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ECO-INDICATORS OF ENVIRONMENTAL IMPACT FOR LATVIAN POWER SUPPLY SYSTEM

LATVIJAS ELEKTROAPGĀDES SISTĒMAS IETEKMES UZ VIDI EKO-INDIKATORI

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Introduction

Latvia uses a broad mix of fuel and technology sources to generate electricity. The combination of energy sources used is referred to as the generation mix. More than half of the Latvia's electricity is generated from hydropower. Natural gas fuel produces over forty-two percent of the generation. Wind power provides nearly one percent of the electricity generation and other renewable resources – such as landfill biogas, and biomass – provide also nearly one percent of the generation mix (Fig. 1). Electricity constitutes a critical input in sustaining Latvia's economic growth and development as well as the well-being of its inhabitants. While the growth of total energy demand per capita has practically deceased since the beginning of 1992, the electricity demand per capita is steadily growing [1]. It is expected that the role of electricity will be even more important for the future service economy. To determine their generation mix, Latvian power industries have understandably focused on price, availability and reliability and less on environmental considerations.

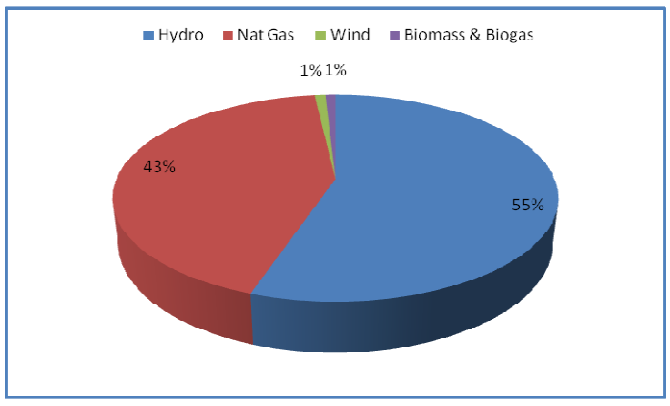


Figure 1. Latvian fuel mix for electricity generation in 2006 [2]

However, it would be myopic to ignore the environmental aspects of electricity generation and supply. In electricity generation, emissions discharge and other environmental effects of power production and distribution affect health of nearby and sometimes distant populations, as

well as the natural environment. Most of these emissions result from the combustion of fossil fuels used in converting thermal energy into electrical energy[1]. This paper focuses on the evaluation of environmental impact of electricity generation mix and electricity supply in Latvia.

Methodology

The evaluation of the environmental performance of electricity generation and supply requires the implementation of a common and comprehensive methodology. Most environmental studies related to energy production are based on life cycle assessment (LCA) approach. LCA is an analytical tool aimed at evaluating the environmental burdens and benefits associated with the entire supply chain of a product or process [3]. Based on ISO 14040 [4], an LCA contains four stages: 1) Goal and scope definition, 2) Inventory analysis, 3) Impact assessment, and 4) Interpretation of the results. Detailed data on electricity production are gathered from power industries and from literature. Background inventory data are mainly based on Ecoinvent [5]. Characterization of environmental impacts is based on the impact assessment methodology IMPACT 2002+ v2.1 [6]. Additionally, the formula below was used to calculate the ecological effect in terms of potential environmental impact (PEI_i) of electricity generation and supply mix.

$$PEI_i = \sum_{i=1}^{n} f_i ER_{ij} \qquad for\ j= 1,2,3,4 \qquad (1)$$

Where f_i is the fraction of electricity from source *i and* ER_{ij} is the emission rate of *i* source associated with *j* damage category.

