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Outlook of the EU energy system up to 2050: The case of scenarios prepared for European Commission's "clean energy for all Europeans" package using the PRIMES model

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ABSTRACT

This paper presents a set of scenarios quantified by the PRIMES energy systems model that have provided input to the Impact Assessment work accompanying the "Clean Energy for all Europeans" package, brought forward by the European Commission in November 2016. The mandatory targets proposed or reiterated in the policy package are for the year 2030, within a decarbonisation context; the horizon of the modelling exercise extends to 2050. The role of electricity is essential for the transition, with energy efficiency and renewable energy sources being central pillars. The ETS mechanism along with bottom-up policy measures deliver the significant GHG emissions reductions needed for the decarbonisation of the EU energy system. The model based analysis reveals a significant shift away from OPEX towards CAPEX, with moderate impact on energy prices in the medium term.

1. Introduction

In November 2016, the European Commission presented the "Clean Energy for all Europeans", commonly referred to as the "winter package", a package of measures to keep the European Union competitive as the clean energy transition is changing global energy markets [1]. The proposed policies and legislation are aligned with the 2030 targets agreed by the European Council regarding GHG emissions reduction, renewable energy and energy efficiency [2]. The interplay between these targets is complex; quantitative analysis, incorporating sophisticated modelling tools, can aid in assessing such interactions and synergies.

The Impact Assessments (IA) are studies which accompany the submission of the policy package to the EU institutions. The IA mainly use quantitative analysis via the design and elaboration of two core policy scenarios, namely EUCO27 and EUCO30. The two policy scenarios were built based on the EU Reference Scenario 2016 [3] and are designed to achieve the 2030 targets as agreed by the European Council.

The analysis of impacts of the two policy scenarios was the input to the Effort Sharing Regulation Impact Assessment [4] and the Staff Working Document [5] accompanying the Communication on low-emission mobility strategy published in July 2016, as well as the Impact Assessment accompanying the proposal for recast of the Directive on the promotion of energy from renewable sources [6] and the Impact Assessment accompanying the proposal for the revised Energy Efficiency Directive [7] published in November 2016. The EUCO27 was also the starting point for the Impact Assessment accompanying the proposal for revised rules for the electricity market, risk preparedness and ACER [8]. The EUCO33, EUCO35 and EUCO40 scenarios included more ambitious targets for the energy efficiency and were part of the Impact Assessment accompanying the proposal for the revised Energy Efficiency Directive. The EUCO3030 scenario also included a more ambitious target regarding the penetration of energy produced from renewable energy sources in the energy mix (Fig. 1).

All scenarios have been designed so as to assist the definition or confirmation of the 2030 energy and climate targets of the EU Council, however, the horizon of the modelling exercise extends up to 2050 as the targets have been set in view of the EU transition towards a low-carbon economy. Thus, all scenarios are decarbonisation scenarios, i.e. they are compatible with a 2 °C trajectory and the EU INDC submitted in view of the COP-21 meeting in Paris in 2015 and achieve above 80% GHG emissions reduction in 2050 compared to 1990 levels, respecting the suggestion of the 2011 Roadmap for moving to a competitive low carbon economy in 2050 [9].

In all scenarios quantified, carbon pricing is a strong driver for

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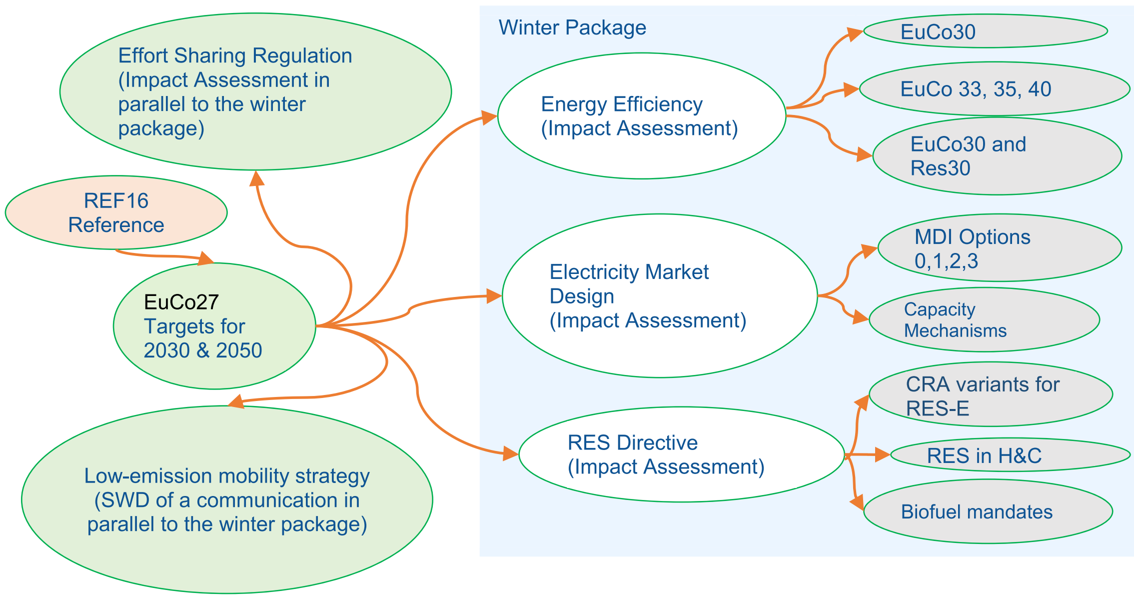

