Analysis of Demand Side Management Products at Residential Sites: Case of Pacific Northwest U.S.

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Abstract This paper provides a quantitative approach to determine important product features that are to be included in smart thermostats. This approach is expected to help decision makers manage product design process by utilizing feedback from customer and expert focus groups. Proposed approach is also expected to help managers review competing products in the market and shape future product design specifications. Data used in the assessment model have been gathered by surveying 22 potential customers who have been living in residential areas, and a group of experts who have been working as product design engineers. Significant findings as well as weak points of the proposed approach have been discovered, and future work initiatives have been proposed.

1 Introduction

Annual Energy Outlook 2008 (AEO2008), a report by the Energy Information Administration, projects a steady demand growth of 0.7 % per year through 2030 [1]. Projected growth in demand has spurned several initiatives aimed at forestalling potential shortages and outages caused by supply–demand mismatches. One such initiative is demand side management (DSM), which essentially focuses on influencing energy consumption patterns of end users especially during peak times when energy supply systems are strained. Moreover, our society today has become more sensitive to negative impacts of energy systems on the environment, and as a result consumers today are more aware of the need to conserve energy.

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DSM provides an opportunity to meet needs of today's energy-hungry yet environmentally aware society.

This section is going to be based on a case company, which is named as "ABC" due to confidentiality provisions. ABC is a startup company founded in 2006, aiming to position itself to make an impact in the DSM market. ABC currently focuses on developing an innovative smart thermostat product and a complementary web service platform. One of the issues that ABC currently faces is the difficulty in determining product features to include in their new product and optimum way to forward their product over competing alternatives. This report highlights investigative research conducted on identification and selection of potential product features; results and their potential implications are discussed. Finally, optimum product features are proposed as recommendations.

2 Demand Side Management

Forecasting electricity loads had reached a comfortable state of performance in the years preceding the recent waves of industry restructuring [2]. Adaptive time-series techniques based upon ARIMA, Kalman filtering, or spectral methods were sufficiently accurate in the short term for operational purposes, achieving errors of 1–2 % [3]. The technology is now providing the opportunity for consumers to respond to fluctuation in price by lowering their energy consumption during peak times. Using this strategy power companies now have the capability to even out the demand for power generation with simple economics rather than building physical power plants. Kirschen states, most consumers, with the possible exception of the largest ones, do not have the financial incentive and the expertise required to contribute effectively to such a complex and time-consuming task [4]. Recent experience in California made clear that introducing competition on the supply side while shielding the demand from liberalized prices seriously distorts the market [5].

3 Technology Assessment Process

To properly assess a technology there are several steps that must be performed. The first step is to identify the problem, and hardest part of this is gap analysis. Gap analysis is to be followed by a technology environment analysis, and evaluation criteria and methodology. Using these techniques a proper framework or model can be created of the technology in question.

3.1 Case Company Gap Analysis

In order to determine the best way forward, a gap analysis needs to be performed. Gap analysis is a business resource assessment tool enabling a company to

compare its actual performance with its potential performance [6]. At its core there are two questions:

- Where is company ABC among the competitors?
- What is the optimum positioning for company ABC?

The gap is defined as: gap = capabilities—needs.

3.1.1 Capabilities of Case Product

Among ABC's key products is Product™. The capabilities of Product™ are broken down into capabilities for residents and capabilities for energy distributors.

3.1.2 Capabilities for Residents

Case company ABC currently has two products, which are referred as "Product™" and "Platform™ Core" due to confidentiality provisions. Product™ is a packaged device whereas Platform™ Core is a web platform, which enables customers to manage their energy usage. System provides optimum trade-off between cost savings and comfort, reducing electric bills by up to 25 % during critical times. Users have the ability to use cell phone to control the settings as well. Internet-based solutions of ABC provide the user-friendly setup, control and reliability that are critical to end-user acceptance, while delivering the security and extensibility that the customers require.

The system moderates heating and A/C temperature settings through the use of an intelligent thermostat that can be controlled from our web interface through the ABC Platform™ Core. Intelligent gateway is a small hardware device that communicates wirelessly, using 802.15.4/ZigBee and other protocols, with several devices within the home, including thermostats, load control modules and other home automation devices. The Platform™ Core performs the on-site communication work, coordinating these devices through the Internet and communicating with the data center [7].

3.1.3 Capabilities for the Energy Businesses: Aggregators, Electricity Generation and Distribution Business

Since Product™ uses the customers' existing broadband connections, it can provide demand response and energy efficiency capabilities. This provides a cost-effective way for energy business to integrate a solution for small site management into their existing demand response systems. Integrating this solution can provide a competitive advantage against other aggregators. Product™ and its underlying platform Platform™ Core have been designed for integration into energy management companies' existing solutions.

3.1.4 Needs of Product™

Needs for Residents:
Residents use Product™ to get cost savings and comfort within the facilities. However, to obtain the advantage, they need to learn how to use it as a skill. What they need is not only the benefit to save energy but also the convenience as much as possible the product can provide. They would rather to have one device to control all the device of the home site than to have separate devices for different controls. So they hope that the product can integrate more features such as fire control, security control, irrigation control, gas leaking control etc. In short, they need a gateway for them to control all the home facilities. It might be a website or telephone service for them [8]. Residents also need more remote means to control devices in their homes. Besides the website, they also need to have more connectivity options like PC, telephone, SMS etc. to access Product™. The users hope that Product™ users hope that the device can be more intelligent in operation of home devices. For example, the users hope that the energy consumption can be as low as possible when there is no one in the house.

Needs of Energy Businesses:
Aggregators, electricity generation and distribution businesses all require information about amount of energy consumed by each subscriber at a given time, especially at peak demand time. That enable them to accurate forecast the energy needed down to the substation level as well as make them charge at different prices during different time. The information, which Product™ will provide, is the input for the Energy Businesses' information system. In order to cooperate with the other parts of the IS, the incoming data must be integrated into the system of energy businesses. A data transfer interface is needed to do this.

In order to reduce the energy consumption in the peak time, the Product™ also needs to control the home facilities to the mode of saving energy. This capability need the 2-way Demand Response because that we not only need to give information for to the energy businesses but also need to respond to the different charge in different time in order to get the highest energy usage efficiency.

3.1.5 Technology Gaps of ABC

To sum up, the technology gaps of ABC includes:

- More features integrated into the product
- More communication means to access the home facilities
- Automated control of the home devices
- Ability to measure the consumed energy in given time periods
- Integration with the system of energy businesses
- 2-way demand response to control home energy consumption.

3.2 Smart Thermostat Environment Analysis

3.2.1 Stakeholders

The smart thermostat technology model has opened up new fronts in the relationship between energy producers, distributors and consumers. Currently, there is potential for interactive response to changes on all sides. Consumers have an opportunity to monitor and adjust their consumption. Energy distributors such as; energy utilities and aggregators currently can use energy data from smart thermostats and advanced metering systems to predict energy patterns, buy energy at better rates and deliver savings to their customers. In 2006, one such utility, PJM Interconnection that serves 13 states and the District of Columbia, realized 2046 MW resulting in payments of $650 million to customers who curtailed their energy usage as part of demand response programs [9].

