Energy Conversion and Management 107 (2016) 67–75

Contents lists available at ScienceDirect

Energy Conversion and Management

journal homepage: www.elsevier.com/locate/enconman

Modelling the Baltic power system till 2050

Andra Blumberga, Dace Lauka *, Aiga Barisa, Dagnija Blumberga

Riga Technical University, Azenes Street 12/1, Riga LV-1048, Latvia

ARTICLE INFO

Article history:
Available online 12 September 2015

Keywords:
Baltic States
Power system
Renewable energy
System dynamics

ABSTRACT

The European Union has given a long-term commitment towards a low-carbon society. Power sector is to play an important role in achieving ambitious emission reduction goals. This article presents results of a research aimed at evaluating development of the Baltic power system under current framework conditions. Special focus is put on renewable energy analysis to estimate the potential of power sector decarbonization.

A dynamic energy-economy model was developed by applying system dynamics modelling approach in order to evaluate changes in the energy system till 2050. Underlying structure of the model is based on energy resource flows according to the national electricity mix of each Baltic State. The model calculates energy generation costs of each technology taking into account national support schemes. Based on cost estimation, the installed capacity of each energy resource is determined. Modelling results suggest that wind energy has the potential to become dominant in the Baltic region. This is explained by increasing competitiveness of wind-generated power price compared to fossil-fuel-based generation. Solar energy has the potential to become popular from 2025 onwards due to decreasing investment costs. The market share of other renewable electricity technologies, such as hydro and biomass, will continue to increase reaching maximum between 2020 and 2030. Biogas plants are still not expected to play considerable role in electricity generation.

1. Introduction

One of the top targets for European Union (EU) is to reduce greenhouse gas (GHG) emissions. Energy sector (the largest carbon dioxide emission contributor in EU) is a key player in climate change mitigation. The European Commission has acknowledged that particularly the electricity sector will 'play a central role in the low carbon economy' [1]. Del Rio [2] has highlighted several arguments underpinning this statement:

- Around 30% of total emissions in EU are from energy sector.
- High potential of GHG emission reduction in energy sector.
- Other sector (like transport) use of electrical energy will probably increase in the future.

Increasing the share of renewable energy in power generation is not only seen as the key element enabling the EU to cut its greenhouse gas emissions. Electricity generated from renewable energy sources (RES) provides both environmental benefits and socio-economic advantages like diversified energy supply, development of regions, rural areas and industry, employment options [3].

1.1. Political framework and current achievements in the EU

Increased use and production of renewable energy is an important step towards achieving the GHG emission reduction goals within EU and international commitments. The Renewable Energy Directive 2009/28/EC established the framework for all EU countries to promote renewable energy sources. It sets obligatory renewable energy targets in order to ensure achievement of a community level reduction of at least 20% below 1990 levels by 2020. In 2014, the EU leaders agreed on a further greenhouse gas emission reduction target of at least 40% by 2030 in order to move towards meeting the long-term goal of EU to cut GHG emissions by 80–95% by year 2050.

The European Commission predicts that it is on track for a 27% GHG emission cut by 2030 under current policies [4]. As outlined in the EC's Energy Roadmap 2050 for moving to low carbon economy [1], in order to achieve the target GHG emission reduction values by year 2050, a reduction of 40% and 60% should be achieved by years 2030 and 2040 respectively. The Energy Roadmap 2050

* Corresponding author.
E-mail addresses: andra.blumberga@rtu.lv (A. Blumberga), dace.lauka@rtu.lv (D. Lauka), aiga.barisa@rtu.lv (A. Barisa), dagnija.blumberga@rtu.lv (D. Blumberga).

http://dx.doi.org/10.1016/j.enconman.2015.09.005
0196-8904/

Nomenclature

CC_i	technology capital costs, EUR/MW h
CHP	cogeneration plant
C_i	the average electricity generation cost for each fuel
EU	European Union
FP_i	fuel cost, EUR/MW h
GHG	greenhouse gas
OC_i	operating costs, EUR/MW h
P_i	a premium, EUR/MW h
RES	renewable energy sources
S_i	fuel share
α	a constant reflecting the variation in costs between the individual users
η	technology efficiency

policy scenarios for RES show a share of around one third gross final energy consumption in year 2030. The electricity sector will have an increasing role in achieving a significant level of decarbonization by 2050.

