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Behavioral Change-Model Based Mobile-Cloud Approach for Rationalized Energy Consumption

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Dedication

I would like to dedicate this thesis to my beloved family: my father William Voskergian, for his love, support, encouragement, and for giving me the determination to overcome many trying moments to pursue my dreams, and my heavenly mother Ghada Nasrallah Voskergian, for her grace, benevolence, blessings, and unconditional love.

"I will continue till I achieve the dream we talked about mum...

You will always be my inspiration..."

Daniel W. H. Voskergian

7/6/2017

Declaration

I Certify that this thesis submitted for the Degree of Master, is the result of my own research, except where otherwise acknowledged, and that this thesis (or any part of the same) has not been submitted for a higher degree to any other university or institution.

Signed: Daniel

Daniel William Hagop Voskergian

Date: 7/6/2017

Acknowledgment

Firstly, I would like to express my sincere gratitude to my dear advisor Prof Salaheddin Odeh for the continuous support of my thesis study and related research, for his patience, motivation, immense knowledge, and most importantly, his confidence in me. His guidance helped me in all the time of research and writing of this thesis. I could not have imagined having a better advisor and mentor for my thesis study.

My sincere thanks also go to Jerusalem District Electricity Company, represented by Eng. Salah Alqam and Eng. Amjad kamal, who provided me with a great opportunity to access a set of data for my research and architectural descriptions of their system.

Last but not the least, the participants of usability evaluation deserve special thanks for taking the time to participate in this study, and for making the research more interesting and useful.

Abstract

Energy efficiency improvement is one of the most important targets to be achieved on every society as a whole and in power system in particular. With the advent of smart grids, residential end users are expected to shift from their passive role as consumers of electricity to an active contributor role, referred to as co-provider, a term that reflects the consumer ability to reduce electricity usage, shift usage from on-peak to off-peak periods, generate and trade excess electricity.

In order to build a persuasive mobile application intended to encourage electricity conservation, promote pro-environmental behavior and empower end-users to take up an active role as co-providers, the thesis starts by investigating the motivations behind electricity consumption behavior in households, and tries to identify the kinds of information needed in a mobile environment to motivate behavioral change towards sustainability.

Based on different environmental behavior change models from behavior science, as well as a user study with prospective users, a hybrid energy consumption behavioral change model was proposed, and a set of well-defined requirements were identified and guided us through the design and development of a mobile cloud application called *Mobile Cloud for Smart Grid Metering (MCSG)*, a solution that uses different technologies to encourage pro-environmental behavior, e.g., *smart meter*, *cloud computing technology*, *mobile computing technology*, *persuasive technology* and *behavioral change techniques*.

The design process was implemented using *User-Centered-Design* (UCD) approach and the research work followed the *Design Science Research Method*.

In comparison to the In-Home Displays (IHD) that solely display instantaneous power measurements, the *MCSG Metering* prototype includes the following behavioral change interventions: real time electricity feedback, historical feedback, self-comparison, normative-comparison, group and individual goal setting, public commitment through social media, automation, tailored information, and utility / event driven / demand response notifications.

In this study, the *MCSG Metering* prototype is tested in regards to its goals and usability, which is of a great significance when it comes to build an appealing energy

management tool that is used regularly for a long period, and before time and money are invested in extended future behavioral change evaluations. The Participants of usability testing scored our interactive application as 84.6%, according to the ranking grade of *System Usability Scale (SUS)* score, our system gets an A, an excellent result but with potential of improvement.

The thesis will describe the architecture, design and implementation of the *MCSG Metering* prototype, in addition to presenting and discussing the evaluations of usability results.

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Acronyms

AMI Advanced Metering Infrastructure.

AMR Automatic Meter Reading

CC Cloud Computing

DR Demand Response

DSM Demand Side Management

DSRM Design Science Research Method

FCM Firebase Cloud Messaging

FR Functional Requirement

HCI Human Computer Interaction

IHD In-Home Display

ISO International Organization for Standardization

JDECO Jerusalem District Electricity Company

JSON JavaScript Object Notation

KWh Kilowatt-hour

MCSG Mobile Cloud for Smart Grid

MIaaS Mobile Cloud Infrastructure as a Service

MPaaS Mobile Platform as a Service

MSaaS Mobile Software as a Service

NFR Non-functional Requirement

NIST National Institute of Standards and Technology

RES Renewable Energy Sources

RESTful Representational state transfer web services.

SCADA Supervisory Control and Data Acquisition

SDK Software Development Kit

SOAP Simple Object Access Protocol

TOU Time-Of-Use, electricity pricing model.

UCD User-Centered Design

UI User Interface

UML Unified Modeling Language

XML Extensible Markup Language

CHAPTER ONE

Introduction

1.1 Problem Statement

It is becoming clear that the world's energy usage is not sustainable, and as a result, reducing energy consumption has been an important objective for many governments and people.

Today, residential, commercial buildings and offices consume more energy than the transportation or industry sectors, accounting for nearly 40 percent of total energy consumption [1] and 36 percent of total carbon dioxide emissions in the European Union. Corresponding rates in China and USA accounts at similar levels [2], making them a prime target for the application of energy efficiencies.

Studies have shown that nearly 40% of energy consumption in household can be contributed to life style factors and behavior of habits. Estimate that 20% of carbon dioxide emission could be reduced by behavioral changes [3]. However, behavioral changes are difficult in practice. Enova [4] stated in a 2012 report on energy efficiency in buildings: "For all types of homes and buildings, the probable main barrier from the society’s viewpoint is a generally low, partly absent awareness about energy use and energy-related measures".

Indeed, energy is abstract, invisible and untouchable. It is consumed indirectly via various energy services; therefore, it is not perceived as a coherent field of action [5]. While people are willing to adjust their behavior in order to conserve energy and reduce their billing cost, the lack of information about their energy consumption would be a major burden that prevent people from doing so. It is difficult for consumers to develop a coherent, comprehensible, and concise cognitive frame of what electricity conservation means and to make it an element of lifestyle.

Obviously, consumption transparency and timely feedback are considered essentials to support those people, and without a tangible manifestation, energy usage will remain abstract, invisible and untouchable. For example, plotted pattern of energy usage enable consumers to identify and eliminate source of energy waste and anticipate trends and plan them in advance. As a result, a higher energy efficiency is expected, greener world approach is anticipated, and high profitability requirement is achieved for all electricity stakeholders. Generally, awareness calls for action and behavior follows awareness. Researches have shown that average reduction of household energy consumption is between 5% - 20% when providing customers different feedback [5] [6] [7] [8].

Nowadays, with the advent of Smart Grids and related technological infrastructure advances, such as smart meters, Advanced Metering Infrastructure (AMI), and the integration of different types of distributed power generation sources, provide excellent potential platform for advanced intelligent home energy management. Residential end users in Smart Grid are expected to shift from their passive role as consumers of electricity to an active contributor one, referred to as co-provider[1]. Nevertheless, to date, from both academic and practical viewpoints, the development and application of intelligent home energy management systems in a smart grid infrastructure is still at an extremely early stage [9].

1.2 Scope of Study

Our aim is to create a household home energy management system that will shape an active participation of end users as co-providers in smart grids, and increases people awareness of their electricity consumption and various power supply information (such as alternative energy, storage energy, main grid), and hopefully as a consequence, motivates behavioral change, reduces electrical usage, shifts usage from peak demand to off-peak period. One solution to achieve this, is to use technology to provide consumers with a detailed information about their electricity consumption, enabling them to monitor, and even take a smart decision by remotely controlling their home appliances. The combination of *smart meters, cloud computing technology, mobile computing technology, persuasive technology* and *behavioral change techniques* would be the perfect tools in this situation.

[1] Refer to section 2.3 for more information.

At the same time, effects on energy consumption are strongly dependent on the design of technology. In order to create a service for co-provider users that will shape an active home energy management that complements smart grid goals, the following parameters need to be taken into consideration to ensure an optimum design: the needs, wishes, abilities of end users and utilities, empirical studies, theoretical means and product design that affect behavior and ensure end-user engagement. Without this deeper understanding, we will run the risk of designing and implementing systems that fail to maximize smart grid goals.

In this aspect, we cooperated with JDECO Company[2] who provided us with an access to AMR consumption data to realize a real word mobile cloud application that promotes pro-environmental behavior[3] and activates consumers' role as co-providers. Through a literature review and behavioral change models related to the research field, and different electricity stakeholders' perspectives, we have identified a set of requirements that guided us through the design and development of the proposed mobile application. Thesis work has followed the design science research method.

In this study, we have evaluated the usability parameter for the mobile application, which we think is essential when it comes to building an appealing energy visualization tool that is used regularly for a long period, and before time and money are invested in the extended future behavioral change evaluations[4].

1.3 Research Questions

1) *What motivates energy consumption behavior?* This thesis investigates the motivations behind how consumers use electricity in their households.
2) *What kind of information needed in a mobile environment to motivate behavioral change towards sustainability?* This thesis tries to identify which information a smart application should present in order to promote pro-environmental behavior.

[2] An overview about JDECO Company is presented in the next section.
[3] Behavior that consciously seeks to minimize the negative impact of one's actions on the natural and built world [107].
[4] More information about future behavioral change evaluations, please refer to *Future Work* section.

1.4 Jerusalem District Electricity Company (JDECO)

This thesis work would not have been possible without the help from and collaboration with Jerusalem District Electricity Company. JDECO is a joint electricity company that distributes and supplies electricity to consumers in and around Jerusalem, Bethlehem, Ramallah and Jericho. The company doesn't own power stations but buys over 95% of its electricity from the Israel Electric Corporation (IEC) and the remaining electricity from the Jordanian National Electric Power Company.

At first, they introduced us to their Automatic Meter Reading system (AMR), its purpose, current state and underlying work of its components (smart meters, concentrator, and control center). Also, a general overview of their Supervisory Control and Data Acquisition (SCADA) system's architecture and functionalities was introduced (Figure 1.1). Finally, they provided us with an access to AMR data, especially consumer's consumption data, which was essential to build our mobile application.

Figure 1.1 Operator window of SCADA system (human-machine interfaces)

1.5 Thesis Outline

The rest of the thesis is structured as follows:

Chapter 2 - Background and Literature Review gives an overview of relevant theory from the respective research fields. In addition, presents various behavioral change models and interventions used for concluding the mobile application requirements.

Chapter 3 - Methodology discusses the different methodologies used in the thesis work, with a detailed description of specific execution followed during the mobile application evaluation.

Chapter 4 - Requirements suggest a set of functional and non-functional requirements for the design of mobile application.

Chapter 5 - Architecture and Design describes the architecture and design of the proposed system; various UML diagrams are presented.

Chapter 6 - Implementation discusses some of the important aspects regarding the implementation of the mobile application.

Chapter 7 - Evaluation Results presents and discusses the results from the usability evaluation that has been conducted to our proposed mobile application.

Chapter 8 - Discussion and Conclusion discusses the main findings and achievements in the thesis work.

Chapter 9 - Further Work proposes directions for future work.

CHAPTER TWO

Background and Literature Review

Literature review is necessary to understand the field to which we aim to contribute to it, to get an overview of the work previously conducted, and how it has been done. This chapter starts by reviewing theories and studies related to the research field such as Smart Grid and Advanced Metering Infrastructure (AMI). It continues by presenting some models that can create behavior change, in addition to a set of intervention studies[5]. The last few sections include a review of newer research field called mobile cloud computing.

2.1 Today's Power Grid

Historically, electricity grid has been a unidirectional broadcast grid, there is a few centralized environmentally and unfriendly power generators (i.e. Nuclear Plant, Coal and Oil Plants) that provide electricity production in a country or a region, and then broadcast this in one way through transmission and distribution network until received by consumers. Remote terminals (i.e. loads) are almost or totally passive [10] [11].

