Young Researcher Symposium IEEE Benelux Chapter IAS/PES/PESC,
April 24 – 25, 2014, Ghent, Belgium

EVALUATING THE CONSTRUCTION OF PROMINENT SCENARIOS FOR A LOW-CARBON EUROPEAN ENERGY SYSTEM IN 2050

Arne VAN STIPHOUT*, Geert DECONINCK**

*KU Leuven, Dept. of Electrical Engineering (ESAT), Research Group ELECTA, B-3001, Heverlee, Belgium
E-mail: arne.vanstiphout@esat.kuleuven.be

** KU Leuven, Dept. of Electrical Engineering (ESAT), Research Group ELECTA,
E-mail: geert.deconicnk@esat.kuleuven.be

KU Leuven is founding member of EnergyVille, a research center on sustainable and intelligent energy systems.

Abstract. Given the stringent climate constraints the European Union has put forward for the power sector, the European energy system will have to change drastically. Although presenting a great number of challenges, the necessary transformation of our energy system also presents us with the opportunity to move towards a more sustainable society. This means balancing economic and social development with environmental protection, otherwise known as the 'triple bottom line'. This work will focus on scenarios for the future energy system with high levels of renewable energy to realize this transformation. A high penetration of renewables will pose significant challenges for the technical operation of the system. To evaluate these challenges adequately the modelling of the energy system has to be sufficiently detailed. The last few years a number of high-level studies have been published exploring possible pathways for the evolution of national and regional energy systems towards a sustainable 2050 energy system. Four prominent studies have been examined in detail as to how they model the operational aspects of the energy system, namely: 'Energy Roadmap 2050' by the European Commission, 'Power Choices' by EURELECTRIC, 'Roadmap 2050' by the European Climate Foundation and 'Battle of the Grids' by Greenpeace. They are compared in terms of how they model supply, demand and the flexibility options of an energy system. Furthermore several ways exist for integrating sustainability considerations during the drafting of the portfolios, rather than assessing the proposed pathways afterwards, as is current practice. The studies are reviewed as to how they integrate sustainability considerations in their modelling process. A number of opportunities are found for the improvement of the construction of roadmaps for a low-carbon European energy system. The main focus is on the assessment the technical feasibility of the proposed supply side configurations.

Keywords: European energy system, flexibility, 2050, roadmap, sustainability.

EXTENDED ABSTRACT

All around the world governments and policy-influencing organizations are constructing roadmaps for the long-term energy future. In the USA the National Renewable Energy Laboratory recently published its Renewable Electricity Futures Study. This study, funded by the US Department of Energy's Office of Energy Efficiency and Renewable Energy, explores the challenges of an energy system with renewable electricity generation levels ranging from 30% to 90% [1]. In other countries progress is slower, but is still obvious. In 2013the National Development and Reform Commission of China issued the report: *China's Policies and Actions for Addressing Climate Change* [2]. In this report a number of guidelines are presented for optimizing their energy structure, such as the development of non-fossil fuel. In this regard the National Energy Administration has issued several Development Plans, amongst others for Solar Energy Generation and Biomass Energy.

In Europe the European Union's ambitious climate policy has for several years driven the Member States to consider the future of their energy system. European Guidelines and Directives already set targets for 2020, including the well-known 20-20-20 goals. Now Europe's view is reaching beyond that, envisaging the 2050 horizon. Limiting the increase in global temperature to 2°C above pre-industrial temperatures with a probability of at least 50% implies halving the global emissions by 2050 [3, p. 15]. Assuming equal per capita emissions by 2050, this comes down to an 85% emission reduction for developed countries [4, p. 34]. Hence "the European Council reconfirmed in February 2011 the EU objective of reducing GHG emissions by 80-95% by 2050 compared to 1990" [5, p. 3]. Following this, the European Commission published 4 roadmaps to outline the European vision, amongst which the *Energy Roadmap 2050* produced by the DG Energy [6]. Given the Commission's limited ability to enforce energy policy, the scope of the document is limited to the analysis of a number of symbolical scenarios and the identification of "no regret" options. Yet, even though the Commission cannot impose binding measures on certain key aspects of the energy problem without the accord of all Member States, the direction it chooses to move in is of key importance (e.g. its decision whether or not to support options such as CCS and nuclear).

