suggested by the Development Plan of the Estonian Electricity Sector until 2018 will cause a sharp change in the amount of CO_2 emission

A power plant's output depends on the climate conditions and the market situation in a certain year. The electricity market regulation must ensure diversity of the production structure in Estonia, at the same time there is a need to ensure sufficient production capacity. Without strict environmental regulations capacity is sufficient. Unless it is possible to buy electricity at a cheaper price elsewhere, regulations require investment in new capacity. However, a justified question also arises in the case where we buy cheaper electricity – for example from Russia – whether the conformity certificate is proper and valid. In the free market, where cheaper electricity is imported from third countries, and these countries are not subject to carbon-free electricity production requirements, home market electricity producers find themselves in a situation of unequal competition.

Pursuant to the forecast made for 2020 (in the Development Plan, presented until 2018) the situation is estimated to change drastically (Figure 1): the share of oil shale-based electricity will decrease to about 40%, and the share of renewable energy will increase to nearly 31% compare to 2010.

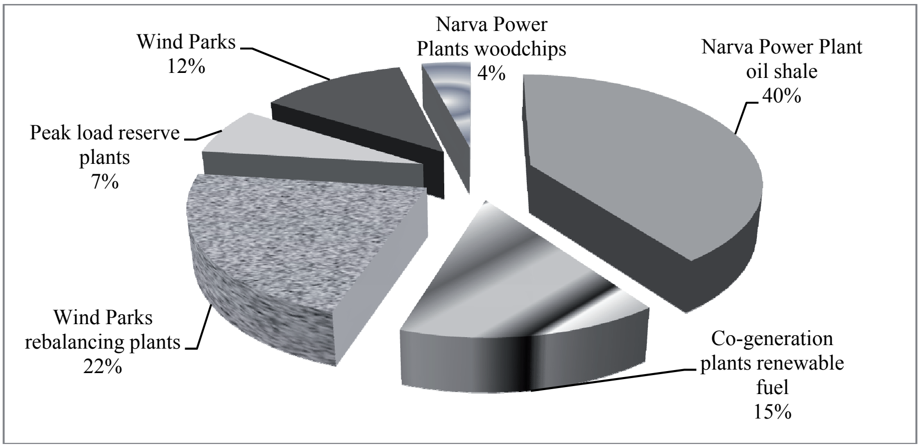

Figure 1. Electricity production in Estonia for own consumption in 2020. (Author's calculations)

Comparing the 2007 national electricity consumption (about 8,200 GWh[28] – exports and transmission losses excluded) to the estimated electricity production in 2020 (estimated to be 10,480 GWh) consumption will grow by about 22%. The results gained by the CO_2 emission calculation method reveal that, in 2020, with electricity production of the best future scenario being 10,480 GWh, the CO_2 emission will be 5.7 million tons. The CO_2 emission will decrease due to various energy sources that are expected to be taken into use at the new power plants to be operated on the basis of renewable energy sources or gas.

Estonia submitted an application to the European Commission for the CO_2 annual emission allowance quantity of 13.3 million tons to cover the period of 2008–2012. The initial quantity that was to be allocated by the European Commission was 12.7 million tons (including reserves). Presently negotiations on the emission allowance quantity continue. The EU energy policy measure foresees reduction of greenhouse gas emission allowances by 1.74% per year compared to the reference year 2005, but the European Commission corrected the quota quantity meant for the time period 2008–2012 that Estonia had applied for stating that the asked quantity was overestimated (European Commission 2009). We assume that the CO_2 allowances basic value for Estonia will be 12.7 million tons. Proceeding from these values at the referred minimal CO_2 reduction rate, the respective CO_2 amount is estimated to be no more than 11.2 million tons in 2020. According to the best scenario proposed for the Estonian electricity production (from 2013 up to 2020), the annual CO_2 quantity is estimated to be 5.7 million tons (by the author's calculations). Thus, the CO_2 emission reduction tempo per year will be 5.2%, which means that implementation of the best scenario of the electricity development plan will bring about an approximately fourfold tempo of CO_2 reduction. In case of a CO_2 emission allowance price of 20 euros per ton (Engebretsen 2008), additional cost for electricity production

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[28] Author's calculation.

will amount to 110 million euros (in case of the quota price 50 euros, the respective sum will already be 275 million euros).

An excessive tempo of CO_2 reduction implies huge investments over a short time period, pressure on the electricity price, additional burden to consumers, and a question whether the chosen best scenario is the most balanced one.

2.2. The cost-competitiveness of oil shale, wood, peat and natural gas will face a significant change in 2015 due to environmental charges, ash handling fees and prices of CO_2 emission allowances

The EU directive on greenhouse gas trading, assessed from the point of view of the best future scenario described in the Development Plan of the Estonian Electricity Sector sets new requirements for the use of fuels – fuels that cause more pollution to the environment (oil shale, peat) will be pushed out of the fuels market and environmentally friendlier fuels (renewable energy sources such as biofuels, wind and solar energy and natural gas) will replace them.

Increasing environmental taxes and charges will give energy producers price signals to move toward the intended change. The increase brought about by ash handling fees will amount to approximately 30% in 2015 compared to the ash-handling fees to the reference year 2010 (no ash is formed in the use of natural gas).

Calculation results reveal that the expected increase in environmental costs will remarkably change the cost-competitiveness between fuels.

Oil shale has the highest rate of pollution charge per one MWh_{fuel} of energy content of the fuel – about 1.75 euros per megawatt-hour. High emission factors – in particular in the case of sulphur dioxide, carbon dioxide and solid particles – are estimated to raise the pollution charge rate by twofold i.e. to approximately 3.75 euros per megawatt-hour by 2015. Oil shale-related environmental costs were 10.6 euro in 2010, which was the highest of the fuels types. Similarly, in 2015 the absolute increase in costs per one megawatt-hour of energy content of the oil shale is estimated to be the largest: depending on the CO_2 quota pricing plan, it will be 13.1–18.5 Euros per megawatt-hour (87–122% increase related to 2010 costs). This trend may threaten the competitiveness of oil shale-based energy production in comparison with the energy producers who use other fossil fuels or renewable fuels.

At present, peat is considered a good alternative to wood chips. The price of wood chips is 12.8 euros per megawatt-hour. The price of peat is lower: 11.7 euros and these balance environmental charges (including ash handling costs and pollution charges) which in the case of peat are higher than in the case of wood chips.

The fuel-related costs of using peat may increase by 1.5–2 times per one megawatt-hour of energy content by 2015: starting from 13.3 and increasing up to 21.2–26.8 euros per megawatt-hour. According to the research results, the increase in the fuel-related costs of wood chips is expected to be very small. But a growing demand for wood chips may lead to a rapid price increase in the market of wood fuels.

As for natural gas, its pollution charge rate per one megawatt-hour of energy content is low. In 2010, it was 0.42, and in 2015 it is expected to be 0.43. No ash is discharged in the case of natural gas, thus no such costs should be considered.

The fuel price per megawatt hour of natural gas is high and therefore the fuel-related costs of these companies that are use natural gas are large as well. Since the emission factor of carbon dioxide is small and other environmental costs are also relatively small, it is possible to reduce the fuel-related growth rate in costs; whereas in the case of other fossil fuels, the emission factor and other environmental impacts are larger.

In the case of wood chips, the environmental costs were and will be the lowest in 2010 and 2015 respectively, compared to other observed fuels, amounting to 0.054–0.11 euros per megawatt-hour as there is no carbon dioxide emission to be taken into account. The lowest ash handling costs in comparison with other solid fuels: 0.19–0.27 euros per megawatt-hour – keep environmental costs and other fuel-related total costs low. In 2010, these costs were 13 euros per megawatt-hour and by 2015 they are expected to be 13.2 euros per megawatt-hour. The above-listed factors will considerably improve the competitiveness of the wood chips producing industry and enable to expand wood chips-based energy production.

The analysis shows that, without the application of environmental regulations, the priority list of fuels by price is as follows: oil shale, wood, peat and natural gas. Adding of environmental charges and the CO_2 emission allowance price to the fuel price changes the priority list as follows: wood, peat, oil shale and natural gas. Due to regulations, the use of renewable fuels will be more preferred than the use of fossil fuels.

2.3. FIT is justified for its effectiveness of introducing renewable energy, but it has an unreasonably high cost in terms of the impact on the consumer price and its over-compensation to owners of power plants

The research paper, which focuses on the FIT paid for producing renewable electricity, shows that Estonia’s FIT system has effectively contributed to the construction of cogeneration capacity. In 2007, the share of electricity produced from renewable sources comprised 1.75% of the total electric energy consumption. But in 2010, it already comprised 9.7% (instead of the planned 5.1%). The future goal, based on the Development Plan of the Estonian Electricity Sector until 2018, is to achieve a 15% share by 2015. Administration costs have been small and the saved external costs have exceeded the size of support: in the case of oil shale the costs arising from externalities amount to 69.2 euros per megawatt-hour, in the case of wood fuel and peat: 9.7 and 25.8 euros per megawatt-hour, respectively.

However, the cost of Estonian FITs have increased at a fast pace from 0.1 euro cents per kilowatt-hour to 0.8 euro cents per kilowatt-hour from 2007 to 2010, and consumers have collectively covered these costs through their electricity bill. At the same time, large cogeneration plants are the ones who earn profit. Costs related to the introduction of FIT increased from 6 million euros in 2007 to 55 million euros in 2011.[29]. In 2010, the support-related cost accounted for about 10% of the consumer's payments for electricity and, the Estonian Competition Authority, who is the regulator of electricity price in the closed market, raised the issue of reducing the tariff. In 2011 the FIT remained unchanged, although the network operator Elering OÜ reduced its compensation to producers to 0.61 euro cents per kilowatt-hour[30] on account of the sum collected in the previous period.

Besides the distributional issues, there are also other reasons for assessing the FIT. A case study was carried out on two cogeneration plants and by comparing their average variable cost of electricity production to the cost price show that the current support system is not efficient (Appendix A). The research results also indicate that resources are being used for supporting production that is also profitable without FITs (IRR 19%)[31]. Both this and the fact that the aims set for 2010 have been exceeded confirm that the current system of FITs is not cost-effective.

Although the current FITs are attractive from an administration point of view, it can be stated on the basis of large differences in cost prices depending on the size of the plant that FITs need to be distinguished by taking into account the size of the plant. Figure 2 (Latõšov et al. 2011) shows that the cost price of cogeneration plants with the capacity of less than 10 $\mathrm{MWh_{el}}$ is considerably higher than that of large plants, and – the smaller the plant, the faster the increase is in cost price. Subtracting FIT from the cost price makes the picture even more interesting: the FIT covers the production cost price of plants with the capacity of 25 $\mathrm{MWh_{el}}$, and if we leave the FIT out, the cost price of the plant becomes similar to the cost price of a support-receiving 4 $\mathrm{MWh_{el}}$ plant. These findings further confirm the results of this research and refer to the fact that large plants are over-compensated by the current system of FITs, but to small plants the FIT is not necessarily sufficient.

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[29] Author's calculation.

[30] http://elering.ee/taastuvenergiatasu/ (in Estonian). Retrieved date 22.09.2011.

[31] Author's calculation.

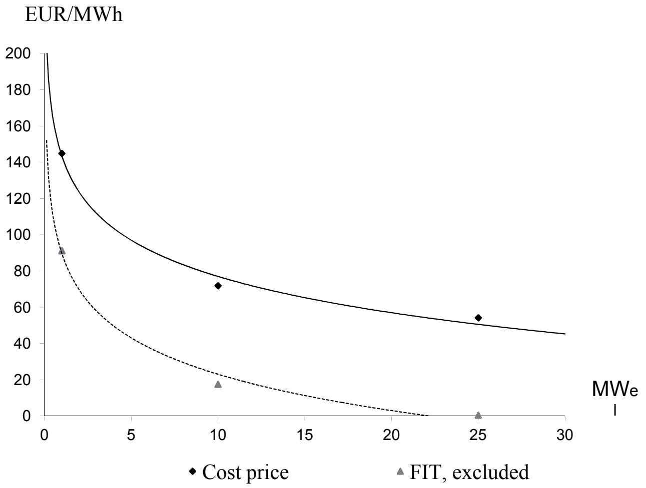

Figure 2. Cost price of cogeneration plants in euros per one MWh_{el}

The greatest drawback of subsidies, taxes and other price formation measures is that the extent of their impact is not clear. In Estonia, as in many other countries, FITs are used for achieving quantitative goals. It is not easy to select a monetary support matching the goal; therefore the regulation by FIT needs continuous revision. Such process of revisions will inevitably be accompanied by uncertainty for companies considering investment. Consequently, as in the case of FIT-based regulation, a compromise needs to be reached between the issues arising from revision and inefficient resource use.

2.4. The use of primary energy method has great advantages in SO_2 capturing costs in pulverised oil shale-fired boilers

Based on the literature and tests carried out earlier, an algorithm was compiled (Appendix B) that helped to model. The basic data changing in the algorithm are: a) C_b – price of oil shale, euros per ton; b) C_{CO2} – price of CO_2 emission, euros per ton; c) C_{NOx} – investment in the circulation of flue gases, million euros; d) C_{ROx} – investment in a finer crushing of oil shale dust, million euros; e) C_W – investment in water injection, million euros; f) t – the number of operation hours of the energy unit per year, hours; g) z – the investments pay-back period, years; h) C_{bting} – price of standard fuel, euros per ton. The basic data of energy unit are: a) N_{max} – max. capacity of energy unit, megawatts; b) N_{min} – min. capacity of energy unit, megawatts; c) N_{opt} – optimal capacity of energy unit, megawatts; d) e_{max} – self-consumption of energy unit at max. load, megawatts; e) e_{min} – self-consumption of energy unit at min. load, megawatts; f) e_{opt} – self-consumption of energy unit at optimal load, megawatts.

The algorithm enables to change the operation- and investments-related basic data and evaluate the effect of these changes on the cost of one ton of SO_2 emission reduction in case of different price changes of CO_2. Earlier, the investments considered necessary for introducing primary technologies to the two bodies of one pulverised oil shale-fired boiler at Eesti Power Plant were assessed as follows:

a) 8 million euros to be invested in a finer crushing of oil shale dust; b) 8 million euros to be invested in the circulation of flue gases; c) 2 million euros to be invested in water injection. The investment sums proposed above are recommendations and may vary depending on the situation. The investments pay-back period, taking into account physical wearing of energy units, is estimated to be ten years.

The modelling result is presented in Appendix C Table 2 and on Figure 5.

The modelling result shows that the BLW-ROx and bL-ROx modes enable to achieve the SO_2 limit values (400 mg/Nm^3) set by the EU in the directive on industrial emissions.

To meet the SO_2 specific emission value established by the European Union for the year 2016: the flue gas circulation, finer crushing of oil shale dust and water injection technologies should be applied to one oil shale-firing boiler for the purpose of studying their impacts on the SO_2 emission.

As the summary article presents a broader treatment of the subject, a number of tests on various modes of the primary method were carried out in order to verify the results gained in the course of modelling. The water injection technology was mainly used in the mentioned tests. The test results are presented in figures 3,4, and in Appendix C, tables 3,4,5.

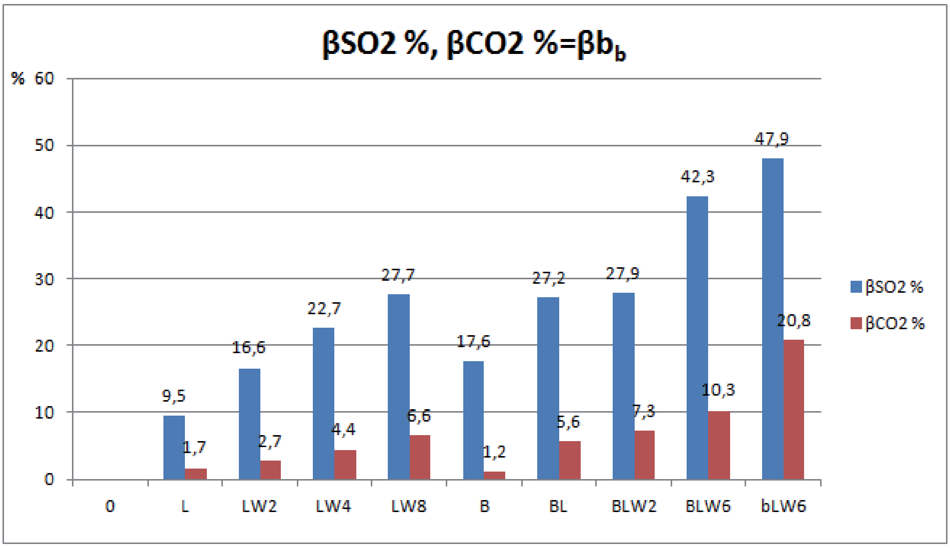

Figure 3. Changes in the SO_2 and CO_2 emissions and in the specific fuel consumption depending on the amount of electric energy produced (Author's calculation)

In the figure above, different modes are presented on the horizontal axis, the letters L and W represent air and water respectively and the B and b signify boiler optimal and minimal load. The numbers mark water injection pressure of the system. The resulting SO_2 and CO_2 emissions and specific fuel consumption on the amount of produced electric energy are presented on the vertical axis, in percentages of emission reduction. The CO_2 emission is directly connected to fuel consumption (i.e. is in proportional dependence).

According to test results, the best SO_2 capture results, 47.9% and 42.3%, were achieved by the bLW6 and BLW6 modes, matching the results projected during the modelling process. At the same time, the CO_2 emission increases. Basic economics teaches us that there is an opportunity cost, i.e. there is a trade-off between reduction in SO_2 and the input of fuel. For a simple BLW-mode solution that does not require investments, sorbents, additional treatment, transportation and storage of emissions, involves an increase in the costs of oil shale and emissions of CO_2.

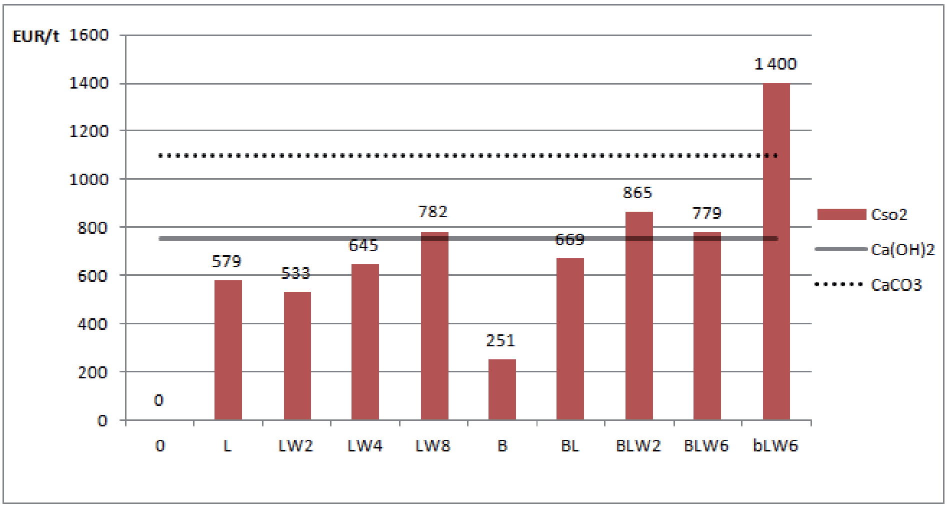

Figure 4. The cost value in euros for the reduction of one ton of SO_2 (Author's calculation)

The cost in euros for the reduction of 1 ton of SO_2 is displayed in Figure 4. Horizontal lines in the figure describe the cost of using slaked lime $Ca(OH)_2$ and limestone ($CaCO_3$) in euros for the reduction of 1 ton of SO_2 (based on the literature). Compared to the maximum permitted levels presented by horizontal lines, only the bLW6-mode exceeds the costs made for the reduction of 1 ton of SO_2 by using sorbents. By applying other modes, the reduction is achieved for equal or smaller costs.

Figure 4 shows that mode B has the smallest cost, at the same time Figure 3 indicates that the capture factor is about 3 times smaller in mode B than compare to mode bLW6.

The SO_2 specific emission limit value set by the EU is 400 mg/Nm^3. The SO_2 emission of pulverised oil shale-fired boilers is on average 2,300 mg/Nm^3. By the bLW method, we can achieve an approximately 50% capture of SO_2, i.e. about 1,150 mg/Nm^3, which still does not ensure the level required by the respective EU directive. Proceeding from the result presented in modelling, we also considered the ROx mode in addition to the bLW mode. The ROx mode requires crushing of oil shale before combustion to make more efficient use of the lime contained in oil shale.

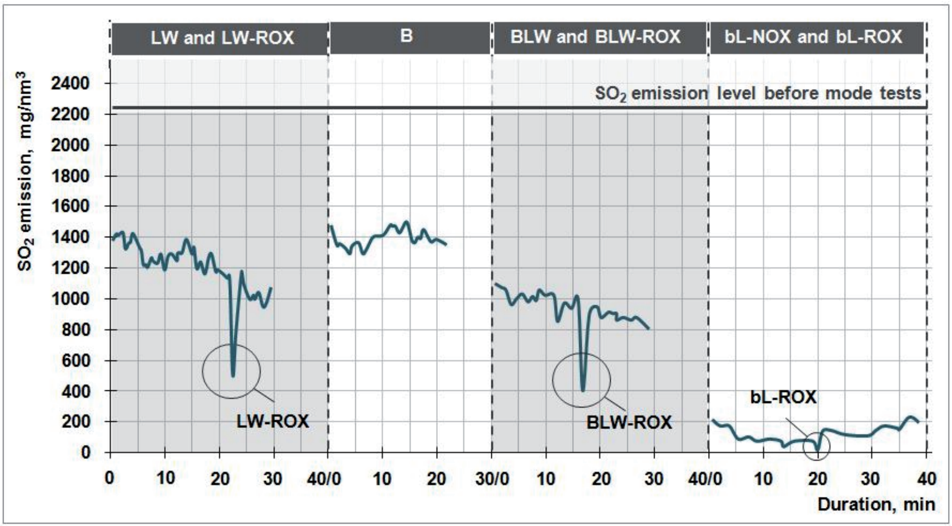

Figure 5. Test results of the use of primary method, SO_2 *mg/m*^{3}

The capture of SO_2 in the boiler is still under development and requires additional research, construction solutions and tests. So far tests and cost calculations have showed significant development potential.

The future of the oil shale power industry will depend on how successful we are in fulfilling the environmentally-related requirements set by the EU. If we are able to implement them cheaper than is the case of coal-fired power plants (Öpik 1987), we will ensure the sustainability of the oil shale power industry in Estonia. However, copying technologies used in coal-firing power plants will require 1.5 times larger investments[32].

2.5. Additional cost of CO_2 allowances influences the variable costs and competitiveness of enterprises participating in EU-ETS

The analysis of energy-intensive enterprises reveals that there are great differences in the changes in their variable costs depending on the fuel used. This is illustrated in Figure 6. The calculations are based on a model, the aggregate formula of which is set out in section 1.1.5.

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[32] Eesti Energia AS has decided to invest in the desulphurisation equipment after the unit boilers at Eesti Power Plant (Narva Elektrijaamad) i.e. to introduce the secondary method – dealing with consequences and the total value of investments in four units reaches nearly 100 million euros (Raidla Lejins&Norcous 2010, Eesti Energia 2010).

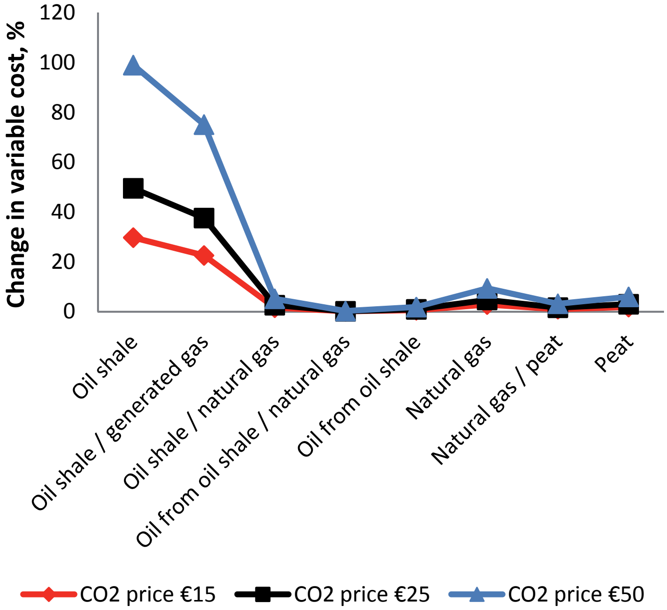

Figure 6. Impact of different CO_2 prices on the average increase in variable costs (%) in 2008–2009. (Author's calculation)

The analysis observes the average increase in costs in 2008 and 2009 by assuming that the included enterprises had to buy their allowances instead of receiving them for free. It is important to observe the 2008 and 2009 costs separately against the background of the global economic crisis that started in 2008. A majority of the studied Estonian enterprises managed to end the financial year 2008 with positive results, but in 2009 their economic indicators substantially decreased. These firms also had smaller variable costs in 2009, whereas their fixed costs remained the same or in some cases even increased.

Annual changes in variable costs do not only depend on the change in CO_2 emissions. Since the production of enterprises is directly related to variable cost due to a bigger consumption of raw material, then production should have a direct effect also on the amount of CO_2 emission. In many cases, the CO_2 emission amounts remained on the 2008 level in 2009. In several cases, the modelled changes in variable costs were bigger in 2009; in particular at enterprises that use oil shale as the primary fuel and which suffered a sharp increase in variable costs.

Some differences can be explained by the fact that the independent third party does not currently audit annual CO_2 emissions, meaning that the data submitted by enterprises have to be presumed as true. Estonia has a specific situation in the European Union context, because all other Member States require auditing of CO_2 emission from their enterprises[33].

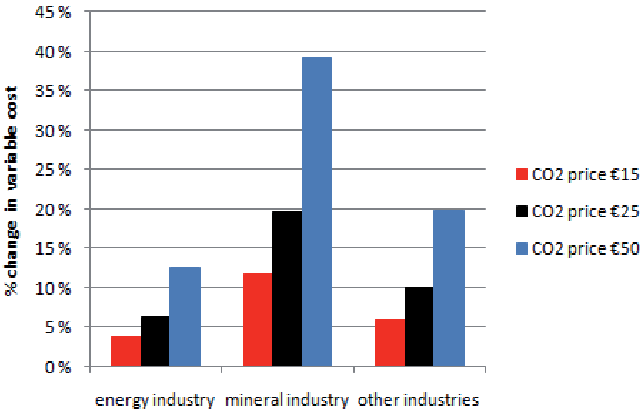

Figure 7. Forecast for change in variable costs across different sectors (Author's calculation)

If variable costs increase as a result of higher costs on CO_2 allowances, the competitiveness of an economic sector depends on the CO_2 emission intensity, on the possibility of shifting additional costs to sales price and on the measures taken in the production cycle for reducing CO_2 emissions. Estonian energy production mainly consists of heat and electricity production. The use of less carbon-intensive technologies is on the rise in the production of heat energy. Combustion of biofuels which causes fewer problems can be pointed out as an example. In Estonia, most electric energy is produced from local oil shale. At present, investments are being made in the modernisation of pulverised oil shale-fired boilers of energy units and efforts are made to meet the stricter environmental requirements that are to take effect after 2016. New fluidised-bed boilers with the best technology available in the market are being constructed for energy units. Considering the above mentioned, it can be concluded that the overall change in variable costs arising from the price of CO_2 emission is expected to remain relatively modest – around 5% – in the Estonian energy sector (Figure 7).

CONCLUSIONS

1. The Estonian government, in the light of the EU energy policy until 2020 and on the basis of the legal acts passed, has taken action with a view to diversifying electricity production in Estonia by broadening the use of renewable energy in

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[33] The Ministry of the Environment has submitted the Ambient Air Protection Act Amendment Act to the Riigikogu. If the Amendment Act is approved, an independent third party will start auditing carbon dioxide emissions also in Estonia.

order to reduce environmental pollution caused by the combustion of our basic fuel – oil shale. The Development Plan of the Estonian Electricity Sector, prepared for the above-mentioned purpose, provides for a change in capacities that will bring about a decrease in oil shale-based electricity to a 40% level and an increase in the use of renewable energy to a 31% level compare to 2010. The best future scenario requires CO2 reductions at a rate of 5.2% per year, while the EU-ETS foresees a minimum annual rate of decline of 1.74%. The projected relative annual change in the CO_2 emission level is 5% faster compared to the set norms specified by EU-ETS which is requiring a huge amount of investments and could have a significant impact on the electricity price, burdening the consumer's budget. These circumstances raise the question whether the chosen best scenario is the most balanced one.

The goals presented in the Development Plan of the Estonian Electricity Sector need to be reviewed and amended, if necessary. There is a significant margin between the objectives of the EU-ETS and the best future scenario of the Development Plan of the Estonian Electricity Sector until 2018.

2. The ranking of environmental costs of fuels will change in 2015 – oil shale which positioned as the least costly in 2010 will fall to third position due to an increase in environmental charges, costs related to ash handling and the CO_2 trade allowances price; whereas wood fuel and peat will occupy the first two positions. Wood fuel positioning as the first in the ranking of fuels' competitiveness in 2015 is attractive for burning in large, up to 300 MW_{el}, combustion installations, which according to estimations will put pressure on the availability of wood in the market thereby leading to price increases. The availability of wood for electricity production purposes requires further analysis.

A decline in the use of oil shale enables to value this mineral resource more as a raw material, i.e. for producing shale oil and other light-fraction fuels that are competitive in the global market of liquid fuels.

Peat will be holding the second place in the ranking of fuels, but the use of peat as a fuel for electricity production is problematic because of its high CO_2 emission level (emission factor in electricity production amounts to 1,233 kg/MWh, Kleesmaa 2010) and large ash content (up to 5%, Latõšov 2010).

The last place in the ranking is occupied by natural gas because of the high fuel price determined by the oil market. But taking into account its cleanness (no ash is formed in combustion) of use and low level of CO_2 emission (specific emission in electricity production is 574 kg/MWh, Kleesmaa 2010), it is a fuel that can be considered to cover the electricity production peak loads and ensure reserve capacities in Estonia.

3. The FIT paid to renewable energy producers is used, in order to meet the 20% target fixed in the EU directive on renewable energy, has fulfilled its purpose in interim stages – the 5.1% goal of 2010 was outperformed by achieving a 9.7% result.

In Estonia, granting of FIT does not involve large administration costs, because supports are similar in the cases of all energy sources.

The analysis shows that the way FITs have been implemented may lead to unproportional profits and cause the share of borrowed capital to increase. At the same time, in 2007–2010 the cost has increased from 0.1 to 0.8 euro cents per one kilowatt-hour for consumers. For example, Estonia's starting position is the same as that of Spain a decade ago, but in Estonia the price rise has been considerably faster. In 2011 the cost borne by consumers was adjusted down to 0.61 euro cents per kilowatt-hour, but this was done on account of the already prepaid sum.

As the FIT to renewable electricity is uniform Estonian supports are neutral in terms of technology, but there exist other reasons which make supports questionable from the efficiency perspective. The research reveals that cogeneration plants with the capacity of 25 MW_{el} would earn profit even without any support. Moreover, market prices considerably exceed the marginal costs of electricity generated from biomass in cogeneration plants with the capacity of 25 MW_{el}. The principles followed by Estonian FIT do not facilitate development of small cogeneration plants. One reason for that is the remarkably larger production cost per unit in small plants.

In conclusion, revision of the FITs is important for Estonia also considering the prospective market liberalisation (in 2013 electricity market will be fully opened and all consumers will buy electricity in the free market).

4. The EU directive on industrial emissions sets stricter limits for SO_2 emission into the air – 400 mg/Nm^3. On average 2,300 mg/Nm^3 of SO_2 (sometimes over 3,000 mg/Nm^3) is released in the combustion of oil shale. There are two methods for fulfilling the requirement: the primary method, as in the case when natural limestone contained in oil shale is already made of use of while oil shale is being prepared for combustion and also in the combustion process; and the secondary method is when dealing with consequences – SO_2 discharged in the course of oil shale combustion is captured after the boiler. Considering the unique properties of oil shale, neither of these methods has been studied on a wide-scale global level. Some short tests have been carried out with respect to the primary method. At the same time, the secondary method is entirely grounded on a test facility-based study or on a coal-based test.

To meet the environmental requirement the primary method was applied and modelled based on the data derived from earlier tests and relevant literature. The result shows that the primary method – crushing of oil shale before combustion, water injection into the combustion zone of the boiler and the regulation of combustion air as well as the selection of load – guarantee the limit value set by the EU. Empirical results confirm the theoretical discourse: about a 50% capture of SO_2 was achieved by a change in combustion air and load, and water injection. If the tests are supplemented by a finer crushing of oil shale, we can presume achievement of the permitted limit value.

The sizes of investments are of great importance, too. The cost of secondary method as a commercial solution amounts to approximately 100 million euros per four energy units, making 25 million euros per one energy unit. But, the investments for implementation of primary method's regimes on commercial level (tested solutions, available equipment) remain within the limits of 100,000 euros per energy unit. This sum of investment does not cover short period simulated primary method regimes, such as RO_x regime.

In order to fulfil the SO_2 specific emission limit value (400 mg/Nm^3) established by the European Union by 2016, and develop a commercial solution for the BLW technology, the use of finer-crushed oil shale dust should be first applied to and tested on one boiler in addition to the regulation of load, regulation of oxygen and water injection. As a result, the combustion flame temperature becomes lower and finer crushing of oil shale enlarges the fly ash chemisorption surface, thus the capture of SO_2 on a required level is achieved.

Other air emissions (in addition to CO_2 and SO_2) included in the EU directive on industrial emissions such as NO_x and solid particles have not been observed in this research. Possibilities for meeting their respective limit values need further research.

5. In the framework of the EU energy policy, greenhouse gas emissions were to be reduced to 20% by 2020. The greenhouse gas trading system EU-ETS was created on the basis of a relevant legal act. A majority of enterprises participating in the system are energy producers who produce electricity or heat or are involved in cogeneration of both.