Fig. 1. Illustration of European Commission studies that have used the EUCO scenarios.

significant emission reduction in the power sector and mainly pushes development of RES which benefit from learning-by-doing requiring low or no out-of-the-market support. In addition, reforms of the EU internal markets of electricity and gas enhance integration of balancing and competition. The latter is supplemented by the development of new interconnection capacity. Energy efficiency is a strong pillar in all scenarios, as it strongly reduces energy demand, with different levels of ambition. The transport sector contributes to the achievement of the climate targets via strong GHG emissions cut, through electrification of cars and LCVs and increased use of advanced biofuels.

This paper presents and discusses key findings from the modelling exercise. Additional illustrations of results can be found on the supplementary information accompanying it.

2. Methodology

2.1. Modelling tools

The scenarios have been quantified with the PRIMES energy systems model which is an EU energy system model which simulates energy consumption and the energy supply system [10]. It is a partial equilibrium modelling system that simulates an energy market equilibrium in the European Union and each of its Member States. The model includes consistent EU carbon price trajectories.

Decision-making behaviour is forward looking and grounded in micro economic theory. The model also represents in an explicit and detailed way energy demand, supply and emission abatement technologies, and includes technology vintages.

The model is a set of sub-modules (i.e. the power sector module, the transport sector module, the industrial module, the residential and tertiary buildings module, the biomass supply module, etc.). Industrial non-energy related CO_2 emissions are covered by a sub-module so that total CO_2 emissions can be projected. The model proceeds in five year steps and uses Eurostat data for the years 1995–2014.

The PRIMES model is suitable for analysing the impacts of different sets of climate, energy and transport policies on the energy system as a whole, notably on the fuel mix, CO_2 emissions, investment needs and energy purchases as well as overall system costs. It is also suitable for analysing the interaction of policies on combating climate change, promotion of energy efficiency and renewable energy sources. Through the formalised linkages with GAINS non-CO_2 emission results and cost curves, it also covers total GHG emissions and total ESD sector emissions [11]. It provides details at Member State level, showing differential impacts across them.

PRIMES has been developed and is maintained by E3MLab/ICCS of National Technical University of Athens in the context of a series of research programmes co-financed by the European Commission. The model has been successfully peer-reviewed, most recently in 2011 [12].

2.2. Scenario description

The impact assessment studies mainly use two policy scenarios, named EUCO27 and EUCO30, along with a number of sensitivities and variants. The scenarios have been conceived using a set of targets for reducing GHG emissions, increasing energy efficiency and increasing the penetration of renewable energy sources in the energy system. In order to meet the targets, concrete bottom-up policy measures have been identified, instead of the use of market based mechanisms such as carbon, renewable and efficiency values, besides the use of ETS.

The two core policy scenarios used reflect the 2030 targets agreed by the European Council, as shown in Fig. 2.

Besides the main policy scenarios, a number of variants and sensitivities reflecting different levels of ambition, as far as the key targets are concerned, were constructed. In detail, the EUCO33, EUCO35 and EUCO40 scenarios build on the EUCO30 scenario but they explore more ambitious energy efficiency targets (33%, 35% and 40% respectively). The EUCO3030 scenario examines also a 30% target for renewables in 2030. All scenarios achieve the long-term milestone to reduce GHG emissions domestically in the EU at least by 80% in 2050.

The approach followed for the modelling of all scenarios is to use a combination of bottom-up policy instruments, such as standards, sectorial obligations and incentive schemes, with carbon pricing through auctioning of allowances for the sectors, such as power generation, energy intensive industry and aviation, belonging to the Emission Trading Scheme (ETS). The bottom-up policies mainly apply to the non-ETS sectors which are subject to the Effort Sharing Regulation. The technology standards, the specific transport policies, and the measures promoting energy efficiency improvement of houses and buildings aim at removing non-market barriers and enable the effectiveness of incentives/obligations related to energy efficiency and renewable policies (Table 1). Most of these policies are varied in stringency/intensity between scenarios. While some policies are fully harmonised at the EU level (standards, carbon pricing) others take into account national conditions.