In Traditional power grid, supply usually follows demand. Based on Load forecasting models developed over time, the utility providers generally over-provision for the demand (considering peak load conditions), if the demand increases above the average, utility may turn on peaker plants, which uses non-renewable sources of energy (e.g. coal fired plants or gas turbine) to generate additional supply of energy to cope with increased demand. The peak load approach is wasteful when the average demand is much lower than peak (low utilization), because electricity, once produced has to be consumed as grid storage is very expensive. Secondly, setting up and maintaining Peaker plants is not only environmentally unfriendly but also very expensive (high cost to the electricity companies) [10].

[5] Experiments aimed to encourage households to reduce energy consumption, conducted by providing people with different strategies, started long before the smart meters were introduced.

Also, given the ever-changing and increasing demand for energy, perhaps impossible in longer run, to match the supply to this peak demand, leading to a poor power quality including blackouts, power cuts, and brownouts. Thus, there is a need for an approach where we can match demand with the available supply.

While this legacy system has served well our community for the last century, less efficient aging infrastructure, environmental and social challenges, direction towards environmentally generating sources, need for reliable, efficient, transparent, greener power grid has led for a call to smarter power grid deployment.

2.2 Smart Grid (SG)

The need for a clean, safe, secure, reliable, resilient, efficient, scalable, economic, manageable, flexible, environmentally friendly and sustainable infrastructure bring forward the necessity for a modernized and intelligent grid for tomorrow, widely known as Smart Grid [12] [13] [14].

Smart grid also called smart electrical/power grid, is an enhancement of the 20th century power grid, defined by [14] as "a two-way flow of electricity and information to create a widely distributed automated energy delivery network". An evolution toward an electricity grid model able to manage numerous generation and storage devices in an efficient and decentralized manner determine the core of the Smart Grid concept [15].

A smart grid is a system that uses information, communication, computational intelligence in an integrated fashion across electricity generation, transmission, substations, distributions and consumption for effective power management [14], and pointing the way to a more environmentally friendly energy generation via incorporation of renewable energy sources into the grid, both at utilities and consumer sides. Such an infrastructure will stimulate utilities and end user to act together to establish environmentally sustainable system [16], Table 2.1 compares between the regular power grid and the Smart Grid.

Regular Grid	Smart Grid
Electromechanical	Digital
One-way communication	Two-way communication
Centralized generation	Distributed generation
Few sensors	Sensors throughout
Manual monitoring	Self-monitoring
Manual restoration	Self-healing
Failures and blackouts	Adaptive and islanding
Limited control	Pervasive control
Few customer choices	Many customer choices

Table 2.1 Brief comparison between regular grid and smart grid [14]

This transition of the electric power system is stimulated by national and international policy goals, such as The European union 20-20-20 target. The 20-20-20 goals aspire a reduction in EU greenhouse gas (GHG) emissions until 2020 of at least 20% below 1990 levels. Furthermore, 20% of EU's energy consumption is expected to come from Renewable Energy Sources (RES) in 2020. In addition, a 20% reduction in primary energy use has to be achieved by improving energy efficiency with respect to 1990 levels.

According to the report from NIST [17], the anticipated benefits and requirements of the Smart Grid are the following: Improving power reliability and quality; Optimizing facility utilization and averting construction of back-up (peak load) power plants; Enhancing capacity and efficiency of existing electric power networks; Improving resilience to disruption; Enabling predictive maintenance and self-healing responses to system disturbances; Facilitating expanded deployment of renewable energy sources; Accommodating distributed power sources; Automating maintenance and operation; Reducing greenhouse gas emissions by enabling electric vehicles and new power sources; Reducing oil consumption by reducing the need for inefficient generation during peak usage periods; Presenting opportunities to improve grid security; Enabling transition to plug-in electric vehicles and new energy storage options; Increasing consumer choice; Enabling new products, services, and markets.

Smart grid comprises of four main layers [11]:

1) Energy infrastructure: represents the physical infrastructure for energy generation, transmission, and distribution.
2) Communication infrastructure: represents the interconnection between all relevant components in smart grid.
3) Information Technology: provides modeling, analysis, web visualization, and commercial transaction.
4) Potential Application: responsible for distinguishing the use cases of infrastructure usage.

Figure 2.1 summarizes components in application, information, energy and communication layers.

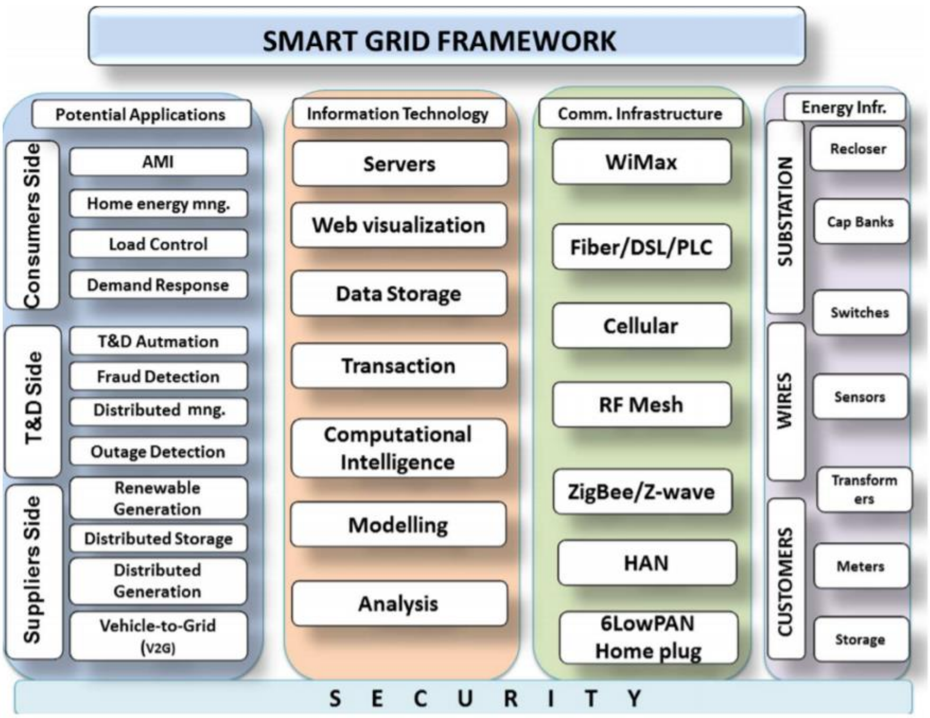


Figure 2.1 Smart Grid framework depicting the potential applications, information technology, communication, and energy infrastructure of the overall system [11]

In the following sections, we will discuss two Smart grids' applications related to our research work, Advanced Metering Infrastructure (AMI) and Demand Side Management (DSM).

2.2.1 AMI – Advanced Metering Infrastructure

It is regarded as a logical strategy to realize smart grid. Unlike Automatic Meter Reading (AMR) with one-way communication, AMI is a technology that enables two-way communication between customer side and utility head end, AMI technology automatically collects diagnostics, consumption, and status data from energy metering devices and sent it back to a central database for billing, troubleshooting and analyzing [14]. Obtaining this data from AMI will eliminate the need for field trips of personnel, on-site meter reading, incorrect manual reading, manual outage reporting and most restoration operations [18]. The two-way communication enables utilities to issue command or price signal to the meter or load controlling devices in real time [19]. AMI applications are summarized in Figure 2.2.

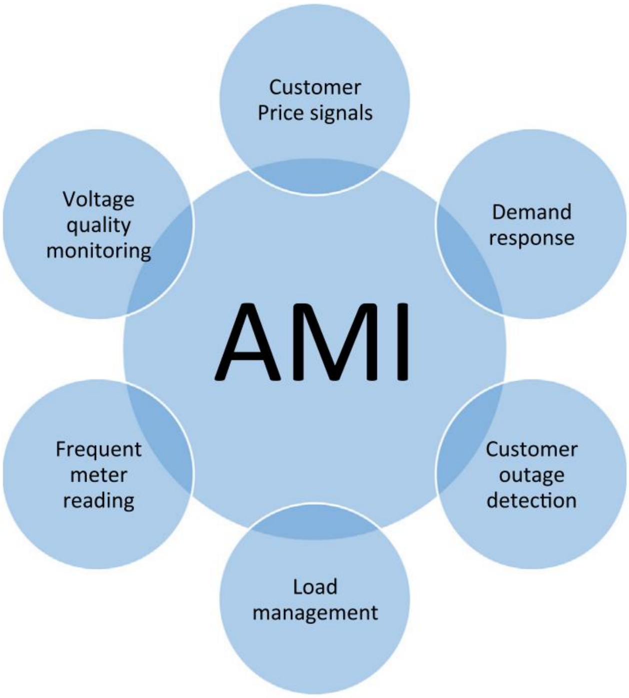


Figure 2.2 AMI Applications [18]

As shown in Figure 2.3, the overall AMI solution consists of several components [20]:

1) Smart meters.
2) Data gathering devices - Data Concentrator.
3) Communication networks.

4) Centralized information management and control systems – Control Center located at the utility end that receives, stores, and processes meters' data.

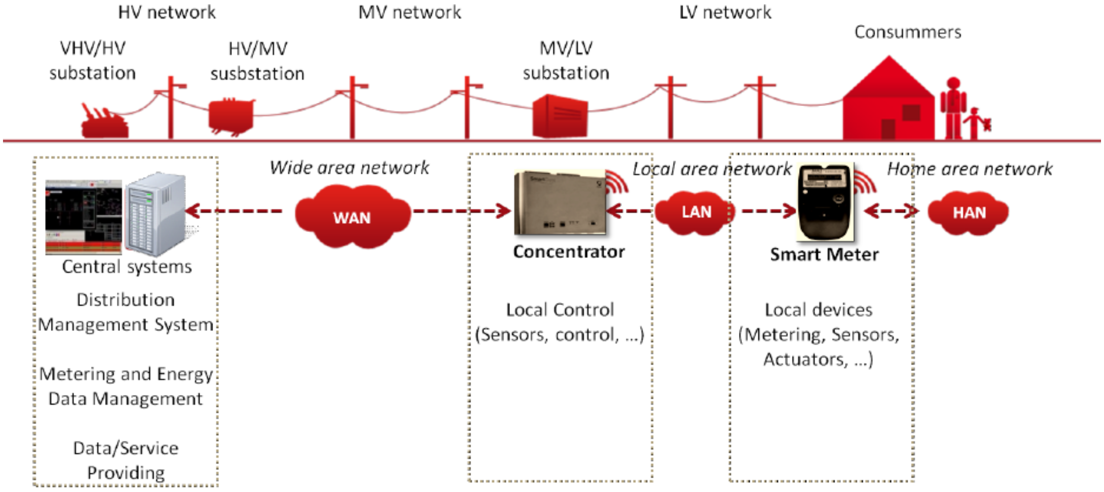


Figure 2.3 Sub-systems of AMI [21]

Such a heterogeneous infrastructure deployment contains different type of metering data measurements [22]:

1) On-demand meter reading: measured data flows from consumer side to control center upon request by utility.
2) Scheduled meter interval reading: measured data flows from customer side to control center at a pre-programed scheduled interval.
3) Bulk transfer of meter reading: measured data of all meters flowing from control center to utility.

Adopting AMI technologies bring about numerus advantages to utilities, customer, and society as a whole, including reliability improvement in electricity service, reduce peak loads, decrease overall plant and capital cost investments, enhanced operational efficiency of utilities, improve customers responsiveness, empowerment of customers to actively participate in management of power supply and demand, enhancing demand-side management, and encouraging greater efficiency decisions by customers and utility providers [23].

