Green energy pricing for digital Europe

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“Digital Europe” is a program that will provide an overall budget of €7.5 billion over the 2021-2027 period for projects in five areas: supercomputing, artificial intelligence (AI), cybersecurity, advanced digital skills, and ensuring the wide use of digital technologies across the economy and society (European Commission, 2020). Among multiple other applications, digitalization will help to make energy systems more connected, intelligent, efficient, reliable and sustainable (International Energy Agency, 2017). However, all the strategic areas listed above have a dark side: They are heavy consumers of electric power for both the feeding of data centers and mainframes, and their cooling systems. The energy consumption of data centers in the EU28 increased from 53.9 TWh/a to 76.8 TWh/a between 2010 and 2018, and is expected to increase to 92.6 TWh/a by 2025 (European Commission, 2020). Current world estimates of Bitcoin electricity use are around 44 TWh/a, to be compared with the total consumption of electricity in France that was 474 TWh in 2019 (Koomey, 2019).

Making digitalization socially profitable therefore requires both an efficient use of electric power by everyone and the greening of power generation. Will digitalization help to save more energy than it consumes?

Responsive demand

Market analyses show that the demand for electricity has low price elasticity, at least in the short run: -0.8 for households in France (Auray *et al*., 2019), -0.1 on average in the USA (Burke and Abayasekara, 2018). Since public authorities in developed countries exclude the use of indiscriminate blackouts or brownouts as a routine balancing solution, meeting a demand that is both weakly price-reactive and strongly time-varying is very costly. It requires some form of MW storage, by installing large production capacities, although some are dispatched only a few hours a year, but also MWh storage by temporary transformation of electricity into another form of energy (*e.g.* in pumping stations and hot water tanks), which entails substantial energy losses during the dual conversion process.

Given the constant progress being made in digital technology, fighting the demand-inelasticity curse is nevertheless getting easier and easier. It is gradually becoming cost-efficient to encourage demand to adapt to supply, both in spot markets (spot pricing, load shedding) and beforehand at predefined prices (priority service, hedging).

Retail tariff and spot prices

Price-based demand response enables electricity suppliers to offer customers time-varying rates that reflect the wholesale cost of electricity in different time periods. This information is expected to enable customers to use less electricity at times when energy is costly.

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Spot pricing

When the electricity supply is competitive, the wholesale spot price continuously reflects the marginal cost of the power system. Then, if consumers must pay kilowatt-hours at the spot price and buy electricity accordingly, the quantity produced and consumed at each moment is the one that maximizes social surplus. The spot price also covers the generation cost and the capacity cost of all operating power plants.

For this to work, consumers must be aware of the high variability of prices and be able to respond to this variability. It requires smart meters to register individual hourly consumption and to provide dynamic billing instead of the usual cumulative bill at a price that does not depend on the consumption time. However, smart meters are not sufficient. Except for large industrial and service customers, most consumers are unable to react very quickly to price variations, especially if they are not present at the consumption location. Consumers who sign retail contracts at spot prices must install smart appliances, for instance, Internet of Things (IoT) devices, programmed to provide the requisite level of services given the market signals conveyed by prices. Yet these standby and command/control devices themselves consume energy. The net balance in terms of saved kWh can therefore be quite low for households but high for industrial consumers. In financial terms, the gains from buying at spot prices rather than at a non-contingent price depend on the variance in spot prices, the duration of peaks, and the reliability, efficiency, and cost of the smart in-house appliances.

Weak forms of spot prices

To make demand more sensitive to wholesale prices without the drawbacks of hourly variations, electricity suppliers can propose soft forms of time-dependent prices. In "real-time pricing", different price levels apply to different time periods on an hourly or sub-hourly basis. "Critical peak pricing" (or "passive demand response") is a contract with a default constant price set for all but a limited number of days per year, chosen by the seller after the contract is signed, and during which the per-unit price increases significantly. In "Time-of-Use pricing", instead of a single flat rate for energy use, rates change for broad blocks of hours. The price for each period is pre-determined and constant.

All these contracts are less demanding in terms of digitalization because customers are expected to adapt their consumption only in periods of energy stress. A simple piece of software with an on/off switch can do the job. But what is saved in transaction costs is lost in terms of efficiency.

Load shedding

With load shedding, the customer buys the right to withdraw a given quantity (the baseline) at a given price, and the option to sell unconsumed kWh on the wholesale market in competition with other bidders, be they producers or consumers of electricity with the same type of contract.

Even though digitalization can help rights holders decide whether to consume or to sell the contracted kWh, load shedding can be an individually profitable solution only for large consumers. As regards residential and small business consumers, aggregators propose to act as platforms that do the work for them against payment. The so-called "distributed load shedding" requires a connection to a central computer server and in-house command and control devices. This digital equipment basically entails a fixed cost, whereas the gains increase with the energy resold. Because of these economies of scale, there is no room for a large number of aggregators.

Priority service

Priority service is a form of demand management where consumers buy electricity power at a price that decreases as the probability of being disconnected by the provider increases. In practice, priority service may take the form of a contract signed at a discounted price that allows the supplier to have the option to disconnect the customer.

