Economics of Data Interoperability in a Data-driven Energy Sector

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ABSTRACT

A market-based energy transition requires active customers, which means they offer their energy flexibility through data-driven services. Implementing these services requires data interoperability standards and processes, and single common front doors. In economic terms, data interoperability lowers the barriers to participate in those services and improves their liquidity and efficiency.

1. Introduction

In the past decade, the massive connection of Renewable Energy Sources (RES) has changed the characteristics of the generation mix, which has become more random, variable and highly correlated with weather conditions, e.g., sun or wind, varying at fine geospatial levels (ESMAP 2020, Davies et al. 2023, Zardo et al. 2022). Inevitably, traditional rigid consumption profiles must become flexible to adapt their consumption to the available RES production at each time. In this regard, hourly electricity markets play a key role when allocating RES generation and consumption schedules, and two opposite outcomes are seen in countries with high volumes of RES: electricity prices become negative when there is a surplus of RES, or electricity prices peak when there is a deficit of RES production and costly pollutant technologies must be called on.

Customers must adapt their consumption profiles and become flexible through implicit flexibility which is expressed by their reaction to price signals. This form of flexibility opens the door to implementing Time of Use (ToU) tariffs, differentiated by hours, days of the week or seasons. However, this is not straightforward and requires the massive installation of smart meters that are able to record hourly consumption of energy in households. This transforms the role of the different stakeholders in the power system, enables frequent data exchanges and communications between them and adds to the complexity of interactions between the different agents. Figure 1 provides an overview of this transformation and contrasts the corresponding data flows in power systems with passive consumers vs. emerging systems with active consumers equipped with smart meters.

As is shown in Case A of Figure 1, prior to the deployment of smart meters, customers had mechanical meters that recorded the accumulated monthly (or bimonthly) electricity consumption, and the possibility of differentiating the time of consumption was limited, at best, to peak and off-peak periods. In Case B, the possibility to record hourly consumption of energy opens the door to implement hourly electricity prices, which has the potential to transform passive customers into active customers, while enabling the suppliers to offer complex dynamic price schedules. These might play a clear role in incentivizing consumption in some hours over others, which increases efficiency and RES integration. However, the possibility of introducing new dynamic pricing strategies will necessarily also impact on the competitive nature of the markets. The net effect of such an impact needs to be carefully considered by considering how static efficiency, i.e., better matching dynamically changing demand and supply, and dynamic market efficiency, that includes the impact on contestability, entry conditions, market power and the speed of innovations, are affected.

The transformation of the energy system made by smart meters goes beyond the implementation of hourly economic incentives to customers. Smart meters have the potential of transitioning the traditional energy sector into a data-driven energy sector. Energy data becomes the core of many system operator processes and new roles such as metered operator, metered data administrator or data access provider, among others, are created (European Commission, 2023a). In this new scenario, the interaction between customers and system operators grows. As defined in the European Commission (2019), smart meters should

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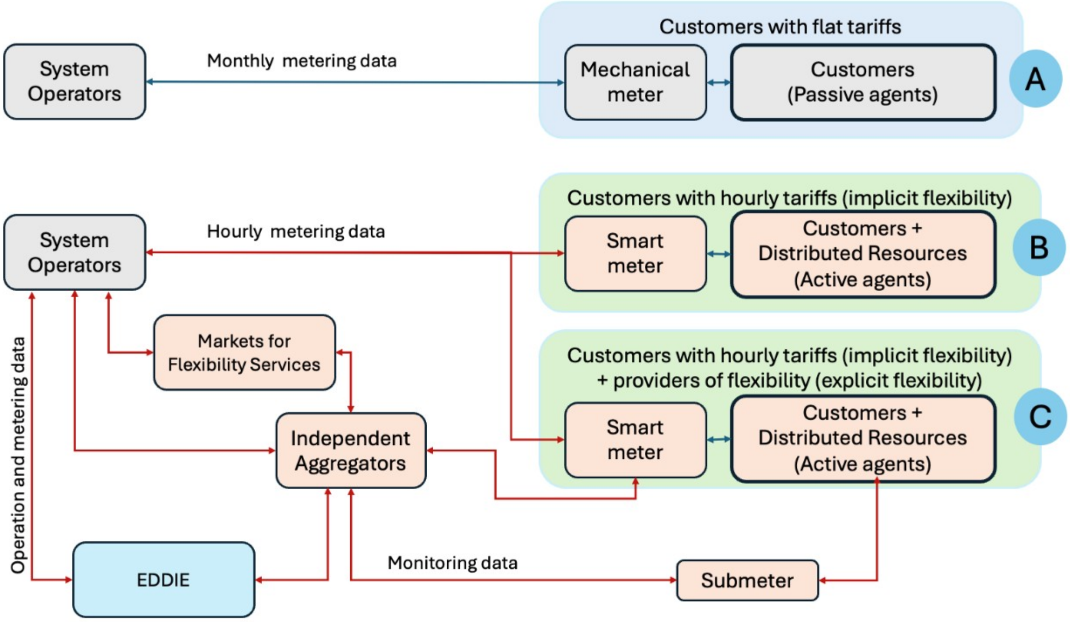

