Consumer Concerns About Smart Meters

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Abstract. Modernisation of the grid is inevitable as aging and outdated traditional power infrastructure is subject to challenges of cost, climate change, distributed power generation, and unstable demand patterns. Engineers identified smart meters as a vital element for modernisation and hastily implemented and deployed them without fully considering their implications. There has been significant consumer concern, and rollouts in various countries have been delayed and even stopped entirely. The resistance from consumers makes it evident that their requirements were inadequately addressed. A major reason for this is that the requirements elicitation process was seriously deficient. This article first analyses the functionalities of a smart metering system from a consumer perspective and discusses the risks to consumer assets that are perceived to, and in some cases do, arise from the introduction of smart meters. It then proposes that proponents of smart meter schemes need to improve their risk assessment and requirements elicitation processes, in order to better understand user realities, needs and concerns and ensure that their designs address them effectively.

Keywords: Consumer perspective · Risk · Smart meters · Consumer concerns · Consumer segments

1 Introduction

Smart metering emerged from a need to effectively manage the electricity requirements of increasingly large populations making more extensive and intensive use of electrical devices. Though the initial interests were focused on accurately measuring power usage, they have progressed to contributing to reductions in production cost and carbon emissions.

Traditional accumulation meters display the cumulative amount of electricity used, in order to enable manual reading on a periodic, typically quarterly basis. Smart meters, on the other hand, record the time of use during short intervals and can be read remotely by the utility. Smart metering technologies offer various possibilities for electricity system stakeholders. For electricity utilities and electricity system operators, they provide tools to address peak demand. With smart meters that enable time-of-use (TOU) tariff, it is expected that peak electricity consumption could be reduced; deferring and even avoiding the need to construct new power plants [1, 2].

From the viewpoint of the utility, the introduction of smart meters was intended to encourage consumers to manage their power usage by showing them how much they

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are consuming and how much more they will have to pay for using electricity during peak periods. That was claimed to offer consumers the chance to change their energy usage patterns. It has also reinforced messages communicated to them by other means, drawing attention to the scope to use renewable sources of energy by installing solar panels [1, 2]. But are consumers sufficiently well-educated and motivated to manage their power usage? And, even if they are, is the proposal practicable?

After smart meter rollouts started in various countries across the globe, consumer concerns arose. In many places, rollouts have been delayed and even stopped, including in some where the scheme had initially been mandated [3]. It appears that industry will face years of battling to convince consumers of the benefits of smart meters. Resolving the impasse is not just a question of technology but of end-user requirements, behaviour and choices.

Most residential consumers have neither time nor inclination to check when critical peak pricing periods have been declared by their supplier, let alone continually follow energy pricing in real time. Consumers have other priorities besides their electricity bill and will prefer to spend only a little time to tweak their appliances' settings.

Promoters of smart grids talk about the potential for a home automation network where all appliances could be operated remotely via the smart meter [4]. On the other hand, current smart metering systems only support remote switching of the entire or partial load. The technologies have not yet advanced to the stage where selective appliances on the consumer side can be turned on and off without manual intervention. Even if smart metering systems reach the stage where such features are supported, residences will remain a long way from full automation. Major appliances like air conditioning systems will need to be retrofitted or replaced to be able to communicate with the smart meter. This modification will be expensive and for most households this will happen very slowly and mostly when systems reach the end of their normal life [1, 2].

Where utilities have imposed functionalities that address their own business needs but are not beneficial to consumers, furious responses have been triggered. It is crucial to that scheme sponsors ensure that consumers are on board and that the power grid transformation is tailored to meet their needs and their willingness to pay.

This paper commences by reviewing the context within which smart meter schemes have been conceived and implemented. It then examines the consumer concerns that have arisen, distinguishing between real and perceived risks. It is proposed that significant enhancements are needed to the risk assessment and requirements elicitation processes used in smart meter projects.

2 Background

The conventional grid assumes central generation of power, and dispersed consumption. The efficiency of the traditional grid is low, because the excess from centrally generated power can't be re-used or stored. Bottlenecks occur in the transmission system and this interferes with the reliability, efficiency, and delivery of electricity. Almost 8 % of output is lost along the transmission lines, while 20 % of the generation capacity exists to meet the peak demand only [5, 6]. To meet increases in demand, it is necessary to build new power plants, transmission and distribution infrastructures.