The CO_2 emission allowances are issued to enterprises free of charge until the end of 2012. From 2013 onwards the quantity of allowed emissions will start decreasing, which puts pressure on the per ton price of CO_2 emissions. This, in turn, will have an impact on companies' total energy costs and influence their overall level of competitiveness in open markets.

Calculations on the impact on variable costs of these companies are based on the price of CO_2 per ton being 15, 25 or 50 euros. It emerges that the cost base is most vulnerable in companies that use only oil shale as their primary fuel. Companies that use other fuels, including mixed fuels, are less likely to be impacted.

Alternative investment and sourcing options need to be highlighted for softening the increase in operation costs when the CO_2 emission starts to impact them. Above all, companies' management teams need to make relevant decisions. The state needs to analyse whether corrective actions are required to protect its companies, yet still allowing for fair competition. Due to size limitations these two topics have not been covered in the current research, but it is extremely important to deal with them in future research.

The data presented in this research enables the comparing and measuring of a cost increase arising from the introduction of CO_2 emission trading at various market rates. The research offers analysis material for management teams of individual companies as well as policy makers.

6. The EU energy policy approved under the European Union Energy and Climate Package for 2013–2020 set a reduction of greenhouse gas emissions by 20% (only CO_2 studied in this paper); a 20% increase in the share of renewable energy; and a 20% reduction in the primary energy consumption. In conformity

with the legal provisions of the EU, Estonia adopted several legal acts on a national level with a view to achieving the goals set.

Based on the results of five research papers, it can be concluded that, due to the effect of the adopted environmental regulations, great changes are expected in Estonian electricity generation. As a result, the two goals set – reduction of CO_2 emission and a 20% increase in the use of renewable energy – will most probably be achieved by 2020, but potentially the cost will be high.

SUMMARY

The European Union has, in the framework of the energy and environmental policy, adopted various regulations for making the energy sector “greener”. In 2009, the European Commission as an executive body of the EU adopted essential regulations for achieving the set goals. The goals were designed to improve and expand the scheme for greenhouse gas emission allowance trading within the Community (EU-ETS) in order to motivate the Member States to make bigger efforts towards reducing greenhouse gas emissions. With a view to fulfilling the Community’s requirement of reducing greenhouse gas emissions, the use of energy produced from renewable sources is being promoted and the share of primary energy in final consumption is being increased. In the production of electric energy, great importance is attached to the Directive of the European Parliament and of the Council on industrial emissions pursuant to which the integrated prevention and control of air pollution are being implemented.

In compliance with the environmental regulations adopted by the EU, Estonia has created a judicial area in the republic with an intention to promote the green energy sector and energy conservation. Notwithstanding the legal acts of the EU, the Estonian government has adopted several important development plans, such as the Development Plan of the Estonian Electricity Sector until 2018 and the Estonian Renewable Energy Development Plan until 2020. The Estonian Electricity Market Act also has its role in the organisation of electricity production in Estonia. In addition, the Electricity Market Act establishes a procedure for applying for supports and the size of feed-in tariffs (FIT) that the producers generating electricity from renewable sources can receive.

In the light of EU and Estonian legal acts, Estonian electricity production is expected to undergo great changes – replacement of oil shale as a fuel of large environmental pressure with environmentally friendlier energy sources, such as biomass or gas for the production of basic electricity.

Research results on the effects of various EU regulations on Estonian electricity production are presented in Table 1.

Table 1. Effect of the EU and Estonian regulations on Estonian electricity production

	EU-ETS	**Environmental charges**	**FITs**	**Industrial emission limit values**
Oil Shale	**–**	**–**	**n.a.***	**–**
Peat	**–**	**–**	+	**n.a.***
Wood	+	+	+	**n.a.***
Natural Gas	**–**	**(–)**	**n.a.***	**n.a.***

*– not applicable

The table above indicates that regulations put the biggest pressure on the electricity produced from the local fuel oil shale as, due to its chemical-physical properties, oil shale has a large impact on the environment.

The CO_2 quota trade launched by the EU has a large effect on the diversification of Estonian electricity production portfolio. Such CO_2-free energy sources as wood and wind have a more preferable position.

The most favourable renewable fuel is wood, and the most favourable fossil fuel is natural gas. Peat with its large CO_2 emissions and ash content, slow natural process in the nature makes utilization complicated, but electricity production based on peat fuel receives FIT, is local fuel and has sufficient reserves.

Legal acts on renewable energy have a positive effect on the use of renewable fuels. Regulation remains positive to technology development (development of more environmental friendly solutions for existing technologies and new renewable fuels based technologies).

The directive on industrial emissions creates a complicated situation for the pulverised oil shale combustion technology-based electricity production. If, by 2016, energy units are not supplied with necessary pollution abatement equipment, which ensures fulfilment of the requirements arising from the directive, the relevant units have to be shut down. Such a situation motivates the management teams of energy enterprises, specialists and researchers to take action for finding solutions (introduction of primary technology), in order to guarantee the operation of existing power plants after 2016.

A continuous increase in environmental charges has a favourable impact on the environment friendliness of Estonian electricity production. At the beginning of the 1990ies the aim of environmental charges was to draw attention to the topic, but twenty years later the size of charges influence management teams of enterprises towards carrying out more in-depth analysis of their production process in terms of environmental protection (e.g. which fuel to prefer), towards introducing new technology (reduction of the SO_2 emission) and dealing with the production-related expenses (ensuring of competitiveness).

Appendix A. A note on the marginal cost

In the assessment of subsidies to renewable electricity, Kleesmaa and his coauthors derive the per MWh average revenue from electricity sales. This is done excluding the feed-in tariff (FIT) for the two combined heat and power (CHP) plants that are under study (Kleesmaa et al. 2011, p. 235). The calculations show that excluding FITs, the plant CHP1 earned 40€/MWh and that the second plant CHP2 earned 36 €/ MWh from electricity sales. In order to make conclusions about economic efficiency, these revenues, i.e. prices were compared to marginal costs. In the paper, marginal costs are approximated by the average variable cost of a plant with same capacity. Depending on the method of allocating costs between heat and electricity production, the resulting average variable costs were found to be 4.7 and 6.7€/MWh, respectively.

In Kleesmaa et al. (2011) the comparison of prices with the approximation of marginal costs shows that there is a significant deviation between prices and marginal costs, hence production is not efficient from an economic point of view. The comparison concerns the short run. Weyman-Jones points out that there is a controversy in energy economics about whether the optimal price should equal the short run or the long run marginal cost (see Weyman-Jones, 2009 p. 29). The reason why short run marginal cost may not be appropriate is that when demand fluctuates or is uncertain, short run marginal cost pricing becomes volatile and cannot guide investment decisions. Therefore, many real world applications have adopted a rule that prices should equal long run marginal costs.

The purpose of this note is to calculate the long run marginal cost and to compare the result to the price in order to judge whether the conclusion about inefficiency will remain in the long run setting.

Following Weyman-Jones (ibid), the short run marginal cost (SRMC) is constant and equal to the per unit operating cost up to the level of capacity installed, then it becomes infinite

$$SRMC = \begin{cases} r: demand \ \leq capacity \\ \infty: demand > capacity \end{cases}$$

$$LRMC = r + c$$

In equation above r denotes the per period cost to produce one unit of output, i.e. the running cost of one unit, which equals the average variable cost derived by Kleesmaa and his co-authors (2011). The constant c is the cost per period to hire the plant or alternatively the cost per period to repay with interest the loan used to buy the plant. In this note we apply the so called Merchant Investor approach to derive c (ibid, p. 31).

One way to apply the Merchant Investor approach is to calculate the cost of installing one unit of capacity, i.e. finding the annuity factor of a plant and dividing by capacity. For this purpose we apply the data gathered by Latõšov et al. (2011, p.145). The investment of a 25 MW_{el} cogeneration plant, with an average annual production of 125,000MWh electricity is 75M€ and its life time is 25 years. Applying the same interest rate as Latõšov, which is 4.5 per cent, we find that the annuity of this plant is about 1.68M€. Dividing the annuity with the average annual production and assuming that electricity related costs make up 50 per cent of production costs we arrive at 6.73€/MWh (1,682,927/(125,000×0.5)= 6.732). Since this estimate of *c* has been derived according to similar assumptions as the higher level of the SRMC, our estimate of LRMC is 13.43€/MWh, which is 6.7+6.73.

As noted above, the prices that were derived for the two case study cogeneration plants were 40 and 36€/MWh, respectively. In comparison to the long run marginal cost (LRMC) that was found to be 13.43€/MWh, our conclusion is that our finding concerning inefficiency is relevant also in the long run setting.

Jüri Kleesmaa and Sirje Pädam

Appendix B. Algorithm of the BLW technology

Calculations are based on the technological and economic analysis algorithm of the BLW technology:

a) η_{SO_2}– the regime medium SO_2 capture factor, %;

$$\eta_{SO_2} = [1 - (C_{SO_2} \div 9000)] \times 100,$$

where

$9000\ (mg/Nm^3)$ – medium SO_2 concentration in flue gases released in the combustion of oil shale fuel, in standard conditions, i.e. by calorific value $Q_a^t = 8{,}6\frac{MJ}{kg} = 2058\ \frac{kcal}{kg}$), sulphur content $S^t = 1{,}75\frac{kg}{GJ} = 1{,}5\%$, oxigen $O_2 = 6\%$, excess-air coefficient $\alpha = 1{,}4$;

b) b_B – the regime medium specific costs of standard fuel, g/kWh,

$b\ _B = (\frac{123}{\eta_E}) \times 100,$

where

$\eta_E(\%)$ – efficiency of energy unit; $\eta_E = \eta_B \times \eta$,

η_B – boiler efficiency, gross, %;

$\eta(\%)$ – efficiency of the electro-mechanical parts (turbine, generator, self-consumption of electricity and heat) and self-consumption of energy unit;

c) q_{SO_2} – the regime medium specific emission of SO_2, g/kWh,

where

$$q_{SO_2} = b_B \times \left(\frac{7000}{Q_a^t}\right) \times S^t \times 2 \times \left(100 - \eta_{SO_2}\right) \times 10^{-4},$$

if $Q_a{}^t = 2000 kcal/kg$ *and* $S^t = 1{,}5\%$, then

$q_{SO_2} = 10{,}5 \times b_B \times (100 - \eta_{SO_2})$ x 0,0001;

d) 4) q_{CO_2} – the regime medium specific emission of CO_2, g/kWh,

$q_{CO_2} = 3{,}5 \times b_B$;

e) Δb_B – the regime medium increase in specific standard fuel consumption, g/kWh,

$$\Delta b_B = b_B - b_{B,O},$$

where

$b_{B,O}$ is 0-regime medium specific standard fuel consumption;

f) Δq_{SO_2} – the regime medium decrease of SO_2 specific emission, g/kWh

$\Delta q_{SO_2} = q_{SO_2} - q_{SO_{2,O}}$,

where

$q_{SO_{2,O}}$ – the 0-regime medium SO_2 specific emission;

g) Δq_{CO_2} – the regime medium increase of CO2 specific emission, g/kWh,

$\Delta q_{CO_2} = q_{CO_2} - q_{CO_{2,0}}$,

where

$q_{CO_{2,O}}$ – the 0-regime medium CO_2 specific emission;

h) C_b – fuel price exceeding expenditure costs by reduction of 1 ton of SO_2 emission, EUR/t SO_2,

$C_b = \Delta b_B / \Delta q_{SO_2} \times C_{b\ ting}$;

i) $C^P_{CO_2}$ – cost of CO_2 emission increase by SO_2 emission decrease, EUR/t SO_2,

$C^P_{CO_2} = \Delta q_{CO_2} / \Delta q_{SO_2} \times C_{CO_2}$;

j) C_{var} – the variable costs value by reduction of 1 ton of SO_2 emission, EUR/t SO_2,

$$C_{var} = C^P_{CO_2} + C_b;$$

k) C_{const} – investment costs value by reduction of 1 ton of SO_2 emission, EUR/t SO_2

$C_{const} = Investeering / (\Delta q_{SO_2} \times N_x \times 0{,}001 \times (1 - e_x) \times t \times z)$,

where

N_x – capacity of energy unit (x is either maximal, minimal or optimal), MW, and

e_x – self-consumption of energy unit at x capacity (x is either maximal, minimal or optimal).

l) $C\sum$ – the costs value by reduction of 1 ton of SO_2 emission, EUR/t SO_2

$C\sum = C_{const} + C_{var}$,

m) β_{SO2} – relative decrease of SO_2 emission, %,

$$\beta_{SO_2} = \Delta q_{SO_2} / 10{,}5 \times 100.$$

Appendix C. Investment values gained on the basis of mathematical algorithm.

Twelve primary method BLW-modes were tested. Their descriptions are found below. The primary method BLW-modes are divided as follows:

1) LW/RO_x-mode, imitating finer crushing of oil shale dust: max. load, sliding excess-air coefficient, water injection into the flame and increasing of the

fly ash concentration; MRS-operation, 3-minute shaking of the primary and secondary screens of the downstream flue gas channel.

2) BLW/RO$_x$-mode imitating finer crushing of oil shale dust: optimal load, sliding excess-air coefficient, water injection into the flame and increasing of the fly ash concentration.

3) bL/RO$_x$-mode imitating finer crushing of oil shale dust: min. load, sliding excess-air coefficient, water injection into the flame and increasing of the fly ash concentration.

4) NO$_x$ flue gas circulation mode, analogous to the LW-mode in capturing SO$_2$: max. load.

5) B/NO$_x$ flue gas circulation mode, analogous to the LW-mode in capturing SO$_2$: optimal load.

6) b/NO$_x$ flue gas circulation mode, analogous to the bL-mode in capturing SO$_2$: min. load.

7) RO$_x$/NO$_x$-mode involving finer crushing of oil shale dust and the flue gas circulation, analogous to the LW/RO$_x$-mode in capturing SO$_2$: max. load.

8) B/RO$_x$/NO$_x$-mode involving finer crushing of oil shale dust and the flue gas circulation, analogous to the LW/RO$_x$-mode in capturing SO$_2$: optimal load.

9) b/RO$_x$/NO$_x$-mode involving finer crushing of oil shale dust and the flue gas circulation, analogous to the bL/RO$_x$-mode in capturing SO$_2$: min. load.

10) RO$_x$/NO$_x$/W: RO$_x$/NO$_x$-mode with the water injection mode, which reduces the SO$_2$ specific emission by 20% compared to the RO$_x$/NO$_x$-mode: max. load.

11) B/RO$_x$/NO$_x$/W: B/RO$_x$/NO$_x$-mode with the water injection mode, which reduces the SO$_2$ specific emission by 20% compared to the B/RO$_x$/NO$_x$-mode: optimal load.

12) b/RO$_x$/NO$_x$/W: b/RO$_x$/NO$_x$-mode with the water injection mode, which reduces the SO$_2$ specific emission by 20% compared to the b/RO$_x$/NO$_x$-mode: min. load.

The columns of Table 2 are titled as follows: 1) Mode – the code of mode; 2) CSO$_2$ – the regime rounded medium SO$_2$ specific emission, milligrams per normal cubic metre, 3) $\Delta\eta_{SO2}$ – the regime medium SO$_2$ capture factor, percentage; 4)η_E – the regime medium efficiency of energy unit, percentage; 5) b_B – the regime medium standard fuel specific consumption, grams per kilowatt-hour; 6) g_{SO2} – the regime medium SO$_2$ specific emission, grams per kilowatt-hour; 7) g_{CO2} – the regime medium CO$_2$ specific emission, grams per kilowatt-hour; 8) Δb_B – the regime medium standard fuel specific consumption increase, grams per kilowatt-hour; 9) Δg_{SO2} – the regime medium SO$_2$ specific emission decrease, grams per kilowatt-hour; 10) Δg_{CO2} – the regime medium CO$_2$ specific emission increase, grams per kilowatt-hour; 11) C_b – the fuel over-consumption cost of one ton of SO$_2$ emission reduction, euros per one ton of SO$_2$; 12) C_{CO2} – the CO$_2$ emission increase cost of SO$_2$ emission reduction, euros per one ton of SO$_2$; 13) C_{var} – the value of variable costs of 1 ton of SO$_2$ emission reduction, euros per one ton of SO$_2$; 14) C_{conct} – investments cost value of 1 ton of SO$_2$ emission reduction, euros per one ton of SO$_2$; 15) $C\sum$ – costs value of 1 ton of

SO_2 emission reduction, euros per one ton of SO_2; 16) β_{SO2} – relative decrease in SO_2 emission, percentage; 17) $C\sum$ – the costs value of one ton of SO_2 emission reduction, euros per megawatt-hour.

Table 2. Investment values gained on the basis of mathematical algorithm. (Author's calculation)

Cb	10	€/t
C_{C02}	20	€/t

t	6000	h
z	10	a

Cbting	35	€/t

C_{NOx}	8	M€
C_{ROx}	8	M€
C_W	2	M€

N_{max}	180	MW
N_{min}	80	MW
N_{opt}	140	MW

e_{max}	0,08
e_{min}	0,1
e_{opt}	0,09

	Režiim	C_{SO2} mg/nm^3	η_{SO2} %	η_E %	b_B g/kWh	q_{SO2} g/kWh	q_{CO2} g/kWh	Δb_B g/kWh	Δq_{SO2} g/kWh	Δq_{CO2} g/kWh	Cb €/t_{SO2}	C_{CO2} €/t_{SO2}	Cvar €/t_{SO2}	C_{const} €/t_{SO2}	C_Σ €/t_{SO2}	β_{SO2} %
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0	2200	75,6	30,1	409	10,49	1287	0,0	0,0	0	0	0	0	0	0	0,0
2	L	1600	82,2	29,4	418	7,81	1318	9,7	2,7	31	127	229	356	0	356	25,5
3	LW	1000	88,9	28,3	435	5,07	1369	26,0	5,4	82	168	302	470	0	470	51,6
4	B	1400	84,4	29,5	417	6,81	1313	8,3	3,7	26	79	142	221	0	221	35,0
5	BL	1100	87,8	28,4	433	5,56	1364	24,5	4,9	77	174	313	486	0	486	47,0
6	BLW	800	91,1	27,3	451	4,21	1419	41,9	6,3	132	233	420	654	0	654	59,8
7	b	1100	87,8	27,2	452	5,80	1424	43,6	4,7	137	325	586	911	0	911	44,6
8	bL	700	92,2	24,8	496	4,05	1562	87,3	6,4	275	475	855	1329	0	1329	61,3
9	bW	600	93,3	25,1	490	3,43	1544	81,4	7,1	256	404	727	1130	0	1130	67,2

	Režiim	C_{SO2} mg/nm^3	η_{SO2} %	η_E %	b_B g/kWh	q_{SO2} g/kWh	q_{CO2} g/kWh	Δb_B g/kWh	Δq_{SO2} g/kWh	Δq_{CO2} g/kWh	Cb €/t_{SO2}	C_{CO2} €/t_{SO2}	Cvar €/t_{SO2}	C_{const} €/t_{SO2}	C_Σ €/t_{SO2}	β_{SO2} %
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
10	LW/ROX	500	94,4	27,1	454	2,65	1430	45,2	7,8	142	202	363	565	103	668	74,7
11	BLW/ROX	400	95,6	26	473	2,21	1490	64,4	8,3	203	272	490	763	126	889	78,9
12	bLW/ROX	50	99,4	23,5	523	0,31	1649	114,8	10,2	362	394	710	1104	182	1286	97,0
13	NOx	1000	88,9	29,8	413	4,82	1300	4,1	5,7	13	25	46	71	142	213	54,0
14	B/NOx	800	91,1	28,7	429	4,00	1350	19,9	6,5	63	108	194	301	161	462	61,8
15	b/NOx	600	93,3	26,5	464	3,25	1462	55,5	7,2	175	268	483	751	256	1007	68,9
16	ROx/NOx	500	94,4	28,5	432	2,52	1359	22,9	8,0	72	101	181	282	202	484	75,9
17	B/ROx/NOx	400	95,6	27,4	449	2,09	1414	40,3	8,4	127	168	302	470	249	720	79,9
18	b/ROx/NOx	50	99,4	24,8	496	0,29	1562	87,3	10,2	275	300	539	839	363	1202	97,1
19	ROx/Nox/W	400	95,6	28,6	430	2,01	1355	21,4	8,5	68	88	159	248	214	461	80,8
20	B/ROx/Nox/W	320	96,4	26,7	461	1,72	1451	52,0	8,8	164	208	374	582	269	850	83,5
21	b/ROx/Nox/W	40	99,6	24,2	508	0,24	1601	99,6	10,3	314	340	612	952	406	1359	97,6

Table 3. Investment values gained on the basis of mathematical algorithm. (Author's calculation)

	Cb	10	**€/t**		**t**	6000	**h**							**Bting**	35	**€/t**		
	$CC0_2$	10	**€/t**		**z**	10	**a**											
	NOxc		**M€**		**oN**	180	**MW**		**eot**	0,08								
	LWc	0,1	**M€**		**bN**	100	**MW**		**ebt**	0,1								
	Wc		**M€**		**BN**	150	**MW**		**eBt**	0,09								
	Regime	**CSO_2**	**ηSO_2**	**ηE**	**bB**	**qSO_2**	**qCO_2**	**ΔbB**	**ΔqSO_2**	**ΔqCO_2**	**Cb**	**CCO_2**	**Cvar**	**Cconst**	**CΣ**	**βSO_2**	**CΣ**	**Invest-ment**
		mg/nm^3	**%**	**%**	**g/kWh**	**g/kWh**	**g/kWh**	**g/kWh**	**g/kWh**	**g/kWh**	**$€/tSO_2$**	**$€/tSO_2$**	**$€/tSO_2$**	**$€/tSO_2$**	**$€/tSO_2$**	**%**	**€/MWh**	**M€**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**16**
1	**0**	2626	70,8	30,1	409	12,52	1287	0,0	0,0	0	0	0	0	0	0	0,0	0	0,0
10	**L**	2338	74,0	29,6	416	11,33	1309	6,9	1,2	22	204	184	387	8	396	9,5	0,5	0,1
11	**LW2**	2132	76,3	29,3	420	10,44	1322	11,2	2,1	35	188	169	357	5	362	16,6	0,8	0,1
12	**LW4**	1943	78,4	28,8	427	9,68	1345	18,4	2,8	58	227	205	432	4	436	22,7	1,2	0,1
13	**LW8**	1780	80,2	28,2	436	9,06	1374	27,5	3,5	87	278	251	529	3	532	27,7	1,8	0,1
14	**B**	2135	76,3	29,7	414	10,32	1305	5,5	2,2	17	87	79	166	6	172	17,6	0,4	0,1
15	**BL**	1812	79,9	28,5	432	9,12	1359	22,9	3,4	72	236	213	449	4	453	27,2	1,5	0,1
16	**BLW2**	1763	80,4	28	439	9,04	1384	30,6	3,5	97	308	277	585	3	588	27,9	2,0	0,1
17	**BLW6**	1376	84,7	27,3	451	7,23	1419	41,9	5,3	132	277	250	527	2	530	42,3	2,8	0,1
18	**bLW6**	1133	87,4	24,9	494	6,53	1556	85,3	6,0	269	499	449	947	3	951	47,9	5,7	0,1

Table 4. Investment values gained on the basis of mathematical algorithm. (Author's calculation)

	Cb	10	**€/t**		**t**	6000	**h**							**Bting**	35	**€/t**		
	$CC0_2$	20	**€/t**		**z**	10	**a**											
	NOxc		**M€**		**oN**	180	**MW**		**eot**	0,08								
	LWc	0,1	**M€**		**bN**	100	**MW**		**ebt**	0,1								
	Wc		**M€**		**BN**	150	**MW**		**eBt**	0,09								
	Regime	**CSO_2**	**ηSO_2**	**ηE**	**bB**	**qSO_2**	**qCO_2**	**ΔbB**	**ΔqSO_2**	**ΔqCO_2**	**Cb**	**CCO_2**	**Cvar**	**Cconst**	**CΣ**	**βSO_2**	**CΣ**	**Invest-ment**
		mg/nm^3	**%**	**%**	**g/kWh**	**g/kWh**	**g/kWh**	**g/kWh**	**g/kWh**	**g/kWh**	**$€/tSO_2$**	**$€/tSO_2$**	**$€/tSO_2$**	**$€/tSO_2$**	**$€/tSO_2$**	**%**	**€/MWh**	**M€**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**16**
1	**0**	2626	70,8	30,1	409	12,52	1287	0,0	0,0	0	0	0	0	0	0	0,0	0	0,0
10	**L**	2338	74,0	29,6	416	11,33	1309	6,9	1,2	22	204	367	571	8	579	9,5	0,7	0,1
11	**LW2**	2132	76,3	29,3	420	10,44	1322	11,2	2,1	35	188	338	526	5	531	16,6	1,1	0,1
12	**LW4**	1943	78,4	28,8	427	9,68	1345	18,4	2,8	58	227	409	637	4	640	22,7	1,8	0,1
13	**LW8**	1780	80,2	28,2	436	9,06	1374	27,5	3,5	87	278	501	779	3	782	27,7	2,7	0,1
14	**B**	2135	76,3	29,7	414	10,32	1305	5,5	2,2	17	87	157	245	6	250	17,6	0,6	0,1
15	**BL**	1812	79,9	28,5	432	9,12	1359	22,9	3,4	72	236	426	662	4	666	27,2	2,3	0,1
16	**BLW2**	1763	80,4	28	439	9,04	1384	30,6	3,5	97	308	554	862	3	865	27,9	3,0	0,1
17	**BLW6**	1376	84,7	27,3	451	7,23	1419	41,9	5,3	132	277	499	777	2	779	42,3	4,1	0,1
18	**bLW6**	1133	87,4	24,9	494	6,53	1556	85,3	6,0	269	499	898	1396	3	1399	47,9	8,4	0,1

Table 5. Investment values gained on the basis of mathematical algorithm. (Author's calculation)

	Cb	10	**€/t**		**t**	6000	**h**							**Bting**	35	**€/t**		
	$CC0_2$	30	**€/t**		**z**	10	**a**											
	NOxc		**M€**		**oN**	180	**MW**		**eot**	0,08								
	LWc	0,1	**M€**		**bN**	100	**MW**		**ebt**	0,1								
	Wc		**M€**		**BN**	150	**MW**		**eBt**	0,09								
	Regime	**CSO_2**	**ηSO_2**	**ηE**	**bB**	**qSO_2**	**qCO_2**	**ΔbB**	**ΔqSO_2**	**ΔqCO_2**	**Cb**	**CCO_2**	**Cvar**	**Cconst**	**CΣ**	**βSO_2**	**CΣ**	**Invest-ment**
		mg/nm^3	**%**	**%**	**g/kWh**	**g/kWh**	**g/kWh**	**g/kWh**	**g/kWh**	**g/kWh**	**€/tSO$_2$**	**€/tSO$_2$**	**€/tSO$_2$**	**€/tSO2**	**€/tSO$_2$**	**%**	**€/MWh**	**M€**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**16**
1	**0**	2626	70,8	30,1	409	12,52	1287	0,0	0,0	0	0	0	0	0	0	0,0	0	0,0
10	**L**	2338	74,0	29,6	416	11,33	1309	6,9	1,2	22	204	551	755	8	763	9,5	0,9	0,1
11	**LW2**	2132	76,3	29,3	420	10,44	1322	11,2	2,1	35	188	507	695	5	700	16,6	1,5	0,1
12	**LW4**	1943	78,4	28,8	427	9,68	1345	18,4	2,8	58	227	614	842	4	845	22,7	2,4	0,1
13	**LW8**	1780	80,2	28,2	436	9,06	1374	27,5	3,5	87	278	752	1030	3	1033	27,7	3,6	0,1
14	**B**	2135	76,3	29,7	414	10,32	1305	5,5	2,2	17	87	236	323	6	329	17,6	0,7	0,1
15	**BL**	1812	79,9	28,5	432	9,12	1359	22,9	3,4	72	236	638	875	4	878	27,2	3,0	0,1
16	**BLW2**	1763	80,4	28	439	9,04	1384	30,6	3,5	97	308	831	1139	3	1142	27,9	4,0	0,1
17	**BLW6**	1376	84,7	27,3	451	7,23	1419	41,9	5,3	132	277	749	1027	2	1029	42,3	5,4	0,1
18	**bLW6**	1133	87,4	24,9	494	6,53	1556	85,3	6,0	269	499	1346	1845	3	1848	47,9	11,1	0,1

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Thesis is based on the following papers:

Kleesmaa, Jüri. Impact of CO_2 trade on electricity producers depending on the use of different energy sources in Estonia. In: Estonian Economic Policy Debate XVIII: XVIII Economics Policy Conference, Värska, 1.–3.07.2010. Berlin*Tallinn: Berliner Wissenchafts-Verlag, Mattimar, 121−139, 2010.

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Kleesmaa, J., Viiding, M., Latõšov, E. Implication for competitiveness of Estonian energy-intensive industry after establishment of CO_2 pricing from year 2013 onwards. Baltic Journal of Economics, autumn 2011. [Forthcoming]

Author's contribution

Article 1. I am the author of this article.
Article 2 . It was my task to present the requirements established for carbon dioxide quota trading, complying with which would efficiently help reduce greenhouse gas emissions to the extent that, based on research data, are necessary to prevent major climate changes.
Article 3. I organised gathering and analysing of materials on institutions, deciding formula, preparation of the concise model and presentation of relevant literature.
Article 4. As a project leader I organised preparation and conducting of the tests and presentation was partly my responsibility; I was completely responsible for discussions, one individual presentation at TUT and as the responsible author also for publishing of the article.
Article 5. Via public information channels I obtained annual statements of all firms which use energy intensively and organised data collection, analysing of materials, deciding formula, preparation of concise models and presentation of relevant literature.

Appendix 1. ”Impact of the CO_2 trade on electricity producers depending on the use of different energy sources in Estonia”.

IMPACT OF CO_2 TRADE ON ELECTRICITY PRODUCERS DEPENDING ON THE USE OF DIFFERENT ENERGY SOURCES IN ESTONIA

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Abstract

The aim of this paper is to identify the main circumstances related to the Estonian energy sector and economy and the facts which are important for development of the research conducted by the author and for clarification of the main viewpoints. The paper provides the principal facts on the first (2005-2007) and second (2008-2012) period of CO_2 (carbon dioxide) trade in Estonia; describes electricity production in Estonia on the basis of the electricity development plan effective in the reference year 2007 and proceeding from that – calculations of CO_2 emissions by kind of fuel used. The paper will touch upon the main legislative provisions concerning renewable energy support, which essentially influence the development of renewable energy generation and indirectly the CO_2 trade. Analogously with the reference year 2007 methods of calculation, CO_2 emissions have been calculated for 2020. The electricity production prognosis for the year 2020 is based on the interpretation of the electricity sector development plan. Computation according to the CO_2 calculation methodology shows that the CO_2 emission amount will be ca 5.7 Mt (million tonnes) in 2020. In 2020 compared to 2007, the domestic consumption of electricity is estimated to grow: in 2007 the domestic consumption of electricity was ca 8200 GWh, in 2020 it is estimated to be ca 10480 GWh, i.e. the growth is ca 22%. Decrease in the emission amount of CO_2 will be gained due to the expected use of different energy sources, compared to those used in 2007, in the designed power plants based on renewable energy sources or gas. The share of oil shale-based energy production will decrease from 83% to 44% resulting in a further reduction of CO_2 emissions from 12 Mt to 4 Mt. In view of the fact that, during consumption, the CO_2 emissions comprise nearly 60% of the gross consumption of electricity production, the research reveals that raising consumer awareness of the use of various energy saving equipment and the promotion of economical lifestyle involve a remarkable potential for reducing the amount of CO_2 emission. To ensure competitiveness of electricity producers in the free market conditions, influenced by CO_2 emission allowance trading, construction of the power plants in compliance with national regulations must be ensured with the help of support schemes, state aid, tax policies and legislative measures. Since the quota trade rules which will apply after the year 2012 are not distinctly clear yet, thus this topic will be developed further in the articles to come.

Keywords: CO_2 trade, energy sources, electricity production, Estonia

JEL Classification: Q410

Introduction

Estonia has, together with other countries across the world, opted for a sustainable path of development where national welfare growth is based on the achievement of balance between the economical use of natural resources and the environment.

The European Union (EU) Directive 2003/87/EC of 13 October 2003 has established a scheme for greenhouse gas (GHG) emission allowance trading with the purpose to:

- Induce society to use resources more effectively and encourage innovations;
- Increase awareness of CO_2 (carbon dioxide) damage from fossil fuel combustion and their cost to society;
- Improve fulfilment of the obligations taken under the Kyoto Protocol for reducing greenhouse gas emissions.

CO_2 quota trade is a symbiosis of power engineering and financial world, which is important for all energy producers and other industries involved in the quota trade. Via energy prices, the CO_2 trade experts influence all enterprises which consume energy. This paper is one of the series prepared in the framework of the research "Impact of Greenhouse Gas Emission Allowance Trading on the Estonian Energy Sector".

The main objectives of the research are:

- To describe the institutions involved in emission allowance trading, emissions trading registry, distribution and certification of emission quotas, and to identify the general economic mechanisms of the scheme and possible effects.
- To evaluate the impact of emissions trading on the economic performance of energy enterprises and their investments.
- Energy enterprises' strategy for emissions trading (marginal cost curve, price of pollution quotas, organisation of emissions trading in practice, conducting of transactions, risk management).
- Trading in pollution quotas (quota market, price).
- To investigate the economic impact of the emissions trading international market on the energy sector.
- To examine the impacts of emissions trading via energy enterprises on the energy sector as a whole (utilisation of renewable energy, implementation of new combustion technologies).
- To study the economic impact of other flexible mechanisms laid down in the Kyoto Protocol (joint implementation, clean development mechanism) on emissions trading and energy sector.

The purpose of this paper is to identify the main circumstances related to the Estonian energy sector and economy and facts which are important for development of the research conducted by the author − *Impact of Greenhouse Gas Emission Allowance Trading on the Estonian Energy Sector,* and for clarification of the main viewpoints. The author of this study analyses the CO_2 air emissions from electricity generation on the basis of different fuel usage in the power production of Estonia by applying a simple determination method intended for calculation of the carbon dioxide emissions into the ambient air. According to common knowledge, this analysis is novel for Estonia and such calculations have so far not been made for Estonia. Consequently, this gives a good opportunity for respective studies at the national level.