Many other stakeholders are also strategically aligning themselves by forming alliances that share ideas to promote innovation in the industry. Smart Energy Alliance is a group of technology companies including Capgemini, Cisco, GE Energy, HP, Intel, and Oracle. Smart Energy Alliance has a goal of implementing Supervisory Control and Data Acquisition (SCADA) systems that give customers more freedom to manage their energy consumption, given the eventuality of smart metering and smart thermostat technology [10]. Another example of this is The NewEnergy Alliance which brings together the technologies, manufacturers, engineers, and service providers across the energy, IT, and building systems industries. The group's members are involved in developing and implementing complementary solutions and technologies to deliver sustainable energy goals for every type of building and customer. A key goal of the alliance is to help empower and create immediate revenue opportunities for members who wish to directly participate in demand response with their products, services and technologies. Another goal for such alliances is to develop and strengthen industry wide standards for home automation. Currently, there are several different communication protocols used by different manufacturers which could lead to interoperability issues.

3.2.2 Market Forecasts

Thermostat market has been steadily increasing. Frost & Sullivan Research group, an international marketing consulting and training company that has done extensive research on the North American thermostat market reports that the market totaled revenues worth $520.1 million in 2002 and has the potential to expand to $754.4 million by 2009. The majority of revenues come from the booming retrofitting segment [11]. The report also notes that many of the participants in the market are looking to maximize this opportunity by exploring novel applications for re-fitted thermostats. These novel applications include the complementary features and capabilities such as demand side management. Other research firms

such as Forester research, another of the world's leading independent technology and market research companies, states that it expects IT environment monitoring to become a $11 billion industry by the year 2010. Environmental monitoring variables include:

- Temperature (high/low)
- Main and UPS power (interruptions)
- Flooding/water (water leaks, air conditioning condensation)
- Humidity (high and low)
- Smoke/fire
- Room entry/motion
- Airflow (A/C or fan status).

There are various different smart thermostat options available to consumers in the market. They offer a variety of technology features such as; electricity controls, water controls, in home display interfaces, phone interface, web interfaces, fire monitors, appliance control, gas leak monitors, among others. The direct competitors for ABC are other smart thermostat manufacturers like Ecobee®, Proliphix® and Venstar® that offer different combinations of the features in addition to basic thermostat control. They also implement different technologies to interface with the additional modules. Table below gives a brief technology survey of some of the competitors in the smart thermostat market of the different technologies (Table 1).

With such a wide array of technology options and providers all competing for market share and industry recognition it can be challenging to determine the best way forward for the company. The situation is further complicated by the fact that recent years have seen a rapid increase in innovations in the industry. To help determine where the real value lies for ABC, in the smart thermostat market, regular assessments may be may be needed to help guide the company decisions and overall strategy.

It is important to note that there are a few off the shelf programmable thermostats that currently retail at about $100 dollars such as; the Rite temp 6000 series, which offer additional features like fan and humidity control. Technology curve for these products tends to trend up slowly by integrating additional features

Table 1 Technology survey

Company	Proliphix	Homeseer	Aprilaire	Carrier	Venstar	ECOBEE	ABC
Cost	$449.99	$344.95	$270.95	$3000	$124	$385	$395
Thermostat connection	Yes CAT5	Yes Z-Wave	Yes RS485	Yes SkyTel	Yes Phone Line	Yes Wi-Fi, Zigbee	Yes Wi-Fi, Zigbee
Additional control	None	Lamp modules	None	Special dampers		Humidity	
Additional connectivity	Web-portal	Web-portal	None	Infinity furnace	Voice recognition/ synthesis	Web-portal	Web portal

with minimal or no increase in price. There are also some technologies in the building automation industry that offer a complete suite of control options including thermostat control and may have characteristics of disruptive technologies for the thermostat market.

3.2.3 Barriers to Pervasive Adoption of Smart Thermostats

Even though the market for smart thermostats has steadily grown, there are some barriers that exist to the widespread adoption of the technology. Several different reports have made an attempt to identify and address these barriers. One such report is the Residential Energy Conservation report prepared by request from the Technology Assessment Board at the Office of Technology Assessment (OTA) [11]. The report cites ease of use and cost, particularly life cycle cost as large barriers to the widespread adoption of smart thermostats. Another barrier identified in the report is that many consumers lack practical knowledge about how to accomplish conservation using existing technology options. This represents barrier to the diffusion of innovations. This effect is compounded further when introduction to a new idea or innovation is involved. Innovations and new ideas often involve uncertainty and a lot of misinformation or no information. There are five stages in the decision process, which are knowledge, persuasion, decision, implementation, and confirmation [12]. Knowledge of the options is an important first step in getting a technology to be widely adopted. Subsequent communication channels further promote the adoption of the technology.

3.3 Evaluation Criteria and Methodologies

According to technology acceptance model perceived usefulness and ease of use are important determinants for customers to adopt a technology [13]. In our study we regarded “Savings” and “Additional Features” as sub parts of “Perceived Usefulness” as these are the competitive advantages that smart grid appliance developers focus on. We regarded “Ease of Use” itself as a determinant in the model.

It was expected that “Cost” would be an important factor in deciding adoption of a technology or a product. In the literature many researchers included this variable in their studies [14].

From several meetings with the company ABC’s Vice President of Business Development, two major determinants important in smart grid technology field have been identified. These are “Service Reliability” and “Additional Features” [15].

Service reliability is considered to be important because many of the smart grid appliances use online communication, which makes their systems vulnerable to cyber attacks and hacking issues. At this point, it becomes very important to protect the system from attacks by the outsiders [15]. Connection availability is

considered to be important because of potential discontinuities in communication. At this point ability to communicate in multiple ways becomes important so as to provide continuing service. Several communication ways have been added by reviewing existing products in the market. These are internet, SMS, mobile phone and telephone connections [16].

To gain a deeper understanding in additional features existing product features have been reviewed in the field and identified the following features, which are integration with water control, integration with home appliances, light control, fire control, phone control, fire control, security control, mode control, gas leakage control, PC control, and in home display control [16].

Accordingly, several major determinants determined to be effective in providing competitive advantage have been identified. These determinants are cost of the product, savings that the product provides, product ease of use, service reliability, and additional product features. As analysis specifically focuses on smart grid applications we have created some sub headings for each major heading to provide deeper understanding of the major determinants.

All in all, these sub determinants for each major determinant can be seen below.

- Cost: Installation cost, product cost and maintaining cost.
- Savings: Energy efficiency savings and demand response savings.
- Ease of Use: Ease of installation, interface, and personalization.
- Service Reliability: Security and connection availability.
- Additional Features: Integration with water control, integration with home appliances, light control, fire control, phone control, fire control, security control, mode control, gas leakage control, PC control and in home display control.

Refer to Appendix: Explanations of Additional Features to see the definitions of the features.

By using both major and sub determinants a model, which is expected to prioritize customer, desires from smart grid appliances have been designed. Please refer to figure below to have a better understanding in the relationships between determinants.

3.3.1 Methodology

Two surveys; one of which consists of eight questions prepared for potential customers, and another survey made of single question prepared for experts to evaluate competitive products; have been developed. Surveys were sent through e-mails and got the responses back in the same way. For potential customer survey, 22 responses have been received from people who live in residential areas and are interested in owning a smart thermostat system. For expert survey, needed data was gathered from experts who have been employed as product development engineers in the field.

Mix of pair wise comparison and scoring method was used for judgment quantification purposes. It is expected that the proposed model would show quick

picture of competitive advantage profiles of each product as well as customer expectations from smart grid appliances in the energy saving technology field.

3.3.2 Assessment of the Determinants

As seen from the Fig. 1 above there is several sub and major determinants, which have hierarchical relationship. To find out the quantitative weights of each major determinant (orange colored variables in the figure above) and each sub determinant (yellow colored variables in the figure above)—except the ones under "Additional Features"—pair wise comparison technique was used.