Modernisation of the grid is essential to address the drawbacks in the traditional system. The key requirements identified for Smart Grid are [7, 8]:

- Accurately measure usage and identify leaks and thefts.
- Identify the demand profile and provide measures to smooth the curves and thereby reduce the overall production cost.
- Enable detection of power failure in real time and speed up the recovery service.
- Provide quicker response to events and alerts

The solution that engineers identified for modernising the grid was to collect detailed consumption data from network end-points by means of Advanced Metering Infrastructure (AMI), and transmit that data frequently to the utility. The replacement of traditional meters with smart meters was considered as a major building block towards the implementation of the Smart Grid. With automated readings, engineers expected that utility operations would become more accurate and more responsive to changing conditions in the power reticulation network.

Over time, the detailed data collected from smart metering systems was seen as enabling the utility industry to introduce TOU billing. Designers assumed that the majority of the users would then be encouraged to switch their usage to off-peak hours to take advantage of the cheaper rates, thereby reducing the demand during peak period. But in a great many, and perhaps most, scenarios, peak hour usage is not easily avoidable by consumers. This is a sensitive social issue in some countries, and utilities and related government entities are being forced to continue with flat tariff rates even after smart meter roll-out. That defeats a principal justification for smart meters.

Meanwhile, additional challenges have confronted the electricity generation and supply industries. There is great pressure for central generation to switch progressively towards lower-carbon-emission alternatives. There has been an explosion in small-scale electricity generation, widely dispersed, and attached to the distribution network. There are at this stage only limited options for control of dispersed generation and hence of managing the risks of voltage fluctuations outside the range dictated by operational Standards. Electric car projects are promising to change demand profiles, but to some extent also supply and storage patterns.

These challenges compound the difficulties for an industry that has been strongly focused on a means of better managing demand, but by means of schemes that are being delayed and even still-born.

3 Consumer Concerns

An analysis of consumer concerns has distinguished a number of issues with the adoption of smart meters. Table 1 provides a summary.

Among the most significant obstacles are inadequate financial incentives, health concerns, security issues and violation of privacy [9–11]. The remainder of this section expands on some of the key issues. There have been reports of increased electricity bills associated with the use of smart meters. The complaints include an uninhabited home being billed more than double previous amounts following the installation of a smart meter. Utilities respond that the bills are accurate and that increases may be due to the precision of measurements which was not available with traditional meters, or leakage or theft of power [12].

Table 1. Consumer concerns over smart meter functionalities

Smart Meter Functionality		Consumer Concerns	Consumer Assets Affected
1	Storage of fine grained consumption data.	Will provide insights into a household's living patterns to the extent that it could reveal the appliances used and activities conducted by the household.	Confidentiality, Security, Safety, Privacy
2	Two way communication and automated meter reading using various technologies.	Data susceptible to interception during transmission leading to modification or destruction of information.	Integrity, Availability of data and power, Privacy, Security
		Exposures to radio frequency waves causing electro hypersensitive (EHS).	Health, Safety
3	TOU tariff to reduce peak demand.	Unable to avoid the peak period due to various reasons.	Comfort, Convenience, Financial
4	Remote switching (disable and enable) of supply.	Possibility of getting disconnected by error or deliberate attempts by anti-social elements.	Safety, Security, Control
5	Enable energy export and calculation of net usage.	Currently smart meter does not check before injecting the energy into the system and that could destabilise the system.	Availability of power, Safety

There have also been complaints that smart meters are causing health problems. The terms idiopathic environmental intolerance attributed to electromagnetic fields (IEI-EMF) and electromagnetic hypersensitivity (EHS) have been coined to refer to a range of complaints that arise from, or are at least perceived to arise from, among other devices, smart meters and/or associated data transmission devices. Utilities respond that the meters comply with industry standards, and that radiation from smart meters is much lower than that from mobile phones [12, 13].

