European Commission

Study on US-EU Integrated Power and Water Systems Modelling

Executive summary

PP-06161-2017

Written by: A. De Vita, M. Kannavou, A. Makrysopoulos (E3Mlab/ICCS)
A. Carlino, A. Castelletti, M. Giuliani, F. Recanati, P. Zamberletti (Politecnico di Milano)
C. Kost, S. Langle (Fraunhofer-ISE)

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Research and Innovation

Study on US-EU Integrated Power and Water Systems Modelling

European Commission
Directorate-General for Research and Innovation
Directorate G - Energy
Unit G.3 – Renewable Energy Sources
Contact Piero De Bonis
E-mail *RTD-ENERGY-SR-US-EU-MOD@ec.europa.eu*
Piero.DE-BONIS@ec.europa.eu
RTD-PUBLICATIONS@ec.europa.eu
European Commission
B-1049 Brussels

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Authors

A. De Vita, M. Kannavou, A. Makrysopoulos (E3MLab/ICCS)
A. Carlino, A. Castelletti, M. Giuliani, F. Recanati, P. Zamberletti (Politecnico di Milano)
C. Kost, S. Langle (Fraunhofer-ISE)

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EXCECUTIVE SUMMARY

1 Introduction

Freshwater is a vital part of present energy systems. It is required both for the functioning of hydro power plants and for thermal and nuclear power plants as coolant. Changes in water availability and surface water temperature directly affect hydroelectric and thermoelectric power generation potential and reliability. The use, in particular, of nuclear power plants (and the reduced availability of hydro) has been a regular occurrence in Europe since the year 2000: in 2003, several thermoelectric and hydro power plants in France, the Danube region, etc. were forced to reduce production or completely shut down because of restricted availability of cooling water. The same has occurred at least in 2006, 2015 and most recently in the summer of 2018 when even power plants in Scandinavia were forced to shut down.

The combination of increased water temperatures and reduced summer river flow due to climate change will affect both hydropower and thermoelectric power generating capacity in Europe, with possibly significant impacts on electricity prices. It is especially during warm periods with low river flows that conflicts arise between environmental standards of receiving waters and economic consequences of reduced electricity generation. Other uses of water (e.g. for agricultural purposes) are assumed to be prioritised over energy in this approach and met at all times.[1]

This study investigates the interdependence of future water and energy systems and quantifies its economic and environmental impact. For this purpose, a soft integration between hydrological and energy system models was implemented. On the hydrological side, the HBV model and the Topkapi-ETH model were used, while on the power side the PRIMES-IEM model and the ENTIGRIS model were used.

The methodology developed within this project was applied to four different regions within Europe:

- **Iberian Peninsula**: multi-country study of the dependence of the power system on water availability in a region with high share of variable Renewable Energy Source (RES) and limited interconnections.

- **Danube River Basin**: multi-country study of the dependence of the power system on water availability in a region with a power generation mix relying on nuclear, hydro and thermal power stations, and relatively more limited variable RES resources.

- **Alpine region**: multi-country study of the dependence of the power system on water availability with focus on the Swiss Alpine region.

- **Adda River Basin**: river basin study to analyse the optimal use of interrelated hydropower plants within a single river basin.

2 Scenario analysis and main results

In order to investigate the future interdependence of water and energy systems in the year 2040, two different climate projections were used by the hydrological models, RCP2.6 and RCP8.5 (in order to explore from very mild to extreme climate change conditions), and three different variations of each climate projection, differentiated by the precipitation level were analysed (average, dry and extreme dry case). The energy system development is

[1] The water flows used within this study are assumed to be already net of agricultural and other uses.

assumed to follow a decarbonisation pathway, following the European Commission scenarios developed for the Clean energy for all Europeans package.

Energy system models simulated the operation of the electricity system of each region for the year 2040, with the installed capacity mix of each region being consistent with a decarbonisation context similar to EUCO30 and constrained by water availability and temperature projections produced by the hydrological models.

