

Measures to Improve Public Acceptance of Smart Metering System

Identifying Requirements for Residential Consumers

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Abstract— Understanding the stakeholder’s needs, particularly the end-user’s need is important when designing and developing a critical infrastructure like power grid. Smart metering systems are considered as a vital element in grid modernisation projects. It provides the utility with a range of opportunities to improve their business. The benefits to other market parties are also clear. But the residential consumers are left behind. Many smart metering projects, across the world, are facing consumers’ resistance. Consumers perceive smart meters as an infringement to their interests and rights. To avoid such situations, objectives of smart metering systems should also reflect consumer needs. Measures need to be devised to elicit and include their requirements. To address this issue we analyse the reported concerns from the consumer and thereby identifying requirements for different consumer segments. That enables us to propose functionalities and applications that will help the user utilise energy efficiently.

Index Terms—energy consumer, smart meter, smart metering system, advanced metering infrastructure, AMI, requirement elicitation, consumer needs.

I. INTRODUCTION

Electricity providers are facing challenge in implementing new technologies to modernise the grid. Though the components of the grid vary from region to region, the key elements are the same. Smart meter (SM) and the Advanced Metering Infrastructure (AMI) are considered as vital elements that can play an important role in managing peak demand [1].

The energy industry is currently facing challenges in maintaining constant delivery of electricity to consumers. One of the main concerns with the power grid is in meeting the peak demand using the traditional infrastructure. Other issues include the smooth integration of a range of low carbon technologies such as renewable energy sources and electric vehicles. A smarter power grid is seen as a necessity for an effective system that is stable, reliable and secure [1-3]. The deployment of smart meters on consumer premises has been the utilities’ starting point for grid modernisation. Such projects involve expensive infrastructure that is paid for, whether directly or indirectly, by consumers, and hence it is important to achieve consumer confidence.

There have been multiple instances of major consumer pushback against smart meters, for example in Victoria, California and Ontario [4]. This has resulted in project-sponsors

battling to convince consumers of the potential benefits and this may continue for years. A technology will not be welcomed by the end user if it is not useful for them, even if it could contribute to solving major issues like lowering carbon emissions and climate change [5].

The utilities introduced smart meters with the expectation that energy consumers would use it as a tool to reduce peak energy usage. The concerned entities expected that, with few market choices, and a smart meter, the consumer would be well equipped to manage their consumptions efficiently [6, 7]. In fact, most consumers feared that they would not be able to avoid the peak periods and that their bills would increase. They suspected that the utility’s motive for the smart-meter rollout was to make a profit at the cost of the consumer [8]. Further, when the system lacked visible benefits, but showed possibilities for harm, other perceived risks like health and privacy became more prominent.

AMI’s business-centric characteristics lacks functionalities useful for the end-user and this is the main motivation for the research described in this paper. The problem domain in AMI, related to the residential consumer, is relatively new in energy industry. In the traditional grid, consumers were passive users and they just had to pay for their usage. In the modern grid, consumers are expected to become active members by managing their power usage. All the concerns from electricity consumers imply that the implemented system is either not useful for them or they have been ignored during requirement analysis. There is a possibility that the consumer requirements were merely assumed by the analysts. Creating a successful system also requires translating the end-users needs into the product scope. Late corrections of requirements errors are expensive and hence it is necessary to analyse and refine requirements before implementing a system.

Through this research we intend to understand consumer concerns and identify measures that could be applied to AMI projects to make them beneficial to the consumers as well. We have used Design Science [9, 10] as the research method for creating artifacts that embody such remedies. Buckminster Fuller’s vision [11] is applied to analyse the problems that the smart metering projects pose to the consumer.

Through this paper we try to identify consumer-focused solutions using smart metering system. The remainder of this

paper is structured as follows. In Section II we provide a background on smart metering systems and in Section III we provide a literature review on residential consumer and their energy choices. In section IV we identify problems underlying the consumer concern. In section V we conduct a detailed problem analysis. In section VI we list the alternative measures based on existing technology. In sections VII and VIII we discuss the proposed measures and evaluate it. Finally in Section IX, we conclude our work discussing future directions.

II. BACKGROUND

The main elements of the Smart Metering System/Advanced Metering Infrastructure (AMI) are, the smart meter, the head-end data storage within the utility and a network to support the two-way communication. The smart meter is designed to record detailed energy usage on the consumer premises. This detailed data is transmitted to the utility to enable billing and Demand Response (DR) operation.