The main objectives of the paper are:

- To provide the principal facts on the first (2005-2007) and second (2008-2012) period of CO_2 (carbon dioxide) trade in Estonia.
- To describe electricity production in Estonia on the basis of the electricity development plan effective in the reference year 2007 and calculations of CO_2 emissions by kind of fuel.
- Touch upon the main legislative provisions concerning renewable energy support, which essentially influence the development of renewable energy generation and indirectly the CO_2 trade.
- To calculate CO_2 emissions for 2020 analogously with the reference year 2007 methods of calculation.
- To forecast electricity production for the year 2020 based on the interpretation of the electricity sector development plan.

Impacts of the European Union climate and energy package (will come into force in 2013) on the energy sector require further in-depth analysis and will not be discussed in this paper.

This paper seeks to identify the major energy sector and economy related circumstances and facts in Estonia that are important for further development and clarification of the research.

The EU GHG emissions trading scheme 2005-2007

The first period of trading lasted from 2005 to 2007 (introduction) when the **CO_2 quota** (this analysis deals with the impact of CO_2 trade only) trading was mainly conducted only between EU Member States.

The GHG emissions quota trading scheme 2005-2007 was like a training stage. Their utility was limited as banking was missing between the first and second stages, and units were overpriced. Overpricing of the units led to that their price approached zero by the end of the period (Figure 1) because of a change in the demand-to-supply ratio as a result of active marketing activity of the industrial sector.

Figure 1. CO_2 trading opportunities for EGL (Elektrizitäts-Gesellschaft Laufenburg). (EGL 2008)

Figure 1 depicts the EUA (European Union Allowances) price fluctuations from December 2004 till April 2008. Sharp declines in May 2006 and in 2007 were caused by the situation in the market where, after the first certified emissions had been publicized, it turned out that there were actually more units available in the market than there was demand for them. In other words, until May-April 2006 when real emissions into the air in the first so-called trading year were identified, the ratio of the emission allowances available on the market to actual emissions was not yet known to the public (e.g. for 2005 the European Commission allocated the emission limit of 16,747,053 t/CO_2 to Estonia but the real emissions were 12, 621,824 t/CO_2, or nearly 4 million tonnes of emission allowances were put on the market (Climate web 2010).

The so-called overabundance of vacant emission allowances on the market was indeed the cause which led to the decline that started in 2006 and lasted till the end of 2007 (when the so-called pre-Kyoto trading period in Europe came to an end).

The EU GHG emission allowance trading scheme 2008-2012

By the start of the new trading period, or the so-called Kyoto first trading period in Europe (2008-2012), the European Commission had made extremely radical cut-back decisions in total emission allowances allocated to Member States (the so-called National Allocation Plan − NAP) to stabilise and prevent the situation which had dominated in the pre-Kyoto trading period. The results are shown in Figure 1, where the EUA price level is perceived to be more or less stable (which is the objective of the carbon dioxide market – real demand in the market determines the actual value of 1 tonne of CO_2).

The CER (certified emission reduction) price development is affected by the fact that in the pre-Kyoto trading period operators had no right/opportunity to use emission units available in Kyoto flexibility mechanisms (flexible mechanisms are based on the following units: clean development mechanism – CDM: **CERs,** certified emission reductions; joint implementation mechanism – JI: **ERUs,** emission reduction units; emissions trading 2008-2012 – ET: **AAUs**, assigned amount units) for fulfilment of their obligations (the operator shall return to the State a number of allowances equal to the actual amount of emissions in the preceding year by 30 April of the year following the accounting year – the transaction takes place via a respective electronic register). In the Kyoto trading period, operators will have such a possibility within the limits allocated to each Member State (e.g. this percentage varies across European countries, but is on average between 10-20%). This means that when the EUAs allocated from NAP to an operator are not enough for the fulfilment of his obligations, he may buy from the market more Kyoto flexibility mechanism units within the nationally allocated limits.

For the 2008-2012 trading period, Estonia made a proposal to the European Commission (EC) for 24.4 million tonnes a year (122 million t/5 years). EC lowered the quotas to 12.7 million tonnes (63.5 million t/5y), i.e. by ca. 52%. 47 operators are involved in quota trading in Estonia, including 39 from energy production, 6 from mineral industry and 2 from paper and pulp industry. GHG emission allowance trading permits are issued by the Estonian Minister of the Environment pursuant to Regulation of the Government of Estonia No 257 of 20 December 2007, which establishes 1st January 2008 to 31st December 2012 as the period of GHG emission allowances from stationary sources of pollution. 11,678,257 tonnes are annually allocated to operators and 1,038,801 tonnes are annually kept in reserve for new operators entering the trading system.

Estonia filed an action with the European Court against the European Commission (Judgement of the Court 2009), claiming that the Commission made grave mistakes in taking the decision and exceeded its authority. The Court agreed with Estonia and stated that the Commission had no authority to substitute in the assessment of NAP Estonia's data with its own, which among other things did not sufficiently take into consideration the Estonian energy policies and was not based on the correct GDP growth prognosis. Additionally, the Court verified a violation of the principle of good administration.

This court judgement means that the European Commission has to take new decisions regarding Estonia's pollution quotas. Estonia may not issue pollution permits until the European Commission has made a new decision. Considering the favourable situation in the previous so-called practicing period 2005-2007, according to which the reference year for the quota trading was 1990 and the reduction percentages for Estonia are governed by the Kyoto Protocol (Ratification of the Kyoto Protocol 2002), Estonia is facing a situation where in 2008-2012 it has to reduce emissions 8% against the 1990 levels. But, considering the actual situation of Estonia in the reference year (we were a part of the USSR and with a different economic structure) and our economic restructuring later, we are in a situation where we have already achieved this target (National Inventory Report 2009). Several energy production enterprises used the favourable situation to improve their economic situation, for example, Eesti Energia AS (EE; 100% of shares owned by the Republic of Estonia), which in the 2006/07 financial year received approximately 95 M€ for selling emission quotas in the Nord Pool electricity exchange (EE's yearbook 2007/2008). In the financial year 2007/08, the impact of trading in emission quotas on economic performance reversed to -8.95 million EUR. Quotas were not sold in 2007 due to the lack of interest in the stock exchange, on the one hand; however, the significantly smaller than expected amount of quotas allocated to EE under the second NAP brought about a need to make additional expenditure for obtaining 2008 quotas. In the financial year 2007/08, EE was estimated to spend 8.95 million EUR (ca. 0.36 million tonnes CO_2/25€/t) on buying quotas.

Electricity production and CO_2 emission in Estonia in the reference year (2007)

According to the statistical overview Energy Balance 2007 prepared by Statistics Estonia (Energy balance 2007) (Figure 1, Table 2), Estonia produced **11402 GWh** of **oil shale**-based electricity, 350 GWh from natural gas, 235 GWh from oil shale gas, 22 GWh of hydro-energy, 91 GWh of wind energy, 36 GWh from other renewable energy sources and 22 GWh from peat.

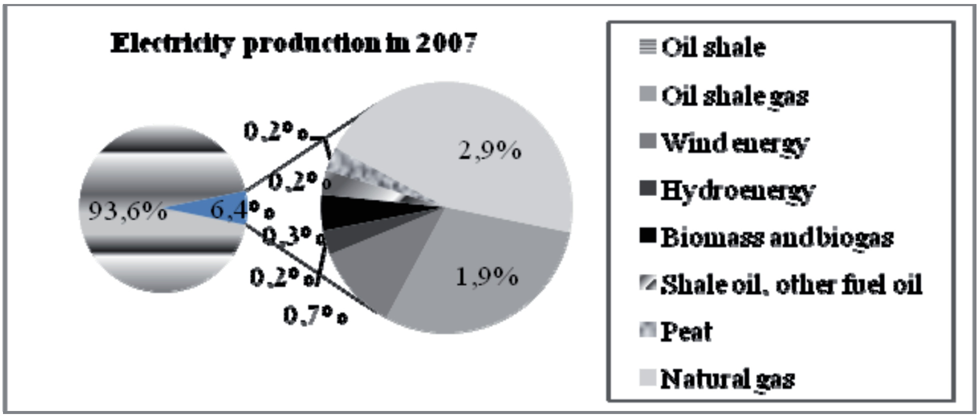

Figure 2. Electricity output of 12188 GWh in 2007. (Development Plan of the Estonian Electricity Sector until 2018)

The reference year for energy production and consumption calculations is 2007, which is also the reference year for Development Plan of the Estonian Electricity Sector until 2018.

Estonia has always managed to cover its electricity demand and also exported electricity. According to the 2007 statistics, electricity production amounted to 12188 GWh (Table 1. Of this quantity, oil shale-based electricity accounted for 93.6%), which implies the amount of electricity measured at the power plant's turbine terminals. If to deduct from this power plant's own use (889 GWh), then the amount transmitted via power networks to consumers is 11299 GWh. A part of it is consumed by local consumers and the other part is sold for exports (2765 GWh). After deducting network losses, domestic consumers consumed 7180 GWh in 2007.

Table 1. Electricity production and consumption in 2007 and CO_2 emission into the atmosphere

Consumer	Consumption (GWh)	CO_2 emissions from electricity production into the atmosphere (Mt)	Percentage of total consumption %
Consumption in Estonia	7180	**7.55**	**58.9**
Network losses	1354	**1.42**	**11.1**
Total consumption	8534	8.97	70.0
Export	2765	**2.91**	**22.7**
Network total	11299	11.87	92.7
Power plant's own use	889	**0.93**	**7.3**
Gross production	**12188**	12.81	100

Source: Statistics Estonia, author's calculations.

The quantity of CO_2 emissions into the ambient air from electricity generation and consumption in 2007 was found by calculating the physical indicators of various fuels used for electricity generation in Estonia and the specific CO_2 emissions from co-generation (1.05 $ktCO_2/GWh$, Table 2).

CO_2 emissions have been calculated by using the determination method of carbon dioxide emissions into the ambient air (Välisõhku eralduva 2004). The special emissions of carbon from combustion of oil shale in Estonian power plants and from depositing shale ash are calculated by using the following formula:

(1) $q_{c\ oil\ shale} = 10\left[C^r + k(CO2)^r_M 12/44\right]/Q^r$, tC/TJ

where
Q^r – calorific value of oil shale, MJ/kg;
C^r – carbon content of oil shale, %;
$(CO_2)^r{}_M$ – mineral carbon dioxide content of oil shale, %; (Ots 2004)
tC/TJ – tons of carbon to Tera Joule;
12/44 – C/CO_2 molecular mass ratio
k – product gained by multiplying the factors which take into account the extent of carbonate decomposition in oil shale combustion in boilers (k_{CO2}) and CO_2 binding in ash fields ($k_{unbound}$) (in pulverised combustion k = 0.64, in fluidised bed combustion k = 0.40).

For calculating the real carbon emissions and carbon dioxide emission values, the actual amount of carbon content in the combusted fuel is multiplied by the value characterising the oxidised part of carbon; the actual carbon emission value (*Mc*) is calculated in gigagrams (*GgC*) by using the following formula:

(2) $Mc = 10^{-3} \times B' \times q_c \times Kc$

where
B' – fuel consumption (TJ);
q_c – specific carbon emission (tC/TJ);
Kc – share of oxidised carbon.

The CO_2 emission into the ambient air from combustion of a different kind of fuel (M_{co2}) in gigagrams ($GgCO_2$) is calculated by using the following formula:

(3) $M_{CO2} = Mc \times 44/12$

where
Mc – carbon emission value (*GgC*).

Total CO_2 emission into the ambient air is calculated by summing up the CO_2 emissions from combustion of all kinds of fuel.

CO_2 emission from combustion of oil shale in the co-generation regime (simultaneous production of electricity and heat) amounts to 12404 thousand tonnes (Table 2, second and fifth cells), while other fossil fuels emit into the atmosphere ca 3% compared to oil shale combustion. Wind energy, hydro-energy, nuclear energy, biomass and biogas as sources of energy are, according to the global agreement, regarded as sources not generating CO_2. Additional note: Estonia does not produce electricity on the basis of nuclear energy.

It is interesting that on the basis of data provided in Table 2, the lower scale of specific CO_2 emissions includes also natural gas (fossil fuel). Natural gas burns more cleanly than other fossil fuels, such as oil shale and peat, and produces less carbon dioxide per unit of energy released. Is this the reason why Russia and the European Union have agreed upon building the Nord Stream gas pipeline? The underwater part of the pipeline starts from the Portovaya Bay near Vyborg and runs approximately 1200 km by the bottom of the Baltic Sea as far as to Greifswald in Germany.

Table 2. Electricity production in Estonia in 2007 on the basis of different fuels

Fuel used for electricity generation (thous.tonnes, million-m^3)	Electricity production, (GWh (total))	Specific CO_2 emission for fuel (kg/MWh)	Electrical efficiency (total) η	Specific CO_2 emission per electricity production, kg/MWh
Oil shale	11402	359	0.33	1087.9
Peat	22	370	0.3	1233.3
Shale oil	30	276	0.3	920.0
Natural gas	350	201	0.35	574.3
Renewable sources	149			
Oil shale gas	235	201	0.32	628.1
	Σ12188			

Source: Statistics Estonia, author's calculations.

Oil shale-based electricity production efficiency has been calculated by taking into consideration that electricity is generated in fluidised bed combustion. We assume that the total efficiency of oil shale-based electricity is on average 33%. Shale gas as a product of *Eesti Energia Õlitööstus AS* is extracted in shale oil production and is burnt in pulverised combustion boilers at Narva Power Plants; thereby the efficiency is lower than in case of fluidised bed technology. *VKG Energia AS* is burning the gas generated in shale oil production in energetic boilers together with oil shale. The efficiencies of the co-generation regime of natural gas, peat, shale oil and fuel oil are, according to producers' information, between 0.3-0.35 or 30-35%.

Considering big reductions in the CO_2 quotas and the EU initiative for much more extensive use of renewable energy, the renewable energy generation is a rapidly growing sphere of activity. The main sources of renewable energy used in Estonia are wind and biomass and to a little extent also hydro and biogas.

The Electricity Sector Development Plan 2005-2015 established the objective to increase the share of renewable energy[1] (Renewable energy resources 2005) to 5.1% in total consumption by 2010 and to increase the share of electricity generated in combined plants of heat and electricity to 20% of total consumption by 2020 (European Renewable Energy Council 2009).

In 2007, renewable electricity accounted for 1.75% of total consumption. The potential output of new renewable electricity production projects that should be completed by 2010 will exceed the target (Kisel 2007).

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[1] Renewable energy resource or renewable source of energy is the energy resource that can be sustained indefinitely, e.g. waves, tides, solar energy, wind, geothermal energy, or which can be regenerated in the course of biological processes in the ecosystem (biomass and biofuel − timber, reed, energy forest, sugar cane etc) without their quantities being essentially reduced in a time span of human significance; is not subject to CO_2 emission trading scheme, the quota is 0.

Support and subsidies for renewable energy

The cogeneration support schemes implemented in 2007 (Electricity Market Act 2003) to increase the share of electricity produced in combined heat and electricity plants to 20% of total consumption by the year 2020, have encouraged erecting of new cogeneration plants (in 2009 cogeneration plants were built in Tallinn and Tartu) and the share of cogeneration is increasing (a power plant is being erected at Pärnu and several small cogeneration plants are being planned in different regions of Estonia). The subsidisation[2] has sharply increased investors' and energy producers' interest in using biofuels.

With its resolution of 28th January 2010, the *Riigikogu* essentially amended the Electricity Market Act so that a producer has the right to receive support from the transmission network operator for the electricity supplied starting from 1st July 2010 if it is generated from biomass in efficient cogeneration regime, unless electricity from biomass is produced in the condensation regime.

The Republic of Estonia also promulgated (Decision No 621. 2010) the law amending the Electricity Market Act, which was passed by the *Riigikogu* on 28th January 2010. At the same time, the President sent the Chancellor of Justice a letter requesting that he should pay special attention to a provision of the aforementioned Act, which will abolish as of 1st May 2007 the support for operators who generate electricity from biomass in summer.

The President can only reject a law as a whole. This would mean that provisions which are in line with the Constitution and must be passed as soon as possible to open 35 per cent of the Estonian electricity market as of 1st April 2010 and to avoid threatening of the construction of an EU supported second submarine communications cable between Estonia and Finland, would also remain ineffective. The Chancellor of Justice has the right to contest single provisions of any law, if appropriate.

In 2009, the Minister of the Environment with his Regulation No.14 approved of the structural aid award measure for more extensive use of renewable energy sources for energy generation. The purpose of the aid was to increase the share of renewable energy sources in the energy balance and to reduce pollutant emissions from the energy generation system. This Regulation should increase producers' and investors' concern for the energy production development in different regions of Estonia and disperse energy concentration in the eastern region.

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[2] For example, peat fuel boiler houses operating in efficient co-production regime are paid for produced and net transmitted electricity according to the Estonian Electricity Market Act, which is 81 cents/kWh (Estonian currency, 1EUR=15.6466EEK), or receive subsidy 50 cents/kWh, correspondingly. For using wood fuel (as a renewable fuel), the subsidies are significantly higher: subsidy of 80 cents/kWh or electricity sold to the net for the price of 115 cents/kWh.

Main provisions and scenarios in the electricity sector development plan

The Development Plan of the Estonian Electricity Sector (Development Plan of Estonian Electricity Sector 2009) underlines that oil shale is a strategic mineral resource for Estonia and electricity generation from oil shale is a characteristic of the Estonian energy sector – nearly 94% of electricity is produced from oil shale.

Considering the best scenario set out in the electricity sector development plan (Table 3), the capacity of co-generation plants must be increased to 300 MW (net capacity during peak hours 260 MW) by 2014; 2x300 MW oil shale fluidised bed combustion units (net capacity 270 MW) should be erected by the end of 2015; by 2012, desulphurisation and denitrification systems (net capacity of 4x150 MW) must be installed in four of the existing old 200 MW oil shale units; by 2013, the capacity of on-shore wind turbines must be increased to 400 MW (Table 3). The decisions concerning the investments in all these capacities shall be made before the end of 2010. For that purpose, application programme of the electricity development plan for 2009-2010 and prognosis up to year 2018 were approved by the Government of the Republic of Estonia. Since then the following has been done: 13th March, the Board of Eesti Energia AS (BEE) signed a contract with the company Alstom for the installation of desulphurisation system (4 units) for the Eesti Power Plant oil shale pulverized energy blocks; on 21st May 2009, BBE took a decision to construct 2x300 MW oil shale fluidised bed combustion units (the procurement process in progress); on 16th July 2009, the Baltic Republics' most powerful Wind Park (Aulepa) with the capacity of 39 MW was opened in Noarootsi Municipality; on 17th December, BBE approved of the construction of Waste to Energy Block (50 MW_{th} and 17 MW_e) at Iru Power Plant (in March 2010, a contract was signed with the enterprise CNIM) (Eesti Energia 2009).

The subsequent increase in the capacity of wind parks (included in the list of renewable energy sources and has a positive effect on the CO_2 trade balance) is most expedient on the sea, but this matter requires further studies. Production capacities must be constructed in the range of the capacity of wind turbines to balance the instability of the production of wind turbines and also to cover the consumption peaks. Partial closure of the units supplied with purification equipment in Narva Power Plants may be considered after putting the shale oil fired gas turbines into service presumably in 2018.

A need to increase the capacity of emergency reserves in 2016 is conditioned by the erection of the submarine cable Estlink 2 (with the estimated capacity of 600 MW).

Such an increase in transmission capacity is also a precondition for future integration of the Baltic Republics' energy market into the Nordic power exchange Nord Pool Spot. Moreover, the new link will increase the reliability of the Baltic energy systems, at the same time reducing their dependence on Russia. Advantages of the second cable between Estonia and Finland were analysed in a cross-regional study with the participation of Nordel, BALTSO and Polish regions, which was completed in February 2009. The results show clearly that the cable will be socio-economically useful for the Baltic Sea region (Figure 3).

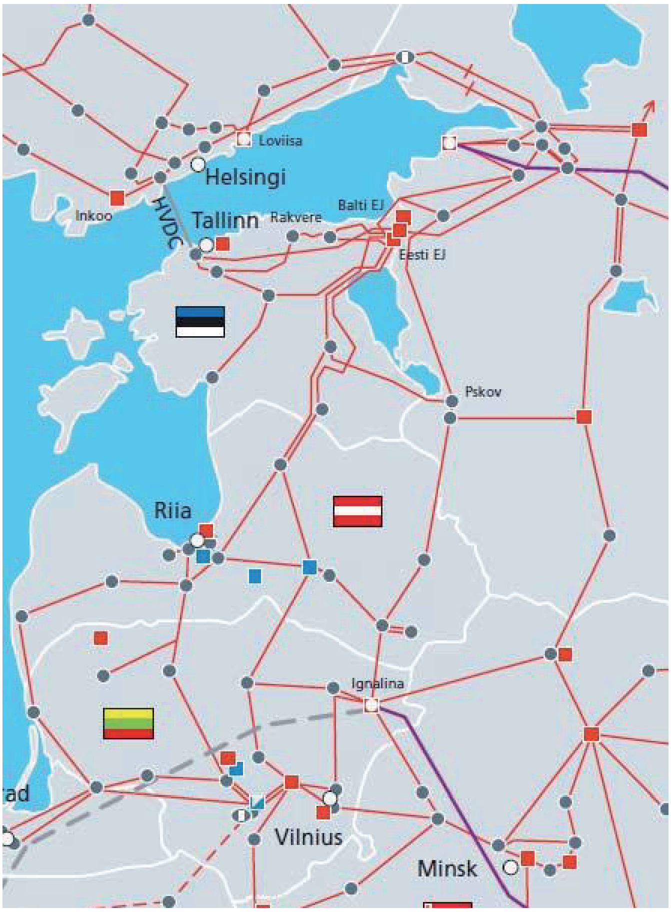

Figure 3. Integration of the Estonian electricity network into the neighbouring countries' network in 2010.

Capacities of the emergency power installations can be used also for ensuring the reserve capacity of nuclear power plants (in CO_2 trade nuclear installations are regarded as not emitting carbon dioxide). All gas turbine installations must be capable of using at least two types of fuel, preferably domestic resources and renewable sources of energy (author's remark).

The electricity production of every power plant depends on the market situation in a particular year and therefore it is nearly impossible to predict the volume of their electricity production. Electricity market regulation must guarantee that the structure of production capacities in Estonia is diverse and we have sufficient production capacities in case it is not possible to buy electricity cheaper elsewhere. However, a justified question arises in the case of importing cheaper electricity (for example, from Russia) about the true existence of the so-called clean electricity certificate. In a free market situation, electricity producers face an unequal competition situation in case of cheaper electricity inflow from third countries.

Electricity production under free market conditions

On the basis of 2020 prognoses, the situation should change fundamentally (Table 4, Figure 4), i.e. the share of oil shale-based electricity generation will decrease to ca. 40%, whereas the share of renewable energy will increase to the approximate level of 31%.

The results gained by using the CO_2 calculation methodology show that the CO_2 emission amount will be ca. 5.7 Mt (million tonnes) in 2020. In 2020 compared to 2007, the domestic consumption of electricity is estimated to increase: in 2007 the domestic consumption of electricity was ca. 8200 GWh (Table 1, export and transmission losses excluded) and in 2020 it is estimated to be 10480 GWh, i.e. the growth is ca. 22% (Table 4). Decrease in the emission amount of CO_2 will be gained due to the expected use of different energy sources, compared to those used in 2007 (Figure 2), in the designed power plants based on renewable energy sources or gas (Figure 4). The share of oil shale-based energy production will decrease from 83% to 44% resulting in a further reduction of CO_2 emissions from ca. 12 Mt to 4 Mt.

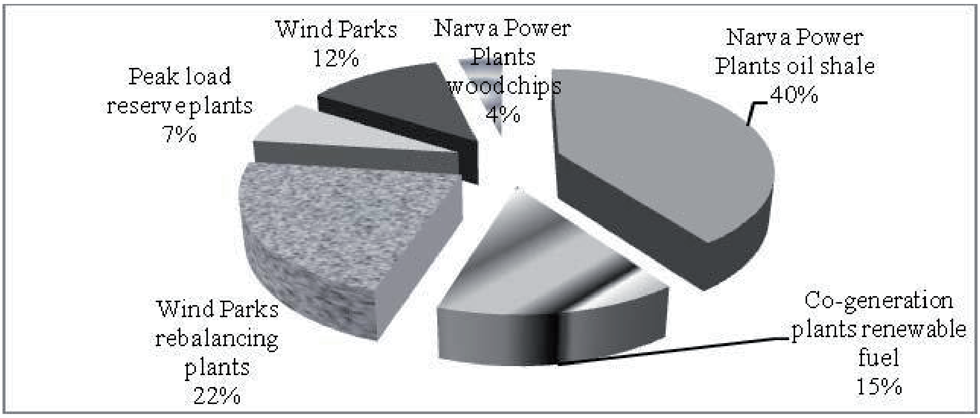

Figure 4. Electricity production in Estonia in 2020. (Author's calculations)

Table 3. Electricity production development trends until 2020

Type of power plant	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Co-generation plants	150	200	220	240	260	260	260	260	260	260	260
Oil shale-based plants	1660	1660	1630	1630	1630	2170	1520	1520	920	920	920
−not renovated	1280	1280	640	640	640	640					
−fluidised bed	380	380	380	380	380	920	920	920	920	920	920
−with purification equipment			600	600	600	600	600	600			
On-shore wind farms*	150	200	200	400	400	400	400	400	400	400	400
Balancing units for wind power							200	200	500	500	500
−including oil shale-based gas turbines							200	200	500	500	500
Peak reserves**	100	100	100	100	100	300	300	300	300	300	300
Emergency reserves**				100	200	300	300	300	600	600	600
Total guaranteed production capacity	**1810**	**1960**	**2150**	**2470**	**2590**	**3230**	**2980**	**2980**	**2980**	**2980**	**2980**

* The capacities are not taken into account in the total guaranteed production capacity

**Capacities under 100 MW

Source: Development Plan of the Estonian Electricity Sector until 2018.

Table 4. Projected electricity production and CO_2 emission values in 2020

Type of power plant	Capacity	2020	Output	Division	Specific CO_2 emission t/GWh	CO_2 emission from electricity generation (Mt)
	MW	Working hours*	GWh	%		
Co-generation plants	260	6000	1560	14.9	0	
Oil shale based power plants	920	5000	4600	43.6		
−including oil shale 90%			4140	39.5	997,2	
−wood chips 10%			460	4.4	0	
On-shore wind farms**	400	3000	1200	11.5		
Off-shore wind farms**	500					
Balancing units for wind power	900	2600	2340	22.3	502,5	
Peak reserves	300	2600	780	7.4	502,5	
Emergency reserves	600					
Total	**2980**	**3517**	**10480**	**100**	**0**	**5.7**
Total renewable electricity	1160		3220	30.7		
Total oil shale			4140			
Total natural gas			3120		0	

* Projected working hours of power plants.

** The capacities are not taken into account in the total guaranteed production capacity.

Source: Author’s calculations.

Conclusions and discussion

In 2007 Estonia generated 12.2 thousand GWh or 12.2 TWh (terawatt-hours) of electricity, including 8.2 TWh for domestic consumption after deducting export losses. The domestic production projected for 2020 is ca. 10.5 TWh, which makes an annual growth of ca. 2.2%. The transmission network operator (now called Elering OÜ) has planned 1.8-3.5% for annual electricity production growth (Development Plan of the Estonian Electricity Sector 2009; Elering OÜ 2009), which is associated with the economic growth of 3-7%. Elering's plans coincide with the author's prognosis.

According to the National Allocation Plan 2008-2012, quotas are allocated to the energy enterprises participating in the CO_2 emission allowance trading scheme in the amount of 12.7 $MtCO_2$ annually. Hence, considering the 2.2% growth of electricity production, we are short of relevant quotas (12.8 $MtCO_2$/y2007) which we need to obtain from the trade sector. In case the European Commission respects the judgement of the European Court to re-negotiate the quotas allocated to Estonia in a positive direction for Estonia (in which the author doubts), then Estonia will have excess carbon dioxide quotas (ca 12 Mt/y) and energy producers will have an opportunity to avail them to make energy generation more effective and consumer friendly.

Considering the prognosis that electricity exports will remain on the level of 2007 (Table 1), i.e. ca 3 $MtCO_2$, the CO_2 emission values in 2020[1] would be ca 9 $MtCO_2$, i.e. ca 30% less than in 2007.

On the basis of calculation results presented in Table 1 we can see that energy can be saved and CO_2 emissions reduced not only by reduction of the fossil fuel usage (for example, implementation of a different economic structure from year 1990 in Estonia, usage of different renewable fuels, etc.), but the relevant spheres where energy can be saved and CO_2 emissions reduced are: energy consumption (the CO_2 emission level ca. 60% of total production), electricity export (correspondingly ca 23%), a smaller effect of network losses (11%) and plant's own electricity use (7%). These intermediate stages concerning the whole power system should constitute the main study targets either when choosing energy efficient products, auditing one's home energy use, implementing energy smart plans when building a new home or saving on transportation costs.

From 2013 the European Union Energy and Climate Package (European Parliament 2010) will take effect. In the framework of this Package, the EU Heads of State and Government set a series of demanding climate and energy targets to be met by 2020 – reduction in EU greenhouse gas emissions of at least 20% below 1990 levels; 20% of EU energy consumption to come from renewable resources; 20% reduction in primary energy use compared with projected levels, to be achieved by improving

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[3] As the quota trading rules for the period after 2012 are not clear yet, this topic will be developed further in the next market analyses and studies.

energy efficiency. This subject is not analyzed in this paper, but will be elaborated in future research.

In order to implement the best scenario described in the Development Plan of the Estonian Electricity Sector until 2018, so as to ensure the competitiveness of electricity producers in the free market conditions influenced by the CO_2 emission allowance trading, the erection of power plants (Development Plan of the Estonian Electricity Sector 2009) must be ensured under national regulations with the help of support schemes, state aid, tax policies and legislative measures. The CO_2 quota allocation policies after 2012 require further in-depth analysis and will be discussed in the next articles.

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Appendix 2. “The Impact of Pollution Charges, Ash Handling and Carbon Dioxide on the Cost Competitiveness of the Fuel Sources Used for Energy Production in Estonia”.

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The Impact of Pollution Charges, Ash Handling and Carbon Dioxide on the Cost Competitiveness of the Fuel Sources Used for Energy Production in Estonia

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Abstract – **The goal of this paper is to estimate the effects of pollution charges, ash handling and of the carbon dioxide quota trade on the competitiveness of natural gas, oil shale, peat and wood chips in Estonia for 2010 and 2015.**

The pollution charges and levels are calculated based on the *Environmental Charges Act*, and *Regulations No 99/2004* and *No 94/2004 of the Estonian Minister of the Environment.*

The calculations show a considerable change in the cost competitiveness of fuels. Fuel related costs of the fossil fuels with high CO_2 emission factors and other environmental impacts may be doubled.

Keywords **– carbon dioxide, cost competitiveness, environmental fees, fuel sources.**

I. INTRODUCTION

This paper draws on the on-going study 'Analysis on the technical and economic consequences of renewable energy based CHP systems in new areas with the lowered useful heat demand or after implementation of energy conservation measures in the areas with older buildings' within the project 'Primary Energy Efficiency', partly financed by Nordic Energy Research, which contributes to the effort of enhancing the primary energy efficiency (PEE) and reducing CO_2 emissions in the energy sector. The objective of the referred study is to create a computer program to estimate the economic and technical feasibility with a view to building a CHP plant based on renewable fuels in the Nordic/Baltic Sea Region countries taking into account local conditions. The novelty of the planned computer program lies in the orientation to the under 10 MW_{el} distributed CHP units based on the existing district heating networks.

The goal of the paper is to estimate the effects of pollution charges for emissions, ash handling and of the carbon dioxide quota trade on the competitiveness of different fossil and biofuels in Estonia.

The competitiveness is determined by the comparison of fuel related costs for different energy sources for the years 2010 and 2015. Fuel related costs consist of fuel price, ash handling costs and environmental fees, as well as the carbon dioxide quota price per one MWh of fuel energy content (based on lower calorific value).

The paper is structured as follows: Section II describes the procedure and methods for determining the emissions of pollutants from combustion plants into ambient air. Then, after an overview of pollution charge rates, the pollution charge rates per one MWh of fuel energy content are calculated. The next section describes the ash handling costs of the observed fuels. Section VI provides calculations of the CO_2 quota amount level per one MWh. Section VII provides calculation and analysis of the impacts of pollution fees, ash handling and carbon dioxide costs (environmental costs) on the competitiveness of fuel costs, as well as an analysis of the fuel-related costs of different energy sources for the years 2010 and 2015.

The last section provides conclusions and proposals based on the calculation results and data set out in previous sections.

II. PROCEDURE AND METHODS FOR DETERMINING EMISSIONS OF POLLUTANTS FROM COMBUSTION PLANTS INTO AMBIENT AIR

Regarding [1], emissions of sulphur dioxide, nitrogen oxides, carbon oxide, volatile organic compounds, solid particles and heavy metals generated by combustion plants and emitted into ambient air shall be determined on the basis of direct measurements and/or calculations. In this paper the determination of emissions of pollutants is based on calculations. This method takes into account different combustion technologies, flue gas cleaning technologies, control devices as well as capacities to define the emission factors of pollutants.

To avoid the complexity of analysis arising from different combinations of capacities, combustion technologies, fuel gas cleaning and control equipment, it is assumed that:

- the thermal capacity of combustion plants is below 50 MW;
- the selected combustion technology provides the lowest emission level compared to all other combustion technologies mentioned in [1];
- the combustion plant is equipped with the most effective control systems mentioned in [1];
- the combustion plant is equipped with the most effective flue gas treatment technology mentioned in [1].

Emissions of carbon dioxide are calculated according to the method described in [2], thereby the carbon dioxide emissions from biofuels equal zero.