2.2.1.1 Smart Meter

A smart meter, which is an important component in this research, is an advanced digital electrical meter that records electrical consumption in much more details than a conventional meter does, and sends it back to the utility for monitoring and billing purposes [24].

The main functionalities of a smart meter [19] [25]:

1) Collecting consumption data: recording consumption data at a high frequency resolution, an interval of 1-hour, 15-minute and even near-real-time are possible. The recorded data is sent back to utility at least on a daily basis. (e.g., 4–6 times per residential meter per day or 12–24 times per commercial/industrial meter per day [[22]]).
2) Support advanced tariff systems and selection of rate options - **T**ime**_O**f**_U**se, **R**eal **T**ime **P**ricing**, C**ritical **T**ime **P**ricing, **V**ariable **P**eak **P**ricing.
3) Remotely connect / disconnect power supply by utility.
4) Load limiting for demand response purposes.
5) Meter tempering and energy theft detection.
6) Power Quality monitoring including: phase, voltage and current, active and reactive power, power factor.
7) Support decentralized micro-generator, i.e., photovoltaic solar system, micro-cogeneration unit, etc.
8) Provide consumed, generated, and reactive metering data from installed onsite distributed generation sources.
9) Ability to Communicate with home management energy systems through communication ports, i.e., (UART), RS-485, Wi-Fi and ZigBee [26].
10) Outage notification that alert utilities when customer lose power and restoration notifications.
11) Provide secure data communication.

Anticipated benefits of purchasing and deploying smart meters are improved billing accuracy, increased energy efficiency, increased customer engagement, and reduced labor costs associated with automated reading [27].

The smart meter alone is not a device that end-user interacts with and therefore does not stimulate energy behavioral changes without intermediary devices. Thus, an intermediary technology (product or service) that displays energy feedback information would be required [16]. The current direction today is toward using in-home displays or dashboards that is solely used inside home.

Smart meter market is on the rise worldwide. Figure 2.4 represents the evolution of smart meter deployment worldwide from 2013 till 2023. The largest market has been North America, Europe and eastern Asia. Other regions like Middle East countries, such as Libya and the United Arab Emirates, are also starting their way into Smart Metering deployment [28].

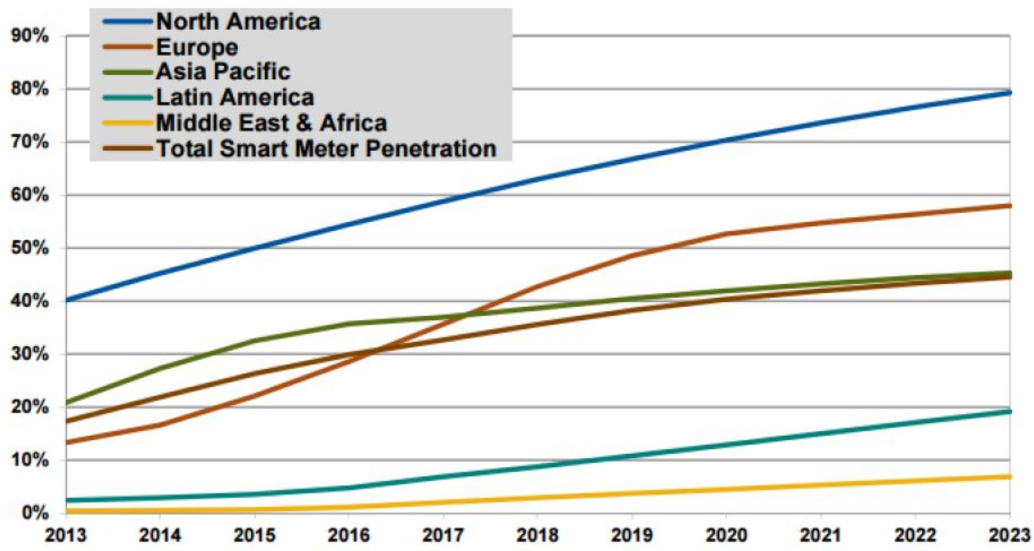


Figure 2.4 Evolution of SM deployment worldwide [28]

2.2.1.2 Data Concentrator

The role of the concentrator is mainly related to the ability to collect information from the Smart Meters in a neighborhood, installed at the consumer's home, and transfer them to the central systems. It is located usually inside power transformers and switch stations, and has a command and control role, it is often called Distribution Transformer Controller [21].

2.2.1.3 Communication Systems.

Communication technologies play a key role in the success of smart grid implementation. Transmission of data has to be guaranteed in terms of reliability, quality, time and security when considering the number of customers and installed smart meters that produce high volume and sensitive data [29]. Paper [22] provides a comprehensive study of different requirements, reviews, technologies and best practices for use by communication engineers when design a smart grid network for different applications, ranging from those used in Home Area Network (HAN), Neighborhood Area Network (NAN), and Wide Area Network (WAN).

2.2.1.4 Control Center

Large volume of information that is made available by the structure of smart grid is managed by the architecture of a centralized control system. It is a multi-modular system that contains lots of modules, such as Meter Data Management System, Consumer Information System (CIS), Outage Management System (OMS), Enterprise Resource Planning (ERP), Power Quality Management and Load Forecasting Systems, Mobile Workforce Management (MWM), Geographic Information System (GIS) and Transformer Load Management (TLM) [19].

Meter data management system is able to support the Information management of a commercial / rate-related nature, intended for billing the use of the grids, for each consumer or independent producer. It is also a role of the Information System to control the quality of data collected, through the implementation of analytical tools pertaining to validation, editing and estimating data, taking into account the infrastructure's technical management needs and the rules set forth for the electricity market [21].

Finally, the Information System should ensure automatic implementation of operations associated with the contractual life cycle of the consumption/production facilities, such as: rate changes; changes in contracted power; cut-off and restoring service due to contractual non-compliance, contract terminations/activations, or others. On the other hand, the Information System guarantees the management of technical information intended for monitoring, controlling and operating the distribution grid, via interaction with SCADA or other types of systems (powers produced and consumed, voltage levels, monitoring quality of service, etc.) as well as updating systems responsible for managing incidents and characterizing grid topology product [21].

2.2.2 Demand Side Management

Demand side management commonly refers to programs implemented by utility companies to manage the energy consumption at the customer side of the meter [23]. Such programs consist of conservation and energy efficiency programs, demand response programs, etc.

Efficiency behaviors are one-shot behaviors and involve infrequent capital improvements "energy-efficiency measures" that produce same or better level of energy service using less energy [30], such process does not require modifying operating practices and behavior maintenance, while curtailment involves using same equipment less frequently and must repeat curtailment behavior continuously to achieve savings and reach optimal effect [31].

Demand Response refers to “a change in electric energy usage by customers from their normal consumption pattern in response to a price augmentation or incentive payment designed to encourage lower consumption of electric energy at times of high wholescale market prices or when system reliability is Jeopardized” [32] [23] .

Price-based option and incentive-based option are examples of demand response programs [23] [11].

1) Rate-based or Price-based programs: The price of electricity may be different at preset times or may vary periodically based on consumption trends.
2) Incentive-based or event-based programs: In this option, utility reward customer for reducing their electric loads or for giving utility some level of control over the customer's electrical equipment. A set of demand reduction signals is sent to the participating customers in the form of voluntary demand reduction requests or mandatory commands.

Examples of programs involved in both categories are shown in Table 2.2.

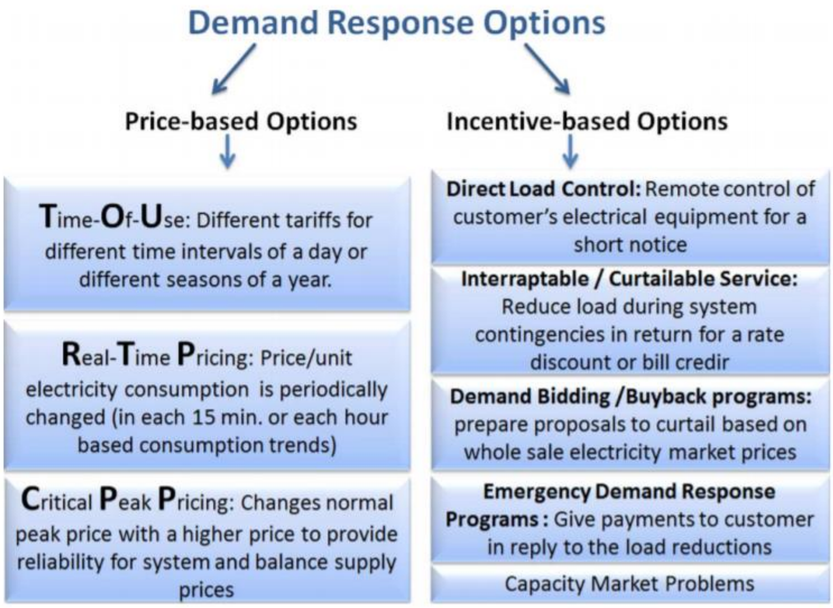


Table 2.2 Price-based and incentive-based programs [11]

2.3 Co-provision Role of Customer in Smart Grid

Past researches on stimulating changes on energy related behavior focused on home energy managements that are concerned merely with efficiency and curtailment [31]. However, as states in the discussion of smart grids, residential end users are expected to shift from their passive role as consumers of electricity to an active contributor role, referred to as co-provider. If end-users are to become co-providers, they will have to be empowered in relation to the four aspects [16]:

1) Efficient energy use: refers to the amount of effort expended by users in a household to reduce energy consumption.
2) Planning or shifting electricity consumption to moments that are favorable for the energy system. Shifting consumption of electricity away from peak demand times in the system.
3) Producing electricity when it is favorable for the local grid.
4) Trading self-produced electricity that is surplus to house- hold needs.

In a smart grid in which end-users are expected to play a more active role in the management of the electric power system, products and services would have to support end-users in their role as co-providers. Micro-generators, energy storage systems, smart appliances, smart/digital meter, dynamic pricing, energy monitoring and control systems, home automation for smart energy use, are categories of smart grid products and services that vary widely in form and function, but generally share common potentials that shape the four aspects of co-provision (consuming, planning, producing, trading) [16].

In this aspect, majority of mentioned products and services needs an intermediary technology for interaction, visualization and to complement usability, in addition, they do not stimulate behavior changes without home energy management systems. Connecting an intermediary device with previous products and services will stimulate awareness of electricity consumption and production, and as result, will stimulate savings duo to increased insight.

Since end users are central players in smart grid systems, our main concentration in our thesis will lay in energy monitoring and control system design that focus on end users as a central consideration, empower them as co-providers and play a role in reinforcement and habit formation.

2.4 Behavioral Change Models

Technology alone is generally not sufficient to induce conservation. In fact, in some cases feedback devices and energy efficient appliances can lead to boomerang effects and take-back effects, where a building occupant adopts inefficient consumption behavior that could reduce or nullify the efficiency gains associated with a retrofit [33]. In addition, although highly accessible information would fair best in raising awareness and knowledge levels. However, awareness alone doesn't not always translate into behavioral changes.

In order for our mobile application to play a critical role in changing people's belief and behavioral towards sustainability, human behavior and behavioral change models are necessary to understand the theoretical underpinnings of energy use behavior, and advance our knowledge of how to deal with customers in smart grid. As a result, technology and behavior science have to complement each other to maximize potential impact of smart grid technologies.