During the period 2005–2011 the electricity generation form RES in Europe has increased from 13.6% to 20.4% [5]. The EurObserv'ER's calculations [6] coincide with this data – renewable energy share of total electricity consumption in 2011 was 20.6%. The increase of the share of renewable energy in the EU can be explained by the combination of higher consumption of renewable energy and of a decrease of the total gross final energy consumption compared to 2010. During 2005–2011 results above the EU average in terms of increased share of renewable energy sources in power generation has been achieved in Portugal, Spain, Denmark, Estonia, Ireland and Germany (more than 10% increase). Moreover, Portugal and Spain, as well Austria, Latvia and the Nordic countries show the best results in terms of overall share of renewable energy in national electricity mix in 2011.

The European Commission renewable energy progress report 2013 [7] shows that 15 of 27 EU Member States haven't reached their indicative goal for RES in electricity mix by year 2010. The wind sector is the most evident to not achieve required installed capacities. This situation is a reason for concern about future progress of achieving the set goals. Current policy initiatives and future investment plans must be ensured as well as barriers avoided for RES development in order to achieve the next goal for year 2020 and beyond.

1.2. The Baltic power system

The domestic electricity market of each of the Baltic States relies on different energy resources for electricity production. Electricity supply in Estonia is based on local oil shale. Since the nuclear power plant Ignalina closed Lithuania's dependence on electricity supply from abroad has increased greatly. Meanwhile in Latvia fossil fuel imports continue to occupy substantial part of electricity generation alongside with hydropower, which is the major source of domestic electricity production. Dependence on fossil fuel sources and electricity import is a common problem of all three Baltic States. Extended use of renewable energy sources is a solution for increased energy independence and reduced environmental impacts associated with electric power generation.

1.2.1. Estonia

Electricity consumption in Estonia is the fastest growing among Baltic States. Annual electricity consumption in Estonia has increased from 5400 GW h in 2000 to 6900 GW h in 2006 and 7400 GW h in 2012. Further increase by 28–30% compared to the average of 2005–2008 is expected [8] reaching 10,910–11,060 GW h by 2020. As most of Estonia's electricity is generated from local oil shale, its economy is highly dependent on fossil fuels which results in high CO_2 intensity in power production sector [9]. Reducing emissions from oil shale power plants will become increasingly topical for Estonia in the nearest future with requirements of the 2001/80/EC Directive coming into force. It sets stringent rules for environmental protection, which will require additional investments, increasing the costs of electricity production.

Estonia has target of reaching 17.6% renewable energy share of gross final consumption of electricity in 2020 (compared to 1.2% in base year 2005) [9]. Estonia's greatest potential in renewables is estimated to lie with the wind power and biomass (see Table 1). At present, Estonia supports renewable electricity by means of a technology non-specific premium added to the market price.

1.2.2. Lithuania

By the end of 2009 around 70% of the total domestic electricity production in Lithuania was generated by the Ignalina nuclear power plant. The situation changed significantly after the disconnection of the second reactor at the Ignalina power plant in 2010. From energy exporting country, Lithuania has turned into the European Union Member State most dependent on electricity supply from abroad. Annual electricity consumption in Lithuania amounted to 11,600 GW h in 2012 and is expected to increase by 21–22% (compared to the base year, 2005) reaching 13,875–14,000 GW h in 2020. Along with the electricity imports, the natural gas dominates in the electricity mix of Lithuania with a share of 55%.

Lithuania has set an aim to increase the electricity produced from RES to 21% in 2020 (compared to 4.9% in 2008) in total electricity consumption [10]. In Table 2 forecast of total contribution of renewable energy technologies in electricity production in Lithuania is presented. Lithuania's greatest renewable energy potential is associated with the use of biofuel (both biogas, and solid biomass) and generation of onshore wind energy. In Lithuania feed-in tariffs for specific technologies are used as promotion tool for electricity production from RES.

1.2.3. Latvia

Latvia has set the highest mid-term renewable energy targets of all three Baltic States. According to the National Renewable energy action plan [11] Latvia's RES target for 2020 is to reach at least 59.8% share of renewable energy in total gross final electricity consumption. Electricity consumption in Latvia was 6848 GW h in 2012, which is a 10.6% increase compared to 2011 level. Electricity consumption in Latvia is expected to increase by 28–48% by 2020 compared to the base year (2005) reaching 8680–10,000 GW h.

The most significant RES in Latvia historically been hydropower, but there also is potential for biomass, biogas and wind power (see Table 3). Despite the significant share of renewables in electricity generation (50.5% in 2011) Latvian energy sector is highly dependent on imported natural gas resources. In 2011, 39.7% of gross electricity generation took place in large natural gas cogeneration plants. Latvia also uses technology specific feed-in tariff to promote electricity production from renewable energy sources.