Emission factors in kilograms per one MWh of fuel energy content are calculated based on the methods described in the above-mentioned regulations and assumptions. Calculation results are shown in Table I.

TABLE I
EMISSION FACTORS IN TONS PER ONE MWh OF FUEL ENERGY CONTENT

	FUELS			
POLLUTANT	**Oil shale**	**Peat**	**Natural gas**	**Wood chips**
Carbon dioxide, CO_2[1]	360	374	201	0
Sulphur dioxide, SO_2	13.0	0.72	0	0
Nitrogen oxides, NO_x	0.54	1.08	0.22	0.36
Carbon monoxide, CO	0.36	0.36	0.14	0.72
Particulates[2]	3.60	0.29	0	0.25
Volatile organic compounds[3]	4.32	0.36	0.014	0.17
Heavy metals	0.0039	0.00028	0.00	0.000104

[1] – kg/MWh$_{fuel}$

[2] – except for heavy metals and compounds of heavy metals.

[3] – except for mercaptans.

III. POLLUTION CHARGE RATES

Pollution charge rates upon emission of pollutants into ambient air are defined in [3]. Charge rates are given until the year 2015. The pollution charges per one ton of pollutant for the years 2010 and 2015 are shown in Table II.

TABLE II
POLLUTION CHARGE RATES PER ONE TON OF POLLUTANT

	EUR/t	
POLLUTANT	**2010**	**2015**
Carbon dioxide, CO_2	2.0	2.0
Sulphur dioxide, SO_2	39.4	145.46
Nitrogen oxides, NO_x	76.4	122.32
Carbon monoxide, CO	4.8	7.7
Particulates[1]	39.4	146.16
Volatile organic compounds[2]	76.4	122.32
Heavy metals	1216	1278

[1] – except for heavy metals and compounds of heavy metals.

[2] – except for mercaptans.

As shown in Table II above, the pollution charges for the year 2015 in comparison to the year 2010 will increase by approximately three and a half times for particulates and sulphur dioxide emissions. A 1.5-fold increase is estimated for nitrogen oxides, carbon monoxide and volatile organic compounds. The pollution charge rates for carbon dioxide and heavy metals will remain on the same level.

IV. POLLUTION CHARGE RATES PER ONE MWh OF FUEL ENERGY CONTENT

The calculation of pollution charge rates per one MWh of fuel energy content is based on the previously calculated data set out in Sections II and III which describe the emission factors per one MWh of fuel energy content and the pollution charge rates, respectively. The results of calculations are shown in Table III.

TABLE III
POLLUTION CHARGE RATES IN EUR PER ONE MWh OF FUEL ENERGY CONTENT

POLLUTANT	**FUELS**							
	Oil shale		**Peat**		**Natural gas**		**Wood chips**	
	2010	2015	2010	2015	2010	2015	2010	2015
Carbon dioxide	0.72	0.72	0.75	0.75	0.40	0.40	0	0
Sulphur dioxide	0.51	1.90	0.028	0.10	0	0	0	0
Nitrogen oxides	0.04	0.07	0.082	0.13	0.016	0.026	0.027	0.044
Carbon monoxide	0.0017	0.0028	0.0017	0.0028	0.0007	0.0011	0.0034	0.0055
Particulates[1]	0.14	0.53	0.011	0.04	0	0	0.010	0.037
Volatile organic compounds[2]	0.33	0.53	0.027	0.04	0.0011	0.0018	0.013	0.021
Heavy metals	0.0048	0.0050	0.00034	0.00036	0	0	0.00013	0.00013
Total	***1.75***	***3.75***	***0.90***	***1.07***	***0.42***	***0.43***	***0.054***	***0.11***

[1] – except for heavy metals and compounds of heavy metals.

[2] – except for mercaptans.

Table III shows that, at the present time, oil shale has the highest pollution charge rate per one MWh of fuel energy content. Combustion of oil shale implies pollution charges at the rate of about 1.75 EUR/MWh$_{fuel}$. Due to high emission factors, especially for sulphur dioxide, carbon dioxide and particulates, the expected pollution charge rate of oil shale will be twice as high and amount to about 3.75 EUR/MWh$_{fuel}$ by 2015.

The pollution charge rates of peat per one MWh of fuel energy content are estimated to be at the rate of 0.9 and

1.07 EUR/MWh$_{fuel}$ for the years 2010 and 2015, respectively.

Natural gas has the lowest pollution charge rate per one MWh of fuel energy content in comparison to other fossil fuels observed. The total charge rate is formed mainly of carbon dioxide emissions which make up 95% of the total. Due to a stable carbon dioxide charge rate for the years 2010 and 2015, the increase in the overall pollution charges is negligible. Pollution charge rates per one MWh of fuel energy content are estimated to be at the rate of 0.42 and 0.43 EUR/MWh$_{fuel}$, respectively.

The approved pollution charge rates applied until 2010 and the emission factors determine the wood chips' pollution charge rate per one MWh of fuel energy content to rise by approximately two times. In spite of a relative increase, the total estimated charge rate per one MWh of fuel energy content will be four times lower compared to natural gas, ten times lower compared to peat and 37 times lower compared to oil shale in 2015. Charge rates will comprise 0.11 EUR per one MWh of fuel energy content.

V. ASH HANDLING

Ash handling costs for the fuels described in this paper depend on:

- fuel ash content;
- percentage of ash to be handled by the ash removing system;
- water content in ash which determines the final weight of ash to be disposed of.

In the case of wet ash removing technology, the wet ash density is much higher than in the case of implementing the dry ash removing technology (ash removal costs are higher). Unburned fuel particles in ash can cause fire in landfill or in other ash storage place. If ash is wet (removed by wet ash removal technology) then the self ignition risks are significantly reduced. Besides, in the case of wet ash removal, there is no dust in the air and ash is always cold — that contributes to a longer service life of the equipment.

The ash handling cost calculations are based on the following assumptions.

- Regarding the information obtained from the oil shale mining company *Eesti Energia Kaevandused Ltd.,* the average ash content of oil shale is 45% and the average calorific value of energy oil shale is 2.3 MWh/t.
- The ash content of peat is 5%. The average calorific value is 3.3 MWh/t. [4]
- The ash content of wood chips is 1% with the calorific value being 2.4 MWh/t.
- Natural gas based combustion does not emit any ash.
- Regarding the information obtained from different landfill owners, the average ash removal costs (ash transportation to a landfill and storing) is 45 EUR/t for the year 2010.
- The average ash removal costs will be 65 EUR/t in 2015.
- The combustion plant is equipped with the dry ash removing system.

The ash handling costs per one MWh of fuel energy content for the years 2010 and 2015 have been calculated on the basis of the above-mentioned information. The results are shown in Table IV.

TABLE IV
ASH HANDLING COSTS IN EUR PER ONE MWh OF FUEL ENERGY CONTENT FOR THE YEARS 2010 AND 2015

FUELS	**YEAR**	
	2010	**2015**
Oil shale	8.8	12.7
Peat	0.68	0.98
Wood chips	0.19	0.27
Natural gas	0	0

VI. CARBON DIOXIDE QUOTA

The CO_2 quota trade is a symbiosis of power engineering and the financial world, which is important for all energy producers and other industries involved in the quota trade.

In the current situation, the CO_2 quota trade rules assume that a combustion plant is not obliged to buy or sell CO_2 quotas if the CO_2 emissions do not exceed the allocated quantity.

Since the quota trade rules for phase III which will apply after the year 2012 are not yet distinctly clear, it is quite complicated to forecast the CO_2 quota price. In general, phase III means a cancellation or a significant reduction in the CO_2 quotas allocated to EU countries and putting into operation a general exchange for trading in CO_2 quotas.

Regarding [5], if CO_2 trading will be prolonged after 2012, the CO_2 quota price level could be in the range of 20 to 35 EUR/t.

The CO_2 quota amount levels per one MWh of fuel energy content are calculated and shown in Table V.

TABLE V
THE CO_2 QUOTA AMOUNT LEVELS PER ONE MWh OF FUEL ENERGY CONTENT

FUELS	**CO_2 QUOTA PRICE**	
	20 EUR/t	35 EUR/t
Oil shale	7.2	12.6
Peat	7.5	13.1
Natural gas	4.0	7.0
Wood chips	0	0

The CO_2 quota amount level per one MWh is proportional to a fuel-specific CO_2 emission factor. Thus the CO_2 quota amount level per one MWh of oil shale or peat is almost twice as high as the respective value of natural gas.

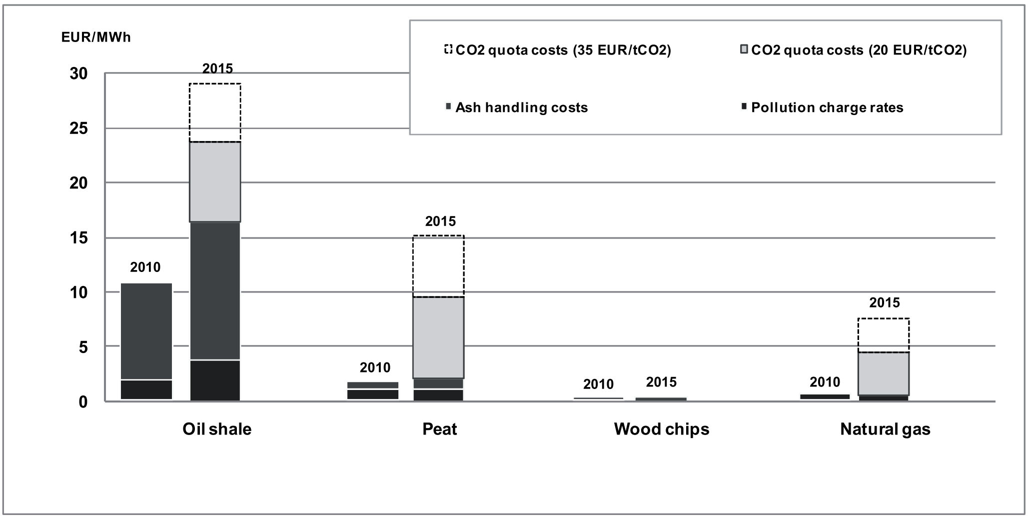

Fig. 1. Environmental costs per one MWh of fuel energy content for the years 2010 and 2015.

VII. IMPACT OF POLLUTION FEE, ASH HANDLING AND CARBON DIOXIDE COSTS (ENVIRONMENTAL COSTS) ON THE FUEL COST COMPETITIVENESS

A. Environmental costs for the years 2010 and 2015

The costs per one MWh of fuel energy content for the years 2010 and 2015 described in Sections IV, V and VI are summarized in Fig. 1.

Oil shale has the highest environmental costs (10.6 EUR/MWhfuel) in 2010 as well as the largest absolute increase in the costs per one MWh of fuel energy content for 2015. The increase will comprise 13.1–18.5 EUR/MWh fuel depending on the assumed CO_2 quota price scenarios.

The environmental costs of peat and wood chips for the year 2010 are estimated to be below 2 EUR/MWh_{fuel}.The environmental costs of wood chips will change insignificantly by 2015. At the same time, due to a high carbon dioxide emission factor, the environmental costs of peat will be 5–8.5 times higher and amount to 9.5–15.1 EUR/MWh_{fuel}.

In spite of a relative 10–18-fold increase in the environmental costs of natural gas from 0.4 EUR/MWh_{fuel} to 4.5–7.5 EUR/MWh_{fuel} (depending on the assumed CO_2 quota price scenarios), the environmental costs for the years 2010 and 2015 as well as the absolute increase in environmental costs are the lowest in comparison to other fossil fuels observed.

B. Effect of environmental costs on the fuel related costs per one MWh of fuel energy content

Fuel related costs contain both the fuel purchase costs (fuel price) and the environmental costs, which were considered in the previous section.

The comparison of fuel related costs for the years 2010 and 2015 enables one to forecast the general trends in fuel competitiveness for the near future.

The comparison is based on the assumption that the fuel price is stable. The change in fuel related costs is induced by environmental costs.

The fuel prices taken as a basis for the calculations are as follows:

- Price of oil shale – 4.6 EUR/MWh_{fuel}. The proposed price is the current average purchasing price for one of the Estonian largest oil shale consumers Eesti Energia AS [6].
- Price of peat – 11.7 EUR/MWh_{fuel}. The proposed price is based on the average peat price levels obtained from Tootsi Turvas AS, the biggest peat milling and exporting enterprise in Estonia.
- Price of wood chips – 12.8 $EUR/MWh_{fuel.}$ The proposed price is based on the latest data published by the Estonian Institute of Economic Research in their web based price information system [7].
- Natural gas – 28 EUR/MWh_{fuel}. The proposed price is an average price of the latest data published by Statistics Estonia [8].

The calculation results are presented in Table VI as well as shown in Fig. 2.

The calculation results reveal that the proposed increase in environmental costs will change the alignment of forces in the cost competitiveness of fuel sources considerably.

At present, peat is considered a good alternative to wood chips as peat has a lower fuel price compared with the ash handling costs and pollution charges of wood chips. By the year 2015, the use of peat will cause an increase in fuel costs by half up to two times higher per one MWh of fuel energy content, while the fuel costs of wood chips will change insignificantly.

TABLE VI

FUEL RELATED COSTS IN EUR PER ONE MWh OF FUEL ENERGY CONTENT FOR THE YEARS 2010 AND 2015

FUELS	**YEAR 2010**			**YEAR 2015**				**Increase of fuel related costs from year 2010 to 2015**	
	Fuel price	**Environmental costs**	**Fuel related costs**	**Fuel price**	**Environmental costs**		**Fuel related costs**		
					20EUR/tCO2 scenario	**35 EUR/tCO2 scenario**		**Absolute increase**	**Relative increase, %**
Oil shale	4.6	10.6	**15.2**	4.6	23.7	29.1	**28.3–33.7**	13.1–18.5	86.5–122.3
Peat	11.7	1.6	**13.3**	11.7	9.5	15.1	**21.2–26.8**	8–13.5	59.9–101.8
Wood chips	12.8	0.24	**13.0**	12.8	0.4	0.4	**13.2**	0.1	1.05
Natural gas	28	0.42	**28.4**	28	4.5	7.5	**32.5–35.5**	4–7.1	14.2–24.9

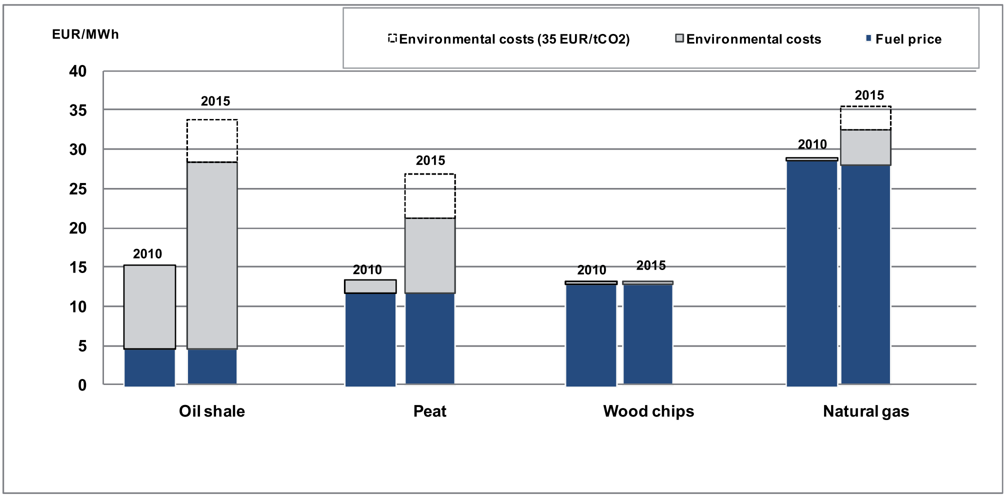

Fig. 2. Fuel related costs per one MWh of fuel energy content for the years 2010 and 2015.

Currently, the fuel related costs of oil shale are almost twice as low as those of natural gas. Due to a larger share of environmental costs in the fuel related costs, as well as due to a 1.8 times higher CO_2 emission factor, a significant increase in the fuel related costs can be expected. By the year 2015, the difference in the fuel related costs between oil shale and natural gas will decrease and account for 5–15% depending on the proposed CO_2 quota price scenarios.

VIII. CONCLUSION

The paper observes the impact of pollution charges, ash handling and carbon dioxide on the cost competitiveness of the fuel sources used for energy production in Estonia. Fuel related costs for different energy sources for the years 2010 and 2015 are calculated with respect to the cases when the fuel related costs consist of fuel price, ash handling costs and environmental fees as well as the carbon dioxide quota price per one MWh of fuel energy content (based on lower calorific value). Calculations are provided based on different assumptions of combustion technologies, flue gas cleaning technologies, control devices, ash handling systems and other data. Thereby, calculation results are valid for the reviewed cases only. Other particular cases should be calculated individually.

Calculation results show that the proposed increase in environmental costs will considerably change the alignment of forces in the cost competitiveness of fuel sources by the year 2015.

Oil shale has a higher pollution charge rate per one MWh of fuel energy content. Combustion of oil shale implies pollution charges at the rate of about 1.75 EUR/MWh$_{\mathrm{fuel}}$. Due to high emission factors, especially for sulphur dioxide, carbon dioxide and particulates, the expected pollution charge rate by 2015 will be twice as high and amount to about 3.75 EUR/MWh$_{\mathrm{fuel}}$. Oil shale has the highest total environmental costs (10.6 EUR/MWh$_{\mathrm{fuel}}$) for 2010 as well as a higher absolute increase of costs per one MWh of fuel energy content for 2015. The increase comprises 13.1–18.5 EUR/MWh$_{\mathrm{fuel}}$ depending on the assumed CO_2 quota price scenarios. Due to a larger share of environmental costs in the fuel related costs, a significant (87–122%) growth in the fuel related costs can be expected. This could be crucial to the competitiveness of the oil shale energy production sector in comparison with other fossil and renewable fuels.

Peat. At present, peat is considered a good alternative to wood chips. The lower fuel price of peat (11.7 EUR/MWh$_{\mathrm{fuel}}$), against the higher fuel price of wood chips (12.8 EUR/MWh$_{\mathrm{fuel}}$), balances the higher environmental taxes (ash handling costs and pollution charges) of peat compared to the lower ash handling costs and pollution charges of woodchips.

By the year 2015, the use of peat will cause an increase in fuel costs per one MWh of fuel energy content in a range from a half up to two times (from 13.3 EUR/MWh to 21.2–26.8 $\text{EUR/MWh}_{\text{fuel}}$), while the fuel costs of wood chips will change insignificantly

Natural gas has low pollution charge rates per one MWh of fuel energy content comprising 0.42 and 0.43 $\text{EUR/MWh}_{\text{fuel}}$ for the years 2010 and 2015, respectively. Ash handling costs equal zero in case of natural gas as it does not emit any ash.

Natural gas has a high fuel price which causes the total fuel related costs to be high, too. But with the carbon dioxide emission factor and other environmental costs being relatively low, natural gas can reduce its difference in fuel related costs compared to other fossil fuels which have a higher carbon dioxide emission factor and other environmental impacts. For example, in the case of oil shale, the difference in fuel related costs is estimated to decrease from about 90% in 2010 to 5–15% in 2015, depending on the proposed CO_2 quota price scenarios.

Wood chips. The lowest pollution fee costs among the considered fuels (0.054–0.11 $\text{EUR/MWh}_{\text{fuel}}$ for the years 2010 and 2015), a zero for the carbon dioxide emission level as well as the lowest ash handling costs (0.19–0.27 $\text{EUR/MWh}_{\text{fuel}}$) among other considered solid fuels allow to successfully keep the increase in the environmental and total fuel related costs small (13 and 13.2 $\text{EUR/MWh}_{\text{fuel}}$ for the years 2010 and 2015, respectively). The aforesaid factors significantly improve the competitiveness of wood chips and provide opportunities to expand the wood chips based energy production.

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Eduards Latišovs, Jiri Kleesmaa, Andres Siirde. Dabas resursu nodokļa, pelnu apstrādes izmaksas un oglekļa dioksīda kvotu ietekme uz kurināmā konkurētspēju enerģijas ražošanai Igaunijā

Pētījuma mērķis ir novērtēt, kā nodoklis par piesārņojošo vielu emisijām, pelnu apstrādes izmaksas un oglekļa dioksīda kvotu tirdzniecība (vides izmaksas) ietekmē dabas gāzes, degslānekļa, kūdras (velēnas kūdra) un koksnes šķeldas konkurētspēju Igaunijā 2010 un 2015. gadā. Nodoklis par piesārņojošo vielu emisijām aprēķināts balstoties uz Dabas resursu nodokļa likumu. Piesārņojošo vielu izmešu apjomi no dažādiem kurināmā veidiem noteikti, pamatojoties uz Igaunijas Vides ministrijas regulām Nr. 99/2004 un Nr 94/2004.

Aprēķinu rezultāti liecina, ka paredzamais ar vides aizsardzību saistītais izmaksu pieaugums jau 2015. gadā var ievērojami mainīt dažādu kurināmo konkurētspēju un to proporciju tirgū. Sakarā ar vides aizsardzības politikas radīto izmaksu pieaugumu, degvielas pašizmaksa (degvielas cenas un vides izmaksu summa uz vienu MWh degvielas ar samazinātu enerģētisko lietderību) degslānekļa gadījumā ievērojami pieaugs (līdz pat divas reizes). Tas varētu būt izšķirošs faktors degslānekļa turpmākai konkurētspējai, salīdzinot ar citiem fosilās enerģijas un atjaunojamajiem enerģijas avotiem. Pašlaik kūdra ir uzskatāma par labu alternatīvu koksnes šķeldai. Zemāko kūdras cenu (11,7 EUR / $\text{MWh}_{\text{kurināmā}}$) pret augstāko koksnes šķeldas cenu (12,8 EUR / $\text{MWh}_{\text{kurināmā}}$) līdzsvaro augstākas dabas resursu nodokļa likmes (pelnu apstrādes izmaksas un maksa par piesārņojušo vielu emisijām). Līdz 2015.gadam kūdras izmantošanas izmaksas pieaugs no pusotra līdz divām reizēm (no 13,3 EUR / $\text{MWh}_{\text{kurināmā}}$ līdz 21,2-26,8 EUR / $\text{MWh}_{\text{kurināmā}}$ l), bet kurināmā izmaksas šķeldas gadījumā mainīsies nenozīmīgi. Dabasgāzei ir augsta cena, tādējādi kopējās degvielas izmantošanas izmaksas ir augstas. Tomēr, pateicoties zemam oglekļa dioksīda emisijas koeficientam un nelielām pārējām ar vides piesārņošanu saistītām izmaksām, dabas gāze var samazināt savu kopējo izmaksu lielumu, salīdzot ar citiem fosilā kurināmā veidiem, kam ir lielāks oglekļa dioksīda emisijas koeficients un arī augstākas citas ar vides piesārņošanu saistītās izmaksas.

Эдуард Латышов, Юри Клеэсмаа, Андрес Сиирде. Влияние природоохранных выплат, затрат на удаление золы и квот на выбросы CO_2 на конкурентоспособность топлива, используемого при производстве энергии в Эстонии

Целью данной статьи является определение влияния природоохранных выплат, затрат по удаление золы и квот на выбросы CO_2 (затраты связанные с охраной природы) на конкурентоспособность природного газа, сланца, торфа и древесной щепы в Эстонии по состоянию на 2010 и 2015 год. Государственная пошлина на выбросы загрязнителей атмосферы из стационарных источников загрязнения рассчитывается, исходя из Закона о Природоохранных Выплатах. Уровни загрязнения для рассматриваемых видов топлива определяются на основании Постановления №99/2004 и Постановления №94/2004 Министра окружающей среды Эстонии.

Проведённые расчеты показывают, что к 2015 году предполагаемое увеличение затрат связанных с охраной природы существенно изменит распорядок сил в ряду конкурентоспособности рассматриваемых видов топлива. В связи с высоким уровнем затрат, связанных с охраной природы, затраты связанные с использованием сланца (сумма затрат связанных с охраной природы и стоимости топлива на один МВтч нижней теплотворной способности топлива) существенно возрастёт (до двух раз). Это может стать критическим фактором, негативно влияющим на конкурентоспособность сланца с другими фоссильными и возобновляемыми топливами. В настоящее время торф рассматривается как хорошая альтернатива древесной щепе. Более низкая цена топлива (11,7 €/МВтч) по отношению к щепе (12,8 €/МВт/ч), уравновешивает более высокие затраты связанные с охраной природы (природоохранные выплаты и затраты на удаление золы). Но уже к 2015 году затраты, связанные с использованием торфа на один МВтч нижней теплотворной способности, составят от половины до двух раз (с 13,3 €/МВтч до 21,2-26,8 €/МВтч) . В то же самое время затраты на щепу останутся практически на прежнем уровне. Природный газ имеет высокой стоимости, которая составляет большую часть затрат, связанных с топливом. Но учитывая относительно низкий уровень выбросов углекислого газа, а также другие затраты, связанные с охраной природы, природный газ может уменьшить разрыв по части затрат на топливо в сравнении с другими видами фоссильного топлива, имеющими более высокий уровень эмиссий углекислого газа, и других затрат, связанных с охраной природы.

Appendix 3. “Subsidising renewable electricity in Estonia”.

Subsidising renewable electricity in Estonia

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Abstract

The purpose of this paper is to assess the impact of Estonia's feed-in tariffs (FIT) on combined heat and power (CHP) plants. The assessment follows previous practice and provides a novel approach by including a case study based on company data. The results of our assessment show that the Estonian FIT system has effectively supported the establishment of CHP capacity and that the administrative costs have been low. In contrast to experiences in other countries we find that the avoided external costs exceed the per MWh cost of FIT. Another feature is that the consumer costs of the FIT scheme have grown more rapidly than elsewhere. Although avoided external costs cover FIT, resources are not used cost-effectively. The case study of two CHP plants suggests that resources are used for supporting production that would have been profitable without FIT.
Keywords: renewable electricity, feed-in tariffs, CHP, energy policy, Estonia.

1 Introduction

Feed-in tariffs (FIT) is the most widely used support scheme for renewable electricity: implemented in 20 EU countries and 30 countries worldwide in 2009 [1]. Denmark and Germany were the first countries to introduce FIT in the mid-1980s and 1991, respectively [2]. Success stories about countries that have exceeded initial goals for renewable electricity seem to be forceful arguments for additional implementation. Further backing from economists supporting the use of price rather than quantity based regulation could be another reason for the popularity of FIT.

According to the national electricity development plan 2005–2015 [3] the goal is to increase the share of renewable electricity to 5.1% of gross consumption in Estonia by 2010. In the succeeding development plan, which stretches until 2018, the goal has been set to extend the share of electricity from renewable resources to 15% by 2015 [3, 4]. For Estonia, these goals imply

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significant changes. In 2007, the share of renewable fuels in electricity production was 1.75% of gross production while the main supply originated from oil shale electricity, which made up 93.6% [4]. Based on capacity under construction, it is estimated that Estonia outperforms the goal in 2010and reaches 9.7% renewable electricity [5].

Estonia's goal to 2020 is to increase electricity produced from renewables in combined heat and power plants (CHP) to 20% of gross production [4]. Following introduction of FIT in 2007, there has been a substantial increase in energy produced from renewable fuels in CHP plants. In 2009 Tallinn and Tartu CHP started operation and the share of renewable electricity is further increasing. Pärnu CHP is under construction and several small CHPs are being planned in different parts of Estonia. Recently, also oil shale electricity producers have begun to use biomass as an input. It seems thus that Estonia shares the experiences of other countries that report a rapid increase of renewable electricity following introduction of FIT [2, 6].

Besides the positive effects, the change seems to have come at a high cost. The costs of FITs have increased from 6 million to almost 55 million Euros between 2007 and 2011 [5]. This cost is collectively paid by consumers by an addition to the price of electricity. In 2010, this addition makes up about 10 percent of the consumer price and the Estonian Competition Authority, who regulates the price of electricity, has questioned the size of the subsidy [7].

The purpose of this paper is to assess Estonia's FIT scheme on CHP plants. Assessments have been carried out by several other authors, see [6] for references. The goal of this paper is to assess whether the current tariff level paid to CHP plants is motivated from an efficiency perspective, and its implications on consumer costs. Another aim is to find the benefits in terms of avoided external costs. The authors are not aware of previous assessments concerning CHP plants, suggesting that this paper may represent the first assessment of FIT on CHP plants. In addition, the case study of this paper applies a novel approach by using company level data.

The next section provides a literary overview about FIT assessments. In section 3, we give details about the Estonian FIT. Section 4 presents calculations that assess the company level impact of FIT on two CHP plants and compares the outcome to marginal cost and cost price. In section 5 we calculate the external costs of electricity produced from oil shale and compare this with electricity produced by biomass and peat in CHP plants. Section 6 summarizes the assessment and the last section concludes the paper.

2 Literary review

A feed-in-tariff (FIT) denotes a guaranteed price to producers of electricity generated from renewable sources, combined with a purchase obligation by grid companies [6]. There principally are two different ways to cover the costs of the policy measure, either by consumers via the electricity bill or via the public budget. An important reason to subsidise renewable electricity is that production costs typically are higher than that of non-renewable electricity [6]. In this sense

FITs represent a second-best policy by giving a subsidy to a preferred choice rather than correcting for external costs of electricity from non-renewable sources. Not only the choice of which market to regulate, but also the FIT levels have been questioned. In an overview of support schemes in 2005, it was shown that German support levels typically were twice the level of those of the Nordic countries, mainly using quantity based regulation combined with green certificates [8]. The same study indicated that the costs of FITs on the margin cannot be motivated by the social benefits from renewable electricity [8, 9]. At the same time, there seems to be efficiency arguments to use FIT for wind power [1]. Most probably these efficiency reasons denote dynamic efficiency in order to provide technology change and support market take-off [6].

Based on German and Danish experiences, Sijm [2] has assessed the sustainability of feed-in tariffs. The German FITs were until 2000 based on a percentage of earlier consumer prices of electricity and varied by the source of energy. After implementation prices rose significantly and due to a rapid expansion of wind power, the system led to competitive distortions between grid companies in different parts of the country. When the German market for electricity was liberated, the system needed urgent revision. The new FITs are based on the production costs of various renewable energy resources with digressive payments during 20 years [2, 10]. Denmark revised its FIT in 2000 for reasons of a high burden on the state budget [2]. In his assessment of FITs, Sijm [2] concludes that FITs are effective in promoting electricity generation from renewable sources, but costly, inefficient and distortive.

Spain is another country that has been successful in renewable energy promotion. In their assessment del Rio and Gual [6] find that the Spanish system has been effective in its support of wind energy, but not equally successful concerning other energy sources. They conclude that although consumer costs were relatively low, increasing from 0.14 to 0.26 eurocents /kWh between 1999 and 2003, the costs are relatively high compared to the externalities avoided.

3 Feed-in tariffs in Estonia

According to the Estonian Electricity Market Act production of electricity from wind, small hydropower and biomass receive the same level of FIT [11, 12]. The FIT for CHP plants differs according to fuel. Generating electricity in efficient cogeneration regime by biomass (wood chips), the producer is paid support at the rate of 54 €/MWh for selling electricity to the network. While operating in efficient cogeneration regime and using waste or peat as a fuel, the producer is paid support at the rate of 32 €/MWh. If wood chips, peat, waste or other fuels are combined, the support granted for selling electricity to the network is calculated in proportion to the fuel used. The FIT schemes apply within twelve years as of the commencement of electricity generation.

After introduction of FIT on May 1st in 2007, the expenses for financing FIT are funded by network charges paid by consumers. In 2010 the renewable energy charge is 0.8 € cents/kWh. An additional line setting out the renewable energy charge was added to the electricity bills of end users enabling customers to see how much they pay for financing feed-in tariffs.

The Estonian electricity market is divided into two – an open market and a closed market. 35% of the market was opened on 1 April 2010. Starting from 2013, the market is going to be fully liberated. While selling electricity in the closed market, approval must be obtained under the law [11] according to the weighted average price limit of electricity. In its approval, the Estonian Competition Authority takes into account operating expenses and returns on invested capital. In order to determine the price, the authority considers the undertaking's annual average residual value of fixed assets and adds 5% as profit margin. The justified rate of return is the undertaking's weighted average cost of capital (WACC).

4 The impact of FIT on CHP plants

The case study takes as its starting point, two 25 MW_{el} CHP plants that began operations in 2009. The evaluation of the investment decision and profitability of the CHP plants are based on annual reports [13, 14]. In order to assess profitability without FIT, we apply the rules of the Estonian Competition Authority and we calculate the per MWh revenue without FIT. The results are then compared to marginal cost and the cost price of electricity (the cost price is the price that exactly balances production costs, not adding profit).

4.1 Ratio analysis

The annual reports consist of the balance sheet, income statement and notes on the accounts. The methodological approach used in the evaluation of the financial reporting is based on ratio analysis, carried out as comparison with accounting benchmarks. Ratio analysis is the main instrument in financial analysis that enables to elicit relations between financial indicators and compare different undertakings with one another.

The investments in the plants were of the same order of magnitude, i.e. approximately 77 M€ respectively. Although no trend analysis can be made on the basis of the publicly available financial results for 2009 of the CHP plants, the data still allow evaluating, in general lines, plant profitability in 2009. Results of the evaluation are displayed in Table 1.

Table 1: Ratio analysis of two CHP plants, 2009.

Ratio	Bench-mark	CHP 1		CHP 2	
		Ratio	Evaluation	Ratio	Evaluation
Net profit margin	5.0%	37.6%	High	10.3%	High
Operating profit margin	17.0%	48.1%	High	23.9%	High
Rate of return on equity capital	15.0%	100.0%	High	34.5%	High
Rate of return on assets	9.0%	11.8%	Normal	2.4%	Weak
Debt coefficient	40.0%	88.2%	High (risk)	93.0%	High (risk)

The table shows that the power plants' rate of return on equity capital is high indicating efficient management in using the capital invested by shareholders. Profit margin that characterises profit on every euro of turnover is also high. The debt coefficient, pointing at how big a proportion of total funds are financed from borrowed funds, is extremely high in both plants. The profitability of assets shows the rate of return on the funds invested in the company irrespective of their source. Profitability is weak in CHP 2 being approximately 5 times lower that of CHP 1.

