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INVESTMENT CHOICES AND CAPACITIES AT RISK IN DECARBONIZING THE EU ELECTRIC SYSTEM

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ABSTRACT

In this paper, we analyze the implications of fully or nearly fully decarbonizing the European electric system by 2050. Future power mixes trajectories are computed with a 5 year time step at country level using eTIMES-EU, a bottom-up optimization model for the EU power sector. By comparing a near carbon neutral case (TGT90) with a fully decarbonized system (NEUTR), we discuss the additional costs, capacities and trading implications. Increasing the ambition from 90% mitigation goal to strict neutrality requires 32.6% more investments in 2050, 394 GW additional solar capacity in 2050 and more reliance on trade between countries.

Keywords: optimization, long-term energy planning, decarbonization, interconnected electric system

1. INTRODUCTION

In line with the Paris agreement to keep temperature increase well below 2°C, the European Union aims at carbon neutrality by 2050. This will have strong implications for the power sector which was responsible for 24% of CO_2 emissions in Europe in 2016. National action plans have been proposed that include phase out policies and targets for renewables. However in an interconnected system, the trajectories are interdependent and raise the questions of speed of change, burden sharing and trade.

Different studies in the literature have investigated the long term of the European electric system [1] [2] [3] [4]. But to our knowledge, no study provided a comparison between investment decisions and system operation for different levels of decarbonization of the electric system. In this analysis, we use a bottom-up optimization model to explore three different configurations of the EU electric system in 2050: a reference case (REF), a system aiming at a reduction of 90% of the base year CO_2 emissions (TGT90) and a carbon neutral system (NEUTR). Our emphasis is put on the impacts of increasing the ambition from a nearly decarbonized system to a fully decarbonized system and we quantify investment decisions that become irrelevant or that are only valid for the most stringent case. These impacts include in particular the volumes and directions of trades between countries. Section 2 presents our model and main assumptions. Section 3 then discusses the simulation results before concluding in section 4.

2. METHODOLOGY

2.1 The European electric sector model

We use a bottom-up optimization model of the EU power system from the MARKAL-TIMES models family to model technologies, production dynamics, regional potentials, and interconnections. eTIMES-EU thus builds up on full technical and economic details of all candidate technologies. An optimization stage then computes optimal investment and operation decisions to supply national electricity demands subject to sets of scenario specific constraints [5]. Competing generation options include: bioenergy (biogas, biomass, biomass with CCS[1]), lignite, natural gas and coal with or without CCS, geothermal, hydro (dam, run of river, lake, pumping and storage), solar (PV, CSP), wind (onshore, offshore) and others (waste, ocean…). eTIMES-EU is a partial equilibrium model with exogenous electricity demands to be satisfied on each time slices.

Spatial and temporal resolution

The model comprises 29 countries distributed in 8 groups. To study the impact of long term energy and define optimal trajectories, the model runs by steps of 5 years between 2016, 2020 and 2050 (with a perfect foresight mode for this analysis). Within each period, 64 time slices are considered. These sub annual time steps model 4 seasons with one week day and one week-end day each subdivided in 8 time steps of three hours.

[1] Carbon Capture and Storage

Furthermore we use a peak reserve factor to alleviate the effect of the averaging on peak electricity demands and force the model to install more capacity to be able to cope with situations of higher demand.

Table 1- Country groups

Alpine Peninsula	Italy (IT)
British Islands	Ireland (IE), United Kingdom (UK)
Iberian	Spain (ES) , Portugal (PT)
CWE[2]	Austria (AT), Belgium (BE), Switzerland (CH), Germany (DE) , France (FR), Luxembourg (LU), Netherlands (NL)
CEE[3]	Czech Republic (CZ) , Poland (PL)
Nordic & Wester Nordic	Denmark (DK), Finland(FI), Norway (NO), Sweden (SE), Iceland (IS)
NEE[4]	Estonia (EE), Lithuania (LT), Latvia (LV)
SEE[5]	Bulgaria (BG), Greece (GR) , Croatia (HR), Hungary (HU), Romania (RO), Slovenia (SI), Slovakia (SK)