Such models tend to vary widely by theory, concept and application. To contribute to a more theoretically guided understanding of how and why people engage in environmentally reasonable behavior, three models were relevant to our research, Heuristic model of environmentally relevant behavior by Matthies [34], an integrated model of various theories and finding in environmental psychology explaining environmentally relevant behavior and provide a basis for behavior change. Geller's model [35], which shows the process of environmental behavior change. And Fogg's model [36], which focus on behavior change factors for persuasive technology design. Finally, we summarize a list of motivational interventions used for changing behavior within behavioral phycology.

These models and interventions will be used as a basis for writing our system's functional requirements in order to have a design that is effective in term of promoting sustainability and altering human behavior towards pro-environmental behavior. Chapter four (4.1) lists a set of system's functional requirements concluded from this chapter.

2.4.1 Heuristic model of environmentally relevant behavior

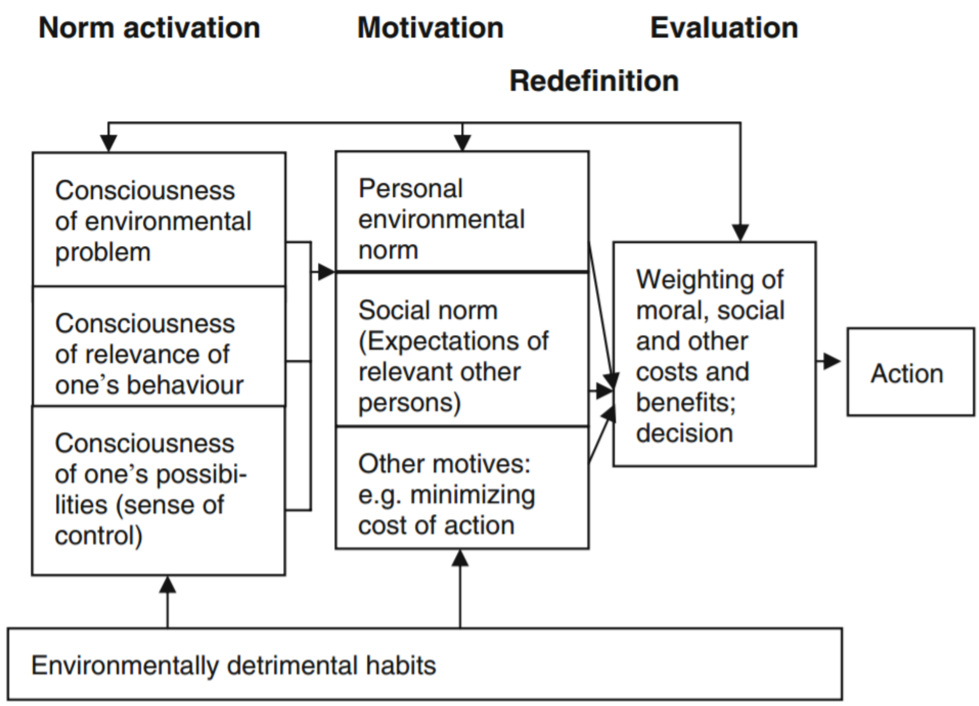


Figure 2.5 Heuristic model of environmentally relevant behavior (Matthies, 2005). Translated by Fisher (2008) [5]

The model [5] [34] divides behaviors into two types: habitual or routinized behavior and conscious decisions. Habits are behaviors performed in the same way on a regular basis without conscious decision. Second, conscious decisions, are active decision-making process, where different individual's values are evaluated before confirming the behavior. In the field of environmentally relevant behavior, most habits are environmentally detrimental, thus, they need to be broken up to react more in a sustainable behavior, this process is called norm activation, which consists of three building blocks. First, the person must realize that there is a problem. Second, a person must realize that his or her behavior is relevant to the current problem. Third, a person must recognize that he / she has possibilities to influence his or her behavior and its outcomes, this is usually labelled as "sense of control".

In the next stage, different motives rise up, and according to the model, it distinguishes three motivations, namely, personal norms, social norms, and "other motives". Personal environmental norms are personal ideas about how one should act in a particular situation. Social norms are ideas about which norms relevant others might hold, since person values social relationships and orient their behavior along to be socially accepted and desired. Other motives, such as a desire of comfort, relaxation, convenience, monitory savings, etc. Furthermore, norms may conflict with each other or with other motives.

Evaluation process is the final stage, a person proceeds to a process of evaluating different motives in how to act, where moral, environment, personal, or social costs and benefits are weighted and as a result, more or less environmentally friendly actions emerge.

2.4.2 Geller's Model

There are many models that focus on behavioral change. The one we are interested in is Geller's model since it focuses on environmental behavioral change and clearly explain the stages of change and types of interventions, as shown in Figure 2.6.

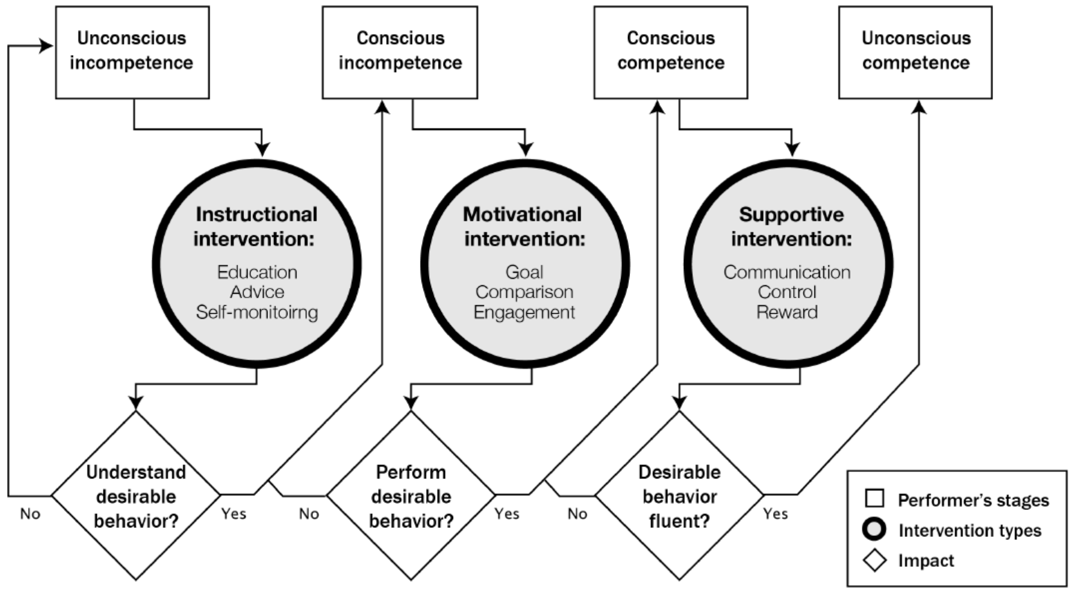


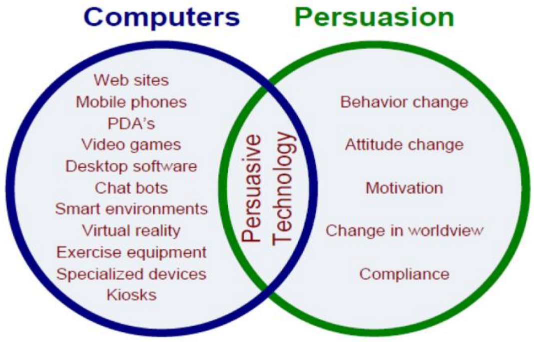
Figure 2.6 Behavior change model for sustainability, adapted from Geller. Simplified by Yun [37]

Geller's model [35] demonstrates four performer stages (unconscious incompetence, conscious incompetence, conscious competence and unconscious competence) and three types of intervention (Instructional, motivational and supportive).

First, unconscious incompetence is the stage where people do not behave in a sustainable way because environment is not a relevant issue for them or because they do not know how to behave sustainably. With the support of informational intervention, people learn what they can do and why this is important. If they understand it, they move to the next performer stage, conscious incompetence. Sometimes, people may not perform the behavior immediately because they need motivation. With the help of motivational intervention, people can adopt environment friendly behaviors more easily and move to the next stage, conscious competence. In conscious competence stage, the person has gained environmental knowledge and performed the required behavior, however, the goal of behavioral change is to make this a habitual behavior, this is achieved using a supportive intervention, where it helps people to repeatedly perform the behavior until they move to the goal stage, unconscious competence. In unconscious competence stage, the pro-environmental behavior has become a routine, thus, assisting in a habit formulation process [35].

Yun [37] has adopted Geller's model to explain nine intervention techniques based on a review of studies in different fields in Persuasive technology, HCI, Uicomp, environmental psychology, energy efficiency, and green buildings, and link them to the three primary interventions. Each concept will be explained in section 2.4.4.

2.4.3 Persuasive Technology – Fogg's Model



Persuasion as defined by Fogg is "an attempt to shape, reinforce, or change behaviors, feelings, or thoughts about an issue, object, or action" [38]. Persuasive technology is an interactive computer technology designed to alter people's attitude or behavior or both without using coercion or deception [39], or a design experience that will influence people's behavior via technology channels [36]. Fogg created a behavior model for persuasive design [36], where he states that three factors must present at the same instance for a target behavior to occur:

1) **Trigger:** the person is being sufficiently triggered or they are being triggered at the right time to perform the behavior.
2) **Ability:** they have the ability to perform the behavior when triggered.
3) **Motivation:** they should be motivated to start a behavior or continue the behavior.

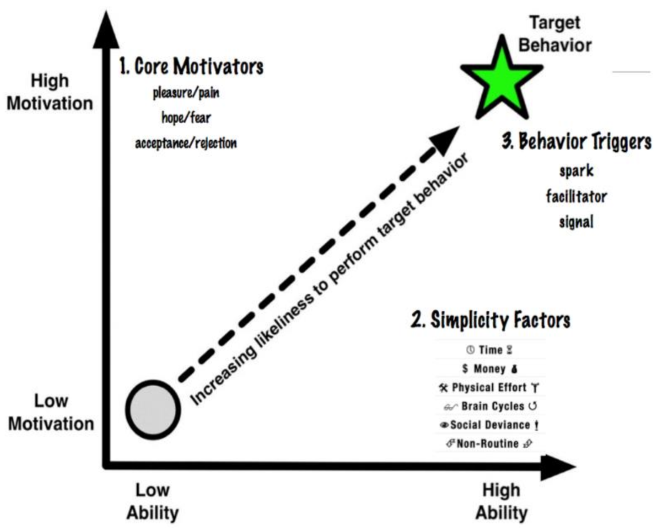


Figure 2.7 Factors of Fogg's Behavior Model: motivation, ability, and triggers [36]

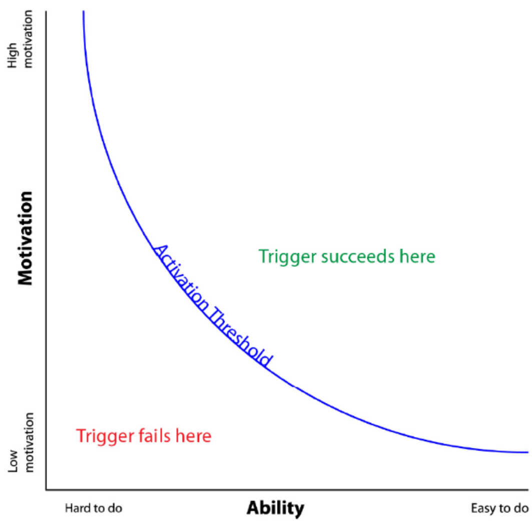


Figure 2.8 Activation Threshold – Fogg's Behavior Model [36]

As shown in Figure 2.7, increasing motivation is not always the solution, however increasing ability (making the behavior simple), motivation, as well as a well-timed trigger is the path for increasing behavior performance.