It can be concluded from the above that due to the implementation of FIT, the new power plants have managed to start profitable economic activity. Despite a large debt burden and strong dependence on borrowed capital, the rate of return on equity capital and the net profit margin hint at management efficiency and ability to gain initial results in activity.

However, case study data covers only one year. Additional sources of uncertainty include the development of prices of renewable fuels and the impact of market liberalisation. Notwithstanding these uncertainties, there are reasons to believe that the plants will continue operations successfully. It is possible to argue that these plants are well prepared to meet changes in input prices. In case of a rapid price increase, there is flexibility to shift fuels. Both plants are licenced to use wood chip and peat as fuel. Boiler technology allows additional fuels and the plants have fuel producing companies as subsidiaries. While market liberalisation will take place on electricity sales, the profitability of heat production can be predicted to be stable due to the continuation of a closed heat market. Since electricity prices in the Estonian market currently are below Nordic spot market prices [15], market liberalisation is expected to lead to price increases.

In theoretical terms, each power plant could generate a maximum of 25 MW * 7200 h=180 GWh of electricity per year. The generated volume of electricity depends on the number of operational hours. A smaller number of stop pages and standstill periods imply more operational hours and more generated electricity.

Pursuant to the actual annual report of 2009, CHP 1 generated circa 128 GWh and CHP 2 generated circa 110 GWh of power. Electricity generation in the plants were in the range of 68%-80% of the theoretical maximum. In CHP 1 the size of support comprised 54 €/MWh * 128 * 10^3 MWh ≈ 6.9 M€. Since CHP 2 used peat, the support size was32 €/MWh * 110 * 10^3 MWh ≈ 3.5 M€. Regarding different plants, FIT revenue accounts for approximately 50–60% of the operating profit, and excluding FIT comprise approximately 40–50%. Dependence of operating profit on the size of FIT can be expressed by eqn. (1).

$$\pi_{el} = \pi_{el}^{excl\ FIT} + (Q_{el} \times FIT_i) \tag{1}$$

where π_{el} denotes operating profit on electricity sales, $\pi_{el}^{excl\ FIT}$ operating profit on electricity sales excluding FIT, Q_{el} generated electricity and FIT_i feed-in tariff for i=1,2 (1=wood chip and 2=peat). According to the annual report, operating profit on the electricity sales of CHP 1 amounted to circa 12 M€; excluding FIT, operating profit would be 5.1 M€. The respective sums for CHP 2 are circa 7.5 M€ and 4 M€. These results suggest that the operating profits of both plants would have been positive also without FIT.

4.2 WACC

Assuming that the plants had operated without FIT and that their electricity prices were set by the Estonian Competition Authority, we apply the method of the regulator [16] according to eqn. (2), which shows the Weighted Average Cost of Capital (WACC).

$$WACC = k_e \times \frac{OK}{(VK+OK)} + k_d \times \frac{VK}{(VK+OK)} \tag{2}$$

where:
k_e– is cost of equity capital (%);
k_d– is cost of borrowed capital or external liabilities (%);
OK – is proportion of equity capital determined by the regulator (%);
VK – is proportion of borrowed capital determined by the regulator (%).

Taking into account the value of the debt coefficient for the financial year 2009 of the power plants CHP 1 and CHP 2 and applying eqn. (2), we find that:

$$WACC_{CHP1} = (6.31 \times 88 + 9.61 \times 12)/100 = 6.74\% \tag{3}$$

$$WACC_{CHP2} = (6.31 \times 93 + 9.61 \times 7)/100 = 6.54\% \tag{4}$$

Assuming that all economic indicators, except investments, are evenly distributed over a 25-year period (according to accounting principle), and taking into consideration the expenditure and revenue (9.7M€ and 24.9M€, respectively) as well as investments of CHP 1, we find that the internal rate of return (IRR) of the plant is 19% on invested funds. Setting IRR equal to WACC, we find that, revenues corresponding to 16.3 M€ would be sufficient to receive WACC from the investment of the undertaking.

Considering the fact that revenue from the sale of heat is a fixed value 12.9 M€ (the amount of generated heat corresponds to the need/weather conditions, and the limit price for heat is confirmed by the Estonian Competition Authority), we gain the needed income from the sales of electricity for achieving the WACC rate that comprises 16.3–12.9=3.4 M€. As the volume of electricity sold in 2009 was 128 GWh, the regulated price per MWh of electricity would equal 3.4 M€/128 GWh=27 €/MWh. By applying the same method as above for CHP 2, we find a price of52 €/MWh. These prices can be compared to the regulated price of oil shale electricity which was 29 €/MWh in 2009 [17]. In principle, this level is the guaranteed or lowest electricity selling price for all plants. Thus, even without supports, provided that electricity is sold at 29 €/MWh, CHP 1 would earn more than necessary for achieving WACC, while CHP 2 would earn less.

There could be several reasons why we receive significantly different results for the two plants. One could be that the plants use different fuels. However, it cannot be excluded that the method of regulation gives incentives to plants to adjust their financial accounts. According to the ratio analysis the rate of return on assets and the debt coefficient are surprisingly weak in CHP 2.

4.3 Price comparison

Since the results of the WACC calculations are somewhat inconsistent, we derive the price excluding FIT from observed sales data. Assuming that the price of electricity was equal to the regulated price implies that the per MWh revenue was 83 € for CHP 1 and 61 €CHP 2, respectively. Using these revenues, we find that electricity sales were 145 GWh and 123 GWh. Since reported sales were smaller, it can be concluded that CHP 1 and CHP 2 earned higher revenues than in the closed market setting. This can be regarded as a result of beneficial contracts entered into with balance providers (Nord Pool Spot's operations). Calculations show that, the average revenues were 40 €/MWh of CHP 1and 36 €/MWh of CHP 2. Based on our analysis, including the above calculations and the previous section suggest that CHP 1 would have operated successfully even without FIT. The evidence of CHP 2 is inconclusive though.

In order to take the analysis one step further we compare the prices to general information about production costs. From a theoretical point of view, we ideally would like to compare prices to marginal costs [18]. Since marginal costs are not available, we approximate marginal costs by average variable costs. In a forthcoming article by Latõšov et al. [19], the authors present cost data of different sized CHP plants in an Estonian context. Using data for the 25 MW_{el} plant, it is possible to calculate the variable cost. Depending on the method of allocating costs between electricity and heat, we arrive at an interval of 4.7–6.7 €/MWh. This is in the same order of magnitude as the average variable cost in the Nordic market, which is 8-9 €/MWh, according to estimates based on [20]. The result shows that both plants receive prices substantially above marginal costs. Comparing revenues to the cost price will provide another benchmark to our case study observations.

The above case study concerns relatively large CHP plants and since unit costs depend on the size of the plant [21] it might not be possible to generalise our results to all plant sizes. In [19], the authors estimate the cost price of electricity of different sized CHP plants. They use data collected in Estonia and the Nordic countries and make calculations of plants with capacity of 1, 10 and 25 MWh_{el} respectively. Assuming a fixed heat price, they derive the per MWh_{el} cost price. Using these observations for fitting a curve, it is possible to approximate the cost prices of a wide range of different plant sizes.

Figure 1 below, indicates that the cost prices of CHP plants with capacity less than 10 MWh_{el} have significantly higher cost prices than larger plants and that there is a rapid increase in cost prices when plant sizes become smaller. Subtracting the FIT from the cost price (see lower curve in Figure 1) shows an even more interesting picture: the FIT covers the cost price of electricity production from a CHP plant with capacity of 25 MW_{el} and when FIT is excluded its cost price is similar to a plant of 4 MW_{el} that receives FIT. These findings confirm the results of the case study and indicate that large plants are overcompensated by the current FIT, while small plants might not receive sufficient support.

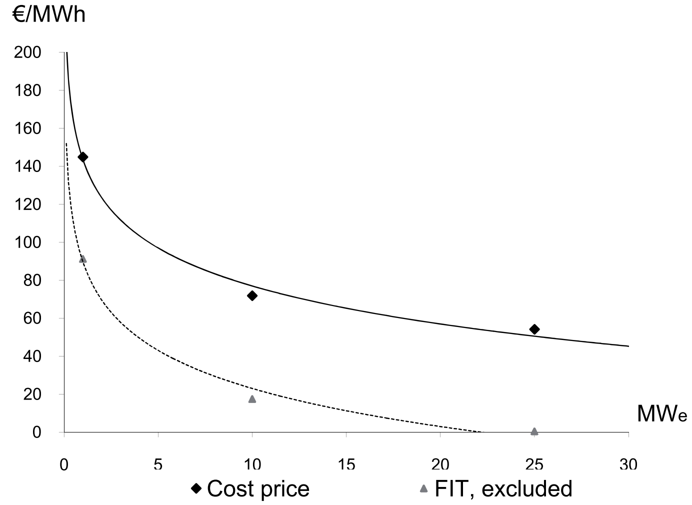

Figure 1: Cost price of CHP plants, euro per $MWh_{el.}$

5 Avoided external costs

A gradual shift from oil shale electricity to renewable sources will have a positive impact on the environment. In order to assess the benefits of FIT in terms of avoided costs, the external costs of air emissions of electricity production from oil shale, wood chip and peat have been calculated. The emission factors are shown in Table 2.

Table 2: Emission factors in g/ $MWh_{el.}$

	Oil shale	Wood chip	Peat
Carbon dioxide, CO_2 (kg)	1156	306	386
Sulphur dioxide, SO_2	7147	400	1676
Nitrogen oxides, NO_X	1075	353	2236
Particulate matter, PM_{10}	494	75	280

Sources: [17, 22–24].

The emission factors of oil shale are based on emission measurements at the Eesti power plant in Narva [22], where about 20% of electricity is generated in fluidized bed combustion and about 80% in pulverised combustion. The external costs were collected from ExternEestimates [25]. Although, Estonia is not represented in ExternE, we follow the application in [26] and base the external costs on Czech brown coal. This transfer of external costs could result in an upward bias, since the estimates also include health effects of pollutants. The risk of bias is due to the fact that population density is higher in the Czech Republic than in Estonia, and the values in use might therefore exaggerate health costs. In the Czech values, health costs make up about 40% of the external cost of brown coal combustion.

Table 3: External costs €/MWh_{el}.

	Oil shale	Wood chip	Peat
Carbon dioxide, CO_2	22.0	5.8	7.3
Sulphur dioxide, SO_2	40.6	2.3	9.5
Nitrogen oxides, NO_X	3.3	1.1	6.8
Total suspended particulates, TSP	3.3	0.6	2.1
Sum	69.2	9.7	25.8

The external costs show relatively large differences. Every MWh of oil shale electricity that can be substituted by electricity produced from wood chip in CHP plants reduces external costs by almost €60 and if replaced by peat, the avoided cost would be about €43.Comparing these values to the Estonian FIT of €54/ MWh and €32/MWh respectively, show that the estimated environmental benefit are higher than the FITs. However, since power plants pay environmental charges, internalisation already takes place. The pollution charges are relatively low though: only about €2 per MWh of oil shale electricity is currently being internalised [17]. Assuming that the influence of a possible upward bias is at an equally low level, the cost of the Estonian FITs are supported by arguments of avoided external costs. An important additional requirement is that the renewable electricity replaces oil shale electricity. So far this replacement has not taken place, but in 2016 when more stringent EU regulation will come into force, pulverized combustion must be equipped with flue gas purification otherwise these boilers have to be shut down [4].

6 Overall assessment

In our evaluation of the Estonian FIT for CHP plants we follow the assessment criteria used previously in literature [2, 6]. One problem though is that the period of assessment is relatively short, stretching from mid-2007 until 2010. Based on evidence so far, Estonia will outperform the target set for 2010, suggesting that the FIT has been effective [5]. The case study showed that large CHP plants have received substantial investment security during the 12 year support period and that the increase of renewable electricity since 2007 has mainly concerned electricity generated by CHP plants. Nevertheless, significant wind power capacity is under construction. According to forecasts, wind energy FIT will double in 2011 compared to 2010 [5].

Since electricity from renewable energy sources receive the same FIT, the Estonian FITs can be judged as technology neutral. However, there are other reasons to question the Estonian FITs from an efficiency perspective. Although the cost price is not covered by the market price of electricity, the case study suggests that 25 MW_{el} CHP plants would have been profitable also without FIT. In addition, market prices significantly exceed the marginal costs of producing electricity from biomass in a 25 MW_{el} CHP plant. On the other hand, pricing at marginal cost would not cover costs since production of electricity in a large CHP plant is characterised by increasing returns to scale.

Construction of small CHP plants has not been encouraged to the same extent by Estonia's FITs. One reason is that small plants have significantly higher generation cost per unit. It is interesting to note that German FITs, which are based on production costs, are differentiated by plant size and do not cover CHP plants fired by biomass that exceed 20 MW_{el} [10].

Another argument for paying a higher FIT than the cost-effective level relates to dynamic efficiency. One motivation is to support a technology to reach market take-off more rapidly than otherwise. Another is general innovation support. However, generation of electricity from biomass in a CHP plant is a mature technology. Therefore, FIT is questionable also from the perspective of dynamic efficiency. From an efficiency point of view, only arguments of avoided external costs can support the current level of FIT. In contrast to experiences in other countries, we find that the avoided external costs exceed the per MWh costs of FIT. The main reason is the high external cost of oil shale electricity.

Between 2007 and 2010, the per kilowatt hour consumer cost has increased from 0.1 to 0.8 eurocents /kWh. In comparison to the Spanish experiences almost a decade earlier, the starting point is equal, but the speed of increase is significantly more rapid in Estonia. The beneficiaries of Estonian FITs have increased their revenues from 6 to almost 54 million Euros during the same time period [7].

The Estonian FIT has low administrative demands as the same FIT has been applied to different energy sources. Setting prices on the closed market according to WACC is rather demanding, though. Our analyses indicate that the current practice might produce distortive incentives and to increase the share of borrowed capital.

7 Conclusion

The purpose of this paper was to assess the impact of the Estonian feed-in tariffs on renewable electricity generation. We have found that the Estonian FIT system has effectively supported establishment of CHP capacity, the administrative costs have been low and the avoided external costs have exceeded the cost of the support. However, the costs of the Estonian FITs have increased at a rapid rate and these costs have been paid collectively by consumers while beneficiaries include large CHP plants.

Besides distributional concerns, there are other reasons to revise the current FIT scheme. The case study of two CHP plants and the comparison of our findings to average cost and cost prices have shown that the current FIT scheme is not efficient. The targets set for 2010 will be exceeded and from an efficiency perspective, this cannot be assessed cost-effective. In addition, the results indicated that resources are used for supporting production that is profitable also without FIT. Even though the current FITs are administratively attractive, the large differences in unit costs depending on plant size, suggest that there is a need to differentiate the FITs to plant size.

The major drawback of pricing measures, such as subsidies and taxes, is that there is uncertainty about the range of impact. In Estonia, as in most other EU countries, FITs are used to reach quantity targets. It is not an easy task beforehand, to choose the level of an FIT that matches the target. Therefore, regulation by FIT requires revisions. Inevitably revisions pose challenges to the investment climate. Therefore regulation by FIT involves a trade-off between the challenges of revisions and the continuation of costly support schemes. Our findings and the forthcoming market liberation, suggest that it is important for Estonia to reform its FIT scheme.

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Appendix 4. “Primary Method for reduction of SO_2 emission and its impact on CO_2 in pulverized oil shale-fired boilers at Narva Power Plant”.

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PRIMARY METHOD FOR REDUCTION OF SO_2 EMISSION AND ITS IMPACT ON CO_2 IN PULVERIZED OIL SHALE-FIRED BOILERS AT NARVA POWER PLANT

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Primary method if used in pulverized oil shale-firing boilers in operation enables to achieve the target value of SO_2 specific emission 400 mg/nm^3. It will also be possible to meet the SO_2 specific emission limit value (200 mg/nm^3) set by the European Union for the new-installed solid-fuel boilers by further optimization of technological parameters of pulverized oil shale firing and construction of oil shale boilers on the basis of primary methods. Optimization would make it possible to design a pulverized oil shale-fired boiler for supercritical and ultracritical steam parameters and to enhance the efficient and environmental-friendly use of oil shale to a considerable extent.

Introduction

Reduction of the sulphur dioxide (SO_2) emission produced as a result of firing pulverized oil shale is one of the most important and complicated problems in the whole complex of ecological problems at Narva Power Plants. Treaty of Accession of Estonia to the EU sets out a requirement to limit the amount of SO_2 emissions to 25,000 tonnes per year starting from 2012, bringing about restriction of electricity production in Estonia.

The LCP directive (Large Combustion Plant Directive) lays down a requirement to considerably reduce the discharged amount of specific emissions, *i.e.* SO_2, NO_x and fly ash, starting from 2016 [1]. This will considerably restrict electricity production in Estonia.

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To fulfil the EU requirements, several different flue gas cleaning methods targeted at the reduction of SO_2 emission (dry, semi-dry, wet, and plasma, photochemical) have been studied and tested [2].

However, the experience gained thanks to these tests shows that the specific nature of the mineral structure of oil shale has not been fully taken into account yet. The possibility to use these methods and the relevant efficiency guarantee are also questionable [3].

Improvement of the capture effect of SO_2 in the pulverized oil shale-fired boilers by applying primary methods shall offer a large reserve for the reduction of SO_2 emission. In the case of oil shale, nature itself has offered a solution for this problem as oil shale kerogen is furnished with the mineral ballast which contains up to 10 times more of the components capable of capturing SO_2 (CaO, MgO, K_2O, etc.) than necessary from the stoichiometric point of view. However, capturing of SO_2 in the pulverized oil shale-fired (PF) boiler varies to a large extent in the case of the currently applied PF methods: 70–80%. The specific emission of SO_2 in the leaving flue gases 1,800–2,700 mg/nm^3 [4] shows that the number changes considerably during the period of boiler operation due to changes in modes and technological parameters. It proves that there exist large reserves for capturing SO_2 in the PF boiler when primary methods are applied, and these reserves are not yet fully made use of. The main difficulty in making use of these reserves for capturing SO_2 lies in the fact that there is no global experience related to combustion of a fuel of similar composition and capturing SO_2 by applying primary methods.

Primary method discussed here deals with the use of oil shale, air and water components. In the PF boiler, which simultaneously functions as a desulphurisation reactor, there takes place a natural desulphurisation process in the course of which the amount of SO_2 emissions is reduced up to four times (the SO_2 capture coefficient of a boiler at Eesti Power Plant is ~75%, and the specific emission of SO_2 is ~2,200 mg/nm^3) [4].

Analysis of the results gained from the research and tests carried out in the pulverized oil shale-fired boiler have revealed that:

- quantity of the SO_2 capture sorbent (components such as CaO, MgO, K_2O, etc.) in oil shale is large, the stoichiometric ratio Ca/S is ~10;
- quality of the SO_2 capture sorbent is low (the content of active components capturing SO_2 in ash is small ~25%);
- efficiency of the SO_2 capture sorbent is low ~8% $((0.75/10)\times 100\% = 7.5\%)$.

The low efficiency of sorbent is related to large losses of sorbent which occur (Fig. 1):

- at large-fraction crushing of oil shale accompanied by a loss of ash (sorbent) – mechanical losses ~50%;
- at high flame temperature, which brings about agglomeration – losses caused by high temperature ~50%;

- at chemical destruction of mechanical and chemical additives contained in fly ash – chemical losses ~50%;
- due to the clogging of fly ash pores with sulphates accompanied by physical destruction – physical losses ~34%.

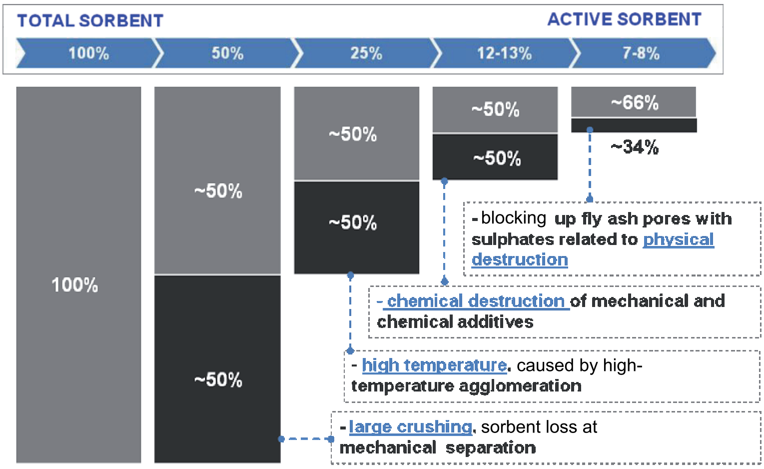

Fig. 1. Sorbent loss in pulverized oil shale boiler.

Calculations of the sorbent loss percentages have been based on the fly ash-focused research carried out in the PF boiler by the team from Universities of Technology in Tallinn and St. Petersburg [5-7].

The SO_2 capturing processes in the PF boiler and in the gas cleaning equipment operating on the basis of dry method are similar [8-11]. Basing on the results gained from the research on adsorption and chemisorption [12], and from the industrial tests focused on the dry sorbent-injection (SI) methods [13, 14], the following conclusions were reached:

- capturing of SO_2 with limestone at the stoichiometric ratio Ca/S ~3 results in ~50% of SO_2 being captured;
- efficiency of the SO_2 capture sorbent is ~16% ($(0.50/3)\times 100\% = 16.7\%$);
- efficiency of sorbent is two times higher ($16/8 = 2$) when the SI method is applied.

A higher efficiency of sorbent is achieved due to:

- selection of the best sorbent (calcite content up to 95% and porosity up to 50%) which reduces chemical destruction;
- preparation of the best sorbent (particle size of crushed sorbent dust up to 30 μm) which reduces chemical separation;

- use of the best sorbent (sorbent is injected into the cooling section of the furnace) which reduces high-temperature agglomeration.

On the basis of the above-listed conclusions, the primary method for capturing SO_2 in the PF boiler was worked out.

Primary method consists of three optimisation levels: mode-related level, technological level and optimal construction level.

The mode-related level involves optimisation of the boiler's operational mode (quantitative modifications) and is related to the impacts that the quantities of oil shale, air and water injected into the boiler have on SO_2 emission.

The technological level involves optimisation of the boiler's technological parameters (qualitative modifications) and is related to a finer particle size of crushed oil shale dust, circulation of flue gases and to the impact of water injection on the SO_2 emission.

The optimal construction level involves optimisation of the boiler's design and is related to new constructional and technological solutions of boiler furnace, flue gas channels, heating surfaces and auxiliary equipment.

The analyses carried out led to the following conclusions:

- the quality of oil shale sorbent (porosity of limestone and its content in the mineral structure of oil shale) is predetermined by nature being intrinsic;
- it is possible to increase the SO_2 capture coefficient and enhance the efficiency of sorbent in the PF boiler, in case:
  - flame temperature is lowered, which will reduce high-temperature agglomeration;
  - oil shale is crushed to a finer particle size, which will reduce mechanical separation.

Results of experimental implementation of primary method

Mode-related level

More than 100 modes were tested during the research carried out on the Eesti Power Plant boiler walls 4-B and 1-B and on boiler No. 8 of the Balti Power Plant with the aim to study the impact of different modes on the SO_2, NO_x and RO_x emissions.

The technical possibilities and economic purposefulness of primary methods were studied with the aim of reducing the SO_2, NO_x and RO_x emissions.

Marking of *modes* and the mode parameters:

- 0-mode: max. load ($N = 0.9\ Nnom$).
- L-mode: 0-mode + sliding excess-air coefficient (full opening of the fan control apparatus at secondary speed). $\Delta\alpha = 0.18$.

- LW-mode: L-mode + injection of water (clarified water from the ash disposal area) into the flame (*via* 4 nozzles into the upper-level burners). $\Delta W = 10$ t/h.
- B-load: optimal load ($N = 0.7$ *Nnom*). $\Delta N = 0.2$.
- BL-mode: B-mode + sliding excess-air coefficient (full opening of the fan control apparatus at primary speed). $\Delta\alpha = 0.20$.
- BLW-mode: BL-mode + water injection into the flame. $\Delta W = 10$ t/h.
- b-mode: min. load ($N = 0.4$ *Nnom*). $\Delta N = 0.5$.
- bL-mode: b-mode + sliding excess-air coefficient (full opening of the fan control apparatus at primary speed). $\Delta\alpha = 0.70$.
- bW-mode: b-mode + water injection into the flame. $\Delta W = 10$ t/h.

Analysis of the modes is presented in Table.

Results of the mode tests (0, LW, B, BLW) are presented in Fig. 2.

Table. **Investment values calculated by authors basing on mathematical algoritm**

Cb	10	€/t
C_{C02}	20	€/t

t	6000	h
z	10	a

Cbcond	35	€/t

C_{NOx}	8	M€
C_{ROx}	8	M€
C_W	2	M€

N_{max}	180	MW
N_{min}	80	MW
N_{opt}	140	MW

e_{max}	0.08
e_{min}	0.1
e_{opt}	0.09

	Operation mode	C_{SO2} mg/nm^3	η_{SO2} %	η_E %	b_B g/kWh	q_{SO2} g/kWh	q_{CO2} g/kWh	Δb_B g/kWh	Δq_{SO2} g/kWh	Δq_{CO2} g/kWh	Cb €/t_{SO2}	C_{CO2} €/t_{SO2}	Cvar €/t_{SO2}	C_{const} €/t_{SO2}	C_Σ €/t_{SO2}	β_{SO2} %
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0	2200	75.6	30.1	409	10.49	1287	0.0	0.0	0	0	0	0	0	0	0.0
2	L	1600	82.2	29.4	418	7.81	1318	9.7	2.7	31	127	229	356	0	356	25.5
3	LW	1000	88.9	28.3	435	5.07	1369	26.0	5.4	82	168	302	470	0	470	51.6
4	B	1400	84.4	29.5	417	6.81	1313	8.3	3.7	26	79	142	221	0	221	35.0
5	BL	1100	87.8	28.4	433	5.56	1364	24.5	4.9	77	174	313	486	0	486	47.0
6	BLW	800	91.1	27.3	451	4.21	1419	41.9	6.3	132	233	420	654	0	654	59.8
7	b	1100	87.8	27.2	452	5.80	1424	43.6	4.7	137	325	586	911	0	911	44.6
8	bL	700	92.2	24.8	496	4.05	1562	87.3	6.4	275	475	855	1329	0	1329	61.3
9	bW	600	93.3	25.1	490	3.43	1544	81.4	7.1	256	404	727	1130	0	1130	67.2

	Operation mode	C_{SO2} mg/nm^3	η_{SO2} %	η_E %	b_B g/kWh	q_{SO2} g/kWh	q_{CO2} g/kWh	Δb_B g/kWh	Δq_{SO2} g/kWh	Δq_{CO2} g/kWh	Cb €/t_{SO2}	C_{CO2} €/t_{SO2}	Cvar €/t_{SO2}	C_{const} €/t_{SO2}	C_Σ €/t_{SO2}	β_{SO2} %
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
10	LW/ROX	500	94.4	27.1	454	2.65	1430	45.2	7.8	142	202	363	565	103	668	74.7
11	BLW/ROX	400	95.6	26	473	2.21	1490	64.4	8.3	203	272	490	763	126	889	78.9
12	bLW/ROX	50	99.4	23.5	523	0.31	1649	114.8	10.2	362	394	710	1104	182	1286	97.0
13	NOx	1000	88.9	29.8	413	4.82	1300	4.1	5.7	13	25	46	71	142	213	54.0
14	B/NOx	800	91.1	28.7	429	4.00	1350	19.9	6.5	63	108	194	301	161	462	61.8
15	b/NOx	600	93.3	26.5	464	3.25	1462	55.5	7.2	175	268	483	751	256	1007	68.9
16	ROx/NOx	500	94.4	28.5	432	2.52	1359	22.9	8.0	72	101	181	282	202	484	75.9
17	B/ROx/NOx	400	95.6	27.4	449	2.09	1414	40.3	8.4	127	168	302	470	249	720	79.9
18	b/ROx/NOx	50	99.4	24.8	496	0.29	1562	87.3	10.2	275	300	539	839	363	1202	97.1
19	ROx/Nox/W	400	95.6	28.6	430	2.01	1355	21.4	8.5	68	88	159	248	214	461	80.8
20	B/ROx/Nox/W	320	96.4	26.7	461	1.72	1451	52.0	8.8	164	208	374	582	269	850	83.5
21	b/ROx/Nox/W	40	99.6	24.2	508	0.24	1601	99.6	10.3	314	340	612	952	406	1359	97.6

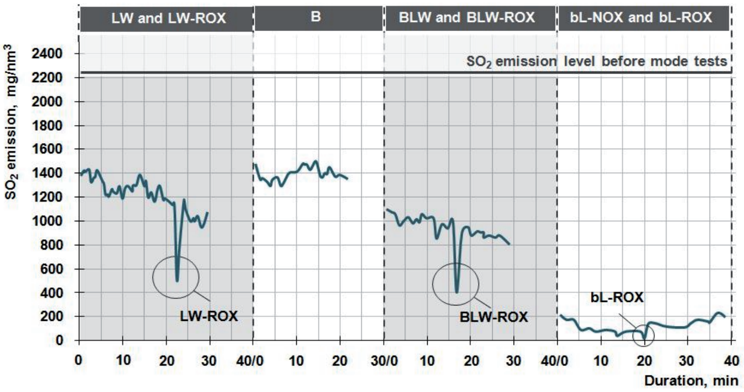

Fig. 2. Results of mode tests of primary method.

Source data subjected to changes:
Cb – price of oil shale, €/t
CCO_2 – price for CO_2 emission, €/t
CNO_x – investment in flue gas circulation, million €
CRO_x – investment in finer crushing of oil shale dust, million €
CW – investment in water injection, million €
t – number of operational hours of the energy block per year, h
z – payback period, y
Cb cond – price of standard fuel, €/t

Source data on energy block:
Nmax – max. load of energy block, MW
Nmin – min. load of energy block, MW
Nopt – optimal load of energy block, MW
emax – auxiliary power of energy block at max. load
emin – auxiliary power of energy block at min. load
eopt – auxiliary power of energy block at optimal load

Columns of the Table:

- Mode: code of mode
- CSO_2: the rounded average specific emission of SO_2 *per* mode, mg/nm^3
- $\Delta\eta$ SO_2: the average SO_2 capture coefficient *per* mode, %
- η E: average efficiency of the energy block *per* mode, % η
- bB: average specific fuel consumption of standard fuel *per* mode, g/kWh
- qSO_2: average discharge of SO_2 specific emissions *per* mode, g/kWh

- qCO_2: average discharge of CO_2 specific emissions *per* mode, g/kWh
- ΔbB: average increase in the specific fuel consumption of standard fuel, g/kWh
- ΔqSO_2: average decrease in the SO_2 specific emissions *per* mode, g/kWh
- ΔqCO_2: average increase in the CO_2 specific emissions *per* mode, g/kWh
- Cb: cost for surplus consumption of fuel per reduction of 1 t of SO_2 emission, €/t of SO_2
- CCO_2: cost for the increased CO_2 emission when the SO_2 emission is reduced, €/t of SO_2
- Cvar: variable costs per reduction of 1 t of SO_2, €/t SO_2
- Cconst: investment cost per reduction of 1 t of SO_2 emission, €/t SO_2
- $C\sum$: costs per reduction of 1 t of SO_2 emission, €/t SO_2
- β SO_2: relative decrease in the SO_2 emission, %

Analysis of the advantages and drawbacks of primary method modes:

Advantages

1. no investments needed (desulphurization takes place in the boiler);
2. no sorbents needed (air and water are injected);
3. no further processing, transportation or storage of the produced solid emissions (sulphates) is needed (removed together with ash);
4. satisfactory level of the SO_2 specific emission ~800 mg/nm^3;
5. satisfactory level of costs related to capturing SO_2 ~654 €/t SO_2 (price of oil shale – 10 €/t and price of CO_2 – 20 €/t) Proposed values are indicative and can be changed according to actual circumstances;
6. in 2012, it will be possible that the existing energy blocks of Narva Power Plants will generate ~6 TWh of electricity per year (taking into account the prescribed quota of SO_2 – 25 thousand t/4.21 thousand t of SO_2/TWh = 5.9 TWh).

Drawbacks

1. inadequate level of the discharge of SO_2 specific emissions (the level required starting from the year 2016 is 400 mg/nm^3);
2. high energy intensity bB = 450.6 g/kWh (increase in the consumption of oil shale by 10.4%);
3. high level of the CO_2 specific emission qCO_2 = 1419.4 g/kWh (increase in the amount of CO_2 emissions by 10.4%);
4. remarkable wearing (erosion) of heating surfaces (an up to 40% increase in the wearing of heating surfaces, since the flue gas velocity increases by up to 14%). In case the SO_2 emission is reduced by 1 t, the increase in the costs related to erosion remains below 1% of total costs;

5. in 2016, it will be possible that the existing energy blocks will generate ~1.5 TWh of electricity (with the permitted level of SO_2 specific emission being 400 mg/nm^3). The specified amount will be produced in co-operation of the Eesti Power Plant energy blocks Nos. 7 and 8 with the Balti Power Plant energy blocks Nos. 11 and 12.

Discussion

Tests of primary method modes indicated that optimisation of the boiler modes induces a decrease in the flame temperature from ~1,450 °C (0-mode) down to ~1,150 °C (BLW mode), causing the reduction of SO_2 specific emission by up to 60%.

A switch-over to primary method modes requires performance of check tests (during ~240 hours) in order to specify the impact of modes on the efficiency, operating reliability and ecology.

Reaching the SO_2 specific emission level ~800 mg/nm^3 is an incomplete solution, since (starting from 2016) the level required is 400 mg/nm^3.

Please note the following principle of dialectics: winning involves losing.

A simple solution (primary method modes), which requires no investments and sorbents, no cleaning, transportation and storage of emissions, involves an increase in the costs for oil shale, CO_2 and wearing of heating surfaces.