Figure 1. Data flows in the power system: Case A represents the system before implementation of smart meters, Case B represents the current system with smart meters, and Case C represents the future system with providers of flexibility and data exchanges with other sectors through EDDIE platform as described in section 2. Note: black arrows correspond to past data flows, red arrows represent data flows in the new paradigm.

also provide real-time data to the customers to allow them to react to the real-time price signals.

2. Economic considerations

Poletti, (2022) from Octopus, a key European supplier, has defined this transition as an historic shift, that moves from the traditional Demand Side Response (DSR), to one of Intelligent Demand. Indeed, historically, energy systems always focused on adjusting energy supply to meet the demand. For instance, DSR was incorporated into the 2005 Energy Policy Act in the United States. In the United Kingdom, the *Economy 7* tariff, utilizing base-load generation to offer cost-effective electricity during off-peak hours, commenced in October 1978 (Hamidi et al., 2009). Moreover, since the 1950s, New Zealand and South Africa have been managing peaks in electricity demand using 'ripple control', first introduced in France, back in 1927 (Poletti, 2022). This method widely used already by 1948 (Ross, and Smith, R., 1948), worked by transmitting a high-frequency signal (ripple) at the substation with the standard 50 Hz power supply over the existing power lines while also having specific receivers installed at the consumer's premises detecting the ripple control signals to activate or deactivate connected devices accordingly (Kwon, 2009). Ripple control helped in grid load management by turning on or off water heaters or streetlights, during peak and off-peak hours balancing the load and preventing grid overloads. It was contextually beneficial for consumers with different electricity tariffs for different times of the day, as it could be used to switch devices to operate during cheaper tariff periods, optimizing energy costs. As a result, Ripple control could be used to support demand response programs where consumers reduce their electricity usage during peak demand periods in response to signals sent by the utility company (Poletti, 2022).

However, DSR techniques arose from the need to optimize a system based on coal fueled and nuclear power plants, matching electricity usage based on systems that could be anticipated with little uncertainty. As the energy system incorporates intermittent RES in the power grid, Poletti (2022) advocated replacing traditional DSR with the data-based energy management concept of 'Intelligent Demand.' This becomes essential, since, not only integrating RES supplies have an intermittent nature, but also the demand for electricity is changing drastically. For instance, the diffusion of Electric Vehicle (EV) home chargers and heat pumps, all necessary tools towards net zero, due to their intermittent timings, could add to the traditional 1kW household demand winter peak an additional 9-12kW load.

An example of "Intelligent demand strategy" is shown in Figure 2, superimposing wholesale electricity prices (grey bars) with "Intelligent Octopus Charging" (red line), between 30th of December 2021 and the 2nd of January 2022, whereby the key (intelligence) element is shown in the almost perfectly symmetric dynamics between the two curves, whereby any decrease in wholesale electricity prices (in p/kWh) is matched with an increase in *Intelligent Octopus Charging* (in MW). Even more interestingly, the spiking of charging in response to negative wholesale electricity prices when wholesale prices go down, can be matched to the instances when *Intelligent Octopus* tariffs send a command to the EVs to start charging.

The interaction between intermittent supply and intermittent demands is what allows data-driven systems