It was found unpractical to pair wise compare 12 features under "Additional Features" by considering the fact that focus group would not be able to keep its concentration fresh and give consistent responses. With this thought in mind it was also aimed to cut down the effort for assessing the interface types under "Interface" and connection types under "Connection Availability". Because of this reason scoring technique was used instead of pair wise comparison technique for assessing the variables colored in blue.

After finding relative weights of each major and sub determinant weights of "Interface", "Connection Availability" and "Additional Features" to were required to be divided between sub features so that weights of all determinants and features in the model could be calculated. Below you can find related information about division of the weights.

To assess the features under "Interface" score of "Interface" was divided between "Website", "Cell Phone", "PC", and "Special Device".

To assess the features under "Connection Availability" the score of "Connection Availability" was divided between "Internet", "SMS", "Mobile Phone", and "Telephone".

To assess the features under "Additional Features" score of "Additional Features" was divided between "Integration with Water Control", "Integration with Home Appliances", "Light Control", "Fire control", "Phone Control", "Fire Control", "Security Control", "Mode Control", "Gas Leakage Control", "PC Control" and "In Home Display Control".

3.3.3 Assessment of the Competitor Products

In the meetings with Vice President of Business Development, a list of competitive products in the smart grid technology field was created to compare with ABC's product. Competing products were chosen among various products according to their performance in major determinants that are proposed to be important to residential customers. By assessing the products it is aimed to have enough data to calculate how much desirable each product is for each variable in the model.

A combination of two approaches was used to assess the products. One approach is to assess the products by using pair wise comparison, and the other one is to score the products by depending on whether they support a specific feature or not.

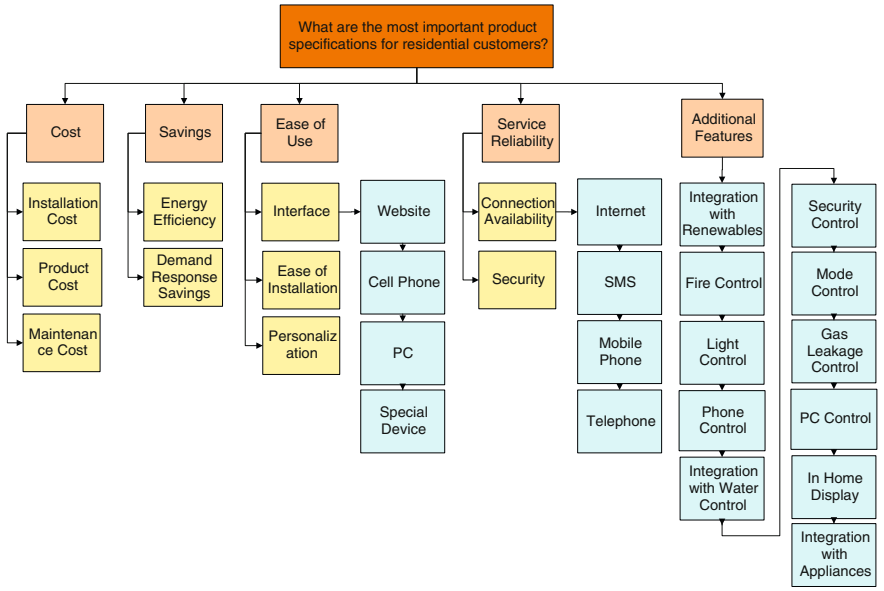

Fig. 1 Model of feature breakdown

Pair wise comparison method was applied to assess the relative performance of each product in terms of "Installation Cost", "Product Cost", "Maintenance Cost", "Energy Efficiency", "Demand Response Savings", and "Ease of Installation".

Scoring method was applied to assess each product in terms of the interface types under "Interface", "Personalization", the connection types under "Connection Availability", "Security" and the features under "Additional Features." For example; if Product A helps users to personalize their product features then Product A gets point, if it does not support then it does not get any point. If one or more than one product supports a specific feature then the total weight of that feature is divided equally between those products, which support that specific feature. If there are two products supporting a specific feature then total weight is divided into two, if just one product supports a specific feature then it gets the full weight of that specific feature- If none of the products has the specific feature then none of the products gets point. The reason for this is that if none of the products has the specific feature then none of them should have competitive advantage against another.

3.4 Quantitative Approach for Assessment

3.4.1 Quantitative Approach to Find the Weights of the Determinants

PCM software was used to convert the data coming from focus customer group survey into weights. —except for "Saving" items and "Service Reliability" items

because to perform PCM there should be at least three variables compared—Below, you can find the relative weights of each determinant in each level (Tables 2, 3, 4, 5, 6).

Table 2 Major determinants

Major determinants	
Cost	0.26
Savings	0.23
Ease of use	0.17
Service reliability	0.15
Additional features	0.19
Inconsistency	0.053

Table 3 Sub determinants-Cost

"Cost" Items	
Installation cost	0.28
Product cost	0.34
Maintenance cost	0.38
Inconsistency	0.057

Table 4 Sub determinants-savings

"Savings" Items	
Energy efficiency	0.56
Demand response savings	0.44

Table 5 Sub determinants-ease of use items

"Ease of use" Items	
Ease of installation	0.33
Interface	0.35
Personalization	0.32
Inconsistency	0.101

Table 6 Sub determinants-service reliability

"Service reliability" Items	Mean
Security	0.50
Connection availability	0.50

Relative score was divided according to each interface type's average score coming from focus customer group survey. This procedure is the same for the connection types under "Connection Availability" and the features under "Additional Features", too. Below you can see the scores of each interface type, connection type and feature (Tables 7, 8, 9).

Table 7 Interface items

"Interface" Items	Scores
Website	0.30
Cell phone	0.30
PC	0.25
Special device	0.15

Table 8 Connection availability

"Connection availability" Items	Scores
Internet	0.28
SMS	0.23
Mobile phone	0.27
Telephone	0.23

Table 9 Additional features

"Additional features" Items	Scores
Integration with renewables	0.09
Fire control	0.07
Light control	0.10
Phone control	0.05
Integration with water control	0.11
Security control	0.12
Mode control	0.06
Gas leakage control	0.12
PC control	0.07
In home display	0.11
Integration with appliances	0.10

To find the overall weights of each determinant multiplication of relative weights was used accordingly. For example; to find the overall weight of "Installation Cost" relative weight of "Installation Cost" was multiplied with relative weight of "Cost". Another example for finding overall weight of "Light Control" feature relative weight of "Light Control" was multiplied with relative weight of "Feature". Below you can see relative and overall weights of each determinant used in the model (Table 10).

