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Results of investment analysis in power transmission in Latvia and Lithuania

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Abstract

The aim of this research is to show how Latvian and Lithuanian power system can become carbon neutral. A scenario methodology is used to analyse the power system in 2050 by the EMPS (EFI's Multi-area Power market Simulator) model and an investment algorithm for evaluation of profitability of expansion of transmission links. There are used four main scenarios: A1, A2, B1 and B2.

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Keywords: development of power system; investment analysis; high share of renewable production

1. Introduction

One of the top targets in European Union (EU) is to reduce greenhouse gas (GHG) emissions and promote renewable energy share in all sectors. All Baltic countries have presented long-term strategies for CO_2 reduction to be achieved by 2030 and 2050. Power sector is a key player in climate change mitigation. The new policy sets a target of at least 27 % for renewable energy by 2030 and is a continuous step towards the ambitious long-term goal of cutting emissions 80–95 % by 2050 [1–3].

In this paper authors study investment analysis in power transmission in Latvia and Lithuania based on EMPS. This paper show results of a scenario methodology where each scenario consists of a possible future and show how to

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react in the future. There were used four main scenarios – A_1, A_2, B_1 and B_2 in investment algorithm in the EMPS model. Scenarios A_1 and A_2 include RES use, where first scenario include today`s connection to Russia–Belarus and the second one without connection. Scenarios B_1 and B_2 two differs with that there no use of RES.

Application of this methodology for the study of a two Baltic state power system free of GHG emissions is described. The input data are mainly based on statistical data from the Latvia and Lithuania and information about established and planned projects for new renewable power production in the Baltic region. Model and algorithm was applied to analyze the power system by 2050.

2. Methodology

A scenario methodology is used to analyse the power system in 2050 by the EMPS model and an investment algorithm for evaluation of profitability of expansion of transmission links [4]. Model and algorithm is adapted from "A carbon neutral power system in the Nordic region in 2050" report.

The EMPS model can be combined with an algorithm for analysis of profitable investments in transmission and generation capacities [5]. This is a one-stage investment analysis that finds profitable investments from a given start-year where capacities are known, e.g. 2010, to a given future year, e.g. 2050. It is however possible to combine several one-stage analyses into a sequence. Before starting the analysis, all necessary inputs for the future year must be specified in the EMPS model, except for those capacities where the model shall derive profitable investments. First, the model is solved for the future year without any new investments, i.e. the capacities used for the future year are the remaining part of the capacities that existed in the start-year. Next, the model checks which investments that are profitable at simulated prices. This calculation includes a comparison between average annual operating profits over simulated climate years towards annualized investment costs. For all investments that are profitable at simulated prices, some new capacity is included before the next simulation.

The EMPS model is now solved again using the adjusted capacities for the future year, and profitability for investments are checked again for the new power prices, and capacities are adjusted again. The algorithm converges when:

- All implemented investments are profitable;
- No additional investments are profitable.

This approach gives a reasonable suggestion for a balanced development of capacities, and simulated prices for the future year will reflect both operating- and investment costs. There are however not any guarantees that the model will find the global optimum for the combination of investments that should be carried out.

The marginal profit for investing in 1 MW extra transmission capacity is calculated by Eq. 1 [4]:

$$\pi_k = \frac{\sum_{t\in T, i\in I, l\in L} \max\left\{0; \left[\mathrm{p}_{i,t,l,m_k}\left(1-t_{m_k n_k}\right)-\mathrm{p}_{i,t,l,n_k}\right]; \left[\mathrm{p}_{i,t,l,n_k}\left(1-t_{n_k m_k}\right)-\mathrm{p}_{i,t,l,m_k}\right]\right\} h_l \cdot 10}{I^{numb}} - \mathrm{c}_k^{inv}, \quad \forall k \in K^{Trans} \tag{1}$$

where

I	Set of climate scenarios, e.g. {1931, …,2012};
L	Set of within-week time-steps, e.g. {1, …,100};
T	Set of weeks, {1, …,52};
I^{numb}	Number of climate scenarios, i.e. card(I);
K^{Trans}	Set of possible transmission capacity investments ;
c_k^{inv}	Annualized investment cost (in Euro/MW per year);
hl	Number of within-week hours in $l \in L$ time-step ;
m_k	Area-number for $k \in K^{Trans}$ investment ;

n_k 2nd area-number for line-investment;

p_{i,t,l,m_k} Power price area m_k (in Eurocent/kWh);

$t_{m_k n_k}$ Transmission loss from m_k to n_k, 0,02;

zk Needed excess profit to increase investment (as a share of investment costs);

π_k Average annual profits (in Euro per MW per year).