Figure 2.8 includes the concept of a behavior activation threshold, a well time trigger is a trigger that happens when the combination of motivation and ability places a person above the behavior activation threshold and they are able to perform the behavior. Otherwise triggers will be annoying, distracting and frustrating.

In general, persuasive design focuses on increasing motivation, increasing ability (simplicity), and triggering behavior. Figure 2.7 illustrates elements of each of these factors to facilitate design process.

The motivation subcomponents are:

1) **Pleasure / Pain:** the result is immediate.
2) **Hope / Fear:** anticipation of good results / bad results.
3) **Social Acceptance / Rejection:** motivation to be socially accepted ultimately influence and inspire people.

The ability subcomponents (elements of simplicity) include:

Increasing ability relies on the power of simplicity, i.e., making behavior easier to achieve. Simplicity is defined by Fogg as "a function of person's scarcest resource at the moment a behavior is triggered. Fogg's behavior model divides simplicity into the following six components that vary by individuals and context.

1) **Time:** if target behavior needs time and individual's available time is little, the target behavior is difficult.
2) **Money:** Individuals without financial resources to complete the task do find the target behavior difficult to achieve.
3) **Physical Effort:** target behavior that requires a great deal of physical effort may not be considered difficult to achieve.
4) **Brain Cycles:** thinking deeply before performing a target behavior does not enhance simplicity.

5) **Social Deviance:** Target behavior that require from people to break society rules are not considered simple.
6) **Non-Routine:** simplicity lies in routine behaviors or activities that are done on a regular basis.

The triggers subcomponents are:

1) **Spark as trigger:** Sparks are triggers designed with motivational aspects to encourage people who lack motivation to perform a target behavior.
2) **Facilitator as trigger:** designed for users with high motivation but lack ability with the aim to trigger a behavior while making behavior easier to achieve.
3) **Signal as trigger:** reminders for people with high motivation and ability to perform the target behavior.

Oinas Kukkonen [40] provided a systematic design methods and methodologies to develop persuasive systems solutions. He highlighted twenty-eight persuasive techniques and guidelines that can affect people behavior, summarized in Table 2.3 .These techniques are categorized in four categories: primary task support, dialogue support, system credibility support, and social support. We will present few of them here that are relevant to our study:

Primary task	Dialogue support	System credibility	Social support
Reduction	Praise	Trustworthiness	Social learning
Tunneling	Rewards	Expertise	Social comparison
Tailoring	Reminders	Surface credibility	Normative influence
Personalization	Suggestion	Real-world feel	Social facilitation
Self-monitoring	Similarity	Authority	Cooperation
Simulation	Liking	Third-party endorsements	Competition
Rehearsal	Social role	Verifiability	Recognition

Table 2.3 Techniques for persuasive system design [40].

1. **Reduction:** a system that reduces complex behavior into simple tasks helps users perform the target behavior.
2. **Tunneling:** using the system to guide users through a process or experience provides opportunities to persuade along the way.
3. **Tailoring:** information provided by the system will be more persuasive if it is tailored to the potential needs, interests, personality, usage context, or other factors relevant to a user group.
4. **Personalization:** a system that offers personalized content or services has a greater capability for persuasion.
5. **Self-monitoring:** a system that helps track one's own performance or status supports in achieving goals.
6. **Rewards:** systems that reward target may have great persuasive effect.
7. **Reminders:** the users will more likely achieve their goals if a system reminds users of their target behavior.
8. **Liking:** a system is likely to be more persuasive if it is visually attractive for its users.
9. **Trustworthiness:** a system that is viewed as trustworthy (truthful, fair, and unbiased) will have increased powers of persuasion.
10. **Social comparison:** if system users can compare their performance with the performance of others, they will have a greater motivation to perform the target behavior.
11. **Normative influence:** a system can leverage normative influence or peer pressure to increase the likelihood that a person will adopt a target behavior.
12. **Competition:** by leveraging human beings' natural drive to compete, a system can motivate users to adopt a target attitude or behavior.

2.4.4 Motivational Strategies for Pro-Environmental Behavior

While models tend to provide us with a philosophical approach, they do not specify specific strategies for changing behavior. In this aspect, we take the advantage of established body of empirical research within behavioral science and summarize a list of motivational interventions techniques to motivate pro-environmental behavior with empirical evidence of their effectiveness:

Education: demonstrating the desired activity and guiding the users through a process, works better than simply describing the behavior, and can have a greater persuasive power [41].

Advice: a group who receive advices on how to reduce their energy consumption showed a difference from a group without advices [5].

Feedback: allow consumers to observe their consumption pattern, and explore where they can save energy. Feedback comprises of several characteristics that determine its effectiveness: frequency, duration, content, breakdown, medium and way of presentation, etc. Quick feedback improves the link between action and effect, and increases consciousness about action's consequences. Different contents frame the problem in different terms (e.g., content may be given in KWh, cost or environmental impacts CO_2), thus, increase comprehension and stimulate different motives, personal and social norms, e.g., desire for cost savings or for minimizing environmental impact. Providing a breakdown, e.g., for a specific appliance, rooms, etc. is the only way of providing a direct link between individual action and a result, thus, allowing consumer to see how and where they can improve their energy conservation. Way information is presented is crucial for its adoption, information needs to capture attention and to be understood to be effective [5]. Researches have shown that average reduction of household energy consumption is between 5% - 20% when providing customers different feedback [6] [7] [5] [8].

Goals: motivating people by challenging them to achieve a goal - reference point. A goal can be set by utilities or by consumers themselves. Studies have shown a 12.3% - 15.1% energy saving difference than the group without goal-setting intervention. However, for maximum effectiveness to be utilized, households need feedback on how they are performing in relation to the goal [37] [42].

Comparison: there are two types of comparison [6] [37] [43]:

- Historic or self-comparison: showing current consumption related to the past. Thus, makes transparent "out of norm" consumption, captures attention for a potential problem and actively stimulate a search for a reason and redress.
- Normative comparison: showing consumption related data with others performance (e.g., neighbors, friends) or with a national or regional average consumption can

stimulate specific motives to change behavior towards pro-environmental behavior, for example, sense of competition, ambition, social comparison, or social pressure may be evoked. However, to use this strategy effectively for residential, comparison targets should be similar, e.g., size / type of house, number of habitants and relevant others are used as a reference group.

Engagement: visual attractiveness is a powerful factor for persuasion. Persuasive technology and HCI consider engagement as an important motivation factor that motivates people in pro-environmental behavior [37] [40].

Communication: it is argued that social networks can increase continuous participation in a social movement and beneficial to motivate people in a long-term sustainability. Systems that play a social role will have persuasive effect for increasing sustainability [37].

Control: providing users with an easy and a simple way to control their energy consumption will have a huge potential for motivating sustainable behavior. Reducing complex behavior into simple tasks increase the cost/benefit ratio of the behavior and motivates users to perform it and to repeat it to get the benefit continually [37] [40].

Rewards: rewards may serve as an extrinsic motivator to conserve energy. Providing a prize for the performance of the target behavior provides a supportive intervention that motivates performers to repeat the behavioral again. However, the effect of rewards is rather short-lived, it may not maintain after discontinuation of the rewards [37] [43].

2.5 Energy display design guidelines

This section provides different options to consider when designing an energy display and the argued advantages of such displays.

Wood and Newborough [43] propsed six dimensions that should be considered when designing an energy-information display system, they consider display location, motivational factors, display units (such as kilo-watthours, dollars, or grams of CO_2), display methods (numerical and diagrammatic), time scale, and category of use.

Jon Froehlich [44] introduced ten design frameworks for feedback systems to which researchers and designers may manipulate and evaluate in their designs: frequency, measurement unit, data granularity, push/pull, presentation medium, location, visual design, recommendation action, comparison and social sharing.

Daphne Geelen has created a set of recommendations for the design of smart grid products and services listed below [45]:

• Give insights into the technical operation of a smart home energy system

• Create goal-driven interfaces with actionable feedback, instead of only consumption and production feedback

• Relate energy feedback information to the community or city level, to provide

insight and perspective

P. Wesley Schultz and Mica Estrada [45] made a study about the effectiveness of three feedback types provided through custom coded in- home display framed as either simple KW consumption, KW consumption with the corresponding cost, and KW consumption with a dynamically derived social normative frame, and found a significant effect on consumption reduction using normative frame at a short term and long term periods, in comparison with the other two, where the results did not differ significantly from the randomized control group.

2.6 Mobile Cloud Computing

Since our proposed system is implemented using mobile cloud computing architecture and uses MIaaS and MPaaS services, this section will provide an overview about this new research field. It will start by introducing cloud computing technology, followed by mobile cloud services and mobile cloud architecture.

2.6.1 Cloud Computing

According to the NIST definition [46]: Cloud Computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.

Virtually unlimited dynamic resources for computation, storage and service provision over the Internet in on demand fashion, flexibility in terms of resource provisioning, scales to meet unpredictable user demands, reduces capital cost to small businesses by providing technologies beyond their reach and payment is only based on how much resource is used are all example of cloud computing advantages, Figure 2.9 summarizes common and essential characteristics of cloud computing technology.

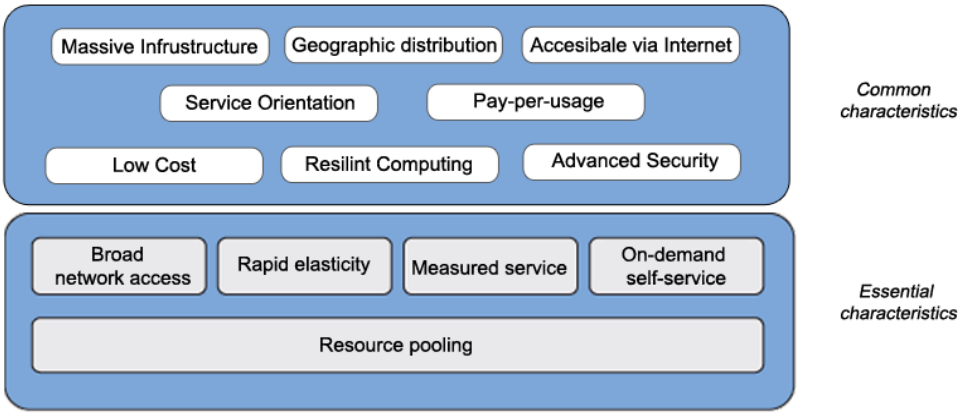


Figure 2.9 Attributes/ characteristics of Cloud Computing

2.6.2 Mobile Cloud Computing

With the increase of complex mobile applications, so do their demand on computing resources. Thus, major hardware and software levels are needed. Unfortunately, hardware level changes may not enable mobile devices to achieve true unlimited computational power duo to size constraints, and therefore, software level changes seem more feasible. One approach is to extend cloud computing services to mobile computing domain, referred as "MobiCloud Computing" or "Mobile Cloud Computing" (MCC) [47].

As defined in [47], Mobile Cloud Computing: "is an integration of cloud computing technology with mobile devices to make the mobile devices resource-full in term of computational power, storage, memory, energy, and context awareness".

In general, MCC overcomes mobile computing constraints in relation to the performance (e.g., limited battery life, storage), environment (heterogeneity, scalability) and security (e.g., reliability and privacy) [48].

Thus, by offloading computation and storage to the cloud, we have the potential to create more powerful mobile applications, enhance energy efficiency without trading off on performance, provide better user experience, reduce resource utilization, provide robustness, improves reliability since the data and application are stored and backed up on a number of computers. In addition, MCC inherits advantages of clouds mentioned earlier for mobile services such as scalability, dynamic provisioning, utility billing, mobility, flexibility, and accessibility [48], [49] .