Table 10 Total results

Items	Relative weights		Overall weights
Installation cost	28 %		7.3 %
Maintenance cost	38 %		9.9 %
product cost	34 %		8.8 %
Cost	26 %	Sum	26

(continued)

Table 10 (continued)

Items	Relative weights		Overall weights
Energy efficiency	56 %		12.9 %
Demand response saving	44 %		10.1 %
Savings	23 %	Sum	23
Interface	Website	30 %	1.8 %
	Cell phone	30 %	1.8 %
	Special device	15 %	0.9 %
	PC	25 %	1.5 %
	Sum		6.0 %
Interface	35 %		6.0 %
Personalization	32 %		5.4 %
Ease of installation	33 %		5.6 %
Ease of use	17 %	Sum	17
Connection availability	Internet	28 %	2.1 %
	SMS	23 %	1.7 %
	Mobile phone	26 %	2.0 %
	Telephone	23 %	1.7 %
	Sum		7.5 %
Connection availability	50 %		7.5 %
Security	50 %		7.5 %
Reliability	15 %	Sum	15
Integration with water control		11 %	2.0 %
Light control		10 %	1.9 %
Phone control		5 %	0.9 %
PC control		7 %	1.4 %
In home display		11 %	2.1 %
Integration with appliances		10 %	1.9 %
Integration with Renewables		9 %	1.8 %
Fire control		7 %	1.4 %
Security control		12 %	2.2 %
Mode control		6 %	1.2 %
Gas leakage control		12 %	2.2 %
Features	19 %	Sum	19
Total			100

3.4.2 Quantitative Approach to Find the Desirability of the Products

To evaluate the focus product group a survey was conducted to expert group. As stated in previous sections experts compared the products in terms of "Installation Cost", "Product Cost", "Maintenance Cost", "Energy Efficiency", "Demand Response Savings", and "Ease of Installation" by using pair wise comparison technique. Refer to Appendix: Focus Customer Group Survey and Expert Evaluation Survey. Below you can see the relative weights of each product in specific items.

After obtaining both relative importance of the determinants and performance scores from each product, each product's desirability on percentage basis is calculated. Due to large number of assessment variables, each product's score will be presented with respect to each determinant. It is expected that this feature of the model will be helpful in comparing competitive advantage of ABC's product with competing alternatives. Proposed approach to combine two sets of data coming from customers and experts divide customer desire points between products according to each of the product's performance scores. For example; overall weight of "Installation Cost" is 7.3 % in the whole model. To divide this weight between products, experts' evaluation is taken into consideration. 7.3 % is divided between products according to their relative weights; 22 % of 7.3 is accounted to ABC, 9 % of 7.3 is accounted to Proliphix etc. This approach is followed for "Installation Cost", "Maintaining Cost", "Product Cost", "Energy Efficiency", "Demand Response Savings", "and Ease of Installation" as well.

For other items such as; "Personalization", interface types under "Interface", connection types under "Connection Availability" and features under "Additional Features" a different approach is used. As stated in previous sections, binary variables are used depending on whether a product supports the specific feature or not. Points from each item are divided equally among the products that support the specified feature. In case none of the products supported a specific feature, none of the products receive any points. Thus, summation of each product's desirability is not equal to 100. It is 96.3 as none of the products support SMS type connection—its overall weight is 1.7—and Integration with Water Control feature-its overall weight is 2.

3.4.3 Best Practice, Veracity of Data and Methods

Firstly, as survey method was used to gather information, data used in the study rely on subjective ideas. As individuals have their own experience the responses may be based on personal bias. This situation brings weaknesses with itself. Also, 22 responses were received which is very limited amount of data in terms of measuring the market trend and preventing personal bias from being significant on the results.

Apart from personal bias it should also be mentioned that there is significant amount of inconsistency associated with the customer focus group. As seen below in the table amount of inconsistency is worth considering as it is greater than 0.1 [17]. Accordingly, as seen from the table below reliability of the responses from "Ease of Use" cannot satisfy the threshold value. Reason behind this situation may be lack of information about each item. If customers were given enough information about the importance of each item they might have made better comparison.

Another important aspect to mention is the judgment quantification methods used. By preferring scoring method to pair wise comparison method, aim was to cut the amount of time and effort spent on filling the survey. However, this

situation might have led missing some of the advantages of pair wise comparison over scoring method. One of the weak points is the division of weights equally between the products that support a specific feature. For example, if weights that each product gets from "Interface" is examined it will be realized that Venstar has the greater desirability although it can only support cell phone interface. Please see Table 11. On the other hand, although ABC, Homeseer and Ecobee can support PC, special device and website interfaces their desirability score are less than Venstar's. This issue could be fixed by not dividing the points between products and just giving the whole points or giving the whole point to a product provided that it can also support all other features which are used by the competitor products (Tables 12, 13).

Table 11 Product evaluation

Product evaluation	Installation cost	Maintenance cost	Product cost	Demand response savings	Energy efficiency	Ease of installation
ABC	0.22	0.19	0.15	0.27	0.23	0.27
Proliphix	0.09	0.19	0.14	0.19	0.19	0.10
Homeseer	0.21	0.20	0.21	0.17	0.21	0.19
Venstar	0.24	0.23	0.34	0.17	0.15	0.24
Ecobee	0.24	0.19	0.16	0.20	0.22	0.20
Inconsistency	0.035	0.016	0.056	0.037	0.034	0.049

Table 12 Final analysis

		ABC		Proliphix		Homeseer		Venstar		Ecobee	
Cost	Sum	4.81		3.77		5.36		7.02		5.04	
	Installation cost	1.61		0.66		1.53		1.75		1.75	
	Maintenance cost	1.88		1.88		1.98		2.28		1.88	
	Product cost	1.32		1.23		1.85		2.99		1.41	
Savings	Sum	5.69		4.37		4.43		3.65		4.86	
	Energy efficiency	2.97		2.45		2.71		1.94		2.84	
	Demand response savings	2.73		1.92		1.72		1.72		2.02	
Easy of use	Sum	5.34		1.39		2.19		3.14		4.95	
	Ease of installations	1.51		0.56		1.06		1.34		1.12	
	Personalization	2.70	1	0	–	0	–	0	–	2.70	1
	Interface	1.13		0383		1.13		1.80		1.13	
	Website	0.45	1	0.45	1	0.45	1	0	–	0.45	1
	Cell phone	0	–	0	–	0	–	1.80	1	0	–
	Special device	0.30	1	0	–	0.30	1	0	–	0.30	1
	PC	0.38	1	0.38	1	0.38	1	0	–	0.38	1
System reliability	Sum	4.28		0.53		0.53		3.70		4.28	
	Security	3.75	1	0	–	0	–	0	–	3.75	1
	Connection availability	0.53		0.53		0.53		3.70		0.53	
	Internet	0.53	1	0.53	1	0.53	1	0	–	0.53	1

(continued)

Table 12 (continued)

		ABC		Proliphix		Homeseer		Venstar		Ecobee	
	SMS	0	–	0	–	0	–	0	–	0	–
	Mobile phone	0	–	0	–	0	–	2.00	1	0	–
	Telephone	0	–	0	–	0	–	1.70	1	0	–
Additional features	Sum	1.50		4.63		2.12		1.82		7.23	
	Integration with water control	0	–	0	–	0.	–	0	–	0	–
	Light control	0	–	0.63	1	0.63	1	0	–	0.63	1
	Phone control	0	–	0	–	0	–	0.90	1	0	–
	PC control	0.35	1	0.35	1	0.35	1	0	–	0.35	1
	In home display	0.53	1	0.53	1	0.53	1	0	–	0.53	1
	integration with appliances	0.38	1	0.38	1	0.38	1	0.38	1	0.38	1
	Integration with renewables	0	–	0	–	0	–	0	–	1.80	1
	Fire control	0	–	1.40	1	0	–	0	–	0	–
	Security control	0	–	1.10	1	0	–	0	–	1.10	1
	Mode control	0.24	1	0.24	1	0.24	1	0.24	1	0.24	1
	Gas leakage control	0	–	0	–	0	–	0	–	2.20	1
Total sum		21.61		14.68		14.63		19.04		26.35	

Table 13 Ease of use

"Ease of use" Items	Mean	Max	Min	Std dev
Ease of installation	0.33	0.57	0.16	0.11
Interface	0.35	0.47	0.21	0.07
Personalization	0.32	0.6	0.11	0.12
Inconsistency	0.101			

It is important to emphasize that one of the gaps that involves in not knowing how customers would react if any of the variables in the model was excluded from the assessment. As stated in the previous section SMS type connection and Integration with Water Control features are not included in any of the products in the field. Accordingly, it is very important to know how people would react to a product, which has these missing features. For example; to what degree weights of "Internet", "Mobile Phone" and "Telephone" would change, if weights of other major or sub determinants change. If this gap is bridged new opportunities or emerging competitors could be analyzed better.