The calibration of the base year

The base year of the model is 2016. Installed capacities for each region were retrieved from the Platts Database and cross-validated with ENTSO-E and Eurostat data. Bioenergy data were taken from [6]. The dynamics of base year production in the model were calibrated with ENTSO-E and EUROSTAT generation data. ENTSO-E[6] data are available at time steps down to 15 minutes low and were aggregated corresponding to the time slices considered in our model. A cross validation was made with EUROSTAT figures. The future electric demand considered in each region is calibrated with the EU Reference Scenario 2016 report [7].

Key country level assumptions

Renewable potentials and available technical options are differentiated by country. Where applicable, phase-out policies have also been considered. Wind and solar power plants have experienced a tremendous growth (+244 GW between 2000 and 2016) and it is estimated that installed capacity covers only 16% of the overall available potential [8]. Wind offshore offers a supplementary opportunity in the three sea basins across Europe [9]. Regarding future hydro power plants, the remaining potential is expected to be of run of river type. Finally bioenergy, though suffering from competition for other usages could provide substantial resources via biomass and biogas [10]. Renewable potentials have been extracted from [8] [11] [12]. Major coal plants phase out announcements were done across the continent and summarized in [13]. The situation of Nuclear power is also much contrasted with independently positions: Germany plans to phase-out nuclear by 2022 and France plans to reduce its nuclear activity to 50% in 2035 against 72.5% in 2016, while new development are planned in UK, Czech Republic, Finland, Hungary, Poland and Romania [14].

2 Central Western Europe
3 Central Eastern Europe
4 Northern Eastern Europe
5 South Eastern Europe
6 European Network of Transmission System Operators for Electricity

2.2 *Scenarios*

We investigate three scenarios with different levels of environmental concern:

A Reference ("REF") scenario: This scenario serves as benchmark and describes the case of a moderate climate ambition in Europe. The CO_2 penalty still rises from 5 € per ton in 2016 to 35 € per ton in 2030 and then remains constant, interconnections develop at the rhythm of TYNDP2016 recommendations and ACER opinions [15]. Current coal phase out policies are applied. The maximum installed capacity for coal in Germany and nuclear in France are also limited at the current capacities.

The Target 90 (TGT90) scenario: In addition to the assumptions of the Reference scenario, we impose here a reduction of CO_2 *emissions by 90% between 2016 and 2050*.

The carbon neutrality (NEUTR) scenario: This scenario imposes a strictly CO_2 *neutral system in 2050*.

Note that for the TGT90 and the NEUTR scenarios, no specific objective is fixed for the countries and the burden sharing is endogenously computed.

3. RESULTS

3.1 CO_2 emissions burden sharing and power mixes

Figure 1 depicts the aggregated evolution of CO_2 emissions by 2050 for all scenarios. In the reference scenario, emissions decrease by 13% over the horizon with a clear reduction before 2035 followed by a partial recovery after. In comparison, the TGT90 and NEUTR scenarios will respectively require an additional mitigation effort of 763 and 872 Mt CO_2 avoided.