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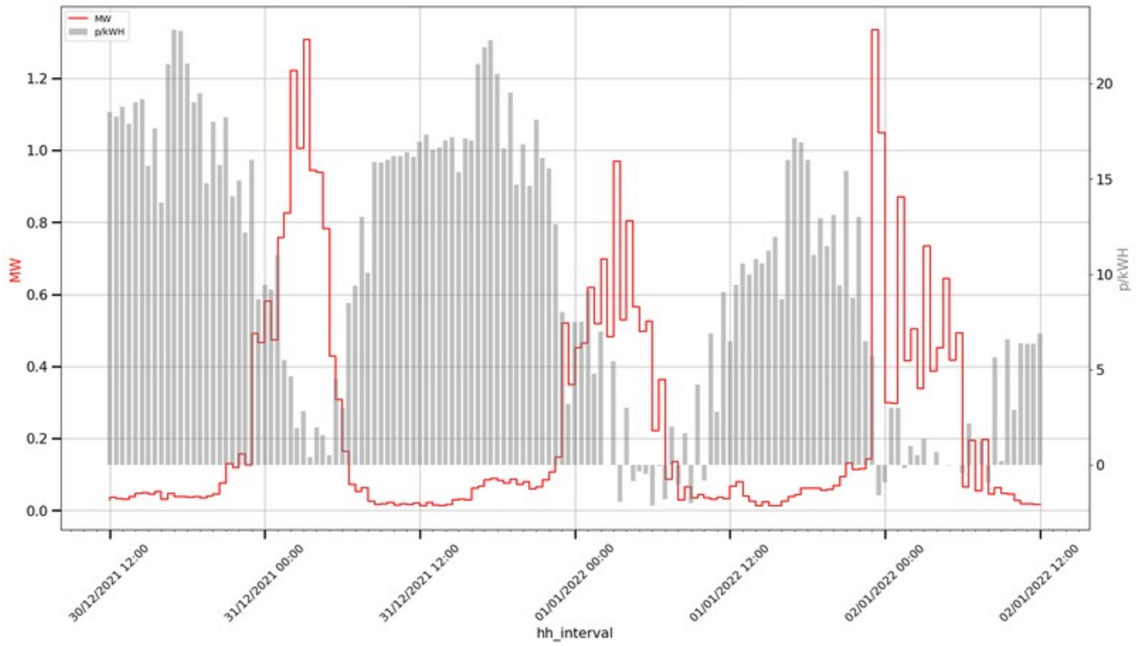

Figure 2 Intelligent Demand and wholesale energy prices with "Intelligent Octopus"
Source: Poletti, (2022) https://octoenergy-production-media.s3.amazonaws.com/images/fig2021-12-30.width-800.png.

and algorithms to achieve the necessary efficiency. However, as these key economic components of demand and supply are transformed, price signals also move to reflect these changes. In this case, it becomes unavoidable to address the potential economic consequences of these new intelligent tariffs that are transforming what economists call market fundamentals. Moreover, in non-monopolistic markets, the strategic implications of these dynamic pricing strategies will also shape the resulting competitive dynamics, market prices, demand and efficiencies in the short term and, in the longer term, innovation rates.

Finally, users might have different cognitive abilities and willingness to invest their time in understanding and comparing alternative complex intelligent tariffs. These differences might be related to socio-demographic factors, or to the level and composition of energy consumption of a household, depending, for example, on whether the household has a home charger, an EV or a heat pump. Each retailer might then find an incentive in using *intelligent* dynamic pricing tariffs, as strategic devices, possibly to soften competition, or discourage entry, due to the potential increase these tariffs might induce on the asymmetry in the switching costs among consumers (Giovannetti and Siciliani, 2023). Hence, it is important to consider the concerns that such tariffs, while necessary in incentivizing intelligent demand, might not be used to segment an incumber retailer's customers, based on their differentiated willingness to switch between intelligent and more rigid tariffs, either within those on offer by the same retailer, or between those offered by competing ones.

3. Operational Considerations

The impacts of RES go beyond the hourly electricity prices and affects the operation of the power system. Grids have limited capacity and grid constraints (congestions or operational constraints) might occur more frequently in highly decarbonized power systems, especially at the distribution grids where many RES and most of the Distributed Resources are connected. These Distributed Resources include in-home devices (electric boilers or heating devices), small generators behind the meter, storage devices or EVs and their charging points. However, the same Distributed Resources can and should be part of the solution for grid constraints as they evolve into active Flexible Resources that respond to the needs of System Operators through the new data-driven services such as flexibility services.

In this model, independent aggregators pool a group of Flexible Resources and offer to the new markets for flexibility services the possibility to modify the consumption or generation patterns of Distributed Resources on request of System Operators to solve their grid constraints. The implementation of this new paradigm requires establishing new data exchange processes between all the involved parties as is shown in Figure 1 (case C). First, System Operators use energy operation data to forecast and anticipate in-advance grid constraints to be later solved by Flexible Resources. This also includes sharing energy operational data from other System Operators to coordinate. Second, Independent Aggregators use energy data from Flexible Resources collected through submeters to assess its potential flexibility to be offered to System Operators. In the European Reform of the Electricity Market Design, submeters are also known as dedicated measurement devices (DMD). Third, System Operators send operational setpoints to the Independent Aggregator to request the activation of its Flexible Resources. Independent Aggregators also implement cross-sec-

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torial data exchanges (e.g., electricity, gas, transportation or heat, among others) as there are many links between energy sectors and electricity flows can be modified through changes in other sectors. In the data exchange processes, submeters play a key role. They are additional smart meters used to monitor energy flows of individual Flexible Resources, which are also needed to validate the activation of Flexible Resources by Independent Aggregators or System Operators (Chaves-Avila et al., 2024).