2.6.3 Mobile Cloud Services

- Mobile Cloud Infrastructure as a Service (MIaaS): enables the provision of storage, hardware, servers, and networking components to on-demand client requests. What characterize IaaS is its ability to dynamically allocate the needed resources to meet the requited quality of service, referred as *elasticity*, and the client actually pay for what he uses.
- Mobile Platform as a Service (MPaaS): offers an advanced integrated environment for developing, testing, and deploying custom mobile applications. The consumer can only control over the deployed applications and possibly application hosting environment configurations.
- Mobile Software as a Service (MSaaS): In MSaaS, users can access an application and information remotely via the Internet through a thin client (e.g., web browser) at anywhere and anytime and pay only for that he uses.

2.6.4 MCC Architecture

Mobile devices connect to the cloud services through mobile network or through access points as shown in Figure 2.10. In the first option, mobile devices are connected to the mobile networks via base stations or satellite link that establish and control the connections between the network and mobile devices. Mobile users' requests and other information are transmitted to central processors that are connected to servers providing mobile network services, such as authentication authorization, and accounting based on multiple criteria (e.g., home agent and subscribers' data) stored in databases. Afterwards, subscribers' requests are transferred to the cloud through the Internet. Subscribers' requests are processed by cloud controllers to provide mobile users with the corresponding cloud services. In the access point case, mobile users connect to the access points through Wi-Fi that is further connected to Internet through Internet service providers [50].

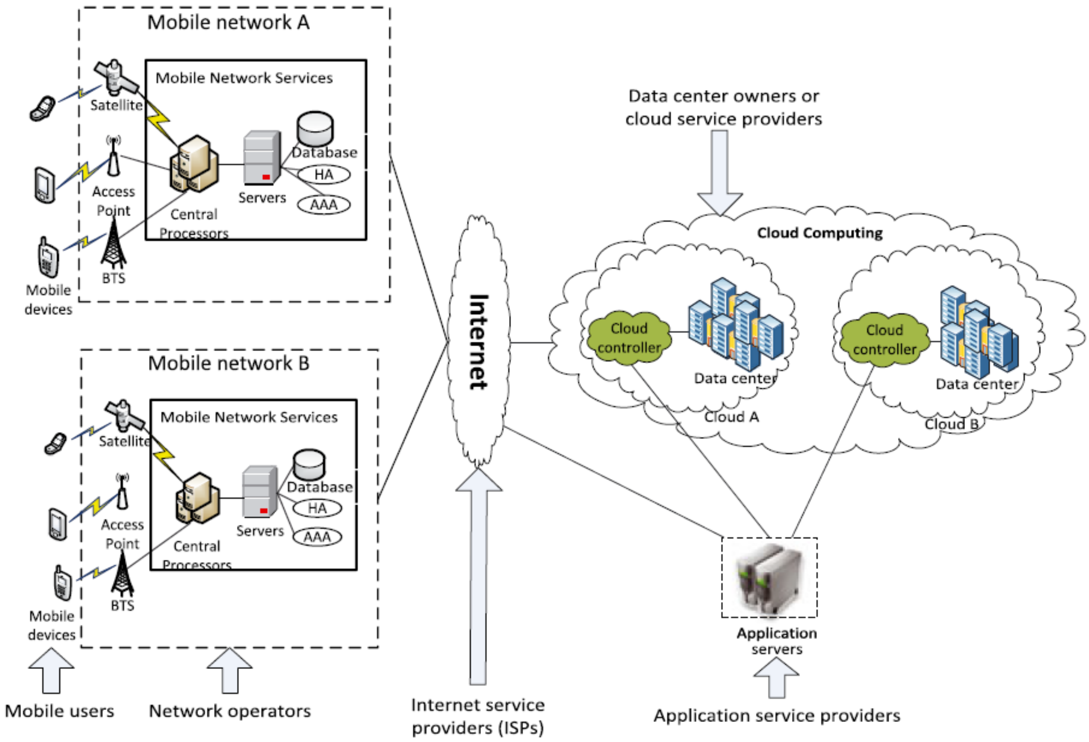


Figure 2.10 Mobile Cloud Computing Architecture [50]

CHAPTER THREE

Methodology Used

This chapter will elaborate on the methodologies used in the thesis work. It will start by describing the overall research method, design science research. Finally, it will describe the evaluation method used in this work; usability testing.

3.1 Design Science Research Method

Research in Information System discipline, especially human-machine systems, involves two complementary but distinct paradigms: behavioral science and design science. Behavioral science seeks to develop and verify theories to predict or explain phenomena "human behavior" with respect to the artifact's use. However, design science concerns with creating new and innovative artifacts intended to solve identified organizational problems "problem solving". An artifact is broadly defined as constructs (vocabulary and symbols), models (abstraction and representation), methods (algorithms), and instantiations (prototype). Figure 3.1 presents a conceptual framework differentiating between both paradigms [51].

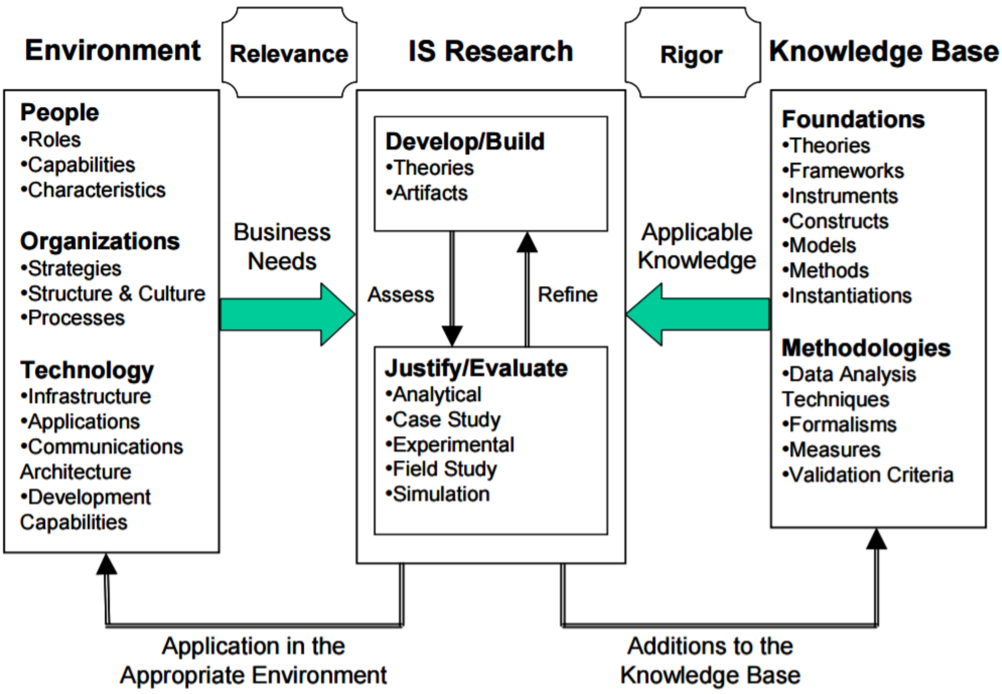


Figure 3.1 Conceptual framework of behavior and design science research methods [51]

The *environment* is composed of people, organizations, and technologies and defines the problem space and business needs. As discussed previously, behavior science addresses the research through the development and justification of *theories* related to the business need. While design science addresses the research through building and evaluation of *artifacts* designed to meet the business need. The development of theories and artifacts are done with application of existing knowledge base, which provides the raw materials from and through which IS research is done. Rigor is achieved by suitably applying existing foundations and methodologies. In both paradigms, research assessment via justify / evaluate activities can result in modification of theory or artifacts. Their contributions are assessed as they are applied to the real-world application environment from which the research problem or opportunity is drawn and as they enrich the content of Knowledge base for further research and practice [51].

In our Thesis, we have followed the Design Science Research Method, with the intended plan to extend our study by applying Behavioral Science for future work[6].

We have followed publication pattern for a DSR study [52] (explained in Table 3.1), and took into consideration the seven guidelines proposed by [51] for understanding, executing DSR study (explained in Table 32):

Section	**Contents**
Introduction	Problem definition, problem significance/motivation, introduction to key concepts, research questions/objectives, scope of study, overview of methods and findings, theoretical and practical significance, structure of remainder of paper.
Literature Review	Prior work that is relevant to the study, including theories, empirical research studies and findings/reports from practice.
Method	The research approach that was employed.
Artifact Description	A concise description of the artifact at the appropriate level of abstraction to make a new contribution to the knowledge base.
Evaluation	Evidence that the artifact is useful. Addressing criteria such as validity, utility, quality, and efficacy via well-executed evaluation methods.
Discussion	Interpretation of the results.
Conclusions	Concluding paragraphs that restate the important findings of the work.

Table 3.1 Publication Schema for a Design Science Research Study [52]

[6] Refer to Future Work section for more information.

Guideline	Description
Guideline 1: Design as an Artifact	Design-science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation.
Guideline 2: Problem Relevance	The objective of design-science research is to develop technology-based solutions to important and relevant business problems.
Guideline 3: Design Evaluation	The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods.
Guideline 4: Research Contributions	Effective design-science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies.
Guideline 5: Research Rigor	Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact.
Guideline 6: Design as a Search Process	The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment.
Guideline 7: Communication of Research	Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences.

Table 3.2 Design-Science Research Guidelines [51]

3.2 User Centered Design

This research aspired to use the user-centered design (UCD) approach from the Human-Computer Interaction field, in the design of the proposed mobile application, where the end users, in this case the electricity consumers, is the focus of the design process. UCD is defined as " a design philosophy and approach that places users at the center of design process from the stages of designing the system requirements to implementing and testing the product" [53]. Figure 3.2 illustrates the UCD design process.

ISO 9241 – 210 identifies six principles to follow in order to support UCD (quote) [54]:

1. The design is based upon an explicit understanding of users, tasks and environments.
2. Users are involved throughout design and development.
3. The design is driven and refined by user-centered evaluation (usability tests).

4. The process is iterative.
5. The design addresses the whole user experience.
6. The design team includes multidisciplinary skills and perspectives.

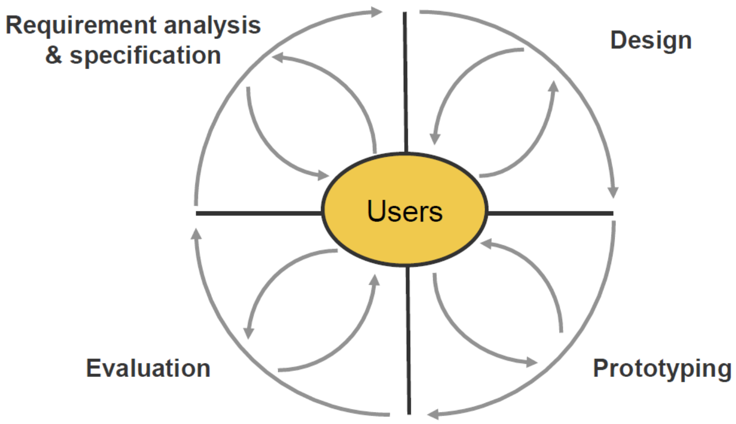


Figure 3.2 UCD design process

In our case, the user has been the central of our consideration, from the requirement analysis and specification, to the design, development and evaluation.

3.3 Mobile Usability

Today, mobile usability has become an important factor for the success or failure of any mobile application in the market. In fact, it is not enough that software performs a set of functionalities, there is no guarantee that the interaction with the software is intuitive or easy to use just because there is a way to complete functional tasks. Usually, if a mobile application is not intuitive or easy to use for consumers, they will ultimately struggle with it and gravitate to others applications that are easier to use.