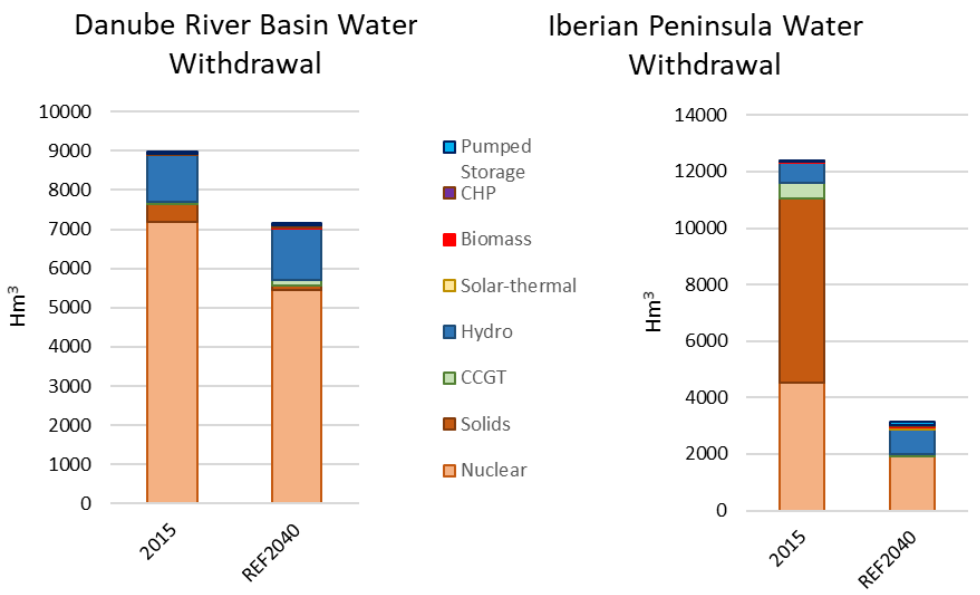

Figure 1 : Water withdrawal for energy system purposes in the Danube River Basin and the Iberian Peninsula

In a decarbonisation context, the energy systems of the Iberian Peninsula and Danube River Basin region (Figure 1) become more resilient to the effects of climate change by reducing their water dependence with increasing penetration of variable RES such as wind and solar.

The analysis of the power system under different water availability scenarios shows a high influence of water availability on electricity prices for future electricity systems (Figure 2 and Figure 3): as water becomes scarcer, electricity prices increase. The lower water availability results in lower power generation from hydropower plants, which has to be covered by thermal power plants with higher marginal cost. The increased participation of thermal power plants in the power generation mix has severe impacts on GHG emissions, thus increasing the carbon intensity of power generation.

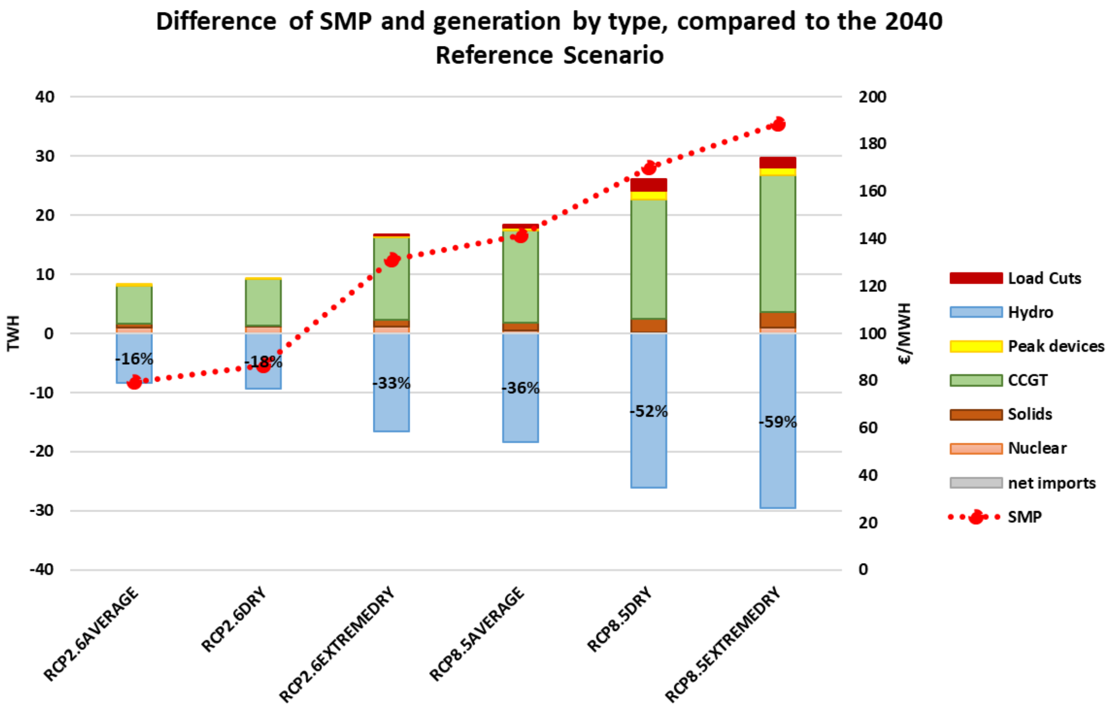

Figure 2 : Difference of SMP and generation by type, compared to the 2040 Reference Scenario for Iberian Peninsula

The future electricity system of Iberian Peninsula (Figure 2) is vulnerable to climate change due to its dependence on hydro availability; the system fails to meet the electricity demand in very dry cases (Load cuts, see Figure 2). Average system marginal costs may increase up to almost 200€/MWh in the Iberian Peninsula under extreme conditions.

The hydrological regime of the Danube River Basin region (Figure 3) is dominated by snow dynamics -at least in the time frame analysed within this study to 2040-, resulting in higher snow melt in drier (and most likely warmer) years, mitigating the effects of higher variability of future precipitation in the region; this is expected to occur towards mid-century, however, this tendency could change in the long run, resulting in overall water scarcity under RCP8.5. As a result, the future electricity system of Danube River Basin is deemed to be resilient to climate change until snow dynamics characterise its watershed; its reliability can however be compromised under extreme climate change scenario, as exemplified in the extreme dry scenario, within this study. Extreme cases where no water cooled power plants are available in the system were not analysed.