Goal and Scope

The purpose of this study is to quantify the life cycle environmental and human health impacts of electricity production and supply in Latvia in order to derive the eco-indicator of environmental damage of the power production and supply which can be used for ecodesign purposes as well as obtain data for further analysis of various electricity generation scenarious in Ļatvia with the aim to minimise environmental impact. The LCA will profile and assess resources consumption and emissions generation from raw material procurement to its conversion to electricity. The system boundary includes fossil electricity production from natural gas, renewable electricity production from hydropower, biomass, wind and imported electricity from Russia, Estonia, and Lithuania. The functional unit used in this study is 1 kWh of electricity produced and consumed. Therefore all impacts are estimated for the above functional unit, which makes the results comparable with the results from LCA of different electricity generation mix and consumption of other countries.

Inventory analysis

The environmental performance of electricity generation and supply in Latvia was analyzed for the year 2006 chosen as reference. The technology portfolio contains both large centralized and smaller decentralized units in Latvia and few other Eastern European countries (for electricity imports). The database Ecoinvent v1.1 was used as background for year 2006. Table 1 gives an overview of the technologies included in the assessment.

Table 1.

Power technologies analysed and their main characteristics [5]

Energy source/ Technology	**Identifier in Fig. 3**	**Technology desccription**	**Net Eff. (%)**	**Allocation exergy to el. (%)**	**Location**
Oil Shale	Liginite[2]	Average present plant for UCTE & energy chain	39%	-	Estonia
Natural Gas	Gas CC	Combined cycle, best technology and present gas chain for UCTE	57.5 %	-	Latvia, Estonia, Russia
Nuclear	BWR	Average boiling water reactor for UCTE and close fuel cycle	33%	-	Lithuania Russia
Hydropower	Reservoir	Average HP reservoir for UCTE	78%	-	Latvia, Lt Russia
	Reservoir	Average HP reservoir for Finland	78%	-	Latvia
	Pump storage	Pumping storage for UCTE	70%	-	Lithuania
Wind	Wind onshore	Present technology, average capacity factor in Grenchenberg	25 %	-	Latvia
Cogeneration Natural gas	Cogen. Lean burn 500 kWe	Average technology on the market	32% (el) 55% (th)	77%	Latvia, Lithuania
Cogeneration wood	cogen at 6400 kWth	Specific cogen in Switzerland	NA NA	NA	Latvia

Impact assessment

The midpoint-damage life cycle impact assessment methodology (LCIA) IMPACT 2002+ v2.1 [6] is used to determine the environmental impacts of the system. This LCIA evaluates the impacts on 14 midpoint categories which are grouped into four damage categories that cover the main environmental indicators. The categories considered are: human health, ecosystem quality, climate change, and resources, and are expressed respectively, in DALY, PDF.m^2.yr, kg CO_{2eq}, and MJ. Normalization is performed at damage level. Characterization and normalization factors are based on European conditions.

Results and discussions

[1] The undesirable environmental effects are significantly larger when the impacts are considered with respect to the entirety of the fuel cycle of any specific fuel. Power generation using conventional methods relies on extracting and transporting a fuel, its conversion into electric power, and finally the disposition of residual products including generation facilities. More recent studies take into account the totality of effects of each fuel cycle.

[2] Lignite was modeled as substitute for oil shale

Figure 3 shows the results obtained applying IMPACT 2002+ [6] to life cycle inventory results (per kWh) for the current electricity generation technologies. Of all electricity generation technologies (either for local or imported source of electricity) reservoir hydropower has the best performance (i.e. the lower the score, the better the performance) of all inventoried electricity generation technologies, followed (in the order) by wind power, while lignite power plant and pumped storage hydropower have the worst performance. Both nuclear power and biopower exhibit close values and natural gas combined cycle scores higher than them. In case resource consumption would not be included natural gas combined cycle would score lower than biopower but higher than nuclear, and biopower would score the worst.