The investment alternative *k* is for transmission between the areas m^k og n^k. If for instance the price in a given week is largest in the area m^k and the price difference is large enough to compensate for the losses in transmission, the marginal profit is calculated as:

$$p_{i,j,m^k}\left(1-t_{m^k n^k}\right)-p_{i,j,n^k} > 0 \quad (2)$$

If the price is largest in area n^k, the opposite difference is utilized, cf. Equation 1.

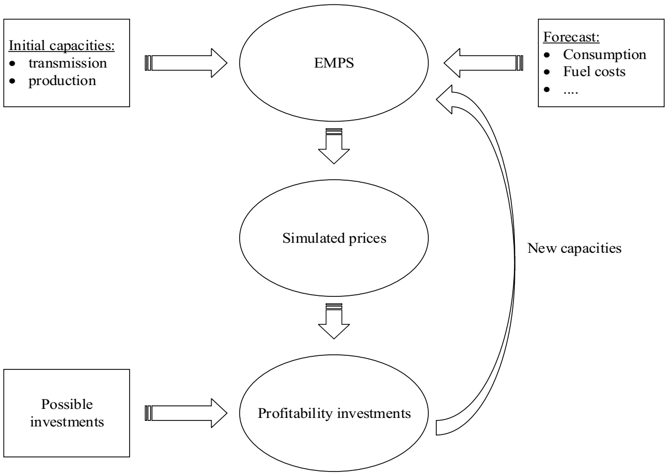


Fig. 1. Investment algorithm in the EMPS model.

For each time-step, the gains of having 1 MW extra capacity are checked. In the EMPS model, the full transmission capacity will always be utilized to send energy towards the high-price area if the price-difference is large enough to pay for the losses. Therefore, the average annual operating profits for transmission lines can be calculated by Equation 4. When the operating profits for all investment alternatives have been calculated the benefits of extra capacity are compared with investment costs. We now interpret the simulated average annual operating profits as the expected annual operating profits, account taken for uncertain climate variables. Then the expected annual profit of investing in 1 MW extra capacity for investment k is [4]:

$$\pi_k^{tot} = \pi_k^{op} - c_k^{inv}, \quad \forall k \in K \quad (3)$$

In every round of the investment algorithm loop, we consider whether the capacity for a specified investment alternative should be increased, decreased or be unchanged. The capacity is increased if the following condition is satisfied [4]:

$$\frac{\pi_k^{tot}}{c_k^{inv}} > z_k \quad (4)$$

There were used four main scenarios in investment algorithm in the EMPS model (see Table 1). Two of the scenarios are based on RES in Baltics, there are no further investments to Russia and Belarus allowed and the difference between these two scenarios are that scenarios A_1 is based on today's connection to Russia and Belarus, but scenarios A_2 is based on there is no connection to Russia and Belarus. The other two scenarios differs with that there is no RES but there are Susplan scenario.

Table 1. Description of four scenario for Latvia and Lithuania.

Scenario A_1	Scenario A_2
- RES scenario in the Baltics	- RES scenario in the Baltics
- with today's connection to Russia and Belarus.	- no connection to Russia and Belarus
- No further investments to Russia and Belarus are allowed	- No further investments to Russia and Belarus are allowed
Scenario B_1	Scenario B_2
- Susplan scenario in the Baltics	- Susplan scenario in the Baltics
- with today's connection to Russia and Belarus.	- no connection to Russia and Belarus.
- No further investments to Russia and Belarus are allowed.	- No further investments to Russia and Belarus are allowed.

The electrical consumption and production data used for investment algorithm is given in Table 2. The start year of data is 2010 and the end year 2050.

Table 2. Yearly electrical consumption and production .Carbon free electricity production scenario for Latvia [6, 7].