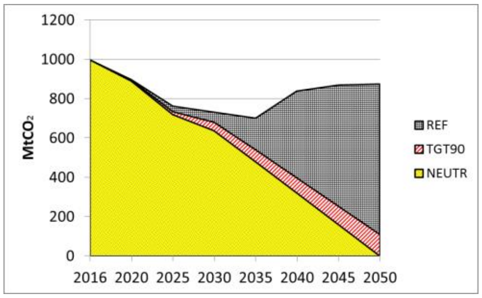

Figure 1- Level of global CO_2 emissions

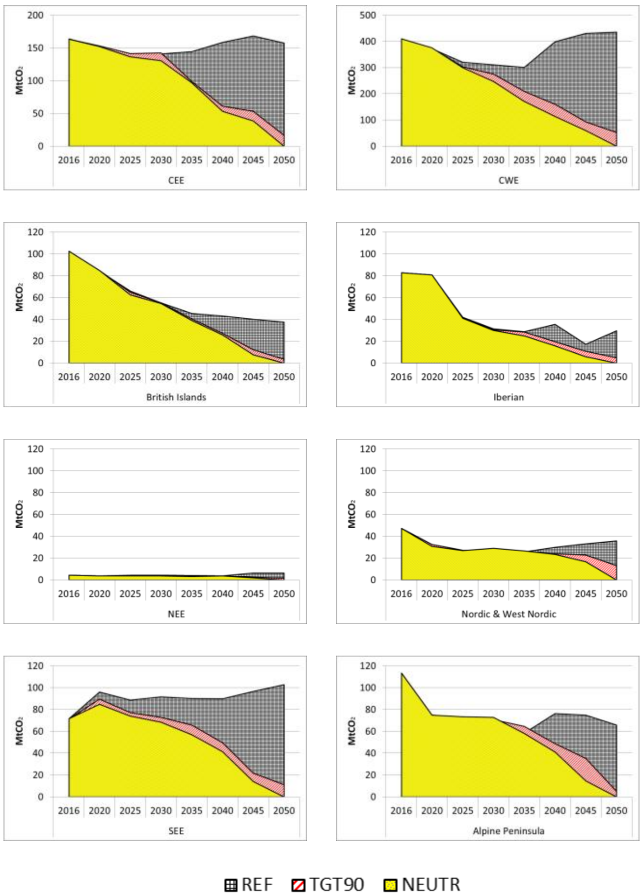

Figure 2- Repartition of the burden sharing between regions

Regions like CWE and CEE which concentrate more than 50% of the base year emissions make the largest efforts to attain carbon neutrality while in the Iberian peninsula existing hydropower potential and capex reduction for solar could significantly decrease emissions even in the reference case (Figure 2)

Achieving the levels of *CO_2* reduction presented in Figure 1 induces profound modifications in the electricity mix. The decrease of emissions before 2035 in the REF case is for instance explained by coal to bioenergy and natural substitution while the subsequent increase is due to the demand growth effect. Alternative solutions

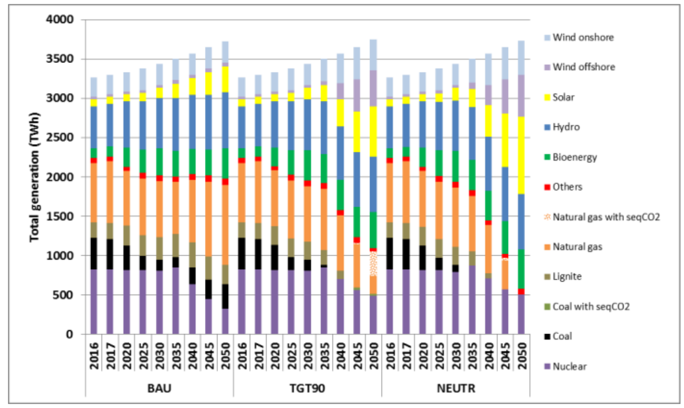

Figure 3- Electric power generation per technology

such as natural gas with CCS are only implemented in the TGT90 scenario to reduce emission from fossil sources but not in neutral case. Finally output from renewables increases from 48% in the REF scenario in 2050 to 86.4% in the NEUTR scenario.