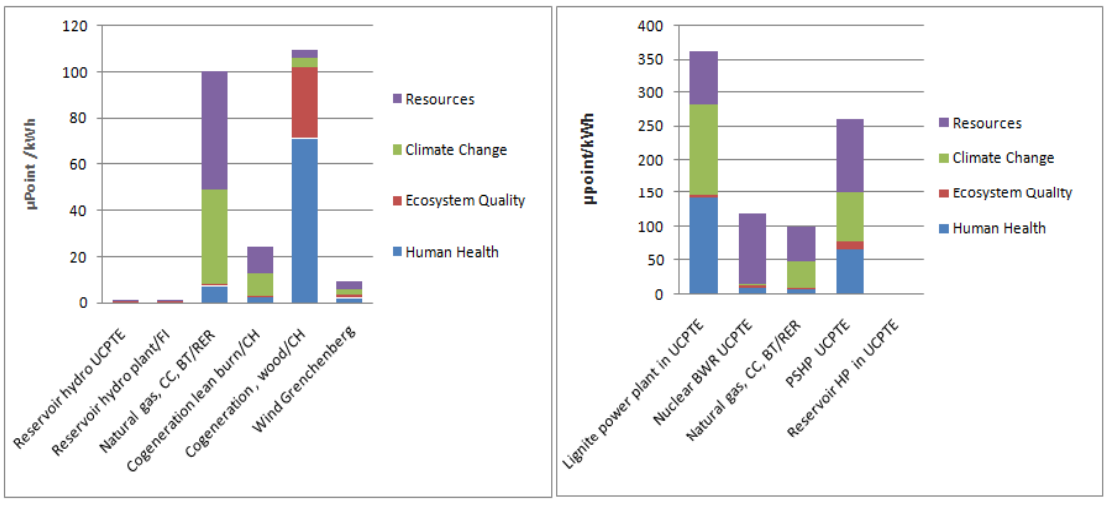


Figure 3. LCIA results for the reference electricity generation technologies in year 2006 in Latvia (left picture) and imported electricity (right picture) using IMPACT 2002+. Results are expressed as "normalized damage"[3]

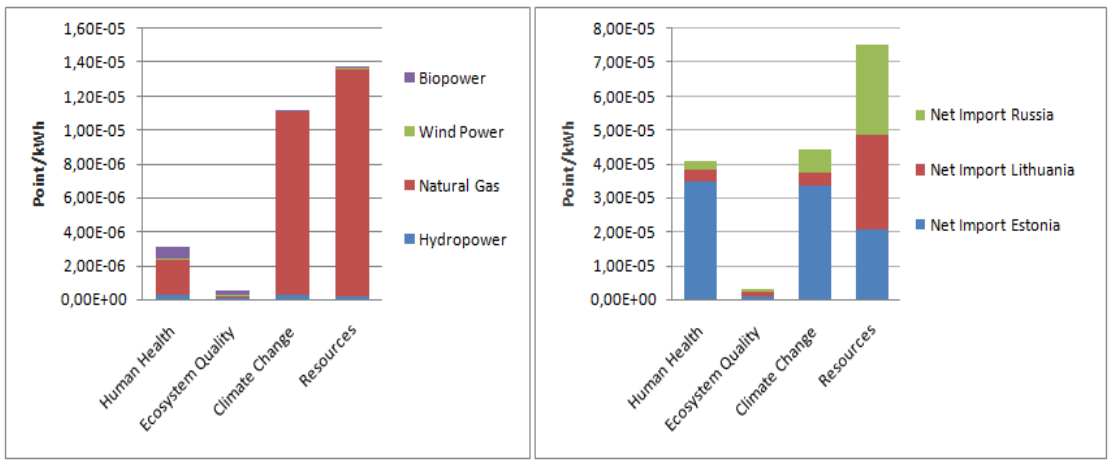
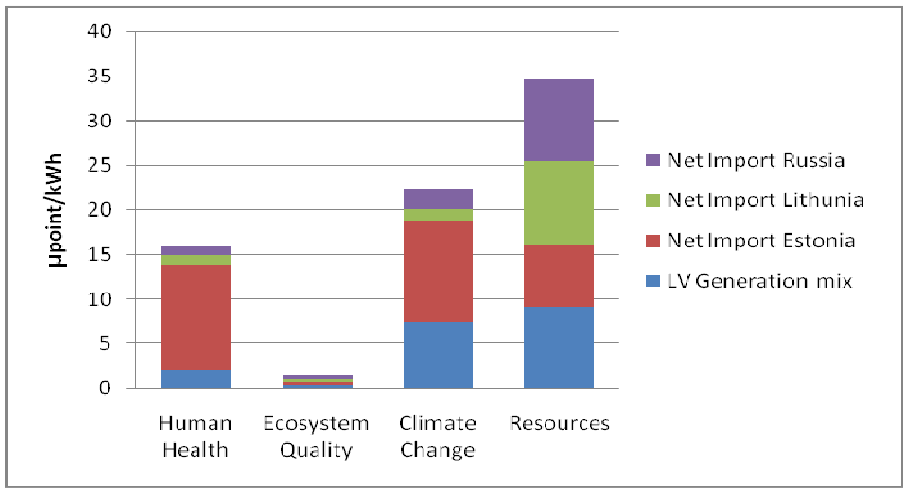