4 Consumer Analysis

Enhancing the ability to respond to price signals could benefit not only the consumers who choose to participate actively in electricity markets, but would also help these markets operate more efficiently and satisfactorily [4]. This is the key component for the consumer's selection of products. Though they care about

additional features that technology will enable, they overwhelmingly prefer cost benefit that an energy demand system would provide. The value of demand side management to electricity customers has not changed since the mid-1980. DSM is still valuable to the extent it lowers customer's bills, particularly if the measures do not detract from comfort, convenience, or performance [15]. From a consumers point of view one of the largest factors contributing to the purchase of these devices is the cost, and savings. The technology that enables this will also enable other functionality that may be of interest to the consumer.

4.1 Smart Thermostat Evaluation

One of the easiest means of penetration into the demand side management market is to design a thermostat that is responsive to signal or in other words able to communicate with the outside world. Criteria for selecting these devices were based on two characteristics such that ability to control the HVAC system through a programmable thermostat and ability to communicate with the outside world in some manner. All of the products investigated took different approaches to solving the demand side management challenge. So a comparison based on features, cost, and other consumer preferences was used in order to compare the products on a quantitative level.

Prior to beginning the investigation there was much speculation on which product created the most value for the consumer's dollars. It was quickly discovered that a product could be created at relatively low cost and still be competitive with products 4–5 times more expensive. For example the University of California performed a study in which they were able to build a proof of concept communicating thermostat with a bill of material cost of $20 [16]. Based on the consumer response and expert response of product definition the Ecobee unit turned out to have the greatest value to the consumer. This resulted from the very large spread of functionality and methods of interface.

4.2 Technology Impact

Products compared in this study will impact consumers in different ways depending on the technology they used in creating the device. Venstar's phone control capability creates an advantage over the other products by allowing the consumer to interact with the device while driving. On the other hand ABC has an interface that allows the user not only to interact with the device from anywhere in the world, but it also transforms the data collected on the unit and the web and transforms it into information that is relevant to the consumer. Technology is not the hurdle in creating a successful product, it is packaging just enough features for

the consumer without adding on additional unwanted functionality that will burden the unit with higher cost.

5 Discussion of the Results

This chapter built upon the summary provided by Daim and Iskin [18]. Overall evaluation of the products can be seen below. According to Fig. 2 Ecobee and ABC seem to have the most desirable products in the focus product group. So it could be stated that Ecobee is the strongest competitor of ABC. In the following section, products that are subject to assessment will be compared with respect to each determinant.

Data was analyzed and desirability of each product from each determinant was calculated. To be able to observe the results figures for each determinant was drawn.

From the Fig. 3 below Venstar seems to have the biggest desirability from cost item which is not a surprise because its cost items are lower than its competitors. ABC and Ecobee have the same desirability.

From the Fig. 4 below ABC gets the highest desirability from energy savings. "Ability of Demand Response Savings" seems to be more attractive than Ecobee's, but the difference would not be considered as significant. Also, as seen from the figure it could be said that nearly every product has the same amount of attractiveness in energy efficiency item.

From the Fig. 5 below ABC and Ecobee seem to have the greatest attractiveness when they are compared to others. While personalization and interface features are equal ABC seems to make the difference from its ease to installation. It should further be noted that ratio of Interface in Ease of Use is considerable.

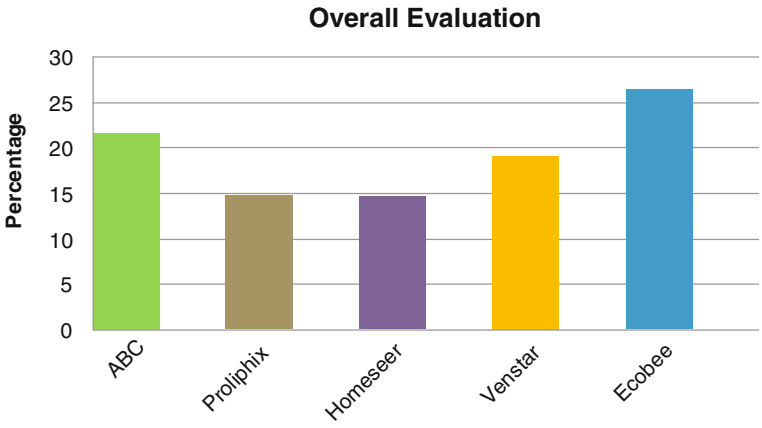

Fig. 2 Overall evaluation

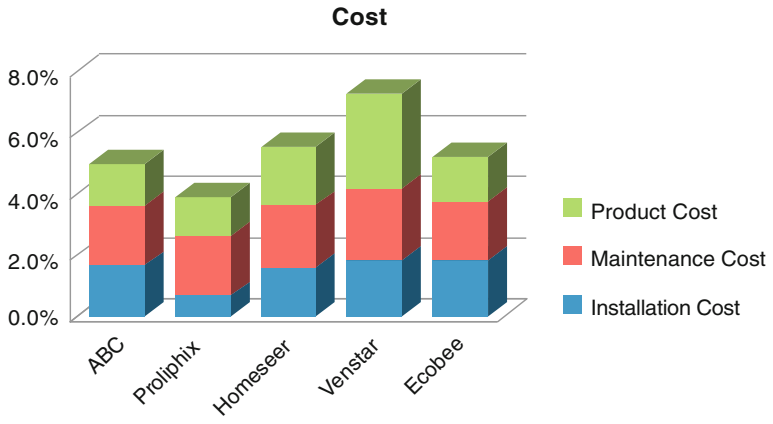

Fig. 3 Cost comparison

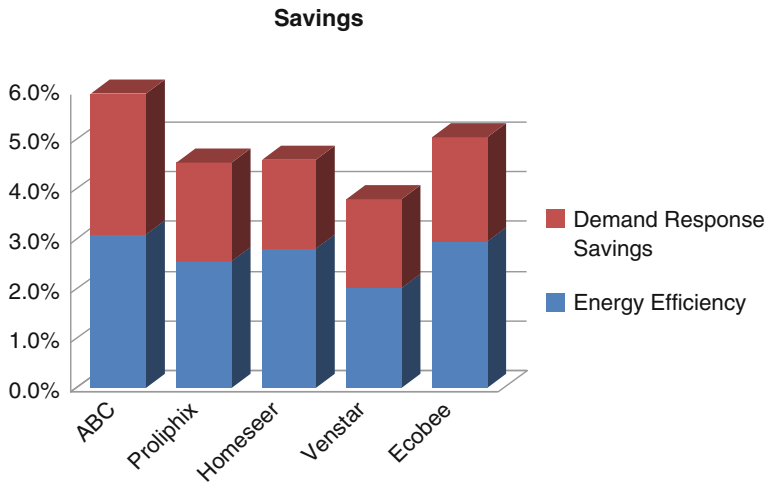

Fig. 4 Savings comparison

Interface is a sub item under ease of use and from the Fig. 6 below it could be said that Venstar is the only product which supports cell phone interface to its customers whereas ABC and Ecobee focus on providing interfaces through website, PC and special devices. The reason why Venstar has greater desirability than the others is the division of the weights equally between the products which support a specific feature.