Since our proposed solution will be realized in the form of mobile application, usability will take a major part in our evaluation. In this section, usability theory will be introduced, then the specific execution in this work will be described, and finally the results from this method are analyzed and interpreted in Chapter 7.

3.3.1 The Limitations of Mobile Applications

Firstly, there are several mobile limitations that may affect quality of mobile apps. These limitations can be grouped into three categories [55]:

Mobile device limitation:

- Limited life batteries.
- Limited storage capacity.
- Limited user interface.
- Heterogeneity.

Wireless network limitation:

- Frequent disconnection.
- Lower bandwidth.
- Variable bandwidth.
- Heterogeneity of networks.

Mobility:

- Physical mobility.
- Logical mobility.

In fact, some of these limitations have a significant impact on usability, such as [56] [57]:

1. Small screen size.
2. Low display resolution.
3. Context in which mobile is used.
4. Low memory.
5. Tiny input mechanism

Secondly, latest market research suggests that the lack of usability is the major factor affecting consumer decisions to reject mobile applications [58]. For instance, only 1% of all mobile applications have been downloaded more than one million times, and once downloaded, one in four mobile applications are never used again [59]. Thus, usability evaluation for mobile applications is essential to meet user needs in term of creating usable apps.

3.3.2 Software Usability Theory

The International Organization for Standardization (ISO) 9241-11 standard defines usability as “the extent to which a system, product or service can be used by specified users to achieve specified goals with **effectiveness**, **efficiency** and **satisfaction** in a specified context of use” [60] [61].

Jakob Nielson specified usability as "a measurement of quality that user is experiencing when interacting with a system", Nielson defined usability as comprising of five quality attributes, **Learnability**, **Efficiency, Memorability, Errors, Satisfaction** [62]**.**

From these definitions, we conclude that usability is not a single, one dimensional property.

3.3.3 Measuring Usability

In our usability evaluation, we used attributes from both definitions (ISO 9241-11 standard, Jacob Nielson) to measure the usability of our prototype in both qualitative and quantitative terms.

- **Effectiveness**: The accuracy, completeness and appropriateness[7] with which users achieve specified goals.
- **Efficiency**: The resources (time, human effort, cost and material resources) expended in relation to the accuracy and completeness with which users achieve goals.
- **Satisfaction**: freedom from discomfort and acceptability, or "the extent to which attitudes related to the use of a system, product or service and the emotional and physiological effects arising from use are positive or negative"[8].
- **Memorability**: How easily an occasional user to reestablish proficiency when he returns to use the system after a certain period of time**.**

[7] In the new draft, appropriateness has been added as an additional consideration when defining effectiveness [61] [103].

[8] Satisfaction definition proposed in the new draft [61] [103].

- **Learnability:** How easy is it for a novice user to achieve specific goals the first time they encounter the design.

ISO 9241-11 identifies three factors that have an impact on the overall design of any product and should be taken into account when evaluating usability:

- **User**: Person who interacts with the product;
- **Goal**: Intended outcome;
- **Context of use**: Users, tasks, device / equipment (hardware, software and materials), and the physical and social environments in which a product is used.

3.3.4 Usability Evaluation Methods and Techniques

According to [56] [63], there are various methods to evaluate the usability of any product, stated briefly here:

1) Heuristic evaluation or expert-based evaluation: a method where human experts evaluate the system to describe problems that may encounter inexperienced users when interacting with the system.
2) Observation: involves observing and collecting data relating to what real users do while interacting with the system using video tapping, Think-aloud protocol and direct observation.
3) Surveys: using questionnaire and interviews to identify user's views and feedback about a given product.
4) Experimental evaluation: a method conducted by experts and/or users to address usability issues using questionnaire, interviews and software logging.

These methods can be applied in two different ways: laboratory tests and field tests [64].

3.3.5 Usability Testing

The source for the text in this section is [65] if not mentioned otherwise.

Usability Testing is a methodology that is aimed to evaluate the ease with which users can learn to use a product or service. Through iterative evaluations with participants, one aims to create products that are easy to learn, easy to remember, easy to accomplish their goals, and are satisfying to use. Usability testing enables software engineers to ideally visualize their software from the eyes of the users, the ones who purchase, download, and use the software to complete their work.

However, until today, many people still get confused between focus group testing and usability testing. Focus group testing is around a small sample of people who assemble together and convey their feedback regarding proposed designs and ideas. Usually, the purpose of focus group testing is to gather quick data concerning feelings and options of a small sample of users. These details should be discovered early on, before the application has even begun development.

On the other hand, Usability testing is much more individualized and personal. The focus is around the software user and their personal unique experience with the software, this reveals an important information about how people use a product, and what problems they may encounter / prevent them from achieving their tasks, and lead to a negative user experience.

In the following sections, we will introduce three important stages in usability testing lifecycle, namely, obtaining participants, task procedure and performance objectives, and explain the specific execution followed in our evaluation.

3.3.5.1 Obtain Suitable Participants

Fundamental to effective usability testing is the candidate selection. Participants to a usability testing should be chosen from the correct application demographic. For example, Gaming application for kids would be ideally tested by young children.

However, Participants selection should fall in the middle of the qualification spectrum to ensure that the tests do not result in excessive false positive or false negatives. False positives indicate that the user is too experienced with similar products and do not encounter as many problems as a typical user because they are more familiar with the product. False negatives often come from inexperienced people who lack the basic qualifications to conduct the test, they do not have the basic fundamental understanding of the subject matter to successfully use the product and hence they are not the desired target user.

Also, a primary factor when selecting a participant is based on the type of device that they are using, different devices have different device controls, IPONE users would waste difficult amount of time navigating through the device controls, which introduce false negatives to the test.

Since our application accounts for a wide spectrum of users, following criteria are considered when selecting candidates for the usability testing:

1) Selecting as many participants to represent such a wide demographic and large community of users as possible, as people of all genders, educational levels, professions are expected to use it.
2) Candidates should have some knowledge and use of computers, the Internet and smartphones.
3) Ability to speak and understand English language.
4) Have no prior experience with similar applications.
5) Candidates own an Android smartphone.

The suitable number of participants to conduct a usability test is discussed by different researches, Nielsen in his article [66] mentioned that the best results would come from testing no more than five participants and running as many small tests as one can afford, he argued that a very few findings or usability issues would be observed after the fifth participants. Iterative usability testing with a few users would ensure optimum use of testing budget, because every iteration is another chance to refine and produce a highly usable product [67].

Nielson and Tom Landauer [66] has illustrated through Figure 3.3 the relation between usability problems found in a usability test with n users.

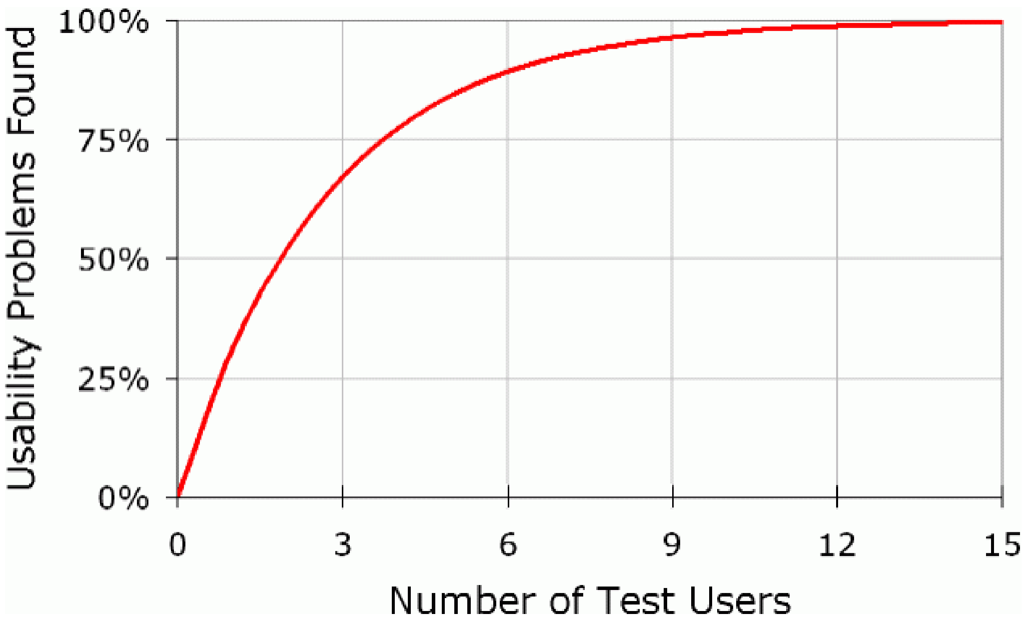


Figure 3.3 Relation between usability problems found with number of test users [66]

We decided to recruited seven representative participants through each iteration, until we reach to a place where our goals are fulfilled and discovered usability issues are minimized to an acceptable degree.

3.3.5.2 Test Procedure (Collecting and Interpreting Usability Results)

After observing users performing a set of tasks, performance metrics and qualitative data have to be collected and analyzed. Performance metrics which are measures of the usability attributes mentioned previously (effectiveness, efficiency, satisfaction, memorability and learnability) are quantitative in nature - measurable results, and includes the following:

1) Success rate - If a user completed a task successfully or not.
2) User encountered errors per-scenario basis.
3) Rating the severity of a problem (severe and less severe errors). Several approaches to assign severity ratings specified in [68]. (less severe errors include fulfilling a task in a less efficient way than expected, which is a burden to the user and yield time waste while using the product).
4) Percentage of the participants who come across a certain error, this usually indicates features related to a task that are the most problematic and need to be addressed.

5) The frequency in which no errors are found. This indicates that participants didn’t have any difficulty with completing tasks and hence the features are intuitive enough.
6) The time it takes for a user to complete a task. Tasks that are too long attribute to frustration with product in use, which yields a negative user experience.
7) Task-level Satisfaction: measures perceived usability of a task. E.g., Single Ease Question SEQ - measure perception satisfaction.
8) Test-Level Satisfaction: measures perceived usability of a test as a whole.
9) The time it takes for a user to achieve a task after a certain period of time after using it the first time. Task time reduction is a measure of memorability and indicates that the system is easy to remember.
10) Percentage of time the users follow an optimal navigation path.
11) Page Interface Counts.
12) Subjective measures.

Qualitative data includes:

1) Participant spoken or written feelings.
2) Problems encountered by the participants.
3) Comments/suggestions.
4) User preferences.
5) Answers to non – numerical questions.
6) Recorded difficulties faced by participants.
7) Facial and body expression during test.
8) Positive feedback which reflects aspects that worked well in a product.

Duo to the nature of their differences, qualitative methods are best used for answering question about Why and How to Fix a problem, while quantitative methods are better suited for answering how many and how much types of questions. Overall, having numbers help researchers to prioritize resources, such as focusing on issues with the biggest impact on user experience [69], Figure 3.4 demonstrates the difference between both methods.

