

## Smart meters and their role in creating a flexible electric grid

The transition to clean energy requires a change in *how we use electricity*, not just in how we produce it. This change includes a shift in the *time* we use electricity, so that we reduce our reliance on the polluting and expensive power plants typically used to meet peak daytime demand, as well as *flexibility*, so that we can better match our electricity use to variable electricity generation from sources like wind and solar. Smart meters (also Advanced Metering Infrastructure or AMI) are one of many tools that can enable us to manage the way we use electricity and better integrate renewable resources. Smart meters can provide the data and communication to help:

- **Reduce peak demand** which can save money [1] and reduce emissions of greenhouse gases [2, 3] and air pollutants [2];
- **Provide better data** to enable more efficient operation of the grid [4];
- **Shift electricity loads** to help integrate variable generation from renewable resources like wind and solar [5, 6].

While more than 40% of United States residences now have smart meters [7], most are underutilized. Only a fraction of these households also have access to additional programs and tools that allow

smart meters to realize their potential value. Here, we describe smart meters and their role in enabling an efficient and renewable electricity system.

### *What is the value of smart meters for electricity users & utilities?*

The value of smart meters can be both immediate and long-term. This value depends on both how and where the meters are used.

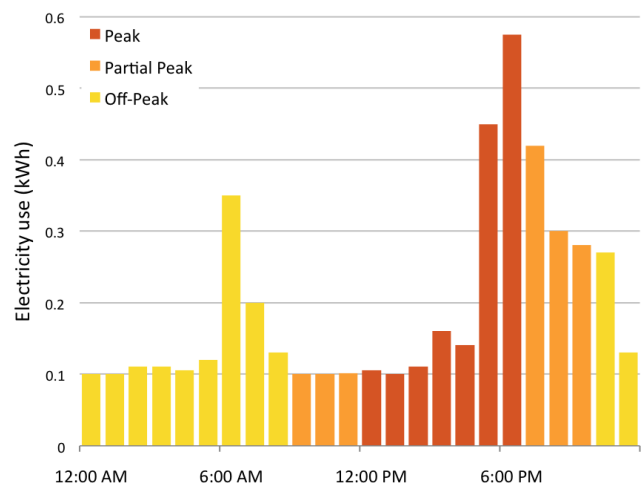
#### 1. Stand-alone benefits of smart meters

The direct value of smart meters includes [1]:

- **Resiliency:** because of constant data sharing, smart meters can enable utilities to identify and quickly respond to outages.
- **Easier data collection:** reduced need for meter reader staff and house visits save the utility money and these savings could be passed on to the customer.
- **More efficient grid operation:** detailed usage data enables utilities to improve grid planning and operation and enables customers to modify their electricity use, increasing efficiency and saving money.

### *What are smart meters?*

Smart meters are distinguished from traditional electricity meters by their increased frequency of data collection and ability to provide direct communication between the utility and the customer, rather than relying on physical visits from meter readers [8]. Data is collected every hour or less, instead of monthly, creating a detailed picture of customer energy use (see **Figure 1**). Smart meters typically relay this data back to the utility by sending wireless electromagnetic signals through a network of other smart meters to a neighborhood collector. The utility can also send signals back to the meter and operate it remotely. The frequency of the signal used is typically around 900 MHz, although some may operate near 2.4 GHz and the frequency varies with the make of the meter [9]. This range overlaps with typical ranges for cell phones or Wi-Fi, although other operational characteristics like location, frequency of use, and intensity are unique.



**Figure 1.** Typical residential electricity use data collected by a smart meter. In some places, customers are charged more for electricity during peak hours to encourage off-peak use.

Savings from these stand-alone benefits, however, are not necessarily worth the cost of smart meters. For example, Faruqui *et al.* [1] found that just these operational benefits would not pay for the estimated €51 billion (\$56 billion) roll-out of smart meters across Europe, and additional programs would be required to recover the investment and realize many of the potential environmental co-benefits.