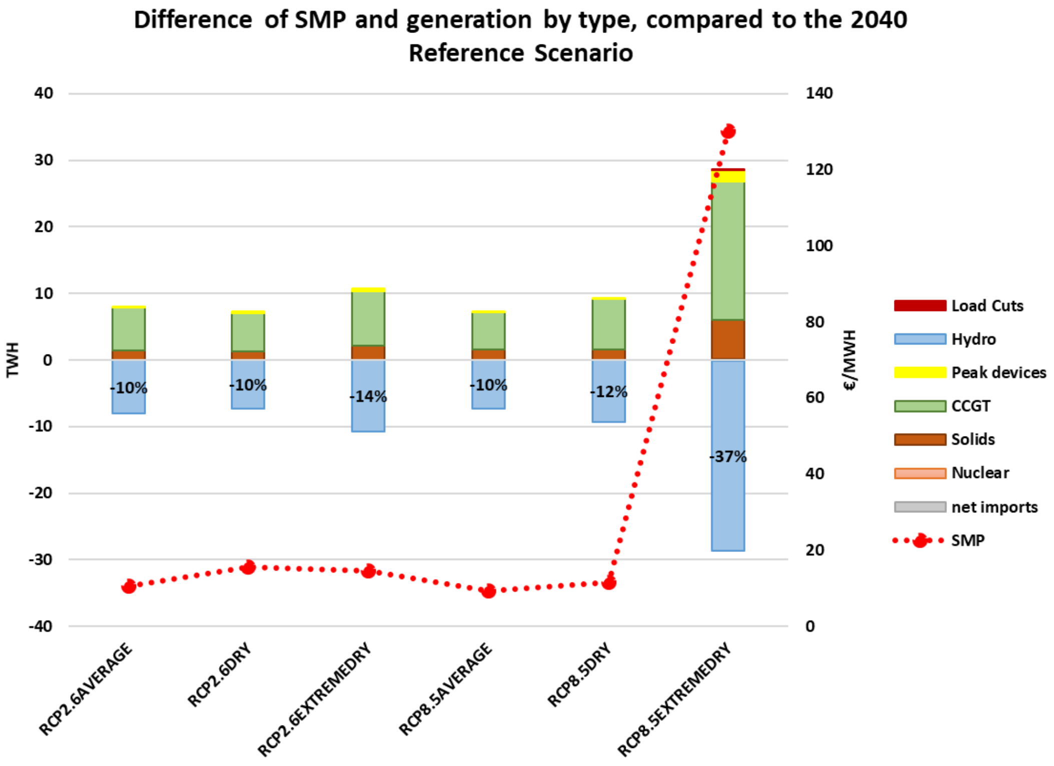

Figure 3 : Difference of SMP and generation by type, compared to the 2040 Reference Scenario for Danube River Basin

The study on the Alpine region shows that reservoir hydropower and pumped storage power plants play an important role in the future energy systems, by storing surplus energy of variable RES and generating in times of peak net load, which will also lead to the economic operation of the pumped storage power plants.

The high-resolution study in the Adda river basin shed new light on the behaviour of hydropower companies. Increased penetration of solar and wind energy reduces overall electricity prices, resulting in shrinking hydropower revenues. Since the effect is more evident on daytime prices when both solar and wind are available, hydropower generation shifts towards night time.

3 Policy recommendations and further research requirements

The effort for the transformation of EU and European energy system in the context of the decarbonisation will be tremendous, also in monetary terms. In order to achieve the 2050 EU climate target of at least 80% GHG reduction, very high penetration of variable renewable energy sources such as wind and solar is required. As a result of this level of penetration of variable RES, the water reliance of the future decarbonised energy system is projected to decrease.

However, the increasing need for flexibility that derives from the stochastic nature of the power generation from variable RES, makes the remaining dependence of the future energy system from water very important for the adequate operation of the energy system. The power plants that will provide the required flexibility will be highly dependent of the water availability (hydro power plants) and water temperature (flexible thermal plants such as CCGT).

Moving towards a decarbonised energy system necessitates that the majority of energy needs, such as heating, cooling and transportation, will be met by electricity and not by traditional energy sources such as fossil fuels. This implies that the need for a reliable and resilient energy system that can guarantee electricity supply under all climate conditions is increased.

Emission mitigation concerns to avoid dangerous climate change are the main drivers for the transformation of the energy system. However, the resilience and adaptation of the future energy system to climate conditions should also be considered, in order to avoid unnecessary investment costs and to ensure reliable operation, under all circumstances.

Further research on the Energy-water-nexus topic should focus on studying the interdependence of water and energy systems in the whole Europe, in order to identify regions where climate change might most affect water resources. Furthermore, analysing the future decarbonised energy system under decreased water and wind availability will provide an indication of the resilience of the future energy system to extreme climate conditions and enhances the strategic planning of the system.

Suggestions for further study include:

- Inclusion of water availability factors in long-term energy system planning tools (e.g. PRIMES)

- Study of the power system linked to the water system at regional scale (e.g. NUTS1), to study flexibility and grid congestion at a sub-country level.

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