In France, this type of "interruptible" service was created by the NOME Act (December 7, 2010) and is now incorporated into the Energy Code (Art. L.321-19). Candidates respond to a call for tenders issued by RTE, the transmission operator. Those selected sign a contract by which they accept interruptions decided by RTE when the normal functioning of the public transmission network is seriously and immediately threatened.

Priority service can be viewed as a particular form of market organization, which should be compared to the spot market. We have seen that for consumers to be able to participate in the latter, they should be able to observe instant prices and adjust their demand on an ongoing basis or have access to technologies allowing them to program their responses to all possible market fluctuations. Priority service achieves the same result at a lower cost by exploiting the fact that the optimal rationing rule corresponds to the order of priority dictated by consumers' willingness to pay (Chao and Wilson, 1987).

The digital equipment necessary to implement priority service falls on the energy seller. Technically, it is very similar to the devices and programs used in distributed load shedding. However, the two types of contracts are backed by quite different financial instruments.

Greening the grid

To align with the objective of carbon neutrality by 2050 ("Green Deal"), the energy sector must be decarbonized. This requires that the use of electricity produced from renewable sources be stepped up, and that the demand be made more responsive to states of nature that affect the supply side.

Digital electric network

Governments promote wind and solar sources to produce electricity. But for a given installed capacity, the output of these sources varies cyclically and randomly. Moreover, the production plants are small compared with hydro, nuclear and fossil-fueled plants, and they are scattered and require an adaptation of the grid.

If the authorities achieve their goals for renewable energies and are able to close both thermal power plants, which generate greenhouse gases and local pollution, and nuclear power plants, which part of the population fiercely oppose, the need to develop technologies to store intermittent energy will become urgent. This will lead to an increase in costs even though renewables have low production costs, because transforming them into reliable electricity involves very high capacity costs. Moreover, this switch from intensive circulating-capital technologies to intensive fixed-capital technologies must be accompanied by digital enhancements. Given the scattering and versatility of renewables and the opportunism of individual and collective prosumers, balancing residual demand and residual supply and providing a last resort supply to prosumers requires the whole electric network to be backed by a material and immaterial digital network.

How can AI help?

With deep learning, algorithms can learn on their own by trial and error. They can help consumers by accomplishing simple tasks, such as the control of heating and air-conditioning systems, based on the number of people present in residential and commercial premises, and even with identity checks, thanks to facial recognition. In addition to these routine operations, AI can also help in combining customer preferences and consumption data with information on the tariff plans proposed by competing suppliers, to provide recommendations for the most suitable electricity contract. Upon acquiring more familiarity with customers' habits, the system can automatically switch energy plans when better deals become available, without interrupting supply (Hodson, 2013).

In many developing countries, the problem is quite different. The supply of electricity is plagued by power losses due to fraud and theft. In some places, this accounts for almost 50% of the injections into the grid. The so-called "non-technical losses" are mainly due to illegal bypassing of electricity meters. They damage the quality of the supplier/distributor's services, jeopardize the safety of populations (fire hazard and electrical accidents), and provoke financial imbalances. Some operators have tried to fix the problem by relying on AI. For example, in Brazil, Enel Distribución Río deployed an anti-theft machine project for medium voltage customers (Siemens, 2021). The system uses digital meters and cellular communication networks to collect data on power use. AI is used to identify unusual patterns in relation to the profiles of customers located in similar areas, and to predict which customers are likely to have illegal connections.

Facing extreme events, it is less sure that AI can take the right decision because data on the consequences of catastrophes at local scale are very scarce. For example, during the winter storm of February 2021 in Texas, some consumers who had signed contracts with dynamic pricing received disproportionately high bills. With a wholesale hourly price equal to the regulated cap ($US 9,000 per MWh instead of the expected $US 25/MWh), embedded algorithms faced an event expected to be encountered only every 10 or 20 years. Depending on the consumer's status (a hospital *vs.* a dancing hall), the wise decision ("to hedge or not to hedge", Borenstein, 2021) should be taken from the initial programming, which is the opposite of machine learning.

Conclusion

The use of devices dedicated to energy savings cannot be profitable without a highly efficient software able to process a small sample of specific data extracted from a very large collection, and to adapt it to specific consumption objectives. Huge progress has been made in this area, but this is not sufficient to ensure successful digitalization of the energy sector. One reason is that current digital technologies rely heavily on the use of personal data, which raises privacy concerns that hinder their social acceptability. Addressing these concerns should therefore be a priority for policymakers who aim at encouraging the use of those technologies. Another reason is that the digitalization of the energy sector has made it a prime target for cybercriminals. Recent examples are the successful cyber intrusion into the European Network of Transmission System Operators for Electricity (ENTSO-E) in April 2020 and the hackers who caused the US Colonial Pipeline to shut down in May 2021. The damages from these cyberattacks are amplified by the negative externalities stemming from the interconnections between energy networks in different areas or countries and those between IoT devices. These externalities imply that the private incentives to fight cyberattacks may be lower than the corresponding social incentives and, therefore, warrant public intervention.

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