Federal Energy Regulatory Commission (FERC) defines DR as “the change in electric use by consumer from their normal consumption patterns in response to changes in the price of electricity and it also refers to the incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardised”. Direct Load Control (DLC) and Time-of-Use (TOU) pricing are the two main programs under DR. DLC is defined as a “mechanism by which the program sponsor remotely shuts down or cycles a customer’s electrical on short notice”. TOU is defined as “a rate where usage unit prices vary by time period, and where the time periods are typically longer than one hour within a 24-hour day. Time-of-use rates reflect the average cost of generating and delivering power during those time periods” [12].

With TOU and DLC, utility can control customer’s energy usage. Utility providers expected that the consumer will use the TOU information to reduce electricity consumption during the peak period. Two ways in which the declaration is provided to the consumer are by means of an In-House-Display (IHD) integrated with the smart meter, and a web-based ‘energy portal’. However, they are optional.

Consumers have issues in accepting smart meter and its functionality. Opposition by residential consumers have become a big decision factor in some smart meter roll-outs [13, 14]. Even a minority segment of consumers can become the reason for abandonment of a project after research and development have been done and a great deal of funding has been committed. It is essential to understand consumer reaction to smart meters.

III. LITERATURE REVIEW

In this section we analyse research studies that have been conducted on energy consumers, their demand choices and factor affecting acceptance of smart meter. The articles that we have considered are listed below.

Kranz et al. investigated smart meters’ acceptance factors in Germany. An online survey on the project website attracted 351 participants in the age range 18 to 78. Perceived usefulness

followed by subjective control were the main factors that affected a person’s attitude to use a smart meter. Perceived ease of use affected perceived usefulness. [15]

Stragier et al. investigated consumers’ perception of smart meter and smart appliances in Flanders, Belgium. A large-scale face-to-face user survey sought insight into the willingness of consumers to adopt smart meters. Factors included housing parameters, mobility, insulation measures, heating, lighting, energy patterns, domestic appliances, ICT and multimedia, ecological behaviour, ecological attitude, socio-demographic parameters like gender, age, income and impressions of smart appliances. Perceived Ease of Use and Perceived Usefulness had significant influence on attitude towards smart metering system. Perceived Ease of Use had a strong influence on Perceived Usefulness. [16]

Dunstan et al. investigated barriers of Demand Management in Australia. About 808 groups from a range of stakeholder groups participated in a survey. The statements “B22 - electricity consumer lack interest in saving energy” and “B23 - consumers want to use power when and how they choose” were not thought by participants to be true. They thought that consumers are interested in saving energy and that consumers’ reluctance to accept smart meters was because of a lack of useful functionality [17].

Firth et al. identified the influence of appliances usage and energy user groups on demand in UK residential consumers. 72 dwellings at five sites were monitored over a period of 2 years. Consumers were segmented into low, medium and high usage. Appliances were classified as active, stand-by and cold use. Consumption increased more than 4% from the first to the second year, with standby appliances being the major contributor, followed by active appliances. Low and high users increased consumption more than medium-usage consumers [18].

McLoughlin et al. identified consumption characteristics based on dwelling and occupant characteristics in Irish dwellings. This study of 4200 consumers looked at the influence of appliances and of income on energy consumption. The largest contributors to demand were tumble dryers, dishwashers, electric cookers and electric heaters as they all had large heating components. The high energy consumers were mostly high income professionals [19].

IV. KNOWLEDGE EXTRACTION

A. Residential- Consumer Characteristics

Based on above consumer studies, the following can be concluded.

1. The primary factor that affects consumers’ acceptance of smart meters is its perceived usefulness. Ease of use of the system significantly influenced usefulness. This is in alignment with Technology Acceptance Model (TAM) factors; Perceived Usefulness (PU) and Perceived ease-of-use (PEOU) [20, 21].
2. The second factor that affects consumers’ acceptance of smart meters is subjective control. The consumer wants to be in control of the operation of their appliances and power

usage. In addition they also want to be in control of the data that is generated by smart meters.