Figure 4. Ecological profile of the electricity generation mix in Latvia (left picture) and the net electricity import mix (right picture) using IMPACT 2002+

The results of normalized damage carried out by IMPACT 2002+ method is reported in Figure 4. It can be seen that resources and climate change cause the dominating environmental effects. The total damage of electricity generation (left picture) is 28,5 µpoint/kWh and is originated from natural gas (94%), biopower[4] (3%), hydropower (2,6%) and wind power (0,4%). More in detail, the damage derives from resources for 48%, from climate change (39%), from human health (11%) and from ecosystem quality (2%) The total damage of imported electricity (right) picture is 164 µpoint/kWh and is originated from the net electricity import from Estonia (55%), net electricity import from Lithuania (22%) and net electricity from Russia (23%). Like in the left picture, the damage derives from resources for 46%, from climate change: 27%, from human health 25% and from ecosystem quality 2%.

Figure 5 shows the eco-load of electricity supply in Latvia. As in the Figure 4, resources and climate change dominate the environmental effects. The total ecopoint of the electricity supply in Latvia is 74,4 µpoint/kWh. The split of the total ecological damage shows the relatively high contribution of the net import from Estonia (41%), followed by Latvian generation mix (25%). The net import from Russia and Lithuania have equal share of (17%) of the total ecological effects of electricity supply in Latvia. However, their shares in different damage categories vary significantly. A detailed observation shows that the damage derives from resources for 47%, from climate change 30%, from human health 21% and from ecosystem quality 2%.



[3] One point represents the average damage in Europe per person and year. Based on IMPACT 2002+ v2.1 [6], 1 Point represent 0,0071 DALY, 13700 PDF.m^2.yr, 9950 kg CO_2 eq. and 152000 MJ for Human Health, Ecosystem Quality, Climate Change and Resource consumption respectively.
[4] Biopower includes biomass and Biogas CHP

Figure 5. Eco-load of the electricity supply in Latvia using IMPACT 2002+

Conclusions

This study was conducted to evaluate the ecological effects of electricity generation and supply in Latvia. This was accomplished by using life cycle assessment as a tool. The results show that the net import of electricity increases the total ecological effect by 161 % from 28,5 µpoint/kWh to 74,4 µpoint/kWh. The net import from Estonia contributes most to this total ecological damage with a share of 41%. This finding highlights that the import source of electricity can drastically increase the total ecological effect of electricity supply. However, this depends on the generation source and the share of the electricity imports in the supply mix.
The scores evaluated under IMPACT 2002+ show that the environmental damage affects mainly the resources, climate change and human health categories. The obtained results present a big concordance with the preponderantly existing opinions in the scientific community until now, based in previous evaluations the electricity supply with higher share of nuclear and renewable sources have in general, a lower impact than the fossil ones. However, thanks to this study it is possible for the first time in Latvia to quantify the total ecological impacts of electricity generation and supply.