In order to meet the SO_2 specific emission limit value (400 mg/nm^3) [1] set as a target for 2016 by the European Union, it is advisable to apply flue gas circulation, finer crushing of oil shale dust and water injection first to one of the pulverized oil shale-fired boilers for the purpose of studying the impacts of these factors on the SO_2 emission.

Flue gas circulation is used to lower the flame temperature, which in turn reduces high-temperature agglomeration.

A smaller particle size of oil shale dust achieved due to finer crushing facilitates the reduction of mechanical losses and enlarges chemisorption surface of fly ash.

For a long time, both primary measures have been widely and successfully applied at coal-firing power plants for the reduction of NO_x emissions [15–20].

Application of the referred primary methods to pulverized oil shale firing shall reduce the emissions of NO_x as well as of SO_2. The results of the tests carried out on the walls of a boiler at the Eesti Power Plant prove the decrease in SO_2 emissions. The tests imitated those carried out earlier on a boiler at the Balti Power Plant where application of finer oil shale and water injection after superheater resulted in an enlarged chemisorption surface of fly ash.

Water injection after superheater activates fly ash. The water injection method is a simplified high-temperature method developed on the basis of the LIFAC gas cleaning method. For a long time, the LIFAC gas cleaning method has been successfully and widely applied at coal-firing power plants for the reduction of SO_2 emissions [21, 22].

The advantage of primary methods lies in considerably smaller investments and operation costs compared to those related to the gas cleaning equipment – *i.e.* SO_2 scrubbers and catalytic reactors for NO_x [23–27].

Earlier, investments to be made in the application of primary methods to pulverized oil shale firing were estimated at one boiler of the Eesti Power Plant (two boiler walls) as follows:

- 8 million € – investment in finer crushing of oil shale dust;
- 8 million € – investment in flue gas circulation;
- 2 million € – investment in water injection.

Values proposed for the above-mentioned investments are indicative and can be changed according to actual circumstances.

Payback period, with physical depreciation of energy blocks taken into account, is estimated to be 10 years.

In Table and in Fig. 3 the source data on investments and operation can be modified, and the relevant impacts, resulting from such modifications, on the cost of the reduction of 1 ton of SO_2 emission can be estimated.

Marking of the technological modes and the technological parameters of modes:

- LW/RO_x-mode imitates finer crushing of oil shale dust: max. load, sliding excess-air coefficient, water injection into the flame and increased concentration of the fly ash. MRS operation (three-minute shaking of the primary and secondary screens of the downstream flue gas channels).
- BLW/RO_x-mode imitates finer crushing of oil shale dust: optimal load, sliding excess-air coefficient, water injection into the flame and increased concentration of the fly ash.
- bL/RO_x-mode imitates finer crushing of oil shale dust: min load, sliding excess-air coefficient, water injection into the flame and increased concentration of the fly ash.
- NO_x flue gas circulation mode, analogous to the LW-mode at capturing SO_2: max. load.
- B/NO_x flue gas circulation mode, analogous to the LW-mode at capturing SO_2: optimal load.
- b/NO_x flue gas circulation mode, analogous to the bL-mode at capturing SO_2: min. load.
- RO_x/NO_x mode involves finer crushing of oil shale dust and flue gas circulation, analogous to the LW/RO_x-mode at capturing SO_2: max. load.
- B/RO_x/NO_x mode involves finer crushing of oil shale dust and flue gas circulation, analogous to the LW/RO_x-mode at capturing SO_2: optimal load.

- $b/RO_x/NO_x$ mode involves finer crushing of oil shale dust and flue gas circulation, analogous to the bL/RO_x-mode at capturing SO_2: min. load.
- $RO_x/NO_x/W$: RO_x/NO_x-mode + the water injection mode which reduces the SO_2 specific emission by 20% compared to the RO_x/NO_x-mode: max. load.
- $B/RO_x/NO_x/W$: $B/RO_x/NO_x$-mode + the water injection mode which reduces the SO_2 specific emission by 20% compared to the $B/RO_x/NO_x$ -mode: optimal load.
- $b/RO_x/NO_x/W$: $b/RO_x/NO_x$-mode + the water injection mode which reduces the SO_2 specific emission by 20% compared to the $b/RO_x/NO_x$-mode: min. load.

Results gained from the tests of the primary method modes LW/RO_x, BLW/RO_x, bL/RO_x are presented in Fig. 2 and Table.

Analysis of the advantages and drawbacks of the primary method:

Advantages

1. satisfactory level of the SO_2 specific emission – 400 mg/nm^3 ;
2. satisfactory energy intensity bB = 430.0 g/kWh (consumption of oil shale increases by 5.4%);
3. satisfactory level of the CO_2 emission – qCO_2=1,355 g/kWh (the amount of CO_2 emissions increases by 5.4%);
4. satisfactory level of the wearing (erosion) of heating surfaces (the wearing of heating surfaces decreases from 40% in the BLW mode to 20% in the B/NO_x-mode, since the circulation of flue gases reduces flue gas velocity, and finer crushing of oil shale dust makes the particles of the oil shale fly ash smaller, thus reducing the kinetic energy and wearing of heating surfaces);
5. satisfactory level of costs related to capturing SO_2 – 461 €/t of SO_2 (optimal ratio of investment costs 214 €/t SO_2, and operation costs 248 €/t SO_2);
6. a technology in no need of sorbent;
7. the produced solid particles are removed together with ash;
8. the SO_2 specific emission target level set for 2016 will not restrict the generation of electricity on the basis of existing energy blocks at Narva Power Plants.

Drawbacks

– Data not available.

Conclusions basing on the imaginary tests of primary method are as follows:

The tests of the imaginary modes of primary method indicated that the SO_2 specific emission limit value (400 mg/nm^3) set by the European Union for 2016 can be achieved through optimising technological parameters of boiler by applying primary methods.

A switch-over to the primary method modes requires actual tests to be conducted in order to specify the impact of technological changes on efficiency, operation reliability and ecology.

For this purpose, the following matters should be clarified:

- possibilities of existing mills for finer crushing of oil shale;
- flue gas circulation possibilities for lowering flame temperature [20];
- water injection possibilities for activating fly ash.

Energy intensity and the amount of CO_2 emission can be reduced by optimising the BLW mode.

For this purpose, the following matters should be clarified:

- possibilities for multiple-stage crushing of oil shale (enrichment of oil shale with kerogen in the first stage and with calcite in the final stage). This should reduce the energy consumption needed for crushing, since only calcite is crushed to finer particles;
- possibilities for multiple-stage combustion (changing the excess-air coefficient in burners). This shall improve the capture of SO_2 and reduce the circulation of flue gases;
- possibilities for multiple-stage injection of water (into superheater, after the economizer and the air pre-heater). This shall improve the capture of SO_2 and reduce the amount of water to be injected.

Conclusions

The application of primary method enables to achieve the target value of SO_2 specific emission 400 mg/nm^3 at firing pulverized oil shale in the existing boilers. It will also be possible to meet the SO_2 specific emission limit value (200 mg/nm^3) set by the European Union for the new installed solid-fuel boilers by further optimising the PF-technology parameters and construction of oil shale boiler on the basis of primary methods. This would make it possible to design a PF boiler for supercritical and ultracritical steam parameters and to enhance the efficient and environmental-friendly use of oil shale to a considerable extent.

The following fact should be taken into account at optimization of boiler construction (*i.e.* improvement of SO_2 capture): the efficiency of desulphurisation depends on two physical-chemical processes – lime burning and lime sulphurization.

Lime burning (dissociation of calcite) occurs in the flame and in the cooling section of the furnace. The efficiency of lime burning depends on the quality of limestone and on technological parameters of the burning process – *i.e.* on temperature and time. The higher the quality of limestone (cleaner, more porous and finer) and the closer the combustion temperature of limestone to the lime agglomeration temperature, the higher the quality of lime and the more efficient the following SO_2 adsorption.

Lime sulphurisation (chemisorption of SO_2) occurs in the boiler; the process starts when flue gases exit the furnace and continues in the boiler's flue gas channels. The efficiency of lime sulphurization depends on the quantity and quality of lime, on concentration of flue gas components and on technological parameters of the lime sulphurization process *i.e.* on temperature and time. The larger the quantity of lime (Ca/S), the higher its quality (cleaner, more porous and finer) and the higher the concentrations of SO_2, O_2 and H_2O in flue gases – the more effective the chemisorption of SO_2.

The closer the lime sulphurization temperature to the lime agglomeration temperature and the longer the period of lime sulphurization – the more effective the chemisorption of SO_2.

Improvement of the capture of SO_2 by optimising boiler construction is a topic which requires further research, construction-related solutions and tests.

In order to achieve the SO_2 limit value (400 mg/nm^3) set by the European Union for 2016 and work out a commercial solution of the BLW technology, flue gas circulation with oil shale dust crushed to a finer particle size should first be applied and tested on one of the boilers. Flue gas circulation lowers flame temperature and the oil shale dust of a finer particle size enlarges the fly ash adsorption surface. Both measures have for a long time been successfully and widely applied in coal-firing power plants for the reduction of NO_x emissions (at oil shale firing, both NO_x and SO_2 emissions would decrease). Considerably smaller investments and operation costs compared with those needed for gas cleaning equipment, *i.e.* the SO_2 scrubbers and the NO_x catalytic reactors, can be pointed out as advantages of these measures.

The future of oil shale power industry will depend on how successful we are in fulfilling the ecology-related requirements set by the European Union. If we are able to implement them cheaper than in case of coal-fired power plants, we will definitely ensure the sustainability of oil shale power industry in Estonia. However, copying of the ecological technologies used at coal-firing power plants will require 1.5 times larger investments and increase the risk by 30%.

Note that the capture properties of oil shale ash are similar to those of cement. Carburizing of ash is an obstacle to the use of semi-dry and wet technologies for capturing SO_2.

Consequently, the primary method of SO_2 capture is a "lifebuoy" to guarantee the continuing development of oil shale power industry in Estonia after the year 2012 (Fig. 3).

Note that in case the application of primary method does not enable to achieve the SO_2 specific emission target value 400 mg/nm^3 in the PF boilers in operation, which is of little probability the additive method (addition of high-quality conditioners, sorbents and convertors into the boiler or electric filter) must be applied.

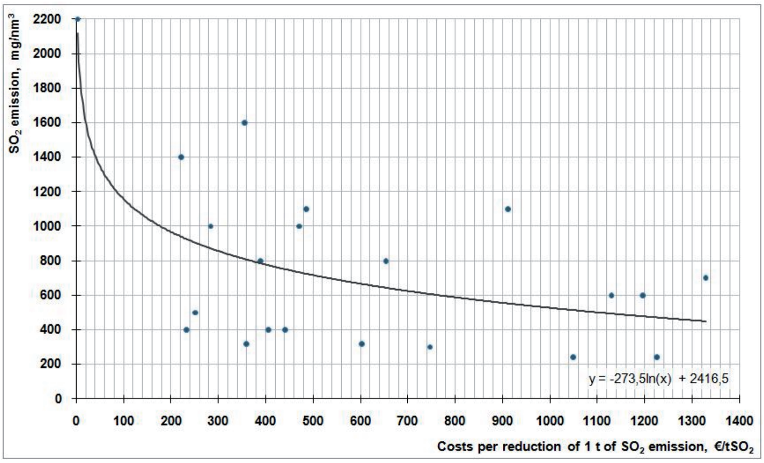

Fig. 3. Costs per reduction of 1 ton of SO_2 emission.

In order not to allow the SO_2 emission level to exceed in 2012 the SO_2 emission quota (25 thousand tons) established by the European Union, a long-term (during ~240 hours) check test on one boiler must be followed by a switch-over to BLW modes, which will make it possible for Narva Power Plants to achieve the output of up to 6 TWh of electricity on the basis of existing energy blocks.

Figure 4 describes how the cost of carbon dioxide influences the cost of one ton of bound SO_2 when using the specific method of SO_2 binding. Vertical axis shows the cost of one bound SO_2 ton in €, and horizontal axis shows the change in the cost of CO_2 ton with CO_2 basic price being 20 €/ton (0% value on horizontal axis).

The smallest effect is revealed by the methods in the case of which a smaller fall in power efficiency and bigger SO_2-binding degree were projected. The initial data displayed in the Table serve as a basis for the analysis of SO_2 effect sensitivity.

Figure 5 characterises how the projected investments, necessary for integrating the specific methods of SO_2 binding into operation, influence the cost of one ton of bound SO_2. Vertical axis shows the cost of one ton of bound SO_2 in € and horizontal axis shows the change in investments expressed in percentages. Basic values of investments have been separately set out in the Table.

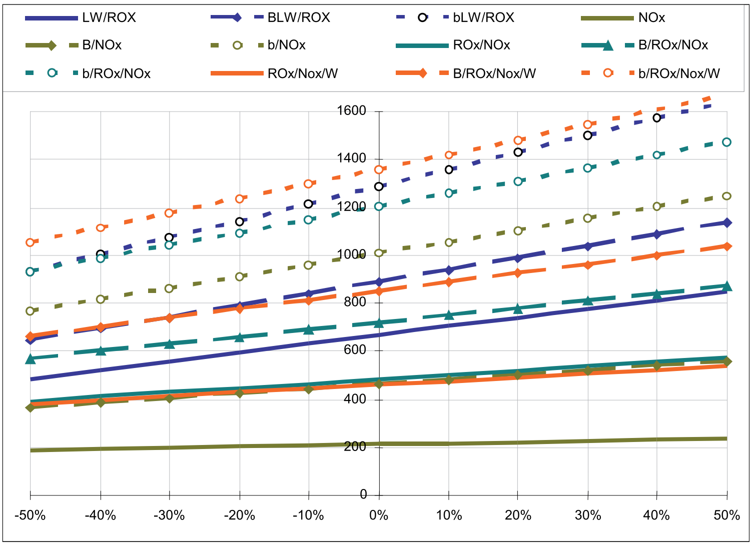

Fig. 4. Cost for 1 ton of CO_2.

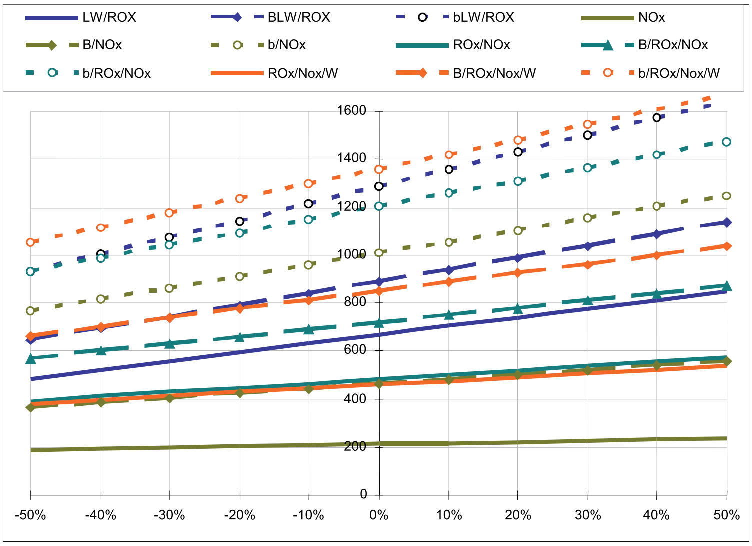

Fig. 5. Projected investments.

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Appendix 5. “Implications for Competitiveness of Estonian Energy-Intensive Industry after establishment of the CO_2 emissions pricing from year 2013 onwards”.

IMPLICATIONS FOR COMPETITIVENESS OF ESTONIAN ENERGY-INTENSIVE INDUSTRY AFTER ESTABLISHMENT OF CO_2 EMISSIONS PRICING FROM YEAR 2013 ONWARDS

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Abstract

In the European Union the rights for CO_2 emissions are distributed amongst energy-intensive companies for free only until end of year 2012. From 2013 onwards the total quantity of allowed emissions will start decreasing, putting pressure on the price of CO_2 emissions. This will influence carbon-emitting energy-intensive companies' costs and determine their ability to sustainably compete in the open markets where prices are fixed. This article offers analysis of an open medium-income country's energy-intensive firms' variable cost elasticity for CO_2 prices at €15, €25 and €50 per tonne, using Estonia as a reference. The analysis reveals that firms using carbon-intensive fuels could experience variable cost increases up to 100% (in the case of using oil shale at CO_2 priced €50 per tonne), which will have paramount influence on total costs. Although such fuel is primarily used in Estonia's electricity generation, biggest impact would hit the country's mineral sector where carbon-intensive manufacturing faces on average 20% variable cost change (at CO_2 priced €25 per tonne) and could eventually move out of the country.

Keywords: CO_2 emissions, energy-intensive industry, cost competitiveness, Estonia.

JEL classification number: Q47, N70

Introduction

In March 2007 the European Union's leaders endorsed an integrated approach to climate and energy policy that aims to combat climate change and increase the EU's energy security while strengthening its competitiveness. This should help create a highly energy-efficient, low carbon economy-based Europe (European Commission, 2011). It became later known for "20-20-20 targets" as the EU's leaders committed to a reduction of greenhouse gas emissions by at least 20% below 1990 levels; 20% of EU energy consumption to come from renewable sources; and a 20% reduction in primary energy use from higher energy efficiency – all by the year 2020.

From 2013 onwards a single EU-wide cap on emission allowances will become effective, reducing the number of allowances available to businesses to 21% below the 2005 level by 2020 (European Commission, 2011). Current free allocation of allowances by EU member country governments will be progressively replaced by public auctioning and the sectors covered by the system will be expanded.

Such a requirement creates a situation where carbon-intensive industries become subject to the emissions allowance cap and may need to pay fees for additional polluting i.e. larger-than-planned emissions quotas. Similarly some participants may emit less than planned and can subsequently sell unused emission quotas for additional income. So while companies develop less carbon intensive technologies they can engage in trading of carbon emissions quotas, which is also known as effective CO_2 trading.

CO_2 trading in the European Union started already in 2005 as a test scheme when it ran until 2007 and was allowed between EU member states only. A revised scheme is now in place with defined quotas and trading allowed between 2008 and 2012. Given that this period is still undergoing and year 2013 brings an introduction of a single EU-wide cap there is substantial uncertainty regarding the cost of CO_2 beyond 2012 (Deutsche Bank's report from 30 August 2010 estimates year 2020 prices at €30 per tonne at EU's current target of 20% CO_2 emissions reductions; rising to €37 per tonne if the target was raised to 30%[1]. At the same time current futures price at the European Climate Exchange stands at €14,49 per tonne for March 2011 and at €22,50 for December 2020[2]). This imposes that all energy-intensive companies that source their energy from fossil fuels or emit CO_2 as part of their production process are likely to suffer increased costs as a result of less CO_2 emissions being available for free trading and upward price trend over following years. In other words, establishment of the new CO_2 allowances will have an impact on such companies' competitiveness in open markets.

The aim of this article is to assess potential microeconomic impact from such rising costs. By calculating companies' energy costs and allocating a potential CO_2 emission supplement on top it is possible to measure firms' variable cost elasticity depending on the source of fuel used and CO_2 emitted. This in turn forms a foundation for assessment of boundaries for competitive cost advantage. Given the newness of CO_2 pricing and modest literature available on such discussions, little knowledge exists today about the consequences of such activity to competitiveness of energy-intensive firms in a small medium-income EU country like Estonia – and consequently directions for policy measures and firm-level decisions.

Carrying out the task requires access to and detailed analysis of carbon-intensive firms' cost levels. This has been carried out as a desk study observing 21 most energy-intensive firms in Estonia who make up recipients of Estonia's carbon-emissions quotas. Many of these firms are major exporters or could potentially become one (including all electricity providers after complete opening of Estonian electricity market in 2013), hence such calculations form an important discussion topic on the economic policy-drafting level. Most of the companies in the study produce energy, yet the list of large-scale polluters also includes manufacturers of

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[1] (Deutsche Bank, 2010)

[2] (ICE, 2011)

industrial goods. Due to lack of more specific financial data the study will only highlight cost variation and not discuss impact on profit margins.

This article is structured as follows. First, a theoretical discussion on implications of cost competition will take place. The authors discuss how to adequately measure competitiveness in the light of policy drafting and point to the need to measure individual firms' cost levels as underlying source of competition. Second, a methodological discussion follows. The authors argue that fuel costs are an important driver of energy-intensive firms' overall cost level and demonstrate how to measure an additional effect of CO_2 pricing. The analysis is carried out as a desk study using researched firms' annual reports. Third, a discussion on findings follows. The authors draw conclusions on which industries are most likely to face larger cost increase if CO_2 quotas were priced at higher levels, based on type of primary fuel used. The conclusion highlights lessons learnt.

Theoretical background

This article strives to analyse how future pricing of CO_2 emissions might impact competitiveness of energy-intensive industries. Hence it makes sense to start by defining what should be understood by competitiveness and bridge the discussion to how it relates to firm performance, i.e. highlighting the importance of measuring costs and profits. Competitiveness is itself a rather vague term which can be probably defined in as many ways as there are people dealing with it. There is no one ideal measure and the large number of different measures that are in common use today often diverge appreciably (Turner & Dack, 1993). This is somewhat natural given that competitiveness can be applied to different levels of assessment and analysis.

Martin et al (1991) call the pursuit of competitiveness a partnership between public policy and management strategy so as to create sustainable operations at micro- and macroeconomic level. It is argued that input factors come from both an individual country's government and the acting business firms – yet much also remains outside direct influence of both, such as input prices or demand conditions (Martin, Westgren, & van Duren, 1991). It is precisely in this context that Turner and Dack (1993) propose measuring countries' relative price and/or cost positions as directly related to overall economic performance. If a country's relative costs are too high, local firms will not thrive and international companies might be more interested in direct imports and minimal operations – hence compromising the country's ability to compete internationally (Turner & Dack, 1993).

Indeed, firms are direct players that define and redefine their business environment and thereby influence total economic balances, meaning that how competitive a country ends up being is a reflection of success of its acting companies. Although Martin et al (1991) do not elaborate further, one could argue that a country's business environment will witness both local as well as international firms – as both of them are competing for local customer's attention (and sale) along with access to local (production) resources.

So it emerges that countries are as wealthy as their firms are. If firms earn profits and can sustainably grow their business then it increases the country's reputation and lures more firms to set up their business there. This in turn contributes to better utilisation of production resources (including labour and material supplies), increases overall quality levels, offers more choice to customers (in the form of end-products) and ultimately contributes to higher tax revenues for the state through increased sales activity.

In order to increase wealth for the society, the aim of firms should be to produce at highest possible quality with lowest possible (direct and indirect) costs. This is particularly relevant in the case of middle-income countries with open economy – such as Estonia – where cheap labour is no longer a sustainable competitive advantage and local firms have to match products and services in their home markets to the quality offered by international enterprises. At the same time such firms still have to differentiate their offering with an argument that they can achieve same results by being less costly. On the one hand this supports Fidelis Ezeala-Harrison's idea that introduction of foreign capital stresses local competition towards better quality and lower costs (Ezeala-Harrison, 1999). This has also happened in Estonia, same as in many other transition economies. On the other hand a statement that "biggest means in maximising firm profits is competition" (Agrawal, Mehra, & Siegel, 1998, p.60) holds true, meaning that prices are fixed by the market and the only way for firms to make profits and grow their business is by keeping all expenses under strict control and aiming for cost reduction not only for marginal costs but also for total unit costs as production quantities increase.

So the discussion shifts to costs as direct determinants of success in competition. This requires awareness of what factors drive costs to alter or change the nature and extent of activities that create costs (Groth & Kinney, 1994), keeping in mind that costs also change over time for a variety of reasons, including among others supply and demand effects and regulatory processes (such as pricing of CO_2 emissions!). Lockamy (2003) goes even further, suggesting that costs be analysed not only internally but also externally, so that firms could identify their cost patterns based on organisational objectives, organisational capabilities and customer requirements (Lockamy III, 2003). In this article's context this could be further interpreted as international benchmarking in cost competition when all of EU faces cost on CO_2 emissions – meaning firms need to define their comfort zones and apply mitigating actions to preserve them.

Theoretically an emission trading system such as the one in EU promotes efficient reductions. Since all participants face the same marginal abatement costs, overall reduction costs are minimized. The price of allowances also encourages dynamic efficiency, since the participants can save allowances by making their production more carbon efficient. The monetary premium of an improvement in technology is that the superfluous allowances can be traded (see e.g. Hussen, 2004). Hence cost increase due to CO_2 pricing should be seen as “necessary evil”, the only question is whether companies and policy makers realize the scope and speed of change.

Methodology

As discussed in the introductory chapter the CO_2 emission quotas for period 2008-2012 have been issued free of charge, but market participants are fixed. Total list of Estonia’s companies registered in the European Commission’s National Allocation Plan for Community Emissions Trading Scheme 2008-2012 comprises 50 entries (European Commission, 2008). These companies make up largest energy-intensive producers in Estonia, meaning they are biggest users of fuels for generation of electricity and/or heat or manufacturing of energy-intensive industrial products – qualifying them for CO_2 emissions allocation.

The list of 50 entries can in fact be narrowed down to only 21 companies, many of them owning regional subsidiaries that make up 49 entries in the above referred list. 50th entry stands for Nordkalk AS, Estonian subsidiary of Swedish Nordkalk AB. Unfortunately its data is only available for analysis on consolidated group level (i.e. comprising also entities from Finland, Poland, Russia and Sweden), so Nordkalk had to be dismissed from the study. Names and field of activity of these 21 companies are listed in columns 2 and 3 in Table 1 below. Most of the companies differ appreciably in terms of structure, activities as well as use of fuels. Many on the list are solely energy producers (electricity, heat or co-generation of both); some companies do not produce energy per se but rather emit large amounts of CO_2 as part of their production process – such as manufacturers of cement, cellulose and pulp, bricks and glass.

Given the smallness of the Estonian context, use of available consolidated statistical data is insufficient for in-depth analysis. As discussion on effect form CO_2 emissions on companies’ activities gains increasing momentum and 21 companies makes up a small sample, this research concentrates on firm-level data analysis using publicly available information (in annual reports). Hence Table 1 is able to list specifics of each of the energy-intensive companies qualifying for CO_2 emissions quotas. Main challenge has been to decide what data to use and how to generalise this.

The basis for discussions in this research lies in a simple microeconomic model according to which the firm’s ability to successfully compete is determined by its ability to lower costs and thereby generate sizeable profits. Hence relevant input drivers for measurement are the sales price, quantity sold, fixed and variable costs (i.e. $P = (p \times q) - (C_F + C_V)$). Multiple ways exist in how much influence the firm’s costs will have, depending on whether the firm acts as a price taker (i.e. sales price is fixed) or whether all competitors would suffer from same cost increase and could forward this to end-users. These have been summarised respectively in Figure 1 and Figure 2.

Table 1. Variable costs and fuel use of Estonia’s companies listed for CO_2 emissions trading as of 2008-2009

No	Company	Category of main activity	Variable Cost (mEUR)		Primary Means of Fuel Which Qualifies for Carbon Emissions Quotas *		Fuel Energy Content (GWh)		Cost of Energy (mEUR)		CO_2 emission				Change in Variable Cost (CO_2 cost €15)		Change in Variable Cost (CO_2 cost €25)		Change in Variable Cost (CO_2 cost €50)	
											metric tonne		mEUR		%		%		%	
			2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	Kiviõli Keemiatööstus OÜ	Treatment of Oil Shale	11	7	Oil Shale	Oil Shale	299	299	1,210	1,470	107 341	107 341	5,37	5,37	15,19	24,40	25,32	40,66	50,63	81,32
2	AS Kunda Nordic Tsement	Cement production	34	25	Oil Shale	Oil Shale	3 000	1 500	12,171	7,378	1 077 000	538 500	53,85	26,93	46,96	32,18	78,27	53,64	156,54	107,27
3	VKG Grupp AS (VKG Energia)	Heat and electricity production. Oil production	41	28	Oil Shale	Oil Shale	79	16	0,320	0,080	28 357	5 665	1,42	0,28	19,95	25,09	33,24	41,82	66,48	83,64
					Generated Gas	Generated Gas	990	890	0,170	0,150	512 820	461 020	25,64	23,05						
4	AS Sillamäe SEJ	Heat and electricity production	6	9	Oil Shale	Oil Shale	345	276	1,400	1,360	123 855	99 084	6,19	4,95	0,30	0,17	0,50	0,29	1,00	0,58
					Natural Gas	Natural Gas	3	3	0,075	0,077	579	579	0,03	0,03						
5	Eesti Energia AS	Heat and electricity production	4 871	5 507	Oil Shale	Oil Shale	29 000	24 000	117,650	118,040	10 411 000	8 616 000	520,55	430,80	3,21	2,43	5,36	4,05	10,72	8,10
					Natural Gas	Natural Gas	1 451	1 516	37,596	40,587	29 161	304 696	1,46	15,23						
6	AS Eraküte	Heat production	17	13	Shale Oil	Shale Oil	153	153	4,240	3,510	42 118	42 118	2,11	2,11	0,05	0,06	0,08	0,10	0,16	0,20
					Natural Gas	Natural Gas	50	50	1,306	1,349	10 130	10 130	0,51	0,51						
7	AS Saaremaa Piimatööstus	Heat production	26	22	Shale Oil	Shale Oil	25	18	0,690	0,400	6 900	4 830	0,35	0,24	0,39	0,33	0,66	0,54	1,31	1,09
8	AS Kuressaare Soojus	Heat production	2	2	Shale Oil	Shale Oil	5	6	0,140	0,140	1 390	1 709	0,07	0,09	0,87	1,11	1,45	1,86	2,90	3,72
9	AS Võru Soojus	Heat production	2	2	Shale Oil	Shale Oil	1	1	0,033	0,029	331	358	0,02	0,02	0,21	0,28	0,34	0,47	0,69	0,94
10	AS ESRO	Heat production	8	5	Natural Gas	Natural Gas	13	7	0,327	0,192	2 535	1 445	0,13	0,07	0,50	0,43	0,83	0,72	1,67	1,45

No	Company	Category of main activity	Variable Cost (mEUR)		Primary Means of Fuel Which Qualifies for Carbon Emissions Quotas *		Fuel Energy Content (GWh)		Cost of Energy (mEUR)		CO_2 emission				Change in Variable Cost (CO_2 cost €15)		Change in Variable Cost (CO_2 cost €25)		Change in Variable Cost (CO_2 cost €50)	
											metric tonne		mEUR		%		%		%	
			2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
11	AS Tallinna Küte	Heat production	83	81	Natural Gas	Natural Gas	800	850	20,731	22,758	160 800	170 850	8,04	8,54	2,92	3,18	4,87	5,30	9,73	10,60
12	AS Nitrofert	Production of nitrogen compounds	59	20	Natural Gas	Natural Gas	1 200	1 30	31,097	3,481	241 200	26 130	12,06	1,31	6,10	1,95	10,17	3,25	20,34	6,50
13	O-I Production Estonian AS	Production of glass	27	20	Natural Gas	Natural Gas	160	170	4,146	4,552	32 160	34 170	1,61	1,71	1,80	2,60	3,00	4,34	6,00	8,67
14	Wienerberger AS	Production of bricks	11	6	Natural Gas	Natural Gas	60	13	1,555	0,348	12 060	2 613	0,60	0,13	1,72	0,65	2,87	1,09	5,74	2,18
15	Horizon Tselluloosi ja Paberi AS	Production of paper, cardboard, cellulose	40	25	Natural Gas	Natural Gas	180	160	4,665	4,284	36 180	32 160	1,81	1,61	1,37	1,95	2,28	3,24	4,57	6,48
16	AS Estonian Cell	Production of pulp	44	40	Natural Gas	Natural Gas	110	110	2,851	2,945	22 110	22 110	1,11	1,11	0,75	0,83	1,24	1,38	2,49	2,76
17	AS Repo Vabrikud	Production of wood tile	35	19	Natural Gas	Natural Gas	818	791	21,208	21,165	165 352	159 715	8,27	7,99	7,17	12,54	11,95	20,91	23,89	41,81
18	Fortum Termest AS	Heat production	34	29	Natural Gas	Natural Gas	200	200	5,183	5,355	40 200	40 200	2,01	2,01	1,78	2,05	2,96	3,42	5,93	6,84
19	AS Anne Soojus	Heat production	9	12	Natural Gas	Natural Gas	200	7	5,183	0,192	40 200	1 445	2,01	0,07						
					Peat	Peat	220	75	0,020	0,010	81 400	27 750	4,07	1,39	1,82	0,04	3,04	0,06	6,08	0,13
20	Tootsi Turvas AS	Production of peat product	10	12	Peat	Peat	50	35	0,004	0,003	18 500	12 950	0,93	0,65	2,89	1,61	4,82	2,68	9,64	5,35
21	Sangla Turvas AS	Production of peat briquet	8	6	Peat	Peat	35	3	0,003	0,001	12 950	925	0,65	0,05	2,34	0,25	3,90	0,42	7,80	0,84

Source: annual reports of the 21 companies and authors' calculations.

* Primary fuel type that qualifies for CO_2 emissions quotas does not necessarily mean that it is also the primary type of fuel used in the company. In many cases the actual primary fuel might be free of carbon-emissions trading, e.g. use of wood pellets so the type listed in the column is in fact secondary used fuel. This is reflected in cost of energy.