3.2 Capacity & investments

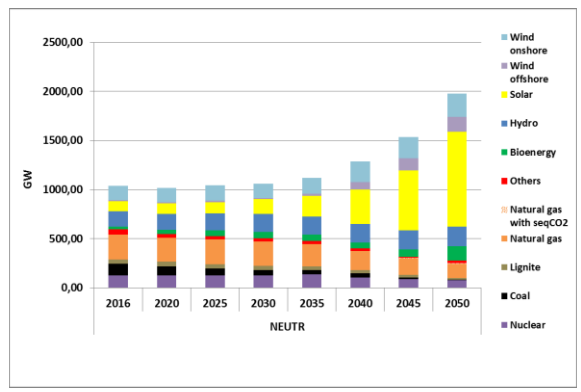

Figure 4- Evolution of capacity in the NEUTR scenario

The total capacity installed in 2050 in the NEUTR scenario amounts to 1978 GW which corresponds to an increase of 91% compared to the base year capacity. In comparison the total capacity only increases by 4% in the REF scenario and by 46% in the TGT90 case. Renewables drive most of this augmentation and we compute the changes in terms of overall investment, selected technologies and trade between a completely decarbonized and a nearly decarbonized power system. These differences show investment decisions that are more risky as they are only valid for the most stringent case or inversely investments that could become stranded because they could be abandoned when the ambitions are tightened. The additional 10% of emissions reduction between the two scenario leads to an overall 32.4% extra investments in 2050 in the NEUTR scenario. Changes in capacity are also depicted on Figure 5. This mostly concern natural gas power plants which are less used in the NEUTR scenario.

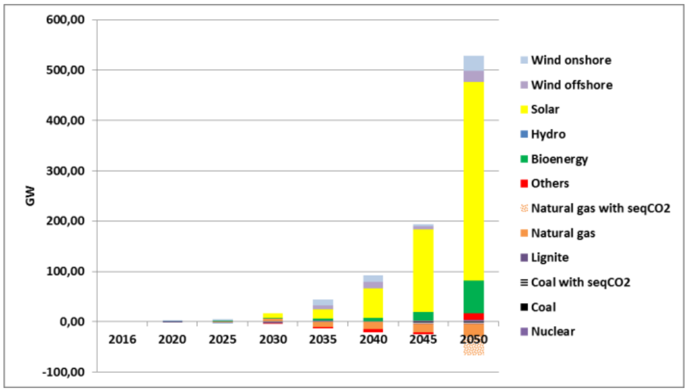

Figure 5- Differences of capacities installed in the NEUTR scenario compared to the TGT90 scenario

These investment choices also affect trading patterns between countries as depicted in Figure 6. The overall activity of interconnections increases by 315 TWh over the period studied with negative net trades for several countries. This highlights a different type of policy risk as these countries will, in our cost competitive analysis, have to rely more heavily on effective implementation in other countries to satisfy their demand.

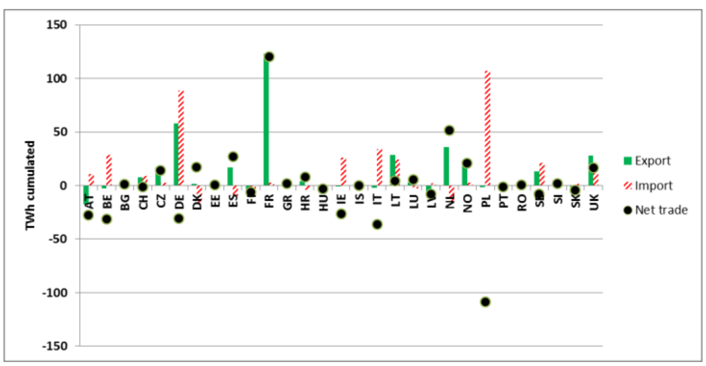

Figure 6- Differences of trade volumes in the NEUTR scenario compared to the TGT90 scenario

4. CONCLUSION

Reducing CO_2 emissions in the electric system is a core preoccupation in European Union. In this context, this study investigates the major differences between a complete decarbonization of the EU electric system in 2050 and 90% reduction of CO_2 emissions between 2016 and 2050. Our results show in the NEUTR scenario a surge in the investments in 2050 (+32.6%) driven by supplementary solar capacity (394 GW) compared to TGT90 scenario. Trade activities are also impacted with 12% more electricity exchanged through the interconnected grid. We believe that such elements are not negligible and should be accounted for during decision making.

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