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Efficient strategies for the integration of renewable energy into future energy infrastructures in Europe – An analysis based on transnational modeling and case studies for nine European regions

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HIGHLIGHTS

- We present the main outcomes of the SUSPLAN EU project.
- It assesses long-term energy infrastructure needs to integrate RES in Europe.
- Regional and transnational analyses are performed for 4 RES scenarios until 2050.
- Major barriers to the integration of RES into energy infrastructure are identified.
- Efficient strategies to mitigate these barriers are proposed.

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ABSTRACT

As a result of the current international climate change strategy, the European Commission has agreed on ambitious targets to reduce CO_2 emissions by more than 80% until 2050 as compared to 1990 levels and to increase the share of renewable energy and improve energy efficiency by 20% until 2020. Under this framework, renewable energy generation has increased considerably in the EU and it is expected to keep growing in the future years. This paper presents long-term strategies for transmission infrastructure development to integrate increasing amounts of renewable generation in the time horizon of 2030–2050. These are part of the outcomes of the SUSPLAN project,[1] which focuses on four possible future renewable deployment scenarios in different European regions taking into account the corresponding infrastructure needs, especially electricity and gas grids, both on regional and transnational level. The main objective of the project is the development of guidelines for the integration of renewable energy into future energy infrastructures while taking account of national and regional characteristics. Therefore, the analysis is based on a two-track approach: A transnational modeling exercise ("top-down") and in-depth case studies for nine representative European regions ("bottom-up").

1. Introduction

The current international climate change strategy implies ambitious targets in the EU to reduce CO_2 emissions, increase the share of renewable energy and improve energy efficiency by 20% in 2020 (European Commission, 2008). Furthermore, the EU is committed to reducing greenhouse gas emissions by 80–95% below 1990 levels by 2050 (European Commission, 2011a). The electricity sector will play a key role in achieving these targets. The EU expects an increase in the share of low carbon technologies in the electricity mix from approximately 45% today to 60% in 2020, 75–80% in 2030, and nearly 100% in 2050. Out of the 100% target in 2050, 50–55% would come from renewable energy sources (RES) (European Commission, 2011d). To integrate these high amounts of RES generation, significant infrastructure extensions will be necessary not only at national level but also at transnational level, especially if large-scale onshore and offshore wind parks in Northern Europe and large solar power facilities in Southern Europe and Northern Africa are to be developed. The development of an integrated energy network has been pointed out as essential for the achievement of the EU's energy policy goals

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[1] SUSPLAN (PLANning for SUStainability) is a project initiated in 2008, and finished in 2011, under the European Union's 7th Framework Program and sponsored by the Directorate General Transport and Energy (DG-TREN). The sole responsibility for the content of this paper lies with the authors. It does not represent the opinion of the European Commission. The EC is not responsible for any use that may be made of the information contained therein.

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of competitiveness, sustainability and security of supply (European Commission, 2010). In this context, the European Commission (EC) published a proposal for a regulation on guidelines for trans-European energy infrastructure, identifying energy infrastructure priorities for 2020 and beyond, and three main groups of strategies to facilitate the development of this infrastructure. These include the streamlining of authorization procedures to reduce their duration and raise public acceptance, allocation of costs according to the benefits achieved by the agents, and provision of market-based and direct EU financial support (European Commission, 2011b).

Under this framework, several relevant long-term roadmaps and large European projects were launched to address the future development of energy infrastructure required to integrate large amounts of RES generation. For instance, the roadmap presented by (European Climate Foundation, 2010) provides a technical and economic assessment of three main de-carbonization pathways with 40%, 60% and 80% RES generation, and the respective electricity transmission grid expansions in the EU. According to this study, the required additional transmission capacity ranges between 50 GW and 165 GW, in the 40% RES and 80% RES pathways, respectively. Also, some European projects under the 7th Framework Programme such as REALISEGRID (realisegrid.rse-web.it), IRENE-40 (www.irene-40.eu) and TWENTIES (www.twenties-project.eu) stand out. The main outcome of the REALISEGRID project is the development of a cost-benefit methodology to assess pan-European infrastructure investments (Miglavacca et al., 2011). The IRENE-40 project identifies network bottlenecks within the electrical transmission system and aims at elaborating a technology roadmap including actions and milestones towards the future electricity network infrastructure up to 2050. In the TWENTIES project, six local demonstration projects are being developed to show that wind farms and flexible load can provide system services, the operation of offshore high voltage direct current (HVDC) networks, and the increase in transmission grid flexibility and capacity due to the application of innovative Flexible AC Transmission Systems (FACTS) and Dynamic Line Rating (DLR).

