Value of Flexible Industrial Demand in the European Power System

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Driven by environmental concerns, the European Commission has set ambitious targets for the decarbonization of the European energy system, which introduces fundamental challenges for both electricity generation and demand sectors. At the generation side, the majority of renewable energy sources are characterized by inherent variability and non-controllability. As the share of such renewable generation sources increases, despite the fact that conventional generators produce less energy, they need to remain in the system and operate part-loaded in order to provide the required flexibility and security to the system. This under-utilization of conventional generation assets implies that the cost efficiency of their operation will reduce. Furthermore, in cases where the flexibility of the conventional generation fleet is not sufficient, the last resort for system balancing lies in curtailing renewable generation. This implies that renewable generation assets with high capital costs are also under-utilized and thus may not achieve their CO2 emissions reduction potential. At the demand side, the envisaged electrification of transport and heat sectors imposes the need for capital-intensive electricity generation and network investments.

The above factors pose serious questions concerning the cost-efficiency of the future low-carbon European power system. In this setting, flexible demand technologies, enabling modification of electricity consumption patterns, have attracted great interest by governments, industry and academia. This is because suitable coordination of demand flexibility can support system balancing and limit peak demand levels and therefore reduce system operation and investment costs. Although significant amount of previous work has focused on residential and commercial demand flexibility, the potential of demand flexibility in the industrial sector has not yet been thoroughly investigated. This constitutes a major knowledge gap, since industrial demand represents a significant share of the total electricity consumption (36% in Europe). Furthermore, in contrast with residential consumers, many industrial consumers already possess the required monitoring, control and communication infrastructure to participate in various sectors of the electricity market, and given their large size, this participation provides strong economic incentives due to their high energy costs, and is not subject to the technical and economic challenges of aggregation.

In this context, the H2020 European project IndustRE has developed a novel, whole-system modeling framework with the aim to comprehensively quantify the potential economic benefits of flexible industrial demand (FID) for the European power system with a horizon to 2030. This framework considers all system sectors, including the generation system and the transmission network, as well as multiple timescales, including the long-term planning timescale, the short-term scheduling horizon and the real-time balancing horizon. The objective of this modeling framework lies in minimizing the total investment and operation cost of the European power system, while meeting certain targets regarding the penetration of renewable generation.

In this framework, the least-cost generation and transmission investment decisions are determined by a holistic optimization model. These investment decisions are then inputted to a stochastic unit commitment model which refines operation decisions by capturing short-term system uncertainties (primarily driven by the stochasticity of the renewable generation output) through statistical modeling and stochastic optimization techniques. Industrial demand flexibility is represented in this framework through a generic, process-agnostic model, which however accounts for fixed energy requirements and load recovery effects associated with industrial processes. The full paper will present the details of this modeling framework.

Case studies have investigated different scenarios regarding: a) the level of industrial demand flexibility, expressed by a parameter α which denotes the ratio of industrial demand that can be shifted in time and b) the level of renewable generation in the European power system, expressed as the percentage of the European electricity consumption supplied by renewable energy sources (RES). Figure 1 presents the generation and transmission cost savings (in billion Euros per year) brought by different levels of industrial demand flexibility (with respect to the benchmark scenario $\alpha = 0\%$) in each of the examined scenarios regarding the level of RES. The three different segments of each bar represent different streams of cost savings brought by FID:

(i) G CAPEX: savings in capital costs by avoiding investments in additional generation capacity.

(ii) T CAPEX: savings in capital costs by avoiding investments in additional transmission capacity.

(iii) OPEX: savings in operating costs by enabling higher utilization of renewable and low-cost generation sources and providing balancing services.

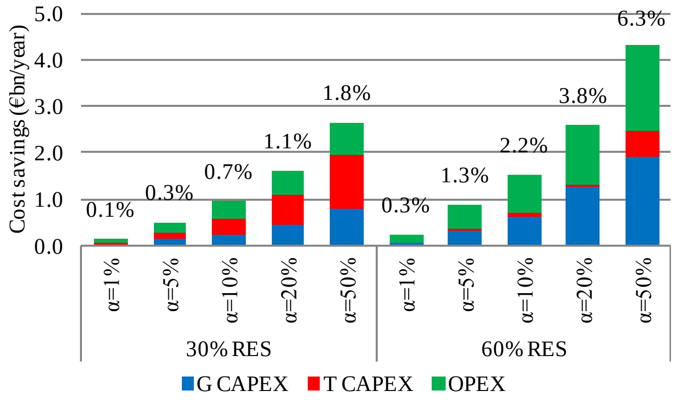

Figure 1: European power system cost savings brought by flexible industrial demand.

As expected, higher levels of FID (higher values of α) enhance the different streams of cost savings and increase the total cost savings, for both RES scenarios. Furthermore, the total cost savings for each level of FID are significantly higher under the 60% RES scenario compared to the 30% RES scenario. This trend is justified by the fact that higher renewable generation levels make system balancing more challenging, increasing the requirements for inefficient provision of flexibility by available conventional generators and investment in additional flexible generation capacity (mainly OCGT). This trend highlights the enhanced potential of FID in the envisaged low-carbon energy future.

It is worth stressing that these total cost savings are very significant, ranging from 136 million Euros per year (for $\alpha = 1\%$ under 30% RES) to 4.34 billion Euros per year (for $\alpha = 50\%$ under 60% RES). Figure 1 also presents these savings as a percentage of the overall generation and transmission costs in the benchmark scenario $\alpha = 0\%$. These findings highlight the huge potential of FID in addressing the system decarbonization challenges and enabling a cost-effective transition to the low-carbon energy future. The full paper will also report other interesting results, such as:

1) The impact of FID on the utilization of different generation sources: FID reduces the utilization of peaking generation (OCGT and oil) and pumped-storage and increases the utilization of available wind and solar generation.

2) The potential of FID in different European countries: This is shown to depend on the level of interconnections with other countries and the level of available flexible generation.