From the Fig. 7 below it could be said that ABC and Ecobee are the only products, which support security function, and they have the same desirability. The ratio of connection availability seems to be low when it is considered to whole.

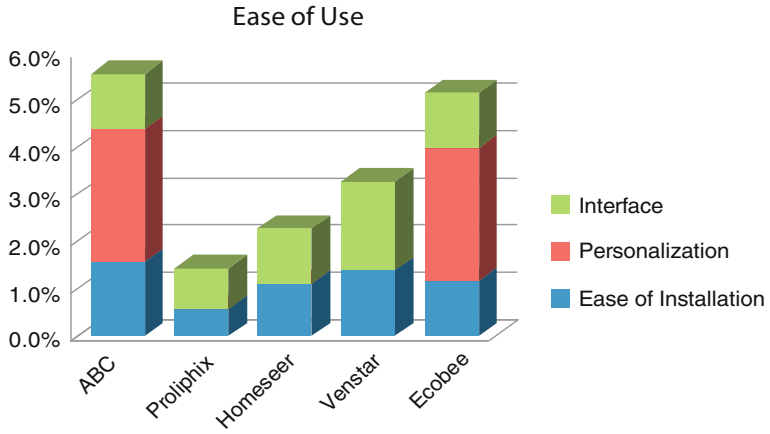

Fig. 5 Ease of use comparison

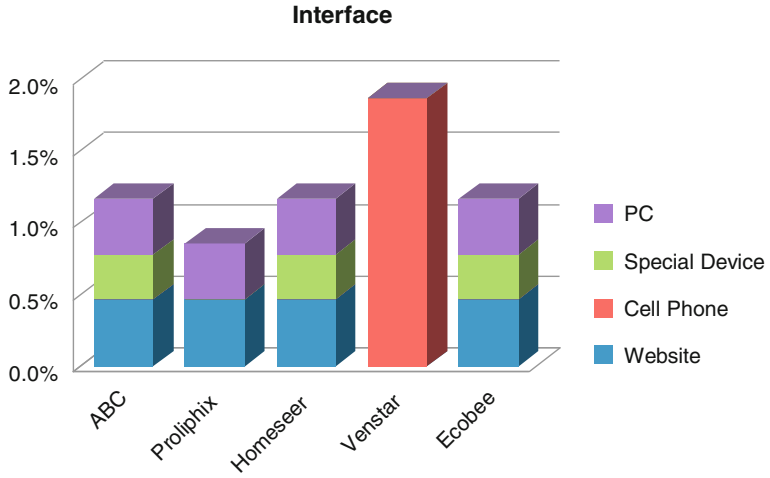

Fig. 6 Interface comparison

From the Fig. 8 below unsurprisingly Venstar's desirability is quite big as it has two ways to communicate within the system where as all other products use internet as its communication way. The reason why Venstar has greater desirability than the others is the division of the weights equally between the products which support a specific feature. ABC and Ecobee have the same amount of desirability in this item.

From the Fig. 9 below, additional feature profile of each product can be observed. Accordingly, Proliphix and Ecobee seem to have the greatest desirability whereas ABC's score is quite low. Reason behind this is the competitive

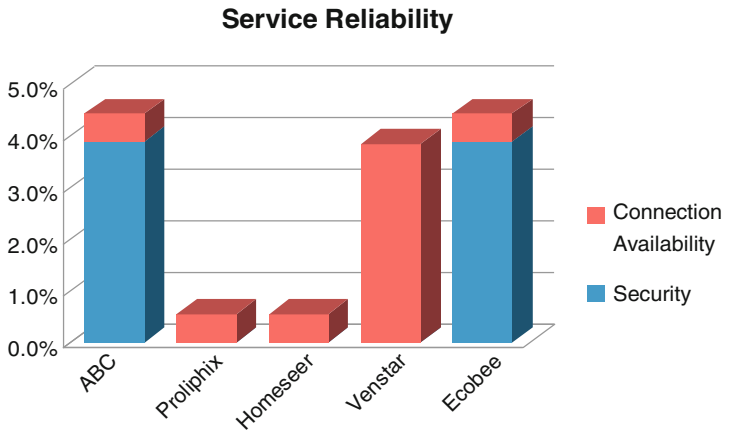

Fig. 7 Service reliability comparison

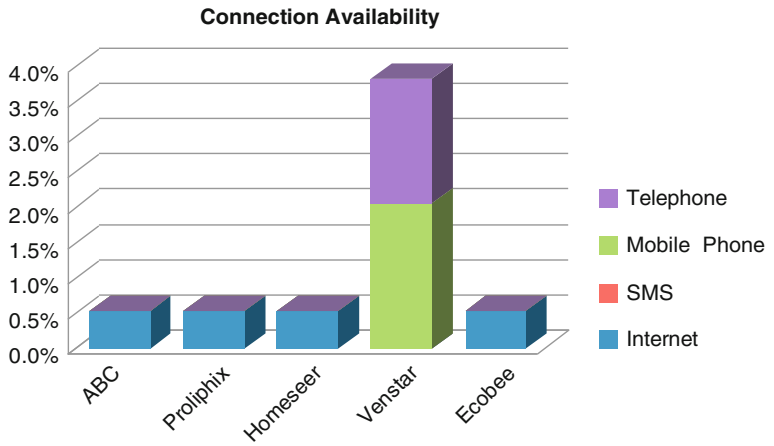

Fig. 8 Connection availability comparison

advantage that the domination of ABC and Ecobee on some of the additional features. For example; Gas leakage control and integration with renewables can only be supported by Ecobee and Proliphix is the only product which can support fire control feature. The reason why ABC has low desirability in this item is that it just focuses on the features which can also be supported by the other products. Apart from additional features ABC and Ecobee do not show significant difference and as a result their desirability is the same, but Ecobee makes the difference through additional features and this causes Ecobee to be more popular. Features that are not included in any of the focus products can be observed from the figure above. It should be noted that their weights are quite considerable (Fig. 10).