The concerns over security and privacy arise from collection and transmission of fine-granularity consumer data from AMI modules. Some reports suggest that Smart Meters are capable of revealing a considerable amount of sensitive data about people and their lifestyle and that it would let the observer know about the occupancy and contents of premises [14]. Current installations lack strong cyber security features, and hence data is susceptible to interception during transmission, which creates the possibilities of modification and destruction of information [15, 16]. There are also fears that malicious hackers may be able to intrude into the grid and cause harm to individuals' equipment, or blackout an area, or perhaps even undermine critical infrastructure.

There are also safety concerns. It has been reported that power surges have caused some smart meters to overheat and start a fire. Poor quality components and improper assembly of meters has been noted as the reason for overheating [17, 18].Utilities respond that smart meters are subject to rigorous safety standards and that the fires are caused by faulty switchboards and unsafe wiring that had hitherto remained undetected. In some cases investigations conducted by a safety regulator have determined that criminal damage was the cause of the fire [18].

There are also concerns about some consumers being unable to avoid peak demand, resulting in huge electricity bills. Utilities expect consumers to utilise smart meter facilities, and adjust their consumption behaviours and patterns accordingly. On the other hand, consumers such as pensioners and others who stay at home most of the time can't survive without heating/cooling systems and without operating other essential appliances during the peak period. People belonging to low income groups cannot afford to have expensive solar panels installed as an alternative. People requiring disability or medical assistance, e.g. for life support systems, also cannot adjust their demand in response to price changes.

4 Perceived vs Actual Risk

When a system embodies risk to the vital assets of the stakeholder, there will be resistance to it. That is clearly evident in the case of smart meters. From the perspective of a consumer, there are significant risks to assets that they value, and there is little evidence of significant gains. To a consumer, it will appear that the utility is forcibly introducing a system that is beneficial to the utility's business but not to the consumer.

But are all described concerns actual risks or are the problems perceived rather than real? Different actors participating in the same system may have a different perception of risk and they react according to those perceptions. The following insights into perceived risk by Bruce Schneider and Daniel Gilbert [19] are useful in analysing the consumer concerns about smart meters.

1. "People overreact to intentional actions and under-react to accidents, abstract events, and natural phenomena" [19].

   – The majority of computer and Internet users are not cautious when using public terminals or do not change the password regularly, thereby exposing personal data. But the same users are worried that personal data will be exposed by smart meters. Most smart meter systems have basic encryption and firewall protection. There are numerous ways in which antisocial elements can cause harm to the public. Even without smart meters, houses are being robbed and occasionally terrorists are planning attacks. What would be the motivation to use the smart meter for future attacks? Are they easier than existing methods?

2. "People underestimate risks they willingly take and overestimate risks in situations they can't control" [19].
   - Electronic devices emit radiation. RF emissions are produced by many wireless devices already found in the home, not just by smart meters. Research suggests that smart meter emissions are lower than those of wireless routers used for internet connectivity, and even less than wireless baby monitors. But unlike those devices, smart meters transmit in short bursts during only a fraction of the day.
3. "People under-react to changes that occur slowly and over time" [19].
   - Residential electricity prices have increased over 90 % in many countries over the past five years and consumers have been paying high flat-rate bills. With TOU tariff the consumer is showing resistance to paying high prices during peak periods. If flat rates continue, it is likely that consumers as a whole will pay more under flat-rate arrangements than they would if a TOU tariff were introduced and production costs were able to be reduced.
4. The way in which risks are communicated can affect user perceptions.
   - Closely associated with consumer protests about health hazards breaches have been media reports to the effect that smart meters cause such problems.
   - Similarly, the smart meter has been described as a spy in the home [20]. This was based on a report that found that detailed smart meter data at one-minute intervals could provide insights into a household's living patterns to the extent that it could reveal the appliances used and activities conducted by the household [14]. This accurately reflects the intentions of the visionaries and even of some design engineers. But it does not describe contemporary capabilities. Most smart meter data is generated on intervals far less frequent than one minute, and inferences are accordingly much harder to draw. Even if and when smart meter data becomes very fine-grained, detailed knowledge of the appliances present in the home and the habits of the consumer might also be required in order to infer living patterns [20].

The above examples showcase some exaggerations that are communicated through social media. If erroneous information sources find ready access to the mass media without effective remedies, then large social impacts, even for minor events, becomes possible [21]. A number of consumer concerns do, however, reflect actual risks that need to be addressed.