	2010	2020	2030	2040	2050
Elektricity consumption, GWh	7 000	8 540	9 700	10 185	10 389
Electricity production from Renewables	3 491	6 284	9 345	10 040	11 450
RES electricity production % from total domestic consumption	49,87	73,58	96,34	98,58	110,22
Electricity demand	6 695	8 540	10 800	11 340	11 567
Hydro, production, GWh	3300	2887	2887	2887	2887
Hydro, Installed Capacity, MW	1576	1576	1576	1576	1576
Biomass CHP, production, GWh	13	535	535	535	535
Biomass CHP, Capacity, MW	6	100	100	100	100
Biogas and syngas production, GWh	107	250	560	1120	2240
Capacity, MW	34	50	100	200	200
Wind onshore, production, GWh	71	1274	1274	1274	1274
Wind onshore, capacity, MW	36	500	500	500	500
Eficiency, %	0	29	29	29	29
PV production, GWh	0	20	135	270	560
Wind offshore production, GWh	0	1 318	3 954	3 954	3 954
Wind offshore production, MW	0	500	1500	1500	1500
Natural Gas, production, GWh	2600	2600	600	600	600
Natural Gas, capacity, MW	540	1030	880	800	800
Total fossil , GWh	2600	2600	600	600	600
Total production, GWh	6 091	8 884	9 945	10 640	12 050
Import GWh	3973	4000	4000	4000	4000
Eksport, GWh	3100	3100	3100	3100	3100

3. Results and discussion

The results from EMPS model and an investment algorithm for Latvia and Lithuania is shown in Fig. 1., Fig. 2. and Fig. 3. The Fig. 1. shows start and total capacities for Latvia–Lithuania transmission line. The start capacity for all four scenarious are 1600 MW. After investments the bigest capacity is for scenario A_2, more than 1900 MW. Investments are shown and analyzed in Fig. 2. and Fig. 3.

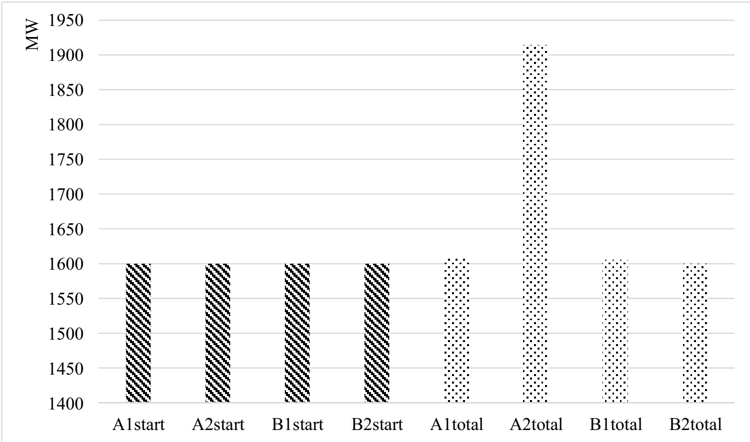


Fig. 2. Start and total capacities for Latvia-Lithuania transmission line.

There are shown total production by four scenarios in Latvia and Lithuania, and production by renewable resources in all scenarios.

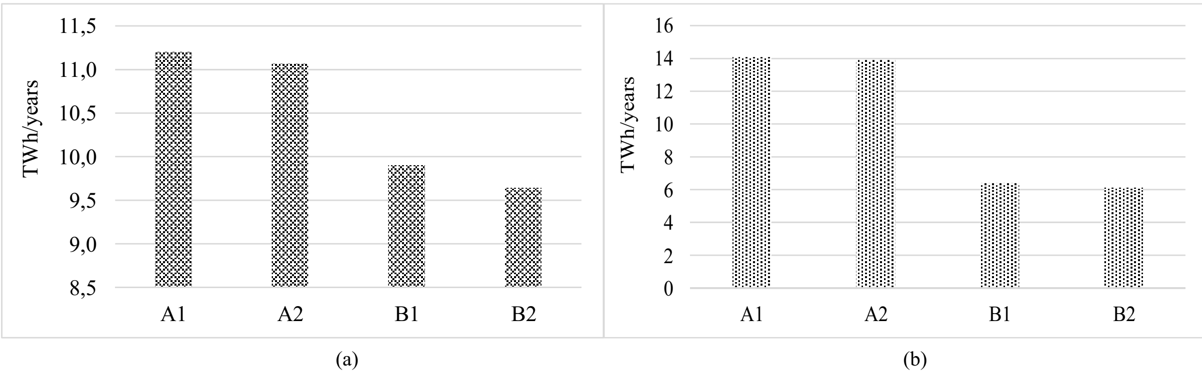
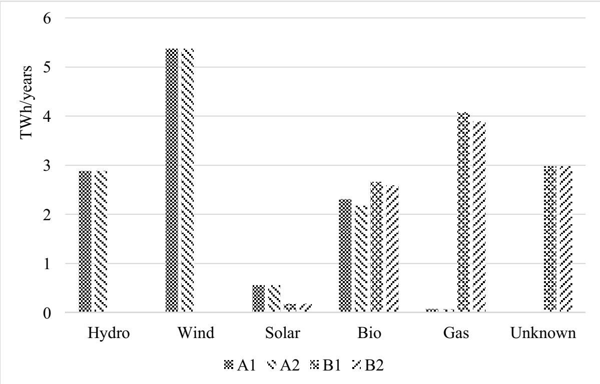


