Increasing the Flexibility of the Power Grid Through **Sector Coupling**

A BRIEF FROM ESIG

The process of decarbonizing the economy involves increasing the electrification of sectors currently dependent on fossil fuels, as additional sectors take advantage of rising levels of low-emission electricity generation. These changing patterns of electricity demand, and rising levels of variable energy resources to provide the clean and low-cost electricity, will increase the need for operational flexibility to balance variability in generation and demand over the course of each day. Fortunately, the end-use sectors—those same sectors whose decarbonization is made possible by the renewable energy resources—can play an important role in providing this flexibility.

Historically, little operational flexibility existed in distribution and end use. Instead, grid operations focused on controlling the large-scale generation resources while treating other sectors as inelastic demand that must be balancing by varying the supply. However, the proliferation of smart meters, smart home devices, electric vehicles (EVs), distributed generation, and storage will challenge the current paradigm and create new opportunities.

The flexibility of certain end-use sectors allows them to use or store electricity when it is abundant and to provide power or switch to other fuels when electricity is scarce. Prime examples can be found in the transportation, building, and water sectors.

Electricity and Transportation

The transportation sector can contribute to short-term balancing of supply and demand by coordinating EV charging with periods of high wind and solar generation. By doing so, the EVs use the clean energy when it is most available and reduce the aggregate variability of both the charging and the renewable generation on the rest of the grid. For example, the blue line in figure 1 shows that the controlled charging of EVs, when coordinating with times when the system can best accommodate the additional charging load and has more abundant clean energy, can result in a smoother impact on the rest of the grid as shown by the yellow line. This smoother pattern tends to reduce costs and operating impacts for the grid as a whole.

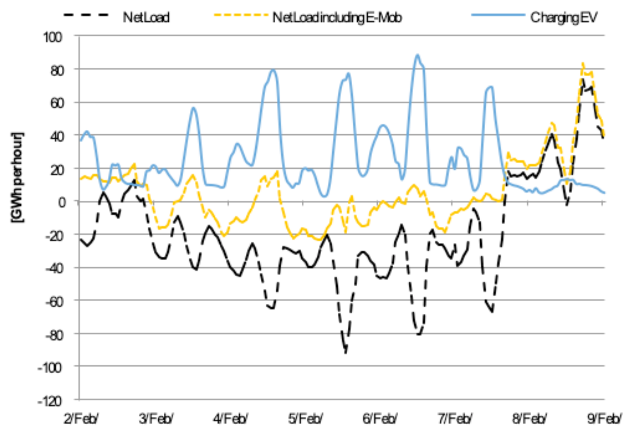

Figure 1: Effect of electric vehicle smart charging for one February week in Germany (source: Fraunhofer IEE).

Electricity and Heat

Immense potential for operational flexibility on the demand side exists in smart homes and buildings, and new time-of-use rates and demand response pilot programs are being developed in many U.S. states. In particular, flexibility in heating applications provides excellent opportunities to support the electricity sector's ability to balance supply and demand, reduce system peaks, and integrate variable generation from renewables. A great deal of resource flexibility can be gained through the use of technologies such as combined heat and power, electric heating, thermal energy storage, and heat networks converting otherwise curtailed renewable electricity into hot water for heating. The investment and operating costs of an integrated heating and electricity system have been shown to be lower than for those systems operating independently. Among other benefits, the integration of these systems can allow system planners to avoid some reinforcements and upgrades to electricity infrastructure.

Combined heat and power systems can increase the overall efficiency of energy utilization by capturing heat that is normally wasted, leading to reduced fuel cost. They can also provide ancillary services to the electricity system, offsetting the need for conventional power plants and saving on fuel costs. Hybrid heat pumps, combining a domestic gas boiler with an air- or ground-source heat pump, can also deliver a number of valuable flexible demand-response services. The operational flexibility of hybrid heat pumps with smart controllability can provide system-balancing services and help to increase the utilization of variable renewable generation; they can perform load-shifting by preheating buildings when variable generation is high and switching to gas when variable generation diminishes.

Hybrid heat pumps can often achieve the emission reduction benefits of a fully electrified heat sector, but at lower cost. Although the hybrid technology requires additional operating expenditure for the gas system and additional capital expenditure in low-carbon generation to offset gas emissions, the use of this technology reduces the aggregate building costs, heating system costs, and electricity system costs (figure 2). These technologies can also help to avoid major reinforcement of electricity infrastructure brought about by the increasing electrification of heating in less flexible ways.

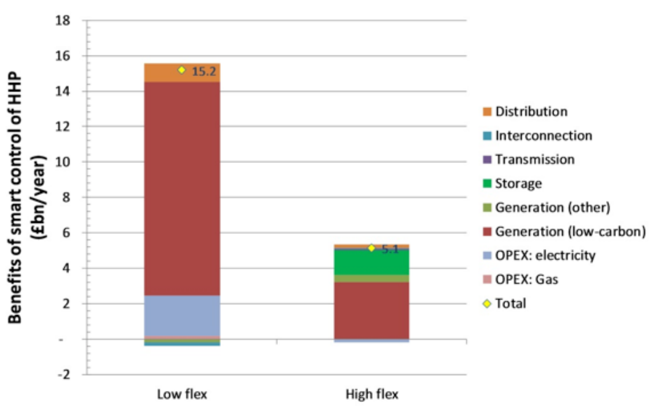

Figure 2: System-level benefits of hybrid heat pump smart control strategies in a system with low and high flexibility. Positive values show benefits, and negative values show additional costs (source: Imperial College).

Electricity and Water

Large amounts of operational flexibility can also be provided to the grid through sector-coupling between the power system and water systems. Pumped storage facilities can contribute to short-term regulation and ramping services as well as respond on a diurnal basis by shifting renewable production to times of greater demand. Water treatment and wastewater treatment plants can be used for load-shifting year round. Many water treatment plants that use water storage tanks can gravity-feed water demand for hours before requiring replenishment. These as well as wastewater treatment plants have wait time built into their processes, often offering many minutes or even hours of load-shifting abilities.

In addition, new plant pumps with variable speed drives may offer frequency regulation through their ability to modulate load. Investment costs for initiating these plants as controllable demands are low. Wastewater treatment plants can also be used for co-generation, with the released methane captured with anaerobic digesters and the biogas used to fuel an internal combustion engine or gas turbine to produce electricity.

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Historically, very little operational flexibility existed on the distribution system or with end-use resources, and grid operations focused on forecasting such resources as inelastic demand that must be balancing with supply. Cross-sector integration provides new synergistic flexibility that will increase as electrification proceeds. Integration across sectors will increase consumer involvement, such as activation of the demand side flexibility via decentralized markets and markets for ancillary services, and optimization methods will be used for coordinated decision-making within multi-level energy systems and between sectors. All of these measures will rely on digital market processes allowing free data and low transaction costs.

Growth in sector-coupling requires the right signals from the market, favorable regulatory rules, new business models, and attractive locations where the infrastructure of several sectors offers opportunities to build the missing links. Understanding the needs and motivations of all stakeholders in the integrated energy system will be critical for achieving large-scale impact.

Adapted from Antje Orths, C. Lindsay Anderson, Tom Brown, Joseph Mulhern, Danny Pudjianto, Bernhard Ernst, Mark O'Malley, James McCalley, and Goran Strbac, "Flexibility from Energy Systems Integration: Supporting Synergies Among Sectors," IEEE Power and Energy Magazine November-December 2019. guest editor, Charlie Smith, ESIG. DOI: 10.1109/MPE.2019.2931054.