The objective of the paper on hand is to provide an overview over some of the main outcomes of the SUSPLAN project, namely barriers and strategies for RES integration in the European context. As well as the previously indicated projects, SUSPLAN attempts to bring solutions to the energy challenges facing the EU, with focus on energy infrastructure development. While the above named projects focus on evaluating costs and benefits of new infrastructure (including new technologies), the SUSPLAN project computes the economically optimized energy infrastructure under different framework conditions (scenarios), represented by varying portfolios of RES generation. The novel aspect regarding this project is that it deals with different types of energy infrastructure – electricity and gas – and covers a long-term time horizon (up to 2050). Furthermore, the analyses within the project are performed not only for the pan-European system but also for selected regional/national systems with diverging RES penetration levels and different issues related to RES integration. Consequently, strategies and policy recommendations for an optimal integration of renewable technologies into future electricity and gas infrastructures were derived at regional/country-based and transnational levels.

This paper's main aim is to present the major barriers and strategies for high RES deployment in an international, European context (it does, however, not include a detailed economic assessment of the different scenarios). The paper is divided into five sections apart from this introduction. Section 2 defines the four storylines considered in SUSPLAN and the methodology adopted to perform the analyses. Section 3 shows the results regarding the deployment of RES potentials across the different storylines and the corresponding energy infrastructure needs. Section 4 describes the main barriers to energy infrastructure development. Section 5 discusses strategies for the removal of infrastructure development barriers. Finally, Section 6 presents the conclusions.

2. The SUSPLAN project approach

2.1. Methodology

In the SUSPLAN project, nine different regions/countries have been selected throughout Europe for comprehensive in-depth analyses of future grid integration of renewable generation technologies. These regions were chosen according to their characteristics (higher or lower potential for RES, incentives for RES technologies, weak or strong infrastructures, etc.) in such a way that other similar European regions could be represented in the analysis. These regions are described in (Graabak and Bakken, 2011) and include the Island of Lewis in North West Scotland (Islands), Norway (Northern Europe), Rhine-Neckar Region in Germany (Central/Western Europe), Pomeranian Region in Northern Poland (North-Eastern Europe), Romania (South-Eastern Europe), Spain (South-Western Europe), Italy (Southern Europe), Serbia (Western Balkan) and Austria (Alpine region). The modeling approach to perform the regional studies comprises three main steps (Auer et al., 2009): (i) identification of the long-term 2050 technical potentials for different RES technologies; (ii) incorporation of barriers and constraints against the deployment of RES potentials and the development of grid infrastructures; and (iii) computation of grid infrastructure costs for different RES penetration levels. Each regional analysis was performed by experts of the respective region/country and involved an in-depth regional stakeholder consultation. The complete results of these analyses are available at the SUSPLAN project webpage (www.susplan.eu).

Taking into account relevant results from the regional case studies,[2] a comprehensive transnational analysis determined electricity and gas infrastructure routes and capacities required to integrate future RES generation. For this purpose, a cost-benefit analysis was performed to determine whether the benefits of the new infrastructure (CO_2 emissions savings and security of supply in a European context) outweigh its costs (Auer et al., 2009).

The regional and transnational analyses together with close consultation with regional experts in the course of several workshops, as well as surveys using questionnaires, provided the basis for the elaboration of strategies and policy recommendations for the implementation of RES technologies and the development of the required grid infrastructures in the pan-European system.

2.2. Future energy contexts: SUSPLAN storylines characterization

Regional and transnational studies in the SUSPLAN project were developed against the background of a consistent framework comprising four storylines – green, yellow, red and blue – with a time horizon up to 2050. The storylines are characterized by two driving forces: Technical development rate (slow or fast) and public attitude towards the adoption of environment-friendly options (positive or indifferent). Within this coordinate system, a consistent set of assumptions has been derived for the

[2] Please note that due to the high complexity of the transnational modeling exercise the scope of the optimization had to be reduced as far as possible, implying that certain regional features had to be simplified. This applies, for example, to the exclusion of some technologies which only play a role in individual countries (such as CSP) or to the simplified representation of power flows beyond the borders of the EU. Also, distribution grids are only analyzed on regional level whereas the transnational analysis focuses on the transmission system.