3. Over time, energy usage increases for the same household living in the same conditions. This implies that consumers are using more appliances than before. Having appliances in stand-by mode is also found to be a major contributor to the problem.
4. Energy wastage can happen due to carelessness and/or ignorance. Most high energy users used carelessly as they could afford to pay for their usage. Low users who had been contributing to wastage did it mainly because of ignorance. They were not aware that certain choices were consuming power that could be avoided, e.g. leaving appliances on stand-by for long durations (several hours and days)

B. Classifying consumer concerns

In this section we are analysing the consumer concerns which will help in identifying solution. Information regarding system risks and consumer concerns were acquired, using publications by entities related to the power industry, and where necessary from media sources [20-25]. Based on the nature of the consumer concerns, we classify them as follows:

- Health concerns
- Information security and privacy concerns
- Cost Concerns
- Safety concern
- Usability and functionality concerns
- Control and Choice concerns

1) *Health Concerns*

There have been complaints that smart meters cause health problems. Complainants use the term Electromagnetic hypersensitivity (EHS) to refer to a range of health issues that they link to transmitting devices. The existence of EHS is contested, and some of the literature refers instead to Idiopathic (i.e. 'cause-unknown') environmental intolerance (IEI) [22]. Smart meters have a communication module for transferring data to the remote server, which may transmit and may receive using electromagnetic radiation. The meter manufacturers respond that they have complied with industry standards, and that radiation from smart meters is much lower than that from mobile phones [23, 24].

2) *Information security and privacy concerns*

The detailed data from smart meters are capable of revealing people's lifestyle, occupancy and contents in a dwelling [25]. Smart meter data is susceptible to modification and destruction during transfer. There are also fears that blackouts and other disasters could be caused by malicious hackers [26]. Utilities respond that the meters have a firewall and basic encryption and there have been no cases of reported attacks.

3) *Cost concerns*

The new infrastructure incurs huge cost. Some costs may be borne directly by consumers, but in any case they fear that they will bear the cost of developing, running and maintaining the system. It is also not clear if smart metering system can reduce bills as claimed by utilities. Consumers have reported

increased electricity bills associated with the use of smart meters

4) *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 [24, 27].

5) *Usability and functionality concerns*

By itself, a smart meter does not enable a consumer to manage their energy needs. They need both notification of peak-periods and the ability to turn particular appliances off or down. The possibility exists for home automation, if all appliances could be operated via the smart meter, possibly remotely as well as locally [28]. But these are aspirations rather than currently-delivered capabilities, and in any case it is not practical for most residences, because people generally replace their appliances only at the end of their normal life

6) *Control and Choice concerns*

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 behaviour accordingly. On the other hand, consumers who stay at home most of the time can't avoid peak as they will have to operate at least some and perhaps most of their appliances. People with low financial capacity may not be able to invest in solar panels and other alternatives [28]. It is also difficult for most consumers to understand the demand signals, decide on a course of action, and make the necessary changes. Consumers are also hesitant to give control over their appliances to the utility. Consumers want to choose how they operate their appliances.

V. PROBLEM ANALYSIS

Doubts exist about the basis of health concerns, and fire risk is a straightforward issue of product safety. This section considers the other concerns identified above, all of which are related to the functionality of the smart metering system.

A. *Factors Affecting Demand Choices*

Consumer resistance has often been associated with circumstances in which the demand response (DR) functionality has been designed without taking into account important factors that affects consumer's energy choices. Existing research [15-19, 29] suggests that following characteristics have been found to affect demand choices:

1. **Occupants in the dwelling:** including sole- and multi-person occupancy, distinguishing families from non-related individuals sharing accommodation
2. **Characteristics of the dwelling:** particularly size, number of rooms, type (detached, semi-detached, apartment), conditions (insulation, weather-proofness)
3. **Occupants' Propensity to Pay:** particularly income and attitude towards convenience (balanced, anything for comfort, go-green, careless, enduring hardship due to no other alternative)