Therefore, leading up to the publication of the European Commission's vision multiple organizations published their own studies in an attempt to influence the European policy. 3 of the most prominent of those have been selected to be compared against *Energy Roadmap 2050* as to how they approach the energy challenge and how they model the energy system and its evolution towards 2050. Thus in total 4 studies will be compared:

1. *Energy Roadmap 2050*; European Commission, DG Energy – [ERM]
2. *Power Choices*; Union of the Electricity Industry – EURELECTRIC [7] – [PC]
3. *Roadmap 2050*; European Climate Foundation [8] – [RM]
4. *Battle of the Grids*; Greenpeace [9] – [BG]

To produce technically feasible supply side configurations for the power sector (i.e. generation portfolios and the corresponding energy system infrastructure) the operation of the electricity system has to be modelled in sufficient detail. Of specific interest for this work is the way in which the different types of operational flexibility of the energy system are represented. These flexibility options will be key in dealing with the intermittent character of the renewable energy sources [RES]. In addition the studies' main assumptions and additional modelling methodologies for supply and demand are reviewed. Finally the studies are evaluated on how they incorporate goals and constraints regarding sustainability.

Operational flexibility can be categorized in 5 aspects: (1) the flexibility of conventional power units, (2) energy storage, (3) demand response, (4) flexibility services from RES units and (5) power exchange [10]. (1) All studies perform a unit commitment and thus take into account the flexibility limits of the conventional power units (such as ramping rates). (2) Storage is almost completely absent in the 4 studies, except for pumped storage. ERM does consider the possibility to transform excess electricity to hydrogen. The possible applications of grid-scale storage are not investigated. (3) RM and BG allow their models to shift respectively 15-30% and 20% of demand within 24 hours. ERM and PC do not explicitly model demand response. Implications of demand response use on the mid and low voltage grid are not considered, nor the limits that these grids or e.g. user behaviour could impose on its potential. Exception is a limited effort by RM for the British distribution grids. None investigate the possibility of demand response to shift demand over a larger timespan than a single day. (4) RM and BG base the output of their RES on weather data. ERM and PC use a deterministic equivalent to model RES output (uniform electricity production over a year). None consider possible balancing energy services of variable RES. Dispatchable RES (e.g. biomass) is used in all studies to help balance supply and demand. (5) All studies perform a DC power flow. ERM and PC only consider cross-border connections. They conclude that the TSO's planned reinforcements of these links will suffice. However, they do not check the balance of the electricity system on an hourly basis throughout the year. RM allows grid reinforcements but represents Europe in only 9 nodes, which limits the validity of their conclusions. BG focusses on the grid needed to facilitate the *Advanced Scenario* of Greenpeace's *Energy [R]evolution*. Their representation of the European grid (with 224 nodes) is therefore logically better. However, their reinforcement strategy is very simplified. Important options such as a possible HVDC supergrid are not considered in any of the studies.

The sustainability of the different scenarios is not explicitly assessed. The studies limit themselves to imposing a limit on carbon emissions, in certain cases supplemented by a target for the share of RES. The integration of sustainability indicators, such as e.g. life-cycle greenhouse gas emissions, in the modelling process or a post-modelling analyses is completely lacking in these policy-determining/-influencing studies.

REFERENCES

[1] M. M. Hand, S. Baldwin, E. DeMeo, J. Reilly, T. Mai, D. Arent, G. Porro, M. Meshek, and D. Sandor, "Renewable Electricity Futures Study," Golden, CO, 2012.

[2] The National Development and Reform Commission, "China's Policies and Actions for Addressing Climate Change," 2013.

[3] Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, *Climate Change 2007: Mitigation of Climate Change*. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press, 2007, pp. 1–863.

[4] EG Science, "The 2°C target - Infromation Reference Document," Brussels.

[5] European Commission, "Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions - A Roadmap for moving to a competitive low carbon economy in 2050," European Commission, 2011.

[6] European Commission, "Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions - Energy Roadmap 2050," Brussels, 2011.

[7] Eurelectric, "Power Choices - Pathways to Carbon-Neutral Electricity in Europe by 2050," Brussels, 2009.

[8] European Climate Foundation, "Roadmap 2050: A practical guide to a prosperous, low-carbon Europe: Policy Recommendations," 2010.

[9] J. Van De Putte and R. Short, "Battle of the Grids," Amsterdam, 2011.

[10] F. Comaty, G. Andersson, and A. Ulbig, "Modeling and Simulation of the European Power System using Power Nodes - Assessing the Value of Flexibility for High-Share Integration of Renewable Energies in Europe," Swiss Federal Institute of Technology (ETH) Zürich, 2013.