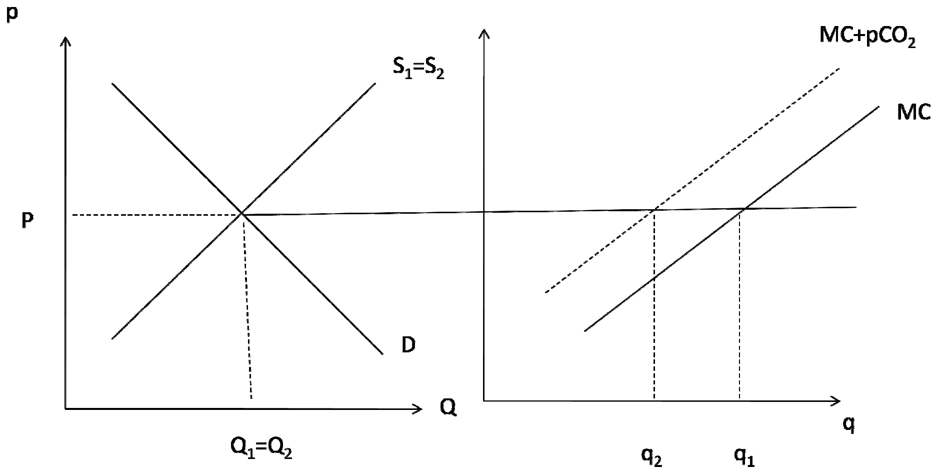

Figure 1. Sales price is fixed at market rates, firm has to absorb cost increase by lowering sales quantity – applicable in export markets (authors' sketch)

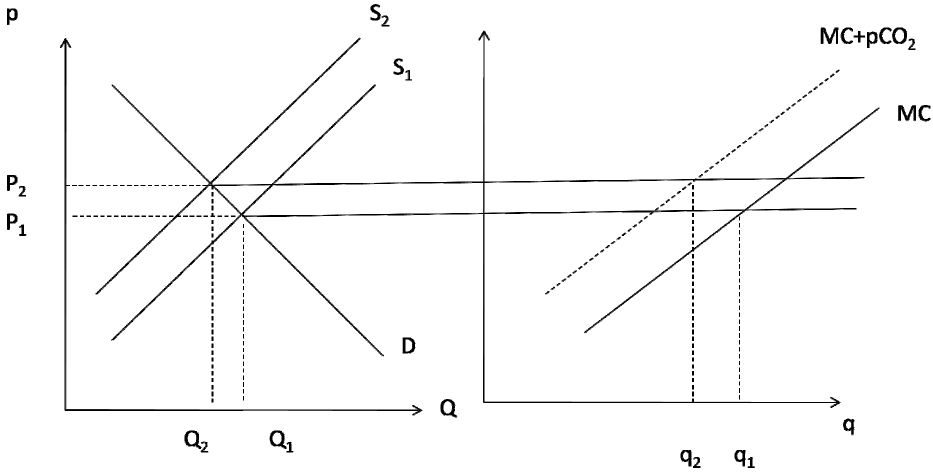

Figure 2. All suppliers bear cost increase from CO_2 quotas, which raises the sales price – applicable in domestic competition (authors' sketch)

It makes sense to assume that competing firms in a small middle-income country of EU (such as Estonia) can only measure their cost advantage ahead of their (international) competitors as the sales price will be determined by the open market and under normal circumstances it should not be expected to change (ref. Figure 1). Whether such firms can stay profitable depends on the average cost curve: as per Agrawal et al (1998) growing business will become possible by increasing efficiency and reducing costs. This means that starting from equilibrium, some companies will go out of business. A *ceteris paribus* environment has to be used for such assumption to highlight the immediate effect on the firms' profits. Again referring to the fact that from year 2013 onwards all firms will be openly competing in free markets with a market-set price but non-comparable individual cost increase, this simplification is somewhat realistic and firms should not expect to be able to pass all of their cost increase on to end-users (ref. Figure 2). Otherwise the firms would have earned more than normal profits in equilibrium.

The firm's fixed costs need to be aligned to the size of its organisation and are often industry-specific (given that some industries might require large investments in capital assets that call for a certain amount of minimum maintenance costs etc). Consequently costs reported and available in annual reports might not be easily comparable across firms, as depth of reporting varies. Given that all energy-intensive firms will be faced with decreasing CO_2 emission quotas from 2013 onwards and CO_2 emissions are directly related to use of burning carbon-intensive fuels, it is clear that operating costs will become under biggest scrutiny. Fuel makes up a considerable portion of the variable costs of energy-intensive firms and hence has a large impact on their total costs and ultimately, ability to generate revenue. According to academician Endel Lippmaa cost of oil shale or coal corresponds to 30-50% of today's electricity cost in Estonia; cost of natural gas even 70-80% (Lippmaa, 2011). Furthermore authors' own calculations based on selected firms' annual reports indicate that in energy-intensive industries variable costs make up around 80% of total costs and fuel costs correspond to around 80% of variable costs (see Annex 1).

In such setting, the research observes the listed 21 Estonian energy-intensive companies' variable costs and source of energy in 2008 and 2009, calculates CO_2 emissions and assesses impact on variable cost change through different price levels of CO_2 emissions in the future. CO_2 emission prices of €15, €25 and €50 per tonne are used to measure firms' cost elasticity with the aim of providing an insight into researched companies' economic activity if all CO_2 quota would have to be purchased at such rates (as opposed to free emissions quotas in 2008-2012) and fuel type remains unchanged. Variable costs of these 21 companies have been sourced from studying their annual reports both for 2008 and 2009; used fuels have been sourced from annual reports (if available) or using public sources and authors' prior interaction with the companies in question. Energy intensity and quantity of CO_2 from various fuels have been based on methodology developed in „Impact of CO_2 Trade on Electricity Producers Depending on the Use of Different Energy Sources in Estonia" (Kleesmaa, 2010) and "Methods for Determining the Carbon Dioxide Emissions into the Ambient Air" (Riigi Teataja, 2004); cost of energy is based on average fuel prices in 2008 and 2009 as published by the National Statistics Authority (Estonian Statistics Authority, 2011). Outcome of the research – i.e. change in variable costs from different levels of CO_2 emissions pricing – is indicated in columns 16-21 of Table 1. This has been calculated using formula (1) as follows:

$$(1) \quad \Delta VC_{i,j,n,e} = \frac{p_{CO2_e} \times CO2_j \times G_{i,j,n} \times Q_j}{VC_{i,j,n,e}} \times 100,\%$$

Where:

$VC_{i,j,n}$ is the variable cost

P_{CO2_e} is the cost of CO_2 emissions

$CO2_j$ is the multiple for special emissions

$G_{i,j,n}$ corresponds to the amount of fuel used

Q_j is the calorific value

Variable costs of observed companies ($VC_{i,j,n}$) are listed in columns 4 and 5 in Table 1. Each value is unique, whereas i stands for individual company ($i = 1, \ldots, 22$); n marks accounting year of variable cost ($n = 1,2$) so that $n=1$ stands for accounting year 2008 and $n=2$ accounting year 2009; and j represents type of fuel used ($j = 1, \ldots, 5$), where $j=1$ stands for oil shale, $j=2$ represents generator gas, $j=3$ is shale oil, $j=4$ is natural gas and $j=5$ represents peat.

Energy content of fuel type ($E_{i,j,n}$) in columns 8 and 9 of Table 1 has been calculated using formula (2):

$$(2) \quad E_{i,j,n} = G_{i,j,n} \times Q_j$$

Where:

$G_{i,j,n}$ – amount of fuel[3] in *metric tons*
Q_j – calorific value[4] in *MWh per metric tonne*

This serves as input to calculating Cost of Energy ($P_{i,j,n}$) shown in columns 10 and 11 of Table 1 using formula (3) as follows:

$$(3) \quad P_{i,j,n} = E_{i,j,n} \times p_{j,n}$$

Where:

$p_{j,n}$ – cost of fuel[5] in *EUR per MWh*

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[3] Calculations use data from plan for CO_2 emissions distribution published by Ministry of Energy, firms' annual reprots and authors' professional experience
[4] Databases and calculations from various sources (Ots, 2004; Mikk, 1997; Vares, 2005; Kleesmaa, 2010, 2011)
[5] Annual reports from National Bureau of Statistics in 2008 and 2009

CO$_2$ quantities ($G_{CO2_{i,j,n}}$) and monetary values ($P_{CO2_{i,j,n}}$) in columns 10-15 of Table 1 have been calculated using formulas (4) and (5) as follows:

(4) $G_{CO2_{i,j,n}} = CO2_j \times E_{i,j,n}$

Where:
$CO2_j -$ special emissions in *metric tonnes per MWh* [6]

(5) $P_{CO2_{i,j,n}} = G_{CO2_{i,j,n}} \times p_{co2_e}$

Where:
$p_{CO2_e} -$ cost of emissions quota[7] in *EUR per metric tonne*

and $= 1, \dots ,3$, whereas *e=1* stands for a price of 15 EUR per metric tonne; *e=2* stands for 25 EUR per metric tonne; and *e=3* stands for 50 EUR per metric tonne.

Special attention must be paid to oil production from oil shale: Eesti Energia's subsidiary Eesti Õlitööstus has no separate CO$_2$ emissions quotas in 2008-2012, which allows Eesti Energia to potentially cross-subsidise its production at the account of emissions from its other subsidiaries. This is likely to change in 2013 but has not been analysed in this research due to inseparability of data.

Main findings

The analysis clearly indicates vast differences between companies' variable cost change based on primary fuel type as summarised in Figure 3 below. In many ways the findings are as expected – if all CO$_2$ emissions quota would have to be bought on the free market then firms that use large quantities of fuel mix with high CO$_2$ content – such as oil shale or combination of oil shale with something else – would suffer highest cost increases. It also emerges from Figure 3 that variable cost increases from all other fuels (oil shale oil, natural gas, peat) would be in the range of around 5% regardless of type of fuel used.

Rather interestingly, companies using only natural gas would have a slight disadvantage over companies using oil from oil shale or peat. Both oil from oil shale as well as peat are domestically produced fuels whereas natural gas has to be wholly imported and is therefore more expensive (according to National Bureau of Statistics in 2009 natural gas cost €27 /MWh whereas the cost of oil shale was only €5/MWh[8]). At the same time processing of natural gas requires smaller fixed costs

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[6] (Kleesmaa, 2010, 2011)

[7] Numeric values have been given

[8] (Estonian Statistics Authority, 2011)

than that of other fuels and any change in cost patter will show up more dramatically in such companies' variable costs – which is also evident in observing companies annual reports. This in combination with higher fuel cost will hence explain higher values for use of natural gas.

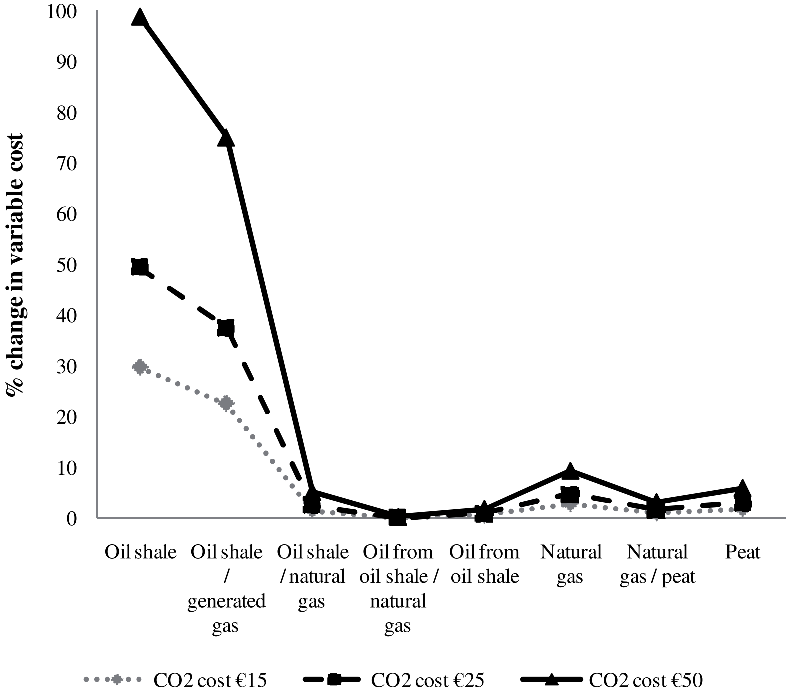

Figure 3. Average variable cost increase (%) from use of various fuel types (authors' calculations)

The results also convey another important message. Latõšov, Kleesmaa and Siirde (2010) have previously argued that it is tempting to look at cost increase in absolute terms, claiming that e.g. cost of using (imported) natural gas as a fuel is several times higher than that of using (domestically available) oil shale. According to authors, it is therefore important to look at relative cost change, where cost of using CO_2-priced oil shale could grow as much as 250% per MWh as opposed to 25% cost increase in natural gas (using €35 /tonne as a reference). As a result, both fuels would remain on roughly the same cost level per MWh (Latõšov, Kleesmaa, & Siirde, 2010).

Calculations performed in this research confirm the importance of measuring relative changes – in worst case scenario of €50 / tonne per CO_2 emission quota analysed firms' variable costs could be exposed up to a 100% change (if using oil shale as primary fuel). This is extremely important, as companies that have built their business model on the use of today-cheap oil shale (instead of e.g. focusing on use of natural gas) would face radical cost increase and without mitigating actions could easily go out of business. This in term changes the relative ranking of competitiveness of the host country, as was also indicated by Turner & Dack (1993) earlier.

The analysis has observed average cost increase for years 2008/2009. In the context of global economic slowdown, which started in late 2008 and has been declared more or less finished by 2010 (although this is a matter of definition), it is also interesting and relevant to observe cost changes for years 2008 and 2009 separately. In the case of Estonia, most companies were able to close accounting year 2008 with healthy business indicators; whereas sales dropped for most companies considerably during 2009. Such firms also bore lower variable costs in 2009 and resulting consequences are also evident in the analysis. Figure 4 below demonstrates that as firms have lowered their operating expenses and variable costs have fallen, CO_2 emissions have fallen too. This proves that a way of decreasing CO_2 related costs would be simply decreasing operations expenses – either by lower production volumes or more preferably, following advice from Groth & Kinney (1994) by changing the nature of activities, e.g. through introduction of energy efficiency.

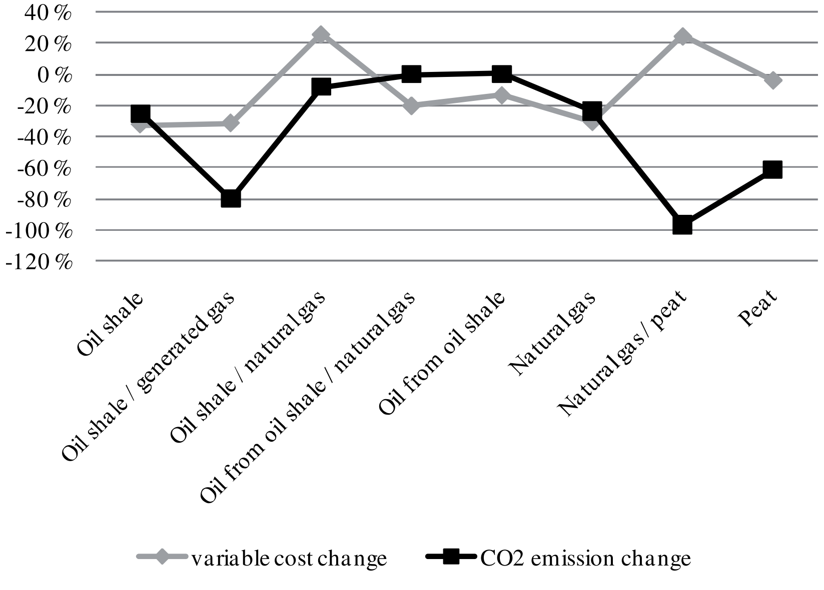

Figure 4. Changes in variable costs and CO_2 emissions from 2008 to 2009 (authors' calculations)

Some discrepancy might be explained by the fact that companies' CO_2 emissions are not audited by independent third-parties, meaning that companies have to be more-or-less trusted for validity of provided data. This situation is unique for Estonia in the context of European Union as all other countries demand audited CO_2 use from their companies.

The carbon emissions quota system divides companies into three broad categories: energy production; mineral industry (construction and production of construction materials); and other activities (mostly paper and pulp production). Hence the analysis has also focused on measuring effect from CO_2 emissions pricing on cost increases in these sectors (ref Figure 5).

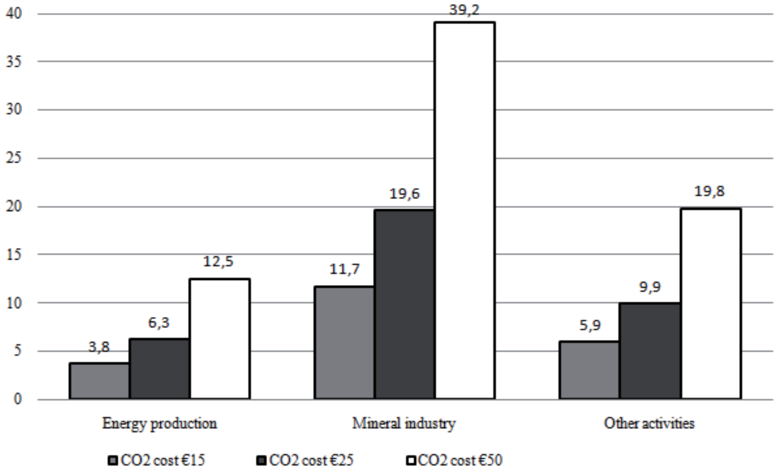

Figure 5. Forecast for change in variable costs across different sectors

As costs rise, competitiveness of economic sectors depends on intensiveness of CO_2 production, ability to forward cost increase to the sales price and measures taken to reduce carbon emissions in the production cycle. Estonian energy production sector is primarily characterised by generation of heat and electricity. Heat production is increasingly using less carbon-intensive technology, such as burning of bio fuels, and is hence smaller source of concern. Most of Estonia's electricity is today produced from burning domestically abundant oil shale. Investments are currently being made to upgrade oil shale pulverized burning boilers of energy blocks and meet stricter environmental standards after year 2016. Also completely new fluidized bed boilers of energy blocks are being built, using best technology available in the market. As a result it can be concluded that the overall change in variable costs from CO_2 emissions pricing in the Estonian energy sector is likely to remain relatively modest at around 5%.

Estonia's (energy-intensive) mineral sector comprises primarily producers of construction materials – bricks, glass and cement. Production of such materials is heavily carbon-intensive and existing technologies cannot easily be upgraded or replaced to less carbon-intensive alternatives. Consequently it is also visible from Figure 5 that of the three sectors biggest impact on cost change would take place there – in the range of 12 to 39%, most likely at around 20%. Given the intensive trade volumes in the construction sector as well as the fact that replacing existing technologies requires considerable investments which might not be attractive at current price levels there is a threat that production in this sector might be moved outside Estonia in the longer term.

In paper and pulp industry the effect is two times smaller from that in the mineral sector. Here cost increase might be more affected by increasing cost of electricity, which relates back to the discussion on the energy sector above. In this regard it also becomes important to note Estonia's complete opening of electricity markets in 2013, when all actors will be able to sell and buy their electricity in the open market Nord Pool spot.

Although Hussen (2004) argued that trading of emissions should encourage technological advances the trial and first trading periods of the EU ETS have not resulted in any major technological improvements. One explanation could be that the initial allocation was too large thereby putting a downward pressure on the price of allowances and reducing incentives for investments in new technology. Uncertainties about future allocation principles, too short trading periods and the threat of leakage are other potential explanations.

All these explanations are valid also for Estonia and hence continue to create uncertainty as to long-term competitiveness of the local energy-intensive industry – although some improvements are made in use of oil shale for electricity generation as described above. Given the country's small size, the local industry experiences significant lock-in effects because the size of the investment is too large and the savings would be too small. It might also be feared that the investment requires capital destruction because there is substantial life time left for the technology in use, and open market-based pricing creates limited possibilities especially in the non-energy sectors to pass on the costs of allowances to consumers.

Conclusion

This article takes the view that in a small open middle-income economy such as Estonia sales prices have to be taken as fixed (either by regulators or by the market itself), which leaves acting firms as price takers. In such situation, controlling costs is of vital importance to companies' competitiveness and thereby also to that of countries, which have vested interest in their companies' good financial health as tax base and employers.

The article has taken an in-depth look at the cost levels of all Estonian energy-intensive companies that are subject to CO_2 emissions registration. Authors take the view that such firms' total costs are largely influenced by their variable costs which are in turn heavily influenced by fuel costs. This assumption is effective regardless of field of activity, be it energy production or carbon-intensive manufacturing of goods. CO_2 emissions are distributed amongst companies for free only until end of year 2012. From 2013 onwards the total quantity of allowed emissions is set to start decreasing, which puts pressure on the price of CO_2 emissions tonne. This will have an impact on the companies' total fuel costs and thereby influence their overall level of competitiveness in open markets.

Calculations of such firms' cost elasticity for CO_2 prices at €15, €25 and €50 per tonne form the basis of this article. Not surprisingly, cost base is most vulnerable to firms that use large amounts of carbon-intensive oil shale as their primary fuel; whereas firms that use other sources of fuel – including mixed fuels – are less likely to be impacted. However importance of the analysis lies in the relative cost change measured – in case of using oil shale such firms' variable costs could increase up to 100% in the worst case scenario.

Although electricity producers rely heavily on oil shale for fuel, analysis demonstrates that in case of CO_2 priced at €25 per tonne actual variable cost change might only end up being around 5% for such firms. More alarmingly it is Estonia's carbon-intensive manufacturers from the mineral sector that become under threat as average variable cost increase reaches up to 20% at €25 per tonne. Since CO_2 emissions pricing is currently only introduced inside EU this means that direct competitors outside the EU will gain significant cost competitive advantage and these industries might move outside Estonia in the longer term. Such threat is less imminent in other industries such as paper and pulp production, where average variable cost changes up to 10% at €25 per tonne.

What is lacking from current research is measurement of profit margins. Some of the researched companies operate in niche markets where supply is scarce, meaning these firms could enjoy much higher profit margins. Hence they could also accept higher cost increases and still remain profitable. Possible variable cost increase as indicated in this study will need to guide decisions taken by the individual firms' management teams.

The findings also have implications for the governing sector, especially when it comes to large-scale users of oil shale. The state needs to analyse whether corrective actions are required to protect its firms yet still allowing for fair competition. This article therefore serves as a starting point for understanding potential cost increase from introduction of CO_2 emissions trading at various market rates and offer analysis material for decision-makers both at individual firm level as well as engaged policy makers.

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ANNEXES

Annex 1 – Illustrative indication of cost levels in selected Estonian energy-intensive companies in 2008

Name	**Activity**	**Total costs (1000 EUR)**	**Variable costs (1000 EUR)**	**Variable cost %**	**Fuel costs* (1000 EUR)**	**Fuel cost %**
Eraküte	Heat production	20 265	16774	83%	14 767	88%
Kunda Nordic Tsement	Cement manufacturing	52 337	46 487	89%	23793	52%
Tallinna Küte	Heat production	83 640	76 039	91%	66 572	88%
Wienerberger	Brick manufacturing	17 837	15 316	86%	6590	44%
Sangla Turvas	Peat briquette manufacturing	8927	8056	90%	6693	83%

Source: authors' calculations based on company annual reports 2008

* Due to use of different annual reporting structures it has not been possible to differentiate pure fuel costs in all cases. Figures are rough estimates.

CO_2 HEITMEKAUBANDUSE KVOODIHINNA KEHTESTAMISE MÕJU EESTI ENERGIA-INTENSIIVSETE ETTEVÕTETE KONKURENTSIVÕIMELE AASTAST 2013

Jüri Kleesmaa(a), Marko Viiding(b), Eduard Latõšov(a)
Tallinna Tehnikaülikool(a), Tartu Ülikool(b)

Euroopa Liidus CO_2 emissioonikoguste õigused on jaotatud tasuta energia-intensiivsete ettevõtete vahel kuni aastani 2013. Alates 2013. aastast arvatavasti lubatud heitkoguste kogused vähenevad survestades seega CO_2 emissioonikaubanduses kvoodihinda. Olukord omakorda mõjutab ettevõtete üldkulusid määrates nende konkurentsivõimet vabal turul. Artiklis analüüsitakse väikse keskmise sisetulekuga maa Eesti energia-intensiivsete firmade, mis kuuluvad Kyoto esimese kaubanduskeemi nimekirja, muutuvkulude elastsust sõltuvalt CO_2 hinnast skaalal 15, 25 ja 50 eurot tonni kohta.

Märtsis 2007 Euroopa Liidu juhid kiitsid heaks komplekslähenemise kliima ja energiapoliitikale, mis on suunatud tõhusa ja tasakaalustatud lahenduste käivitamisele vajalikus ulatuses kliimamuutustega toimetulemisele, Euroopa Liidu (EL) energiajulgeoleku kindlustamisele ja üheaegselt konkurentsivõime suurendamisele. See peab Euroopas aitama tagada kõrge energiaefektiivse ja madala süsinikusisaldusega majanduse loomisele. Hilisemalt sai see tuntuks kui „20-20-20“ eesmärk, mille saavutamisel EL liidrid kohustusid vähendama võrreldes 1990 aastaga kasvuhoonegaase 20%, 20% taastuvenergiat tarbimises ja 20% primaarenergia kasutamises.

Alates 2013 aastast jõustub ühtne üleeuroopaline heitmete piirmäär, mis vähendab ettevõtete heitmete kogust kuni 21% lähtudes 2005.a. tasemest kuni aastani 2020. Tasuta kvootide kogused senini eraldatud Euroopa Liidu riikide valitsuste poolt asendatakse järk-järgult heitmekogustega avalike oksjonite kaudu ja heitmekaubandusest osalevate sektorite hulka laiendatakse. Taoline nõue loob olukorra kus süsinik-intensiivne tööstus muutub emissioonikvootide piirmääras osalejaks ja tekib vajadus maksta täiendavat tasu saastamise eest, st rohkem kui planeeritud emissiooni kvoodid. Samuti mõned teised asjaosalised võivad emiteerida emissioone vähem planeeritust ning kasutavad võimalust müüa mittekulutatud heitmekvoote täiendava sissetuleku saamiseks.

Euroopa Liidu CO_2 kaubandus algas nn katse skeemiga aastal 2005 ja kestis kuni aastani 2007 ning toimus ainult EL liikmesriikide vahel. Uuendatud kauplemise skeem on nüüd asendatud heitmekvootide kaubandusega aastateks 2008-2012. Heitmekaubandus antud hetkel on toimiv ja muutusi läbitegev ning alates aastast 2013 toob ühtse üleeuroopalise kvoodi piirmäära, mis loob märkimisväärse määramatuse CO_2 kvoodihinna suhtes võrreldes aastaga 2012. Näiteks Deutsche Bank'i raportis 30 august 2010 prognoositakse 2020 aasta hinnaks 30 eurot tonn EL praegusest eesmärgist 20% emissiooni vähendamisest ja suureneb 37 euroni tonn kui eesmärki suurendatakse 30%-i. Samal ajal praegune ja edaspidine hind Euroopa

Kliimamuutuste Agentuuri poolt prognoosituna on 14,49 eurot tonn märtsis 2011 ja 22,50 eurot tonn detsembris 2020. Üldiselt, uus CO_2 emissioonikaubandus avaldab mõju ettevõtete konkurentsivõimele avatud turul.

Tulenevalt sellest võib tekkida olukord, et uus hind saab olema poliitiliselt moonutatud ja ei peegelda turu õigeid tingimusi, kui valitsus on huvitatud kaitsma oma ettevõtteid. Taolises olukorras saab kriitiliseks konkureerivate firmade kuluelastsus – kui palju täiendavat kulu peab firma kandma kuni ta kaotab oma konkurentsieelise. Tulemusena erasektorit koormab kogukulu kasv või kulu kasv kandub üle lõppkasutajale. Euroopa Liidu liikmesriigid võivad samuti otsustada kaitsta oma ettevõtteid kulukasvu eest olulise, asjakohase poliitikaga, aga see tõendab keerulist määratlust, et vabu ja õiglasi rahvusvahelisi reegleid ei saa rikkuda. Arvestades CO_2 hinna kujunemise uudsust ja taoliste diskussioonide kohta käivat vähest kirjanduse kättesaadavust eksisteerib vähene teadmine tänapäeva vajalikest poliitilistest abinõudest ja firma tasandil otsustest, mis lõppkokkuvõttes avaldab mõju taoliste energia-intensiivsete firmade konkurentsivõimele väikese sissetulekuga Euroopa Liidu liikmesriigis nagu Eesti.

Antud uuringus püstitatud ülesande täitmine nõuab juurdepääsu ja detailsemat analüüsi energia-intensiivsete firmade opereerimiskuludest. Uuring on limiteeritud 50 peamise energia-intensiivse Eesti firma analüüsiga ja diskuteerimisega CO_2 emissioonikulu võimalikust mõjust firmade üldkuludesse ning sellest lähtuvalt nende üldisesse konkurentsvõimesse. Eesti kontekstis on lubatud heitkoguste kaubanduse skeemis ettevõtted klassifitseeritud kolme suurde majandusharru. Energiatootmine, mineraalitööstus ja teised tegevused. Teiste tegevuste all on asetatud põhiliselt paberitootmisega tegelevad ettevõtted ja mineraalitööstuse alla tsemendi, kruusa, lubja jt toodete tootmine. Paljud nendest firmadest on peamised eksportijad või potentsiaalselt selleks saamas, kui näiteks elektriturg täielikult avaneb aastal 2013. Seega autorite arvates esitame küllaltki tähtsa teema arutlemiseks tehtud arvutuse ja analüüsi mudeli alusel, mis näitab, kuidas tulevased muutused võivad mõjutada Eesti konkurentsvõimet Euroopa Liidus.

Analüüsi tulemused näitavad, et firmad, kes kasutavad kütusena põlevkivi kui primaarenergiat on kergemini haavatavad kui firmad teiste või kombineeritult kütuste kasutajad, näiteks maagaas, põlevkiviõli, turvas või omavahel erinevate kütuste kombinatsioone moodustades.

Uuringu diskussioon põhineb lihtsal mikroökonoomilisel mudelil, milles ettevõtte kasum avaldub müügihinna ja muutuv- ning püsikulude vahena. Firma püsikulud võiks reastada organisatsioonide suuruse ja tihti tööstusliku orientatsiooni järgi – näiteks mõned tööstused võivad vajada suuri investeeringuid varade soetamiseks vajades selleks vaieldamatult teatud miinimum hoolduskulusid. Selguse mõttes ja konkurentsivõime hindamiseks täiendava CO_2 kvoodihinna mõju korral kriitiliselt hinnatud firmade püsikulud ei ole antud uuringus arvestatud.

Autorite uuring käsitleb ettevõtete muutuvkulusid majandusaasta aruannete andmete alusel eeldusel, et ükskõik milline muutus muutuvkuludes mõjutab otseselt firmade üldist kulude taset. Analüüsi teoreetilises käsitluses on juba muutuvkulude tähtsuse prioriteetsus tähelepanu keskmes ettevõtete lühiajalise firmakulu konkurentsivõime hindamisel. Autorite analüüs toob esile energiat genereerivate ettevõtete kulude struktuuris muutuvkulude suuruseks ca 80% üldkuludest ja kütuse osakaaluks muutuvkuludest ca 80%, mis on siiski hea indikaator kogukulu muutuse hindamisel sõltuvalt CO_2 emissioonikvoodi hinnast.

CO_2 emissioonikoguste hinnad 15, 25, 50 eurot tonni kohta on analüüsi aluseks ettevõtete kuluelastsuse hindamiseks eesmärgiga mõista uuritavate firmade majanduslikku aktiivsust olukorras, kus kogu nõutav kvoot tuleb osta vabaturult vastandlikult perioodiga 2008-2012. EL heitmekaubanduse nimekirja, vastavalt Euroopa Komisjoni otsusega, on määratud 50 Eesti ettevõtet. Samas majandusaasta aruanded nimekirjas esitatud ettevõtete kohta on vähem, kuna osa neist kuuluvad ühte gruppi ja aruanded esitatud konsolideerituna, seega uuringus analüüsitakse 21 firmat, millesse kuuluvad nii firmad gruppidena kui eraldi juriidiliste üksustena. 2008 ja 2009 aasta firmade majandusaasta aruannetest on analüüsis alginfona kasutatud muutuvkulusid ja kütuseid, mille kohta info saadaval. Täiendavalt arvestati autorite kogemusi ja avalike allikaid lähtematerjali kogumisel, koostamisel, analüüsis kasutamisel. Kütuste energiasisalduse ja CO_2 koguste arvutamise aluseks on metoodika, mis kinnitatud Keskkonnaministri määrusega aastal 2004. Kütuste hinnad baseeruvad statistikaameti andmetel ning ettevõtete muutuvkulud on arvutatud CO_2 emissiooni ja muutuvkulude väärtuste järgi.

Erilist tähelepanu tulevikus tuleb pöörata Õlitööstuse arengule, kuna praegusel hetkel Õlitööstus ei ole arvestatud Eesti mastaabis erinevate ettevõtete järgi täielikult CO_2 kaubanduse esimese perioodi 2008-2012 Kyoto skeemi. Samas võib olukord alates aastast 2013 muutuda ja tegemist saab olema arvestatavate CO_2 kogustega ning sellest tingitud majanduslike mõjudega.

Erinevate majandussektorite konkurentsivõime säilimine kasvavate kulude juures on mõjutatud sellest, kui intensiivne on CO_2 tootmine, milline on ettevõtte suutlikkus kanda lisanduvad kulud toote lõpphinda ning milliseid meetmeid rakendatakse kasvuhoonegaaside emissiooni vähendamiseks tootmistsüklis.

Eesti energiatootmise sektorit iseloomustab põhiliselt elektri ja soojuse tootmine. Põlevkivi tagab endiselt üle 90% Eestis toodetud elektrienergiast ja jääb veel põhikütuseks pikaks ajaks. Analüüs näitab, et ergitootmissektoris CO_2 hinna 25 eurot tonn juures muutuvkulude muutus moodustab ca 5%. Mineraalitööstuse sektoris moodustub muutuvkulude muutus juba ca 20%, mis oma olemuselt on hoiatussignaaliks, et selle haru tootmine võib liikuda Eestist välja. Paberitööstuses muutuskulude muutus jääb 10% piiresse.

Analüüsis on vaadeldud keskmise muutuvkulu tõusu aastatel 2008/2009. Arvestades maailmamajanduse langusperioodi, mis algas 2008 ja loodetavasti liigub tõusuteed aastast 2010 on oluline ja huvitav jälgida kulumuutust eraldi aastatel, st 2008 ja 2009. Eestit arvestades ja majandusaasta aruannetega tutvudes näeme, et enamik firmasid lõpetas 2008.a. äritegevuse positiivse saldoga, samas müük 2009 aastal langes. Need firmad kandsid madalamaid muutuvkulusid aastal 2009, kuid püsikulud jäid samaks. Analüüsist näeme, et firmade opereerimiskulude vähenemisega vähenevad ka muutuvkulud ning samuti vähenevad CO_2 heitmete kogused. Tulemus kinnitab lihtsat arusaama, CO_2 heitkogustest tingitud kulude vähendamine mõjutab otseselt ettevõtte majandustegevust – kas madalam toodangumaht või energiaefektiivsuse suurendamine.