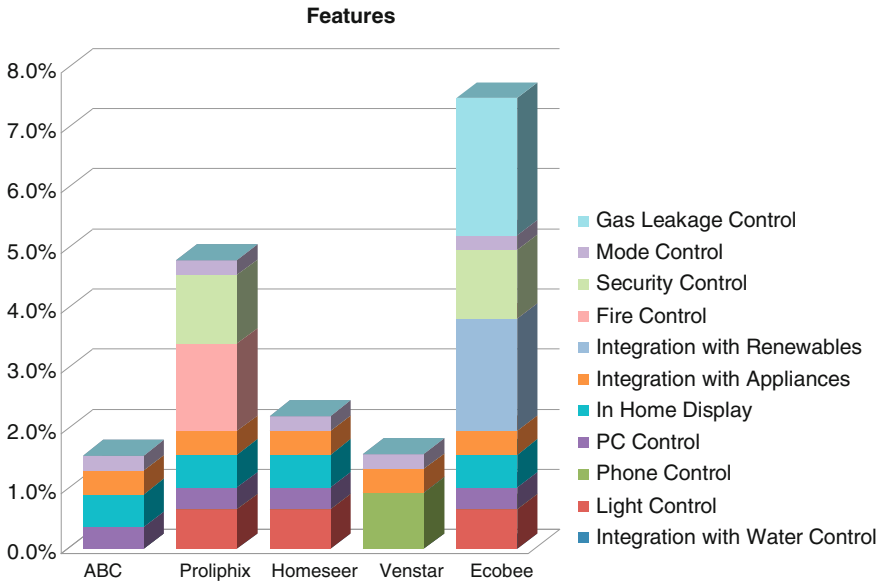

Fig. 9 Feature comparison

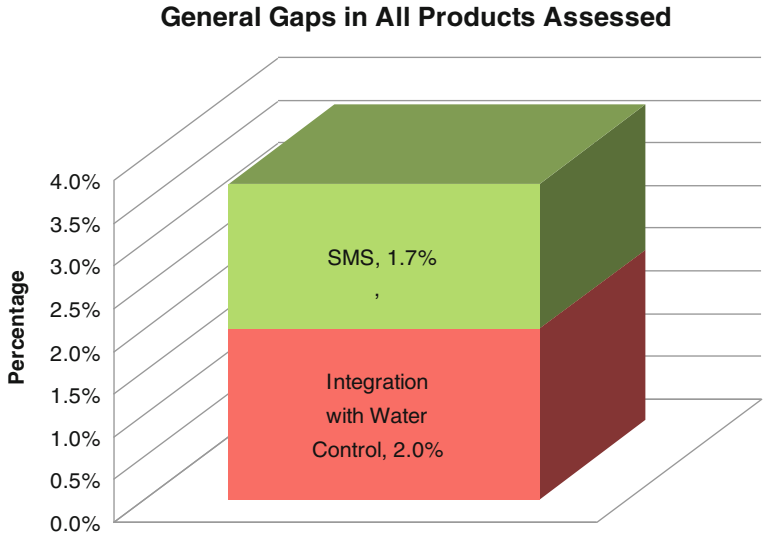

Fig. 10 General gaps in all products assessed

6 Recommendations for ABC

As seen in the Fig. 11 below, surveyed customers are concerned about additional features as much as low cost and savings potential at a higher level. A similar pattern can also be observed at the sub-determinants level, please refer to Fig. 12 below for further detail (Fig. 12).

According to results it can be stated that ABC has an advantage in providing "Energy Savings" and "Demand Response Savings". The "Cost" could also be considered as competitive as its desirability is not too low. In terms of "Ease of Use" ABC ranks among the best of the products assessed. It may be worth their while to continue to develop better interfaces to make it as simple and intuitive as possible. Investing in a simple, easily understandable and accessible user guide will also make it easier for customers to pick and recommend their products. If ABC can improve its system to support cell phone interface it could provide competitive advantage as none of the products except Venstar provides this feature. Considering "Service Reliability", adding new communication ways such as; telephone, mobile phone and SMS would help ABC create competitive advantage against its competitors. One of the most important points for ABC is the additional features that it can provide. As mentioned in previous sections ABC is one of the least desirable products in this section. Adding new features will dramatically

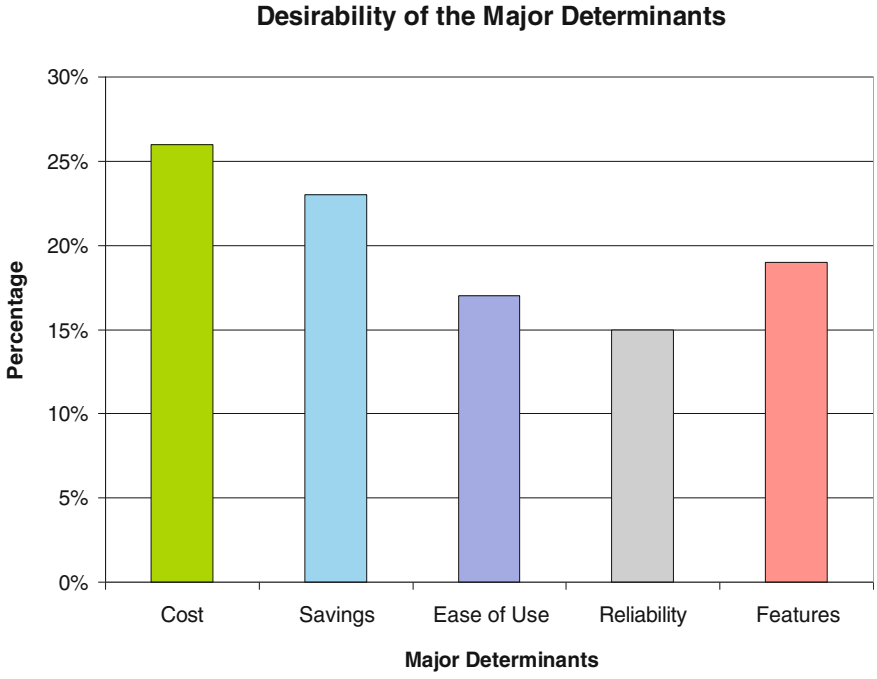

Fig. 11 Desirability of major determinants

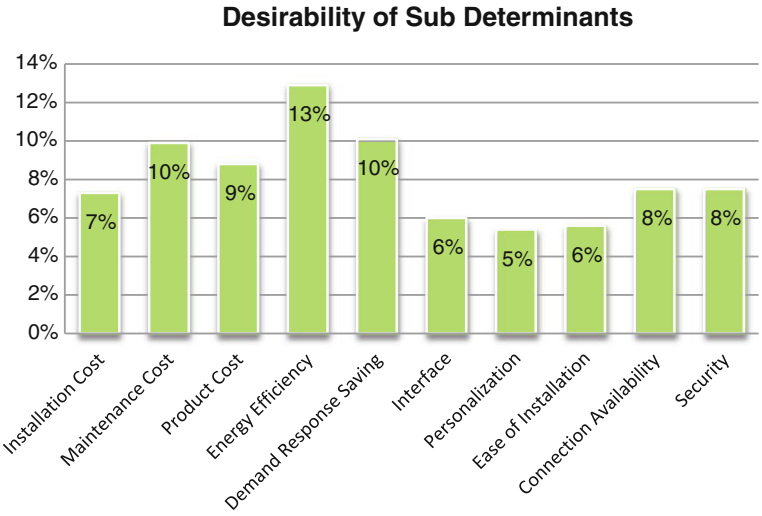

Fig. 12 Desirability of sub determinants

increase customer perception in positive way especially "Gas Leakage Control" and "Integration with Renewables" By not only adding missing features but also adding the features of SMS connection availability and integration with water control, ABC could ease its market acceptance. To achieve this end, ABC could consider seeking partnerships with OEM's and other technology providers to ensure that their product is fully compatible with, and fully supports, other technology modules that may add value to ABC products. Some R&D effort will be needed to add new features as mentioned above.

7 Conclusion

Many interesting results were derived from analysis of the survey data. The survey identified some strengths and weaknesses of ABC that make sense. It is believed that ABC is one of the stronger competitors in the market, but must focus much effort on minimizing cost. It is important to note that bias is added to survey based on the way a question is phrased, and it has been identified that this as an area for future work. Also a small sample size of participants can create a lopsided impression of the devices and functionality desirability. A larger sample size, with better-defined questions, using the analysis we developed, could help lower and risk and focus ABC in their future steps.