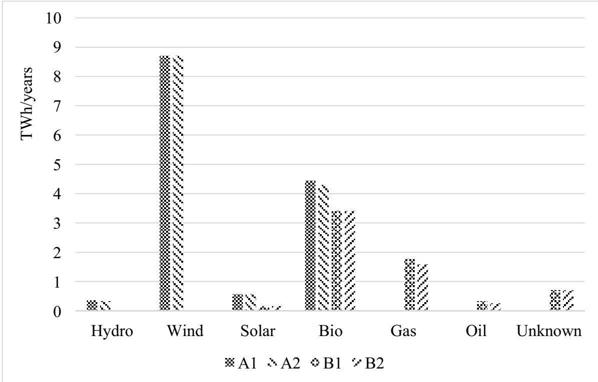
Fig. 3. (a) Total production in Latvia by scenarios; (b) Total production in Lithuania by scenarios.

As it can been seen from Fig. 3 (a) and (b), then the scenarios A_1 and A_2 by total production is quite similar. Also it does not differ so much between two Baltic states – Latvia and Lithuania. The both of the scenarios are based on renewable energy sources use and no further investments to Russia and Belarus are alowed. The main diference in these two scenarios are that scenarios A_1 has today`s conection to Russia and Belarus, but scenario A_2 no futher conection to Rusia and Belarus. The total production in Latvia in scenario A_1 is 11.2 TWh/year and in scenario A_2 is 11.1 TWh/year. In Lithuania in these two scenarios production amout in A_1 scenario is 14 TWh/year and in scenario A_2 is 13.9 TWh/year. Scenarios B_1 and B_2 is similar for Lithuania, but for Latvia total production in these two scenarios difers. In Lithuania total production for scenarios are about aproximetly 6 TWh/years, but in Latvia total production in scenario B_1 is 9.9 TWh/years and in B_2 is 9.6 TWh/year.

Analyzing four scenarios by used sources, it is seen in Fig. 4. (a) and (b) pictures that Lithuania has bigger potential in RES used for production. For comparison, Lithuania has bigger potential in wind and bio - resources use for production, but Latvia has hydro use potential. The sun use for production is quite similar for both of Baltic States. The wind potential for Latvia is more than 5 TWh/year and in Lithuania more than 8 TWh/year. Bio-resources used for production in Lithuania is 2 times higer than Latvia. In Latvia using bio-resources can be produced about 2 TWh/year but in Lithuania more than 4 TWh/year. Hydro source use for production in Latvia is almost 3 times higher than Lithuania, where in Latvia it is almost 3 TWh/year, but in Lithuania 0.3 TWh/year. Results from scenarios B_1 and B_2 is different for Latvia and Lithuania. The both of scenarios are based on renewable and non-renewable resource use for production.



(a)



(b)

Fig. 4. (a) Production in Latvia by sources in different scenarios; (b) Production in Lithuania by sources in different scenarios

The main difference between Latvia and Lithuania are gas as source use in both scenarios. Latvia is more dependent and production from gas is more than 2 times higher than in Lithuania. These two scenarios include solar and bio-resources use for production. The two of scenarios also include some unknown resource use for production.

Investment algorithm let predict investment amount and total production amount. The more appropriate scenarios for Latvia and Lithuania are RES scenarios.

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