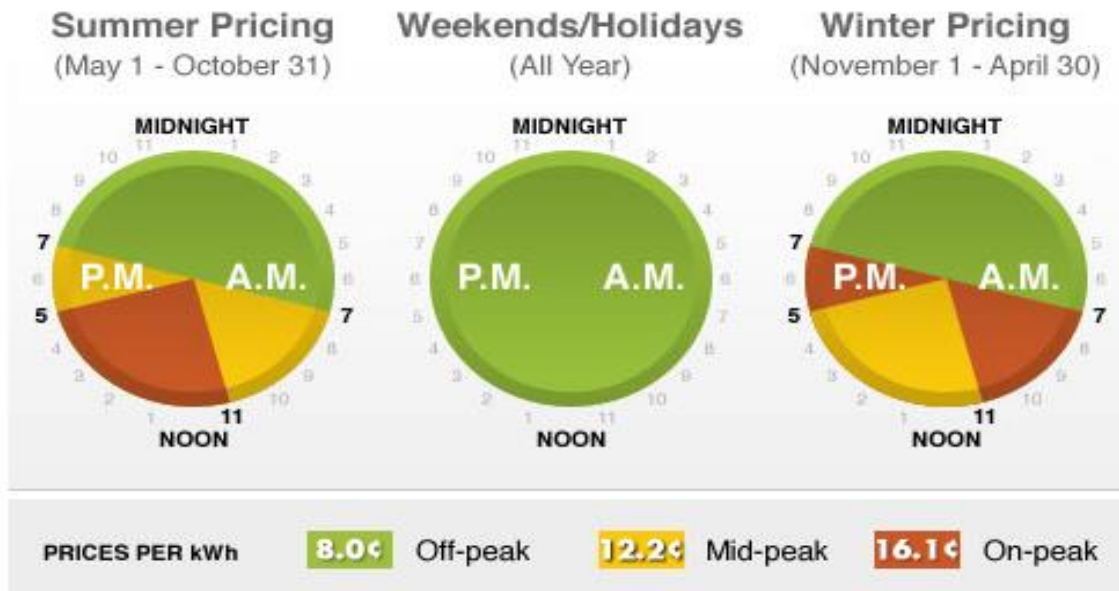


Fig.1. TOU tariffs issued by Ontario Energy Board (OEB) effective from May 2015 [28, 29]

4. **Appliance Working Mode:** including stand-by, active, cold (appliance in continuous use but do not draw a constant amount of power).
5. **Other factors:** including climatic and weather conditions, health-related factors (e.g. continuous life support systems), security-related (e.g. security and theft control systems), and occupation-related (work at home office and production units)

B. Scenario analysis

The above analysis makes it evident all residential consumers cannot be assumed to be homogeneous. They do not all respond to the demand response signal in the same way. In this section we analyze how different consumer segments will respond to the TOU signal on a winter day and the issues they will face. TOU Tariff rates effective in Ontario, Canada are shown in figure 1.

The higher rate is from 7 am to 7 pm, with peak-rates 7 am – 11 am and 5 pm – 7 pm. The analysis assumes that electricity is used for all purposes, which are primarily heating, cooking and cleaning. Then we identify several segments, referred to below as the common case and specific cases.

1) *The Common case*

Most residential consumers are active between 7 am and 10 pm. So they have some unavoidable energy needs during that period of the day. In general, heating will be required from 5pm – 7 am in most cases and even more in others.

2) *Specific Cases*

- **A single working professional** is out of their dwelling during work hours. They can also avoid cooking by eating out. They can also choose to be away from home during the peak demand periods. Their usage can then be limited to night/resting time.

- Families with children fall into two segments:
 - a) **Working parents with school-going children** can avoid consumption during work-hours, but after and before work-hours they have unavoidable energy requirements for cooking, cleaning, etc. It is not easy to avoid those activities or the peak period 6 am – 9am and 4 pm – 7pm].
 - b) **Stay-at-home parents with young children** can organize some high energy consumption activities during off-peak time, e.g cooking and washing, but they cannot avoid heating the dwelling, and if it is not energy efficient their heating requirements will be higher. They can possibly go out during the day to reduce energy usage, but it is not easy to make it a daily activity.
- **Pensioners and people with medical needs** face a situation very similar to Stay-at-home parents, but as they may have mobility issues and medical conditions that prevent them from leaving out, they will have energy needs throughout the day. Moreover they may also have life-supporting machines that will draw even more electricity.
- **Work-from-home professionals** work and live in the same premises, and hence have energy needs throughout the day. Their energy needs will be high throughout their work-hours.

From the above analysis it is evident that very few consumer-segments can adapt their energy needs to reflect the TOU pricing periods. In effect, TOU tariffs penalise many consumer segments for factors that are outside their control. It is clear that important end-user realities and needs have not been taken into account during the requirement engineering process that has been applied to the smart metering projects.