1. Fires and explosions arising from the introduction of smart meters is an actual risk. It is unacceptable to reduce cost of production by using poor quality components, inadequate assembly or short-changed quality control. In addition, a utility cannot blame existing conditions for causing a fire. When a traditional meter is replaced as part of a utility-sponsored scheme, it is the sponsor's responsibility to ensure that the existing wiring and conditions are safe for smart meter operations.
2. Software quality must be assured. The meter firmware that calculates the power usage needs to be demonstrated to be accurate and free from bugs. Erroneous billing due to firmware and system defects is unacceptable.

3. Discrimination against some categories of consumer is an issue that needs to be addressed, not ignored. This applies to individuals who depend on electrical devices for life-support, safety or maintenance of critical quality-of-life services; and to low-income and low-educational-level households.
4. Data Disclosure appears to be a design fault in many schemes. Data with potential sensitivity is passed from smart meters up through other organisations, without controls in place to minimise its distribution and to maximise its aggregation.
5. Data Interception is a genuine risk in many scheme designs.
6. Remote switching of devices, although not at this stage delivered functionality, is more than a gleam in the eyes of utilities and ambitious designers.
7. Instability of Supply is a genuine risk where distributed generation is closely coupled to medium- and low-voltage transmission lines.

For smart meters' potential benefits to be realised, a thorough risk assessment is necessary, to ensure that the drawbacks are understood and their impacts minimized on all stakeholders. Ultimately it will be the consumer who will have to bear the cost of running such a system and if the system's safety and security aren't guaranteed, consumer preparedness to accept the scheme will inevitably be harmed.

An important insight arising from the analysis conducted in this section is that not only is it essential that real risks be addressed, but it is also necessary that potential misperceptions be recognised in advance, fears allayed, and the ground prepared to counter misinformation when it appears within communities, in social media and in mass media venues. We have earlier devised a risk analysis framework specifically for Smart Grid with a perspective based approach [22]. Using our framework, risk analysis can be easily conducted from the perspective of a consumer.

5 Consumer Requirements Elicitation

The previous section has established the need for risk assessment to be conducted from the consumer perspective. It is common to perform a risk assessment late in a project, and all too often it is performed only once deployment is already under way. However, in most cases, retro-fit costs are far greater than designed-in costs and hence it is highly beneficial if the necessary features are incorporated within the design at the earliest possible stage, rather than deferred until after deployment.

To ensure early discovery of features that are needed to ensure consumer acceptance, a suitable framework needs to be selected for the specification of requirements and the subsequent design and deployment activities. The project's objectives and scope need to reflect consumer needs, rather than only those of the sponsor and the other organisations that exercise institutional and market power within the domain. For this to be achieved, it is crucial that the framework selected place great stress on the very early phase of requirements elicitation.

Consumers need to be identified as stakeholders. Means need to be devised to not merely gain their feedback on requirements specifications, prototypes and design documents, but also to meet with them, or suitable proxies for them, at the very outset of the project, and develop an understanding of their perspectives. Great care must be taken not to rely unduly on intermediaries, because many of them are too far removed from consumers themselves to provide designers with appropriate understanding [23].

The authors, as the next phase of the project, are developing the selection criteria for a suitable requirements engineering framework for smart grid and smart meter projects.

6 Consumer Segmentation

The previous section identified the need for consumers to be identified as stakeholders. Earlier sections established that consumers behave according to their perceptions of risks rather than to actual risks. The perception of risk is dependent on consumer expectations, preferences, and ability to tolerate the risk. Different consumers have different expectations for the same situation. For instance, if an event creates a loss, there is a possibility that one consumer is able to tolerate it whereas another is not. A further relevant factor is the opportunities that the consumer has available to them when they are contemplating taking a risk [16, 24]. Figure 1 is a representation of response of different consumer groups using an adaptation of CORAS.