In all these processes, the need to set data interoperability requirements between system operators, metering administrators, customers and manufacturers of their home devices become relevant. As defined in European Commission (2019), interoperability means the "ability of two or more energy or communication networks, systems, devices, applications or components to interwork to exchange and use information to perform required functions". The same Directive sets the need to further develop "interoperability requirements and non-discriminatory and transparent procedures for access to metering data, consumption data, as well as data required for customer switching, demand response and other services."

The definition of the data interoperability provisions for the red data arrows in the Case C (Figure 1) have relevant economic implications on the performance of markets for the new data-driven services: a lack of interoperability in the data exchanges might require a manual data processing or implementing additional costly software and hardware solutions Thus, data interoperability requirements set the entrance costs to participate in these markets and the economically feasible minimum bid unit to recover all the operating costs associated to the data communication flows. This data interoperability also includes the home devices that should react to the request of the aggregators, i.e., manufacturers must include data interoperability solutions to their devices.

In consequence, interoperability requirements constraint the number of potential participants in these markets, which in turn impacts the liquidity that sets the efficient performance of new data-driven flexibility markets. Thus, power system costs are reduced, and consumer surplus is maximized. However, such requirements might also open new channels for leveraging market power and information rent between data and energy platforms.

4. A European Distributed Data Infrastructure for Energy (EDDIE)

A complementary solution to improve data interoperability is setting national common-front doors, where Independent Aggregators can access all the energy data with a single communication link and regardless of who generates this hourly data. In this context, the European EDDIE (European Distributed Data Infrastructure for Energy) introduces a decentralized, distributed, open-source Data Space as these challenges have broad implications on an industrial, economic, and social level in Europe and beyond.[1]

Solutions tested in EDDIE also open the discussion about the adoption of centralized, decentralized or hybrid data architecture. Centralized corresponds to a single data platform that hosts all the information, while a decentralized corresponds to a group of platforms interconnected between them with a common front door as defined in EDDIE. In the middle, hybrid architecture corresponds to a combination of centralized and decentralized solutions. The adoption of an architecture model also has relevant economic implications. Decentralized solutions can make better use of existing data platforms and reduce their implementation time and cost, accelerating the implementation of flexibility services. However, this requires data interoperability requirements between them, as well as a common front door to access all the data. Centralized solutions can be more feasible solutions when any energy data platform is implemented from scratch. Additionally, their implementation costs might be higher than decentralized solutions.

Potential economic benefits of data interoperability go beyond the processes related to energy consumption and flexibility services. Recently approved European Data Act aims for a fair and innovative data economy based on the sharing of data of multiple connected objects or the Internet of Things (European Commission, 2023b). Data Act seeks to harmonise the access and use of data across Europe, which includes the development of interoperability standards for data-sharing and for data processing services. In economic terms, the European Commission estimates that 80% of the industrial data is not currently exploited and could create an additional GDP of EUR 270 billion by 2028 and increase competitivity.[2] Data interoperability also overcomes potential vendor lock-in or switching between data processing services, which means removing barriers to entry and exit, main characteristics of markets in perfect competition. Information asymmetry is another shortcoming that will be significantly mitigated by making data interoperable between different sectors. It will facilitate the emergence of new cross-sectoral innovative data-driven solutions (European Commission, 2020). For instance, facilitating seamless data exchanges between the mobility and the energy sectors removes entry barriers, streamlines access to information and, leads to optimized usage of EVs while increasing competition and lowering costs for consumers/users in both sectors. For manufacturers of home devices, data interoperability requirements are essential to enable third parties (beyond the manufacturers) to activate these devices. Otherwise, independent aggregators must install additional costly communication solutions.

Finally, defining data interoperability standards is critical and might become inefficient when incumbents lobby to impose their interoperability standards on the rest. This would provide a competitive advantage for the incumbent over the rest and would create entry barriers for some providers, limiting the number of providers. Thus, ending with markets in non-perfect competition.

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Footnotes

[1] https://eddie.energy

[2] https://ec.europa.eu/commission/presscorner/detail/en/ip_22_1113

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