VI. ALTERNATIVE MEASURES

Apart from accurate billing, the utilities' main business goal in introducing smart metering system is to facilitate demand curtailment. Alternative measures could be considered which may incur lower implementation cost and risks. Three such alternatives are discussed below:

A. Load shedding at feeder level

Electricity substations have control mechanisms by which load can be selectively shed at feeder level [32]. If the demand is much more than generation capacity, this mechanism can be used to shed load in that area for short intervals. This demand curtailment method is easier, as it does not have too many extra parameters to consider. The provider only needs to choose the feeder and time-period for which the load has to be shed. This mechanism is already in use and usually the time and details of when the load will be shed will be declared in advance so that the end-users can take necessary measures to overcome the power loss. It can, however, have serious consequences for some consumer segments, such as people with medical needs and home-working professionals.

B. Higher tariffs for excessive usage beyond units allotted

Another mechanism that is used for demand management is higher tariffs for excess usage. There is an allotted quantum of energy for each household in a given period. Usage above the allotted amount incurs a higher tariff. This way demand is not curtailed, but the higher production costs can be transferred to the user.

C. Prepayment meters with restriction in the units allotted for a family

Prepayment meters are in use in few countries. Payment has to be made in advance, and the consumer can only use for what has been paid for. In countries where a consumer cannot be disconnected by law, the end-user continues to get minimum amount of energy until the next payment is made. This method could be used for limiting excessive usage. Every household could be allotted a set amount of energy, beyond which they cannot purchase, thereby restricting demand.

VII. PROPOSED MEASURES

A. Identifying User groups

As it is observed that there are cheaper mechanisms to induce demand reduction, the introduction of smart metering systems requires justification. User requirements analysis needs to take into account not just the providers' needs but also those of consumers. In this section using the artifacts identified by analysing the problem; we are proposing consumer classification that will cover a wide variety of consumer and then identify requirements that suit those segments. Consumer segmentation is based on users' capability to utilise the demand signals issued by the utility. The proposed classification is shown in Table I.

TABLE I. USERS TYPES BASED ON FLEXIBILITY WITH POWER USAGE

Flexible Consumers		
This category of users can follow the demand signals issued by the utility. This includes mostly single, working, less stay at home consumers.		
Non-flexible Consumers		
Low usage but can't avoid peak period - This category of consumer has low energy consumption but they cannot avoid the peak period. This includes working families with dependent kids.	Low and Medium usage with constant usage throughout the day - This category of user includes stay-home parents with young children, and pensioners. They may be able to shift some or a lot of their high energy needs to off-peak or shoulder period.	High usage – They have high energy requirements due to various reasons. The high usage consumers are discussed below.
High usage – Non Flexible consumers		
Due to unavoidable medical conditions e.g. having life support machines, some consumers need to run various devices and hence have less control over demand. They will need it to be functioning 24x7.	Due to work from home/ home based business - These consumers need energy supply for running their business without any hindrance during the business hours and hence cannot follow the demand signals. Some users may only have medium energy requirement for their business.	Due to high profile lifestyle supported by very high income - These consumers have very high energy needs to match their standard of living. They may have an expensive security system operating continuously, lighting systems and many other devices.

B. Identifying User Requirements

Based on the analysis done in the previous section, we propose an informative feedback and varied billing for each consumer types. Consumers need a system that will provide them with informative feedback on their usage patterns and provide them with hints to make intelligent choices and avoid energy wastage. The customised billing options will provide user with opportunity to make changes/ reduction in their usage pattern within their limitation. Table II and III provides user requirements for feedback and billing.

TABLE II. INFORMATIVE FEEDBACK FOR INTELLIGENT CHOICES

1. Their current usage
2. Energy consumption choices <ul style="list-style-type: none"> • Saving mode – This mode should show them the most cheapest energy choices • Essential Usage mode – This mode should show them the average required energy needs for the number of occupants mentioned. • Maximum Usage mode – This mode should show them maximum consumption limits under recommend standards for the total number of occupants so that the consumer understands that beyond this level there is wastage occurring.
3. Energy saving tips - The system should include hints of items that could be operated/ avoided at different time of the day. It should be based on the demand signals from the utility. This will exclude the guess work out of the user
4. Warnings for high usage - Warning should be provided during i) peak period and ii) Over usage during a billing cycle.
5. Provision to set consumption limits – There should be option for the consumer to provide a desired bill amount for the billing period and get information on consumption limits within that billing cycle. The information should show the user how much energy they can use per day to match the billing amount.