Siin võib ka üheks põhjuseks välja tuua tõsiasja, et CO_2 koguste kontroll ei toimu akrediteeritud sõltumatu tõendajafirma poolt. Taoline süsteem on unikaalne Euroopas ja vajab muutmist, et anda suuremat kaalu CO_2 koguste tekkimise tõendamisele ja hilisemale kasutamisele heitmekaubanduse skeemis.

Appendix 6.

ELULOOKIRJELDUS

1. Isikuandmed

Ees- ja perekonnanimi	Jüri Kleesmaa
Sünniaeg ja –koht	28.06.1952 Väike-Maarja, Lääne-Virumaa, Eesti
Kodakondsus	Eesti

2. Kontaktandmed

Aadress	Kastani 16B-2, Tallinn, Eesti
Telefon	+371 5066357
E-posti aadress	juri.kleesmaa@ttu.ee

3. Hariduskäik

Õppeasutus (nimetus lõpetamise ajal)	**Lõpetamise** aeg	**Haridus** (eriala/kraad)
Tartu Ülikool	2002	Ärijuhtimine/Magister
Tallinna Polütehniline Instituut	1977	Soojusenergeetika/ soojusinsener
Tallinna Spordiinternaatkool	1970	Keskharidus

4. Keelteoskus (alg-, kesk- või kõrgtase)

Keel	**Tase**
Eesti	Emakeel
Inglise	Hea
Vene	Hea
Soome	Hea

5. Täiendusõpe

Õppimise aeg	**Täiendusõppe teema ja õppe korraldaja**
2010	Firmaväärtus. Version Koolituse OÜ
2010	Hoonete energiatarve ja sisekliima, EKVÜ
2006	Kasvuhoonegaaside tõendaja, EN-Vision (UK) LTd
2005	Volitatud soojustehnikainsener, ESTIS

6. Teenistuskäik

Töötamise aeg	**Tööandja nimetus**	**Ametikoht**
2009–…	ÅF-Estivo AS	Äri- ja arendusjuht
2006–2008	ÅF-Estivo AS	Ärisuunajuht, energeetikanõustaja
2004–2006	ÅF-Estivo AS	Müügijuht
2002–2004	Chemi-Pharm AS	Tegevjuht
1993–...	Pentagra OÜ	Juhatuse liige
1987–1993	Soojustehnika labor, TTÜ	Juhtivinsener, nooremteadur
1985–1987	EKE Tehnokeskus	Juhtivinsener, sektori juhataja
1980–1985	Tootmiskoondis LIVIKO	Projekteerija, tsehhijuhataja, kommertsdirektor
1977–1980	Dvigatel	Katlamaja vahetusinsener

7. Teadustegevus

Artiklid:

Kleesmaa, J. CO_2 kaubanduse mõju elektritootjatele erinevate energiaallikate kasutamisel Eesti tingimustes. Eesti majanduspoliitilised väitlused XVIII: XVIII majanduspoliitika teaduskonverents, Värska, 1.–3.07.2010. (Toim) Sulev Mäeltsemees (Tallinna Tehnikaülikool), Janno Reiljan (Tartu Ülikool). Berlin*Tallinn: Berliner Wissenchafts-Verlag, Mattimar, 121–139, 2010.

Latõšov, E., Kleesmaa, J., Siirde, A. The impact of pollution charges, ash handling and carbon dioxide to cost competitiveness of fuel sources for energy production in Estonia. Scientific proceedings of Riga Technical University. Environmental and Climate Technologies, 4(13), 58–63, 2010.

Kleesmaa, J., Pädam, S., Ehrlich, Ü. Subsidising renewable electricity in Estonia. In: Energy and Sustainability III: (Toim) Mammoli, A. A., Brebbia, C. A., Villacampa Esteve, Y. WIT Press, 2011, (Ecology and the Environment; 143), 229–241.

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Borovikov, V., Kleesmaa, J., Tiikma, T. 2005. Analysis of experimental results of sonic cleaning system in oil shale boiler. Oil Shale, 22(4), 475–485.

Kleesmaa, J., Kruus, H., Tiikma, T., Vaht, A. 1999. Iru Elektrijaama aurukatla nr. 2 konvektiivsete küttepindade akustilise puhastuse efektiivsus. Keskkonnatehnika nr 6, lk 26–29.

8. Kaitstud lõputööd

Magistritöö: „Katla akustilise puhastussüsteemi juurutamise tasuvusuuring", 2002. Juhendaja Helje Kaldaru, MBA, TÜ.
Diplomitöö: „Gaasiturbiinseadmel TG-16M põhineva laboratoorse katsestendi projekteerimine koos koormusseadmega", 1977. Juhendaja Dmitri Jegorov, Soojusenergeetika, TPI.

9. Teadustöö põhisuunad

Süsinikdioksiidi (CO_2) kaubandus.
Energeetilistes katELdes vääveldioksiidi (SO_2) vähendamise meetodid.
Energiamahukate ettevõtete majandustegevuse analüüs.
Elektritootmisele kohaldatavate toetuste analüüs.
Kütuste hindade prognoos lühi- ja pikas perspektiivis.

10. Teised uurimisprojektid

Konsultatsioonid:

2011, Eesti Tuuleenergia Assotsiatsioon, Tallinn
Väikeste elektrituulikute pakettlahendused

2010, Kohtla-Järve Soojus AS, Ahtme
Ahtme elektrijaama jätkusuutliku arengu uuring peale aastat 2010

2010, Konkurentsiamet, Tallinn
Katlamajade maksumuse, tehnilise lahenduse ja tegevuskulude eksperthinnang

2010, Merko, Tallinn
Eesti koostootmisjaamade rajamise võimalused

2010, VKG Energia OÜ, Kohtla-Järve
Jõhvi-Ahtme soojusvarustuse äriplaan

2010, Majandus- ja Kommunikatsiooniministeerium, Tallinn
Energiasäästupoliitika tulemuslikkuse analüüsi meetodite määramine

2010, AS Viisnurk, Pärnu
AS-i Viisnurk koostootmisjaama ehitamise eeluuring

2010, AS Eraküte, Tartu
AS-i Eraküte Tartu võrgupiirkonna soojuse ja elektri koostootmisjaama eelhinnang

2009–2010, Eesti Energia Kaevandused, Narva
Feasibility Study Regarding the Handling and Storage of Oil Shale, Biomass and Rubber Chips at Eesti Power Plant

2009–2010, Narva Õlitehas, Narva
TSK-140 utilisatsioonkatla moderniseerimine ja hankekutsedokumentide ettevalmistamine

2009–2010, Narva Elektrijaamad, Narva
Põlevkivi tolmpõletuskatla väävliühendite (SO_2) vähendamine primaarmeetoditega

2009–2010, Konkurentsiamet, Tallinn
Katlamajade maksumuse, tehnilise lahenduse ja opereerimiskulude eksperthinnang

2009–2010, Tartu Elektrijaam, Tartu
Tartu elektrijaama lisajahutussüsteemi hankedokumentatsiooni ettevalmistus ja omaniku inseneriteenused

2009, Eesti Energia, Tallinn
Gaasimootoril põhineva koostootmisjaama tehnokirjeldus

2009, 4-Energia, Tallinn
Maardu hüdroakumulatsioonjaama eeluuring

2009, Gas Power, Tallinn
200 MW_{el} võimsusega gaasiturbiinelektrijaama rajamise eeluuring

2009, Dalkia, Jõgeva
Jõgeva linna soojusvarustuse analüüs ja AS-i Eraküte Jõgeva katlamajas kohaliku kütuse kasutusele võtmise eeluuring

2009, Eesti Energia AS, Tallinn
Narva 2 x 300 MW_{el} energiaplokkide hankekutsedokumentide ettevalmistamine

2008, Eesti Energia Põhivõrk, Tallinn
Eesti Energia Põhivõrgu gaasiturbiinelektrijaama ehitamise eeluuring

2007–2008, Iru Elektrijaam, Maardu
Iru jäätmeenergiaploki teostatavuse uuring

2007–2008, Tartu Elektrijaam, Tartu
Tartu KTJ-i jäätmeenergiajaama teostatavuse uuring

2008, AF Consult Oy, Soome
Põlevkivituha transpordisüsteemi renoveerimise multikriteeriumide analüüs

2007–2008, Narva Elektrijaamad, Eesti
AS Narva Elektrijaamad energiakompleksi arendusprojekti keskkonnamõjude hindamine (KMH) ja keskkonnamõjude strateegiline hindamine (KSH)

2006–2007, Narva Elektrijaamad, Narva
Eesti Elektrijaama soojusvarustussüsteemi rekonstrueerimine

2006, Eesti Energia, Tallinn
Eesti eri piirkondades koostootmisjaamade ehitamise eeluuring

2006–2007, Tartu Ülikool, Kääriku
Kääriku Spordibaasi energiamajanduse arendus

2006, Vesmann OÜ, Saaremaa
Eeluuring. Rohtpelletite valmistamise võimaluste uuring

Appendix 7.

CURRICULUM VITAE

1. Personal data

Name	Jüri Kleesmaa
Date and place of birth	28.06.1952, Väike-Maarja, Lääne-Viru County, Estonia

2. Contact information

Address	Kastani 16B-2, Tallinn, Estonia
Phone	+372 5066357
E-mail	juri.kleesmaa@ttu.ee

3. Education

Educational institution	Graduation year	Education (field of study/degree)
Tartu University	2002	MBA / M.Sc.
Tallinn Polytechnic Institute	1977	Thermal Power Engineering / M.Sc.
Tallinn Sport Boarding-School	1970	High school education

4. Language competence/skills (fluent, average, basic skills)

Language	Level
Estonian	Mother tongue
English	Good
Russian	Good
Finnish	Good

5. Special Courses

Period	Educational or other organisation
2010	Company's Value, Version Training OÜ
2010	Buildings Energy consumption and inside climate, EKVÜ
2006	GHG Verification, EN-Vision (UK) Ltd
2005	Authorized Thermal Power Engineer, Estonian Association for Heat Engineers

6. Professional Employment

Period	Organisation	Position
2009–…	ÅF-Estivo AS	Business and development manager
2006–2008	ÅF-Estivo AS	Business manager
2004–2006	ÅF-Estivo AS	Sales manager
2002–2004	Chemi-Pharm AS	Manager
1993–...	Pentagra OÜ	Member of Board
1987–1993	Thermal Power Laboratory, TTY	Engineer, junior scientist
1985–1987	Technical Centre of EKE	Leading Engineer, manager of sector
1980–1985	LIVIKO Group	Designer, chief of department, sales manager of Group
1977–1980	Dvigatel	Boiler house engineer

7. Scientific work

Published articles:

Kleesmaa, Jüri. Impact of CO_2 trade on electricity producers depending on the use of different energy sources in Estonia. In: Estonian Economic Policy Debate XVIII: XVIII Economics Policy Conference, Värska, 1.–3.07.2010. Berlin*Tallinn: Berliner Wissenchafts-Verlag, Mattimar, 121–139, 2010.

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Borovikov, V., Kleesmaa, J., Tiikma, T. 2005. Analysis of experimental results of sonic cleaning system in oil shale boiler. Oil Shale, 22(4), 475–485.

Kleesmaa, J., Kruus, H., Tiikma, T., Vaht, A. 1999. Effectiveness of acoustic cleaning system of heat surfaces of steam boiler at Iru Power Plant. Environmental Technique, no 6, p 26–29.

8. Defended thesis

Master Thesis: Feasibility Study of Implant of Boiler Sonic Cleaning System, 2002, Supervisor Helje Kaldaru, MBA, TÜ.
Diploma work: Design with load device of laboratory testing display unit based on gas turbine equipment, 1977, Supervisor Dmitri Jegorov, Thermal Power Engineer, TPI.

9. Main areas of scientific work/Current research topics

Carbon dioxide (CO_2) trade.
Sulphur dioxide (SO_2) reduction possibilities with different methods in energetic boilers.
Analysis of energy intensive industry economical activity.
Analysis of subsidising systems of electricity production.
Prognosis of fuel prices in short and long terms perspective.

10. Other research projects

Consulting Assignments:

2011, Wind Power Cluster, Tallinn, Estonia
Study about small wind power units support schemes in selected countries over the world and overview about Estonian situation from this point of view

2010, AS Kohtla-Järve Heat, Ahtme
Ahtme PP function extension after year 2010

2010, The Ministry of Economic Affairs and Communications , Tallinn
Study about developing of monitoring system of energy saving policy

2010, VKG Energia OÜ, Kohtla-Järve
Business plan of VKG Energy about heating supply of Jõhvi-Ahtme

2010, Competition Department of Estonia, Tallinn
Expert estimation about boiler houses costs, technical solutions and operating costs

2010, Merko Ltd, Tallinn
Research work of possibilities to establish CHP in Estonia

2010, Viisnurk Ltd, Pärnu
Pre-feasibility study of establishing CHP at AS Viisnurk

2010, Eraküte Tartu Ltd, Tartu
Feasibility study of establishing CHP at AS Eraküte Tartu network area

2009–2010, City Tallinn, Tallinn
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2009, EE Shale Oil Industry Ltd, Auvere
Modernization of TSK-140 unit's utilization boiler and TED document preparation

2009, EE Narva PP Ltd, Auvere
Oil Shale pulverized boilers SO_2 concentration reduction with primary methods

2009, OÜ Energiasalv, Tallinn
Maardu Hydro accumulation pump-station pre-feasibility study

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Multicriteria analysis

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2008, Grüne Fee Ltd, Tartu
Study about energy usage

2007–2008, Tartu KTJ, Tartu
Feasibility study of Waste to Energy PP at Tartu

2007–2008, Iru PP Ltd, Maardu
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2007–2008, Oil Factory of Narva, Narva
Tender Documents of EPCM of Oil Factory

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Environment Impact Assessment (EIA) and SEIA of Energy Complex of Narva PP and clarification subject with Bankengruppe KFW of Germany according to IFC standards

2006, Tartu University, Kääriku
Study of Sport Sector energy supply

2006, Vesmann OÜ, Saaremaa
Study for usage of biomass

2006, Estonian Energy Ltd, Tallinn
Pre-feasibility study of different regions of Estonia for CHP building

KOKKUVÕTE

Keskkonnaregulatsioonide majanduslikud meetmed elektri tootmisel Eestis

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Euroopa Liit, mille koosseisu 1. maist 2004 kuulub ka Eesti, on seadnud energia kasutamise alal oma peamiseks eesmärgiks kujundada lähimatel aastakümnetel ühtne energia- ja keskkonnapoliitika, mis põhineb selgetel püüdlustel ja ajakaval üleminekuks süsinikuvaesele nn rohelisele energiamajandusele ja energia säästmisele. Energia otstarbekohasema kasutamise tingivad ka fossiilsete energiaallikate kasutamisega kaasnevad suuremad keskkonnamõjud võrreldes bioenergiaga.

Euroopa Komisjon eeltoodud ülesannete lahendamiseks esitas Euroopa energiapoliitika dokumendi COM(2007) 1 (Brüssel 2007) eesmärgiga suurendada Euroopa Liidu energiavarustuse kindlust, julgeolekut, konkurentsivõimet ja võidelda kliimamuutuste vastu. Kavandatud eesmärkide saavutamiseks võttis Euroopa Komisjon 2009. a vastu olulised regulatsioonid, millega täiustati ja laiendati ühenduse kasvuhoonegaaside saastekvootidega kauplemise süsteemi, edendatakse taastuvatest energiaallikatest toodetud energia kasutamist ja primaarenergia tarbimist aastani 2020.

Vastavalt Euroopa Liidu vastu võetud keskkonnaregulatsioonidele on Eesti loonud vabariikliku õigusruumi rohelise energiamajanduse edendamiseks ja energia säästlikumaks kasutamiseks.

Eesti elektritootmine baseerub põhiliselt põlevkivienergial, st umbes 90% Eestis kokku toodetud elektrienergiast moodustab kohalikust kütusest põlevkivist toodetud elektrienergia. Kuigi põlevkivi kasutamine elektritootmiseks Eesti kontekstis on kohaliku kütuse ja energiajulgeoleku seisukohast vajalik, siis keskkonnakaitsest lähtuvalt on see kõrgete emissioonitegurite tekitamisega keskkonda koormav.

Euroopa Liit seab oma keskkonnaalaste regulatsioonidega Eesti ette küllaltki keerulised ülesanded põlevkivielektri asendamiseks teiste energiaallikatega, mis vajavad oskusi nii tehniliselt kui ka majanduslikult otstarbekaid otsuseid vastu võtta.

Kuna Eesti elektritootmine täna ei kindlusta Euroopa Liidu seadusandlusega määratud keskkonnanõudeid ja Eesti viib sisse parasjagu erinevaid reguleerimisviise, mis peaksid neid täitma, siis lähiajal on elektritootmises oodata suuri muutusi.

Käesoleva viit artiklit ühendava artikli eesmärk on uurida majanduslikke ja keskkonnareguleerimise mõjusid Eesti elektritootmisele perspektiivis aastani 2020. Artikkel hõlmab nelja meedet: süsinikdioksiidi heitkoguse ühikutega kauplemist, soodustariife, keskkonnatasudega (sh tuhakäitlus ja emissioonidest tingitud kulu) kaasnevat kulu ning tööstusheidete piirnormide mõju elektri tootmisele. Iga esitatud uurimus on keskendunud konkreetsele juhtumile, kuid siduvaks teemaks uurimuste vahel on regulatsioonide mõju elektritootmisele Eestis.

Kokkuvõtva artiklitel baseeruva töö uurimisobjektiks on Eesti elektritootmine ja seadusandlike aktide mõju selle struktuuri kujundamisele aastani 2020. Lisaks uuritakse ka muid, elektritootmisega mitteseotud energiamahukaid ettevõtteid seadusandlike aktidega loodud uues tegutsemiskeskkonnas.

Elektritootmise parima stsenaariumi valik avaldub suuresti CO_2 kaubanduse mõju tulemusena, mis reguleerib lubatud heitkoguste kvootide hulgaga elektritootmise portfelli mitmekesistamist kuluefektiivselt, võimaldades omakorda ergutada tehnilist arengut.

Kütuste tootmisharu konkurentsivõimet mõjutab keskkonnatasude üha suurenev määr. Elektritootmisele kinnitatud soodustariif on taastuvenergia kasutuselevõtu tõhususe perspektiivist lähtudes põhjendatud, kuid see mõjutab põhjendamatult palju tarbijahinda ja on ülekompenseeritud jaama võimsust arvestades.

Euroopa Liiduga liitumislepingus on fikseeritud kohustus piirata 2012. aastast alates SO_2 heitmeid 25 000 tonnini aastas. Töötusheitmete direktiiv kohustab oluliselt vähendama 2016. aastast alates atmosfääri eriheitmete SO_2, NO_x ja lendtuha emissioone. See piirab elektritootmist Eestis.

Elektritootjate traditsiooniline arusaam keskkonnaregulatsioonidest nagu atmosfääriheitmete piirnormid, saastetasud ja kasvuhoonegaaside kaubanduse lubatud heitühikute kvoodid on, et need mõjutavad firmade konkurentsivõimet, piiravad elektritootmist ja on elektritootmise seisukohalt pärssivad ning mitteproduktiivsed. Atmosfääriheitmete piirnormid seavad rangeid nõudeid tehnoloogia kasutamisele, saastetasud ja kaubanduskvoodid sunnivad atmosfääriheitmetega tegelema ning avaldavad mõju tootmisprotsessi kõrvalsaadustele, mis eelnevalt olid regulatsioonide mõjust vabad.

Konkurentsivõime reguleerimisel keskkonnaregulatsioonidega on majandusteadlaste käsitlusel põhimõtteliselt kaks suunda: esimene väidab, et keskkonnareguleerimine on konkurentsivõimele kahjulik (Oates, Palmer & Portney, Simpson 1993) ning teine suund kinnitab, et keskkonnareguleerimine parandab konkurentsivõimet juhul, kui see on mõistlikult rakendatud (Porter & van der Linde, 1995). Empiirilised tulemused ei poolda ühte ega teist (Lanoie 2008). Antud uurimuse tulemused viitavad võrdlemisi väikestele muutustele energiatootmises.

Elektrijaama toodang sõltub aasta turusituatsioonist ja seepärast on keeruline aasta elektritoodangu mahtu prognoosida. Elektrituru regulatsioon peab tagama Eesti tootmise struktuuri mitmekesisuse. Meil jätkub endal tootmisvõimsust ilma rangete keskkonnaregulatsioonideta, kui mujalt pole võimalik elektrit odavamalt osta. Siiski tekib ka odavama elektri sisseostmise korral – näiteks Venemaalt – õigustatud küsimus, kas vastavussertifikaat on nõuetekohane. Vabaturul, kus kolmandatest riikidest imporditakse odavamat elektrit ja neile ei rakendu

Euroopa Liidu süsinikupuhta elektritootmise nõuded, on elektritootjad ebavõrdses konkurentsis.

2020. aastaks tehtud prognooside kohaselt, täiendavalt arengukavas toodud aastani 2018, peaks olukord põhimõtteliselt muutuma: põlevkivil rajaneva elektritootmise osatähtusus väheneb umbes 40%-ni, taastuvenergia osatähtsus aga suureneb ligikaudu 31%-ni.

Euroopa Liidu kasvuhoonegaaside kaubanduse direktiivist lähtuvalt seab elektrimajanduse arengukava parim stsenaarium uued tingimused kütuste kasutamisele – keskkonda saastavamad kütused nagu põlevkivi ja turvas tõrjutakse kütuseturult ja asendatakse keskkonnasõbralikumate kütustega nagu taastuvad energiaallikad ja looduslik gaas. Analüüs näitab, et ilma keskkonnaregulatsioonideta on soodustatud kütuste kasutuse järjestus hinna järgi järgmine – põlevkivi, puit, turvas, looduslik gaas. Kui hinnale lisanduvad keskkonnatasud ja CO_2 kvoodihind, siis kasutusjärjestus muutub – puit, turvas, põlevkivi ja looduslik gaas. Regulatsiooni tulemusena langeb eelistus taastuvate kütuste kasutuselevõtule võrreldes fossiilsete kütustega.

Kulude suurenedes sõltub majandussektori konkurentsivõime CO_2 eraldumise intensiivsusest, võimalusest kanda lisanduvad kulud üle müügihinnale ning tootmistsüklis süsinikuheitmete vähendamiseks rakendatud meetmetest. Eestis toodetakse enamik elektrienergiat kohalikust põlevkivist, mida on külluses. Praegu investeeritakse energiaplokkide põlevkivi tolmpõletuskatelde moderniseerimisse ja püütakse selle poole, et täita pärast 2016. aastat kehtima hakkavaid rangemaid keskkonnanõudeid. Energiaplokkidele ehitatakse uusi keevkihtkatlaid, kus rakendatakse parimat turul saadaolevat tehnoloogiat. Seda arvestades võib järeldada, et CO_2 heitmete hinnast tulenev muutuvkulude üldine muutus Eesti energiasektoris võib jääda suhteliselt tagasihoidlikuks: 5% lähedale.

Kuigi Hussen (2004) väitis, et heitmekaubandus peaks soodustama uudse tehnoloogia kasutuselevõttu, ei ole Euroopa Liidu heitmekaubandussüsteemi katsetamise ajal ega esimestel kauplemisperioodidel suuremaid tehnoloogilisi uuendusi tehtud. Üheks selgituseks võib olla asjaolu, et esialgu jagati kvoote ülemäära palju. See surus kvoodi hinna alla ega virgutanud investeerima uude tehnoloogiasse. Muude põhjustena võib nimetada tuleviku jaotuspõhimõtete suhtes valitsevat määramatust, liiga lühikesi kauplemisperioode ning süsiniku lekkeohtu.

Taastuvelektri tootmiseks makstavate toetuste süsteem on Eestis tõhusalt toetanud koostootmisvõimsuste rajamist – kui 2007. a oli taastuvatest energiallikatest toodetud elektri osakaal 1,75% kogu elektrienergia tarbimisest, siis 2010. aastal moodustas see juba 9,7% kavandatud 5,1%-i asemel. Halduskulud on olnud väikesed ning säästetud välismõjudest tingitud kulud on ületanud toetuse suuruse: välismõjust tingitud kulu põlevkivi kasutamisel on 69,2 eurot megavatt-tunni kohta, puitkütusel ja turbal vastavalt 9,7 ja 25,8.

Siiski on Eesti toetused suurenenud kiires tempos 0,1 eurosendilt kilovatt-tunni kohta 0,8 eurosendile kilovatt-tunni kohta aastatel 2007 kuni 2010 ning tarbijad on need kulud kollektiivselt kinni maksnud, samal ajal kui tulu saavad suured koostootmisjaamad. 2007 ja 2011 on toetuste juurutamisega seotud kulu kasvanud 6 miljonilt eurolt 55 miljoni euroni. Need kulud katab tarbija elektri hinna kaudu. Toetusega kaasnev kulu moodustas 2010. a umbes 10% tarbija eelarvest.

Peale jaotusega seotud probleemide on muidki põhjusi toetuse kasutamise kohta. Kahe koostootmisjaama kohta tehtud uurimus koostootmisjaamade elektritootmise keskmise kulu ja omahinnaga on näidanud, et praegune toetuste süsteem ei ole tõhus. 2010. aastaks seatud eesmärgid on ületatud ja tõhususe seisukohast ei saa seda pidada kuluefektiivseks. Uurimustulemustest selgub veel, et ressursse kasutatakse sellise tootmise toetamiseks, mis on ka toetuseta tulus (IRR 19%) (Kleesmaa jt 2011).

Kuigi praegused toetused on halduse seisukohast atraktiivsed, saab jaama suurusest sõltuva omahinna suurte erinevuste alusel väita, et toetusi on vaja eristada jaama suurust arvestades. Alla 10 $\mathrm{MWh_{el}}$ (Latõšov 2011) võimsusega koostootmisjaamade omahind on tunduvalt kõrgem kui suurtel jaamadel ning et mida väiksem on jaam, seda kiirem on omahinna tõus. Toetuse lahutamisel omahinnast muutub pilt veelgi huvitavamaks: toetus katab 25 $\mathrm{MWh_{el}}$ võimsusega jaamade elektri tootmise omahinna ning kui toetus välja jätta, sarnaneb jaama omahind toetust saava 4 $\mathrm{MWh_{el}}$ võimsusega jaama omahinnaga.

Need tähelepanekud kinnitavad uurimistöö tulemusi ja viitavad sellele, et praegu kehtivat toetust saades on suured jaamad ülekompenseeritud, toetus väikestele jaamadele ei pruugi aga olla piisav.

Subsiidiumide ja maksude ning muude hinnakujundusmeetmete suurim puudus on see, et nende mõju ulatus ei ole selge. Eestis nagu paljudes teisteski Euroopa Liidu riikides kasutatakse toetusi kvantitatiivsete eesmärkide saavutamiseks. Eesmärgiga sobivat toetust ei ole kerge valida ja seepärast on vaja toetuste regulatsioon uuesti läbi vaadata. Läbivaatamine toob paratamatult kaasa investeerimisprobleemid. Seega on toetuspõhise reguleerimise puhul vaja leida kompromiss läbivaatamisest tulenevate probleemide ja kulukate toetuste jätkuva maksmise vahel.

Euroopa Liidu energiapoliitika kinnitatud energia- ja kliimapaketiga aastateks 2013–2020 määrati eesmärgiks 20%-ne kasvuhoonegaaside (töös käsitletud ainult CO_2) vähenemine, taastuvenergia osatähtsuse suurenemine 20% võrra ja primaarenergia tarbimise vähenemine 20% ulatuses.

Vastuvõetud keskkonnaregulatsioonide mõju tulemusena viie uurimistulemuse alusel saab järeldada, et Eesti elektritootmises on oodata suuri muutusi, mille tulemusena kaks püstitatud eesmärki – CO_2 vähendamine ja taastuvenergia kasutamise suurendamine 20% ulatuses – on saavutatavad aastaks 2020.

Regulatsioonid avaldavad enim survet kohalikust kütusest põlevkivist toodetud elektrile, kuna põlevkivi keemilis-füüsikaliste omaduste tõttu on see kütus ümbritsevat keskkonda koormav.

Euroopa Liidu poolt käivitatud CO_2 kvoodikaubandusel on suur mõju Eesti elektritootmise portfelli mitmekesistamisel. Eelistatumad on CO_2-vabad energiaallikad nagu puit ja tuul.

Taastuvkütustest soosituimaks osutub puit ja fossiilsetest gaaskütus. Turbakütuse laialdasemat kasutamist elektritootmisel piiravad tema kõrge CO_2 emissioonimäär, suur tuhasisaldus ja pikaajaline looduslik taastumine. Teisalt on turvas kohalik kütus, elektritootjale turbast ektritootmise tõhusal režiimil makstakse toetust 32 eurot megavatt-tunni eest ja aktiivne varu tööstuslikuks kaevandamiseks on 775 miljonit tonni.

Toetuste juurutamisele avaldavad positiivset mõju taastuvenergia õigusaktid. Tehnoloogia arendamise seisukohalt jääb regulatsioon neutraalseks, sest uut tehnoloogiat ei arendata, vaid kasutusele võetakse juba olemasolev.

Tööstusheitmete direktiiv seab keerulisse olukorda põlevkivi tolmpõletuse tehnoloogiaga toodetava elektri. Juhul kui aastaks 2016 ei ole energiaplokid varustatud vajalike puhastusseadmetega, mis tagavad direktiivist tulenevate nõuete täitmise, siis tuleb plokid sulgeda. Taoline olukord aktiveerib energiaettevõtete juhtide, spetsialistide ja teadlaste tegevust lahenduste leidmisel, et tagada energiaplokkide töö ka peale 2016. aastat.

Keskkonnatasude pidev suurendamine mõjub Eesti elektritootmisele soodsalt. Kui 1990-ndate alguses oli keskkonnatasude mõju nn tähelepanu juhtiv, siis tänapäeval mõjutab nende suurus ettevõtete juhte keskkonnakaitse seisukohast lähtuvalt tootmisprotsessi rohkem analüüsima kütuste eelistuse järgi, juurutama uut tehnikat emissiooni vähendamiseks ja tegelema toodangu kulukohtadega konkurentsvõime tagamisel.

Põlevkivienergeetika tulevik sõltub sellest, kuidas suudame täita euronõudeid ökoloogias. Kui suudame seda teha odavamalt kui kivisöejaamad (Öpik 1987), tagame põlevkivienergeetika jätkusuutlikkuse Eestis. Kui aga asume kivisöejaamade ökoloogilisi tehnoloogiaid kopeerima, nõuab see poolteist korda suuremaid investeeringuid ja lisab 30% riski.

ABSTRACT

The goal of this article is to serve as a connecting link between five articles in order to put into perspective and to study economic and environmental effects of electricity production in Estonia until the year 2020. The article embraces four measures: trading in the carbon dioxide emission quotas, Feed-in-Tariffs, costs originating from environmental charges (including ash handling and emission-related costs) and the impact of industrial emission limit values on electricity production. Every presented research work focuses on a certain case study; whereas the effects of regulations on the electricity production in Estonia form a connecting theme between these research works.

The object of the research work based on the above referred to articles is Estonian electricity production and the effect of legislative acts on the shaping of its structure until the year 2020. In addition, other energy-intensive enterprises not related to electricity production are observed in a new activity environment created due to the application of legislative acts.

The main research tasks are, on the assumption that the best scenario of the Development Plan of the Estonian Electricity Sector will be implemented, to give a quantitative assessment of the CO_2 emission by taking into account actual operation hours, and to compare the result with the objective set out in the EU Greenhouse Gas Emission Trading System; to assess the impact of additional costs arising from environmental charges, ash handling and the price of CO_2 quota on the competitiveness of the industries of such fuels as oil shale, wood, peat and natural gas in the fuels market in 2015; to assess, on the basis of the economic activities of two power plants, the application of Feed-in-Tariffs, and to explain whether the current tariff is justified from the perspectives of efficiency and economic productivity, and how it influences consumer prices; to analyse the possibilities of using the primary method BLW for the purpose of achieving the permitted SO_2 emission level established in the European Union environmental regulations for oil shale combustion.

Based on the results of five research works, it can be concluded that, due to the effect of the adopted regulations, great changes are expected to take place in Estonian electricity generation. Regulations have the greatest pressure on the electricity produced from the local fuel oil shale. The CO_2 quota trade launched by the European Union has a large impact on the diversification of the electricity production portfolio. Such CO_2-free energy sources as wood and wind have a more preferable position. Wood appears to be the most favourable fuel among renewable fuels, and gas fuel the most favoured fuel among fossil fuels. Peat with its large CO_2 emissions and ash content, slow natural process in the nature makes utilization complicated, but electricity production based on peat fuel receives FIT, is local fuel and has sufficient reserves. Legislative acts on renewable energy influence the introduction of supports in a positive way. The regulation remains neutral from the perspective of technological development, since no new technology is being developed; instead the existing technology is being made use of. The directive on industrial emissions puts the pulverised oil

shale combustion technology-based electricity production into a complicated situation. If, by 2016, energy units are not supplied with necessary cleaning equipment, which ensures fulfilment of the requirements arising from the directive, the relevant units will have to be shut down. Such a situation motivates the management teams of energy enterprises, specialists and researchers to take action for finding solutions, in order to guarantee the operation of energy units after 2016. A continuous increase in environmental charges has a favourable impact on Estonian electricity production. At the beginning of the 1990ies the aim of environmental charges was to draw attention to the topic, but at present the size of charges influences management teams of enterprises towards carrying out more in-depth analysis, from the perspective of environmental protection, of their production process by preference of fuels, towards introducing new technology with the aim of reducing emission, and towards dealing with production-related expenses in order to ensure competitiveness.

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