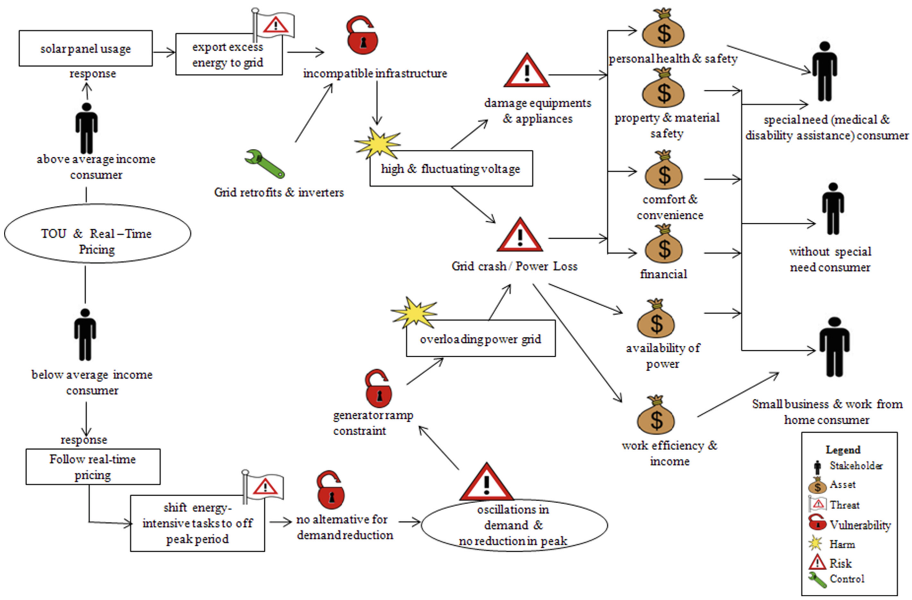

Fig. 1. Issues that could arise from renewable resources and TOU tariffs

Despite the many sources of difference among consumers, there is a tendency by designers to lump all customers together into a single entity. All users are considered to want the same things [25].

In order to avoid public reactions against smart meter schemes, sponsors must take stakeholder analysis beyond this limited conception of an army of undifferentiated consumers. Stakeholder segmentation offers details that the traditional "one lump" views cannot. Representatives for each stakeholder segment need to be identified, and included in requirements elicitation activities. In order to avoid a coarse-grained stakeholder analysis, intensive focus groups and other structured brainstorming activities are required [26].

In the specific context of smart meter schemes, some relevant consumer segments that have different requirements are as follows:

- People requiring medical and disability assistance.
- Pensioners and concession card holders.
- Households with low incomes, a single income, or a single parent.
- Wealthy people with additional security requirements for person and property.
- Households living in particular types of premises, including free standing houses, and units, flats and apartments.
- Households that include the owner of the property – variously as head-of-family and as landlord – tenants/renters/lessees, and boarders/sub-lessees.

The possibility exists that the agendas of different stakeholder segments may give rise to incompatible and inconsistent requirements. In such circumstances, stakeholder segments need to be ranked, in order to resolve requirements conflicts and make appropriate decisions.

7 Conclusions

Smart meters have great potential, but harbour risks for various stakeholders, particularly for consumers. The perception by end-user that they are subject to significant cost, safety, security and privacy risks has proven to be a significant impediment to progress.

In this article we have discussed consumer concerns about smart meters, and have identified how consumers perceive risk. The analysis identified the need for recognition of consumers as stakeholders, and a much more careful approach to requirements elicitation from consumers, including consumer segmentation. We contend that these measures are essential pre-conditions for successful smart meter projects.

The context is rapidly changing, however, and parallel developments also need to be factored into smart meter projects. Of particular significance is distributed power generation through domestic solar panel installations, and the sale of surplus power into the grid. Legacy architecture was designed for electrical flows from central power stations to appliances. In areas with a high concentration of solar cells, voltage levels may become unstable. This can have negative consequences for consumers' equipment, but it can also trigger shutdowns in order to take load off the grid [27]. Some of the measures suggested are battery storage and retrofits to present infrastructure, but those will be costly.

A further concern is that real-time pricing could overload the power grid. If enough consumer power usage does become highly responsive to real-time price changes, it is quite feasible that rapid swings in demand could represent a serious threat to the reliability of supply. The careful analysis of consumer requirements advocated in this paper is relevant not only to smart meter projects but also to many other aspects of grid modernisation.

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