TABLE III. BILLING OPTIONS TO SUIT CONSUMER CATEGORY

Billing based on TOU	
This aligns with utility providers' current plan to charge user based on TOU rates.	
Billing based on Usage	
This is calculated based on number of occupants and other parameters	
Usage within a recommended level – People using within recommended limits and with minimal wastage of energy shouldn't be penalized for not being able to avoid the peak period. They should have an option to pay lower rates even for the peak period. This will encourage them to continue using less energy.	Usage above a recommended level - these users can be further classified into three: high profile and careless users; people with medical conditions and home based business. The users with usage above recommended level is further discussed below.
Usage above a recommended level	
Careless and High-profile users - They don't require any concessions on their bills as their high usage is their choice. They have to pay as per the utility provider's	People who can't avoid due to various limitations - They require concessions in billing and they should be offered other
	People doing business/work at home – They should have different tariff rates for business hour and after business hours. Rates for commercial purposes should be higher than the con-

settings. But as feedback, they should be given sufficient reminders to alter their energy choices.	alternatives like solar panel to supplement their energy needs.	sumer off-peak rate but it shouldn't be as high as consumer peak-rates, so that the consumer will be not penalized for setting up a home-based business. They should also be offered other alternatives like solar panels to supplement their energy needs.
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C. Recommendations on System Modification

On the basis of the analysis conducted above, it is now feasible to propose modifications to existing smart metering architecture. Currently, in the smart metering system there is only an In-House-Display (IHD) and an online energy consumption displaying system for feedback. The IHD displays the consumption data recorded in the consumer's smart meter and the online system displays the energy data that is transmitted and stored at the utility's side. Both the systems also display the demand signal like peak period and tariffs rates. The need exists for an intelligent feedback mechanism rather than just display of usage data and tariffs. The current data does not make the consumers well informed about the choices they have. Hence the smart metering system needs to incorporate a system that uses both consumer input and signals from the utility. As the system provides the user options to input information on energy behaviour, it is referred to as Consumer Energy management System (CEMS). Additional information such as weather data may also be drawn from external entities for fine tuning the calculations. An overview of the modified system is provided in figure 2. The recommendation on billing options can be done within the smart metering module based on the setting provided by the utility.

D. Proposed Functional requirements

1) Accurate Usage details.

This feature is currently present in many smart meters. The usage is displayed using the IHD integral to or connected with the smart meter and also in the provider's online usage display system. This usage data may also be displayable in the proposed CEMS by synchronizing it with head-end data.

2) Energy consumption and Billing related advices.

These advices mainly rely on consumer input. CEMS will allow the user to input data related to dwelling characteristics, occupant characteristics and appliance characteristics. This will give sufficient information to calculate the energy requirement for the household. It can be fine-tuned with the weather data from external entities. The accuracy of the calculation will be dependent on the information provided by the user. Further, the system will have to fetch the demand signals from the utility. Based on this information, the billing and warning information can be generated. To calculate consumption information by providing a bill amount, the demand signal from the utility alone is sufficient. The user can input a desired amount and the