7.1 Future Work

It is very important to predict customer desirability trend when there is potential for market to have a new feature emerging or an emerging product with existing features. Future studies could revise focus customer group surveys by adding or omitting some of the features and conduct a similar assessment. It would be possible to observe how the weights of customer desire moves between determinants. This knowledge would help managers to give decisions about product features. Organizations could save capital by not investing every emerging R&D projects but could save a lot by investing capital on the features, which are to provide competitive advantage.

Acknowledgments We would like to thank Brian Muchilwa, Nathan Hadlock, Bing Wang, and Mike Hoffman for their valuable contributions to successful completion of this study.

A.1 Appendix

A.1.1 Explanations of Additional Features

Integration with water control: Ability to control water consumption within the residential area for example; measuring the moisture in the earth and making decision to water the grass or not.
Integration with home appliances: Ability to control the energy consumption of the home appliances within the residential areas for example; closing television when it is idle.
Light control: Ability to manage lights in the house for example turning off the lights when there is no one in the room or turning on the lights when there is someone in the room.
Fire control: Ability to control fire alarm system.
Phone control: Ability to communicate with phone.
Security control: Ability to communicate with alarm system.
Mode control: Ability to set the device for specific conditions for example setting it to holiday mode when you are on vocation.
Gas leakage control: Ability to detect gas leakage.
PC control: Ability to communicate with PC and allowing users to reach their devices through their PC.
In home display control: Ability to manage and communicate with video or audio systems within the residential places.

A.1.2 Focus Customer Group Survey

1. If you were to buy a smart grid device for your house which of these additional "Features" would be important to you? Please, rate the features on scale of 1: Least important-10: Most important

Integration with water control
Light control
Phone control
PC control
In home display
Integration with appliances
Integration with renewables
Fire control
Security control
Mode control
Gas leakage control

2. If you were to buy a smart grid device for your house which of these "Interfaces" would be suitable to you? Please, rate the interfaces on scale of 1: Least suitable-10: Most suitable

Website
Cell phone
Special device
PC

3. If you were to buy a smart grid device for your house which of these "Connections" types would be suitable to you? Please, rate the connection types on scale of 1: Least suitable-10: Most suitable

Internet
SMS
Mobile phone
Telephone

4. If you were to buy a smart grid device for your house which of these "Ease of Use" items would be important to you? Please, rate the percentages according to information given.

Ease of installation	Interface
Ease of installation	Personalization
Personalization	Interface

5. If you were to buy a smart grid device for your house which of these "Savings" items would be important to you? Please, rate the percentages according to information given.

Energy efficiency	Demand response savings

6. If you were to buy a smart grid device for your house which of these "Reliability" items would be important to you? Please, rate the percentages according to information given.

Security	Connection availability

7. If you were to buy a smart grid device for your house which of these "Cost" items would be important to you? Please, rate the percentages according to information given.

Installation cost	Product cost
Installation cost	Maintenance cost
Product cost	Maintenance cost

8. Please, rate the percentage of items below in terms of their importance according to the information given.

Cost	Savings
Cost	Ease of use
Cost	Reliability
Cost	Features
Savings	Ease of use
Savings	System reliability
Savings	Features
Ease of use	Reliability
Ease of use	Features
Reliability	Features

A.1.3 Expert Evaluation Survey

9. Please, rate the percentages of buying specific product according to the information given.

Installation cost		Maintaining cost	
ABC	Proliphix	ABC	Proliphix
ABC	Homeseer	ABC	Homeseer
ABC	Venstar	ABC	Venstar
ABC	Ecobee	ABC	Ecobee
Proliphix	Homeseer	Proliphix	Homeseer
Proliphix	Venstar	Proliphix	Venstar
Proliphix	Ecobee	Proliphix	Ecobee
Homeseer	Venstar	Homeseer	Venstar
Homeseer	Ecobee	Homeseer	Ecobee
Venstar	Ecobee	Venstar	Ecobee

Product cost		Energy efficiency	
ABC	Proliphix	ABC	Proliphix
ABC	Homeseer	ABC	Homeseer
ABC	Venstar	ABC	Venstar
ABC	Ecobee	ABC	Ecobee
Proliphix	Homeseer	Proliphix	Homeseer
Proliphix	Venstar	Proliphix	Venstar
Proliphix	Ecobee	Proliphix	Ecobee
Homeseer	Venstar	Homeseer	Venstar
Homeseer	Ecobee	Homeseer	Ecobee
Venstar	Ecobee	Venstar	Ecobee

Demand response saving		Ease of installation	
ABC	Proliphix	ABC	Proliphix
ABC	Homeseer	ABC	Homeseer
ABC	Venstar	ABC	Venstar
ABC	Ecobee	ABC	Ecobee
Proliphix	Homeseer	Proliphix	Homeseer
Proliphix	Venstar	Proliphix	Venstar
Proliphix	Ecobee	Proliphix	Ecobee
Homeseer	Venstar	Homeseer	Venstar
Homeseer	Ecobee	Homeseer	Ecobee
Venstar	Ecobee	Venstar	Ecobee

References

1. DOE U (2004) Annual energy outlook 2004 with projections to 2025. Report#: DOE/EIA-0383
2. Bunn D, Such LB (2000) Forecasting loads and prices in competitive power markets. Proc IEEE 88:163–169
3. Bunn DW, Farmer ED (1985) Comparative models for electrical load forecasting. Wiley, New York
4. Kirschen D (2003) Demand-side view of electricity markets. IEEE Trans Power Syst 18:520–527
5. Caves D, Eakin K, Faruqui A (2000) Mitigating price spikes in wholesale markets through market-based pricing in retail markets. Electr J 13:13–23
6. Gap Analysis—Wikipedia, the Free Encyclopedia (2008) Wikipedia. http://en.wikipedia.org/wiki/Gap_analysis. Accessed 15 Dec 2008
7. Powermand-Wireless Automation Made Simple (2008) The PowerMand executive team. http://www.powermand.com/corp/index.jsp. Accessed 12 Nov 2008
8. Gehring KL (2002) Can yesterday's demand-side management lessons become tomorrow's market solutions? Electr J 15:63–69
9. Anonymous http://www.pjm.com/documents/ferc/documents/2008/20080630-er05-1410-000.pdf
10. About | Smart Energy Alliance (2008, 12 12) Smart energy alliance. http://www.smart-energy-alliance.com/about/. Accessed 12 Nov 2008
11. OTA of congress of US, Residential Energy Conservation, Library of Congress Catalog Card Number 79-600103, pp 30–60. http://www.princeton.edu/~ota/disk3/1979/7914_n.html
12. Rogers EM (1995) Diffusion of innovations. Free Press, New York
13. Venkatesh V, Davis F (2000) A theoretical extension of the technology acceptance model: four longitudinal field studies. Manage Sci 46:186–204
14. Kargin B, Basoglu N, Daim T (2009) Adoption factors of mobile services. Int J Inf Syst Serv Sect 1:15–34
15. Hoffman M (2008) Technology assessment meeting. (Iskin, Hadlocna, Muchilwa, & Wang, Interviewers)
16. TSC_Systems_Eng (2008) TSC systems. http://www.tscsystems.com/foreigners/english/product/TSC_Systems_Eng.pdf. Accessed 12 Nov 2008
17. Hallowell DL (2008) Six sigma. Analytical hierarchy process (AHP)—getting oriented. http://software.isixsigma.com/library/content/c050105a.asp. Accessed 11 Dec 2008
18. Daim T, Iskin I (2010) Smart thermostats: are we ready? Int J Energy Sect Manage 4(2):146–151