## 2. Reducing grid demand with pricing & behavioral initiatives

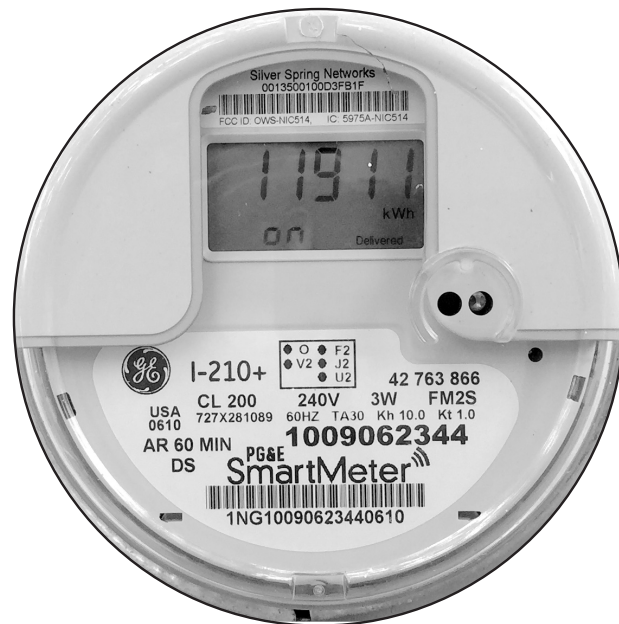
One of the largest potential benefits of smart meters is their ability to enable demand response programs, where customers are encouraged to either shift or reduce electricity use during peak hours. The power plants used to meet peak demand are typically used for only a few hours of the day, and tend to be expensive and inefficient. They also emit more air pollutants, such as carbon dioxide and NO<sub>x</sub>, than larger gas plants [10]. Demand response programs can help reduce these emissions [2] and save money by reducing the need to operate these plants or build new ones to meet growing peak demand [1]. Smart meters can be used to implement both price signals and behavioral incentives to help reduce both peak and total demand.

### Time-dependent pricing

An analysis of 34 pilot studies found that changing the electricity price at different times of day reduced peak demand anywhere from 0-58% [11]; greater reductions were seen at higher peak prices, and the reductions were nearly doubled when additional technologies like smart thermostats or in-house electricity displays were used in tandem with smart meters and time-varying rates.

### Behavioral interventions

Sending customers specific data about their electricity usage compared to that of their neighbors has been found to inspire overall efficiency savings of approximately 2% [12]. The data collected can help consumers identify when they use the most electricity and shift that use to off-peak hours.



## 3. Future benefits of smart meters

Smart meters can also provide grid benefits that will be realized over the course of many years:

- **Fewer upgrades:** lower peak demand can defer the need to build new transmission, distribution, and generation capacity.
- **Renewables integration:** flexible demand enabled by smart meters can help integrate both local and large-scale wind and solar resources by balancing out intermittency [6].
- **Appliance-specific use data:** the application of complex algorithms to detailed smart meter data can be used to identify electricity consumption of specific household appliances, which could potentially be targeted for efficiency measures; these and other advanced data applications will require clear privacy agreements [13].

### References

1. A. Faruqui, D. Harris, and R. Hledik, "Unlocking the €53 billion savings from smart meters in the EU: How increasing the adoption of dynamic tariffs could make or break the EU's smart grid investment," *Energy Policy*, vol. 38, no. 10, pp. 6222–6231, 2010.
2. N. Gilbraith and S. E. Powers, "Residential demand response reduces air pollutant emissions on peak electricity demand days in New York City," *Energy Policy*, vol. 59, pp. 459–469, 2013.
3. W. Gans, A. Alberini, and A. Longo, "Smart meter devices and the effect of feedback on residential electricity consumption: Evidence from a natural experiment in Northern Ireland," *Energy Econ.*, vol. 36, pp. 729–743, 2013.
4. H. Allcott, "Rethinking real-time electricity pricing," *Resour. Energy Econ.*, vol. 33, no. 4, pp. 820–842, 2011.
5. B. Dupont, K. Dietrich, C. De Jonghe, A. Ramos, and R. Belmans, "Impact of residential demand response on power system operation: A Belgian case study," *Appl. Energy*, vol. 122, pp. 1–10, 2014.
6. A. Pina, C. Silva, and P. Ferrão, "The impact of demand side management strategies in the penetration of renewable electricity," *Energy*, vol. 41, no. 1, pp. 128–137, 2012.
7. Institute for Electric Innovation, "Utility-scale smart meter deployments: building block of the evolving power grid." *Edison Foundation*, Sep-2014.
8. G. Pepermans, "Valuing smart meters," *Energy Econ.*, vol. 45, pp. 280–294, 2014.
9. V. C. Gungor, D. Sahin, T. Kocak, S. Ergut, C. Buccella, C. Cecati, and G. P. Hancke, "Smart grid technologies: communication technologies and standards," *Ind. Inform. IEEE Trans. On*, vol. 7, no. 4, pp. 529–539, 2011.
10. J. A. Gouw, D. D. Parrish, G. J. Frost, and M. Trainer, "Reduced Emissions of CO<sub>2</sub>, NO<sub>x</sub> and SO<sub>2</sub> from US Power Plants Due to the Switch from Coal to Natural Gas with Combined Cycle Technology," *Earths Future*, 2014.
11. A. Faruqui and S. Sergici, "Arcturus: international evidence on dynamic pricing," *Electr. J.*, vol. 26, no. 7, pp. 55–65, 2013.
12. H. Allcott, "Social norms and energy conservation," *J. Public Econ.*, vol. 95, no. 9, pp. 1082–1095, 2011.
13. K. C. Armel, A. Gupta, G. Shrimali, and A. Albert, "Is disaggregation the holy grail of energy efficiency? The case of electricity," *Energy Policy*, vol. 52, pp. 213–234, 2013.