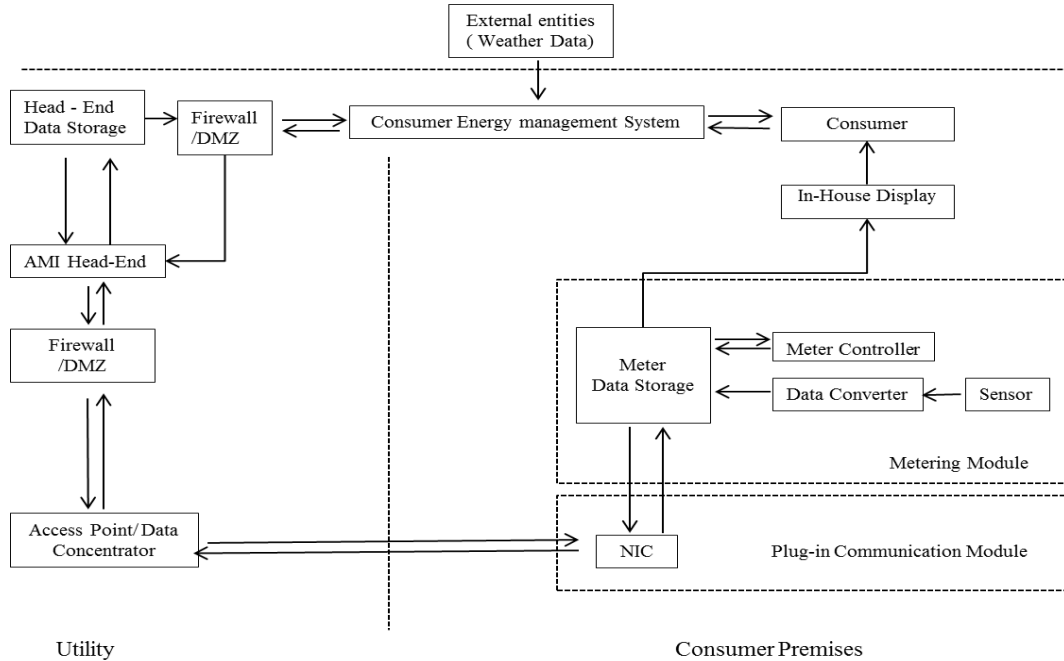


Fig.2. Proposed Smart metering system architecture

TABLE IV. PROPOSED MODE OF OPERATION FOR CEMS

Mode	Operating pattern
Standalone	The application should be able to work without connecting to the rest of the system. The present demand signals can also be fetched from the utility's website and entered manually. Consumers who are particularly concerned about privacy and data-sharing with the utility can use the application in this mode. There should also be option for these consumers to synchronize their offline details with the utility if they wish to. To run the application in this mode, the user does not even need a smart meter in their premises.
Online and partially synchronize with utility	The application should be able to work with minimal sharing options. This option is useful for user who would like to get favorable billing option from the utility. The user can share their self-entered user-profile with the utility. They can also opt for receiving the demand signals when connected online. Even for this mode, the user does not even need a smart meter in their premises.
Online and fully synchronize with utility	The application should also be able to work in full automation. In this mode the system will fetch consumer's usage data stored in the head-end, receive all alters and demand signals from the utility and provide all possible hints and tips to the user. For the application to operate in this mode the user requires a smart meter and they should consent the utility to have remote access to their data.

system can calculate the consumption threshold to match the desired bill amount.

3) *Billing Option for different Category*

The smart meter is capable of storing accumulated usage data for each demand period (peak, off-peak and shoulder). The rates that are applied will vary according to the user type. The head-end will have to store a user profile based on the user category and it will have data regarding allotted energy for the household, the category the household belongs to, and the rates that apply for the category. For each billing cycle, this information will be applied to generate a customized bill for the user. For a home-based business, because their power-usage for commercial purposes depends on their business-hours, it is better to have their meters accumulate data based on work-time (working hours, outside working hours) rather than demand period.

E. Proposed Non-Functional requirements

1) *CEMS should be able to operate both online and as a standalone program.*

The proposed system should be able to operate in 3 different modes as stated in Table IV.

2) *User profile data stored by the utility is used only in accordance with the terms of the consumer's consent*

A user profile will be stored at head-end to choose the billing category and other related matter. The utility should ensure that the details are only used for the billing purpose and that a third party can gain access to it only with consumer consent.

VIII. SYSTEM EVALUATION

A. Evaluation of Design

This section discusses how the proposed features affect the current system.

1) *Feasibility with the current context*

The design measures that we propose primarily add end-user value to the smart metering system so that consumers can make informed choices. Current smart metering systems have an online energy management system that displays the consumer's usage, alerts from the utility and demand signals. From this information, users have to make assumptions and make decisions. With the CEMS, the information is already processed so that it can be easily used by the consumer. Even consumers who have opted out of smart meters installed in their premises can use this system because it can work as a standalone tool. Even if the user does not have access to real time consumption data, they can receive tips on how to reduce energy wastage based on the data they input to the system.