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Njakou Djomo S., Simanovska J., Bažbauers G., Valters K. Latvijas elektroapgādes sistēmas ietekmes uz vidi ekoindikatori
Pētījums ir veikts, lai apzinātu un izmērītu elektrības ražošanas un piegādes radīto ietekmi uz vidi Latvijā. Noteikta Latvijā saražotās un arī importētās elektrības ieguvei izmantoto, gan ar fosilo kurināmo, gan atjaunojamiem resursiem darbināmo elektrotehnoloģiju ietekme uz vidi, par atskaites gadu ņemot 2006.gadu. Pētījums aptver gan lielās centralizētās, gan mazās izkliedētās spēkstacijas Latvijā un dažas citas spēkstacijas Lietuvā, Igaunijā, Krievijā (elektrības importam). Kaitējums videi novērtēts, izmantojot IMPACT 2002+ metodiku. Inventerizācijas analīzē iekļauti parametri, kas raksturo resursu izmantošanu (enerģiju, izejmateriālus) un emisijas atmosfērā, ūdenī, augsnē. Enerģija un materiālu plūsma tika normalizēta uz elektrības kilovatsundu (funkcionālā vienība). Vides ietekme ir aprēķināta un apspriesta, balstoties uz 4 kaitējuma kategorijām: cilvēka veselībai, ekosistēmas kvalitātei, klimata pārmaiņām un resursiem. Aprēķināts, ka Latvijas elektroapgādes radītais ekoloģiskais kaitējums ir 74,4 µpoint/kWh.

Njakou Djomo S., Simanovska J., Bažbauers G., Valters K. Eco-indicators of environmental impact for Latvian power supply system
This study is performed to identify and quantify the environmental impacts of the generation and supply system of electricity in Latvia. The environmental performance of technologies for domestic electricity generation as well as the electricity import including renewable and fossil systems is analyzed for the reference year 2006. The assessment covers the large centralized and small decentralized power plants in Latvia and a few other power plants in Lithuania, Estonia and Russia (for electricity import). The environmental damages are assessed by using the IMPACT 2002+ methodology. The inventory analysis involves parameters describing resources uses (energy and raw materials) and emissions to air, water, and soil. The energy and material flows were normalized to kilowatt-hour of electricity (functional unit). The environmental effects are calculated and discussed on the basis of their contribution to the four damage categories: human health, ecosystem quality, climate change, and resources. It was found that the total ecological damage of the electricity supply in Latvia is 74,4 µpoint/kWh.

Някоу Дйомо С., Симановска Я., Бажбауерс Г., Валтерс К. Эко-индикаторы Латвийской системы электроснабжения
Исследование произведено для определения и измерения экологического вреда, который вызывает производство электричества и электроснабжение в Латвии. Принимая 2006-й год за отчётный, определено влияние произведённых в Латвии и импортированных технологий для получения электричества как из фоссильного топлива, так и из возобновляемых энергоресурсов.
Исследование включает и большие централизованные, и малые, рассеянные электростанции в Латвии, а также некоторые электростанции в Литве, Эстонии и России (для импортированного электричества). Для определения экологического вреда использована методика IMPACT 2002+. В инвентаризационном анализ включены параметры, которые выражают использование ресурсов, (энергию, сырьё) и выбросы (в атмосферу, в воду, в почву). Энергия и поток материалов нормализирован на один КВтч (функциональная единица). Влияние на окружающую среду определенно и рассмотрено на основе 4 категорий влияния: человеческое здоровье, качество экосистемы, изменения климата и ресурсы. Определен экологический ущерб системы производства электричества и электроснабжения в Латвии: 74,4 µpoint/kBт.