2) *Effects on other Smart Metering Functionality*

The proposed measures do not affect the technical specification of the smart meter. The billing categorization is a customizable feature. Smart meters have the capability to categorize usage data based on time period. The time period can be programmed to the meter to classify consumption. Currently this is done based on demand period, because this setting is sufficient for most of the user categories. For home-based workers, the meter needs to be programmed to classify time period based on work-time. These are customizable settings within the smart meter that can be easily changed. These features also do not affect remote operations or communication features of the smart meter.

3) *System Limitations*

The two design adaptations proposed are dependent on user information. The user profile needs to be accurate as it will be used to calculate bills. Hence the utility will have to use other verification methods to make sure that such information provided by the user is truthful. They will need to verify tenancy contracts, income certificates and government approved documents on special needs and family member listings.

For the feedback system, the data accuracy is not as vital as it is for the billing system. The users should be informed that the calculations will be based on their input and hence discrepancies will be observed if they don't provide accurate information. The utility provider can educate the consumer in appropriate use of the facility.

The details entered for the feedback system could profile the user. It could provide [16] detailed information about appliances, their use, and the lifestyle of the user. These recommendations therefore do not solve the existing privacy issues that the system is facing, but neither does it aggravate it. But consumers have choice to work with the application as standalone and that way they can choose not to share their information with the utility. Needless to say, the system needs to be secure, to ensure there is no theft of user profiles and user data.

B. Effectiveness of the system

In this section we discuss the effectiveness of the smart metering system in a particular setup. For that we choose the smart metering project in Australia. The Department of the Environment, Water, Heritage and the Arts (DEWHA) prepared the initiatives for the smart grid system in Australia and it primarily focused on distribution and retail value chain elements. Two main applications that were considered as part of the primary smart grid technologies were the customer-side application and its key enabling application.

DEWHA also insisted that trials should be made to fully test the benefits of the consumer applications. For the trial they also suggested that customer segments with different patterns of electricity use be identified and included, because each segment appeared likely to respond differently to the customer applications components being tested [33]. The Victorian Government mandated the implementation of smart meters for residential customers in 2006 and the rollout commenced in 2009. The system mostly used RF mesh technology for its communication. Energy price deregulation was also introduced for all consumers to complement the smart meter roll-out. But there was huge resistance the TOU tariff scheme from consumers and advocacy groups such that the providers had to permit consumers to remain on the old flat-rate tariff, even after the deployment of smart meters [34].

The Australian Smart meter scheme clearly shows that smart meters were rejected by the consumers as it was not clear how the consumers could benefit from the system. Our proposal considers different consumer segments and suggestions that support each group. Using our proposed scheme different user groups can be provided different billing options.

IX. DISCUSSION AND CONCLUSION

Smart metering systems have the potential to contribute to smart grids and improved energy management. These systems benefit the utility because billing is more accurate and manual reading costs and errors are avoided. The infrastructure required for the system is vast and the meters are expensive. This cost is ultimately borne by the consumer, yet in projects to date they have gained very limited benefits from smart meters.

To tackle consumer concerns the commonly provided solution is to educate and engage the consumer to use the system [35, 36]. But that does not justify the need to introduce smart metering system. The alternative measures we have suggested in section VI are sufficient to reduce demand. If consumers have to actively engage in power management, the system should provide them with useful and easy to use choices.

As part of our research we have earlier identified a security analysis framework specifically for the smart grid [37], options in smart metering system to improve privacy and provide more control options to consumers [5]. We have also identified specific functionalities to benefit different consumer groups [28]. In this paper we have identified different feedback and billing options to suit different consumer segments.

A limitation to the research was that user survey and field testing was not a feasible. Moreover we have not considered

the usage of electronic vehicles (EV). EVs may draw more power. Hence it can make a huge difference in the power requirement for the concerned consumer. But we would like to suggest keeping EV power requirements separate from other residential energy requirements until they are widely used. It would be preferable to keep a separate power line for charging EVs and billed separately.

We started our analysis by choosing the problem situation in smart metering system. Then preferred states were identified by extracting consumer-friendly user requirements. Based on the requirements, an abstract architecture and functional specification were proposed. It was then shown how those features could be added to the existing system. We have proposed adaptations to the artifacts that feature intelligent feedback mechanisms and more billing options to suit different consumer categories. The evaluation suggests that current smart metering systems can be readily modified to add the proposed features. But the efficiency relies on the accurate details provided by the user.

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