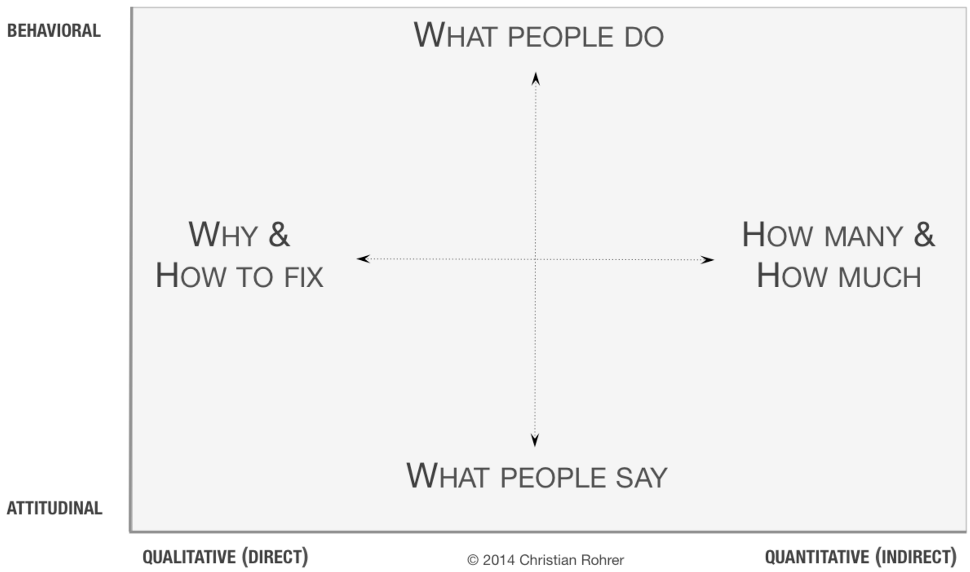


Figure 3.4 Questions answered by research methods across the landscape [69]

In our usability evaluation, we have used SEQ and SUS to measure the task-level and test-level satisfaction, explained more in the following paragraphs.

Single Ease Question – SEQ

The Single Ease Question is a 7-point rating scale that assess the user perception of how easy or difficult a task. Usually, SEQ is given immediately after a user finish with a task. It has been found that SEQ performed about as well or better than other complicated measures of task-difficulty like the interval scaled Subjective Mental Effort Questionnaire SMEQ, and ratio scaled Usability Magnitude Estimation [70]. It has been found that ratings with difficulty correlate (not strongly) with other performance metrics like task-time and task completion. Asking reason beneath user rating can provide direct diagnostic data of what feature that leads to frustration and negative user experience.

System Usability Scale - SUS

The System Usability Scale (SUS) Questionnaire provides a quick, low cost, valid and reliable way to measure the perceived usability for hardware, software, mobile devices and websites. SUS is typically administrated immediately after each session, allowing participants to record their initial feelings and responses. It consists of 10 questions with five response options, ranging from Strongly agree to Strongly disagree. Each form is calculated to give a usability index or a score between 0 – 100 [71].

SUS Score indication [72]:

- From 85 – 100: The system is best imaginable and provides high level of usability.
- 80.3 or higher: People love the system and will recommend it to their friends.
- 68 or higher: The system is acceptable but can improve.
- 51 or lower: The system has a series usability issues that need to be fixed.

The good thing about SUS is that it alternates the tone of each item, odd items are phrased positively, and even items are phrased negatively. The alternating tone intended to reduce acquiescence and extreme response biases caused by respondents not having to think about statements, the respondent now has to read each statement carefully and make an effort to think whether they agree or disagree with it. Nowadays, SUS has become an industry standard, used in over 1300 articles and publications [73].

3.3.5.3 Performance Objectives

Performance objectives are criterions for acceptable usability results. Researches can reveal usability issues by looking at the problematic tasks for which participants were most and least able to meet performance measures. Researches can use existing performance measures or create their own.

In our evaluation, we had the following performance objectives to stop our usability iterations:

PO #1 More than 80% completion rate per task.

PO #2 Less than 0.5 for the average error rate per task.

PO #3 More than 80% satisfaction per task.

PO #4 Less than 40% difference between novice and expert time-based efficiency per task.

The previous performance objects have been set based on the following facts [74]:

Fact #1 The average task completion rate is 78%.

Fact #2 The average number of errors per task is 0.7.

Fact #3 The average task difficulty using the Single Ease Question is 68%.

CHAPTER FOUR

System Requirements

In the implementation of the proposed mobile application, we will try to take both perspectives of customers and their counter stakeholders, such as the government, grid owners, electricity suppliers, third party service providers. Both have different motivations, requirements and benefits. The objective of residential customers is how to reduce their overall consumption, and hopefully as a consequence, to see a reduction in their billing cost, this may therefore contradict with the business goals. The business-oriented stakeholders may be more interested on load control, where they want to match demand with the available supply, instead of doing the opposite where supply is adapted to the demand, and as a consequence, reduces overall plant and capital cost requirements and also increases the system reliability.

Based on the behavioral change models and interventions discussed in section 2.4 , and taking different electricity stakeholders perspective (consumers and utilities), a set of system requirements are identified in the form of functional and non-functional requirement.

4.1 Functional Requirement

Functional requirements are activities or functionalities that a system must be able to perform. In this section, the basis for each functional requirement is from previous literature study, and different stakeholders (consumers and utilities) requirements.

FR1: The application should provide real time feedback to monitor current power consumption and immediate effect of actions.

FR2: The application should provide access to historical electric consumption with multiple options, i.e., hourly, daily, weekly, monthly, yearly.

FR3: The application should provide different measurement units / frames (i.e., kWh, KW, ILS, CO_2, etc.).

FR4: The application should provide self-comparison functionality, e.g., ability to compare past period with current consumption data.

FR5: The application should provide self-other-comparison functionality, e.g., compare with average consumption of comparable households, defined standard house consumption or neighbor house consumption.

FR6: The application should provide appliance-specific consumption monitoring.

FR7: The application should provide comparison of energy used by two or more appliances during a certain period.

FR8: The application should display electricity prices in an appropriate way (i.e., Time_Of_Use prices, Real Time Pricing, etc.).

FR9: The application should provide the ability to remotely monitor and control household devices (i.e., schedule time for later use).

FR10: The application should provide feedback about the most appropriate times to operate devices.

FR11: The application should provide goal driven interfaces. Consumer or utility can set a consumption goal for different time period (i.e., today, month, etc.).

FR12: The application should allow consumer to monitoring the progress of his goal, e.g., feedback on how they are performing in relation to the goal, average amount of energy KWh consumed / remained.

FR13: Real-time notifications including utility, event-driven and demand response messages, e.g., receiving notifications about potential savings and need for reduction by the utility.

FR14: The application should provide descriptive-plus-injunction messages. (sad/happy faces).

FR15: The application should provide positive and negative reinforcement.

FR16: Make public commitments using social media (ex, Facebook).

FR17: Providing tailored information relevant and applied to the household current situation.

FR18: The application should provide consumption usage distribution across different periods (off-peak, mid-peak, on-peak).

FR19: Information about the performance of the storage systems, such as the state of charge.

FR20: Information about community or neighborhood level such as shared facilities, wind turbine, or co-generator that provide electricity to the entire community.

FR21: Amount of energy used in different rooms or zone of the house for a certain period.

FR22: The application should provide general savings tips.

FR23: The application should provide virtual rewards when environmentally target behavior is achieved.

FR24: The application should provide personalized content for different audience.

FR25: The application should provide competition platform, where different consumers can compete each other.

4.2 Non- functional Requirements

Non-functional requirements specify the system quality attributes, characteristics and how the system should behave. Non-functional requirement is divided into three categories: product, organizational, and external requirements. Below, we present the most important classes of the non-functional requirements expected from the system:

NFR1: Usability: Since our application accounts for a wide spectrum of users (educational levels, professions, etc..), and will be used on a daily basis for a long period, it should be easy for them to install and use the application. SUS questionnaire is used to test this quality attribute. The SUS score should be more than 80.3, as this score indicates that the system is best imaginable and provides a high level of usability according to [72].

NFR2: Performance[9]**:** Since the app will monitor electricity and control home appliances in real time, a response time of one second or less should be the minimum time for the application to function properly, including internet connection speed, server response time, etc. This time is based on Nielson study, where he defined that 1 second is the time limit for the user's flow of thought to stay uninterrupted [75].

NFR3: Reliability[9]**:** since the app will have control features, no data should be lost during the traffic, especially control data.

NFR4: Security[9]**:** power consumption data gathered by the app reveals a wealth of information about individual customer's daily behavior, thus security and privacy are vital. In our case, a secure system able to authenticate user connections to the system is required. Also, communication with external systems, user's consumption data, logged data and other privacy sensitive information should be kept secure.

NFR5: Availability[9]**:** The application should be available 24 hours a day. User should be able to access the application and receive notification anytime anywhere as long as the smartphone is up and running with available network connection.

NFR6: Storage[9]**:** the maximum of android APK file size is 50MB, thus, the application should take up as little storage space as possible. However, this criterion is not a critical issue, since all the storage and functions capabilities of the mobile app will be offloaded to the cloud.

In this study, due to time constraints, we will evaluate only the Usability requirement, which is of great significance when it comes to building an appealing energy visualization tool that is used regularly for a long period by different ages, educational levels, etc., and before time and money are invested in extended future behavioral change evaluations.

[9] Not explored in this thesis

CHAPTER FIVE

System Architecture and Design

This chapter will describe the architecture, design of the mobile application that has been developed based on the requirements from the previous chapter. It will start by discussing the reasons beyond the choice of smartphone and android platform to work with, then, it will describe the Android architecture in general and the specific architecture of the proposed system. Finally, it will present various UML diagram representations of the overall system and MCSG Metering application.

5.1 Why Smartphone Over Other Presentation Medium

In this section, we will discuss about some facts that persuaded us to choose mobile computing over other mediums for realizing our proposed solution: [76] [77] [78]

1) Majority of people nowadays have smartphones.
   - according to Ericsson Mobility Report, there are over 2.6 billion smartphone users worldwide, this figure is expected to grow to 6.1 billion by 2020 [76] [77].
2) Smartphones is a powerful communication and persuasive tool that reach user anywhere anytime.
   - According to Google's report "Micro-moments": 87% always have their smartphone at their side, day, and night and on average, people check their phones 150 times per day and spend 177 minutes using them [76].
   - Smartphones enable on-the-go delivery of any content via push notifications that can grab user attention in anywhere and anytime.
   - In November 2015 Pew Research Center report goes into more detail with respect to weekly usage, citing 46% of respondents using one to five apps per week, whereas only 35% use six to 10 [79].
3) Mobile phones are becoming a primary tool for accessing services over laptop and PC
   - According to StatCounter Global Stats finds that mobile and tablet devices accounted for 51.3% of internet usage worldwide in October 2016 compared to 48.7% by desktop [78].

In addition to the previous facts, providing a mobile service that is able to meet the consumer's needs in a different context, anywhere and anytime will provide the best value to the user. Such a platform will enable energy consumers to priorities their energy saving efforts on a continuous basis.

Thus, smartphones and mobile applications are definitely a candidate for the application in this thesis.

5.2 Mobile Android

Since the main concentration is on the artifact itself (porotype), the choice of application platform has been pragmatic. The choice fell on Android for the following reason:

- According to a recent study International Data Corporation [80], Android has dominated the smartphone market with a share of 86.8% in 2016 in comparison with other platforms.
- Development tools are free.
- I had a previous experience with the platform and Android studio tool.

5.3 Android Architecture

Each android application consists of a primary building block called Activity. An Activity takes care of creating a window on the screen and handles the interaction with the user interface. Each Activity consists of two main files: A Java code file that handles the interaction with user interface and an XML layout file that defines the layout to be shown on the screen. In spite of multiple screens in our application, a single Activity is used, this is done with the help of Fragments, where a part of the user interface in an Activity is replaced each time. Fragments is used to better modularize the code, build more sophisticated user interfaces for larger screens, and help scale the application between small and large screens. A Fragment consists also of a Java file and XML layout definition. It can be added as a part of Activity layout or programmatically inside the activity java class. Though Activities and Fragments have their own life-cycles, Fragment Lifecyle is dependent on its Activity, as illustrated in Figure 5.2 and Figure 5.1.

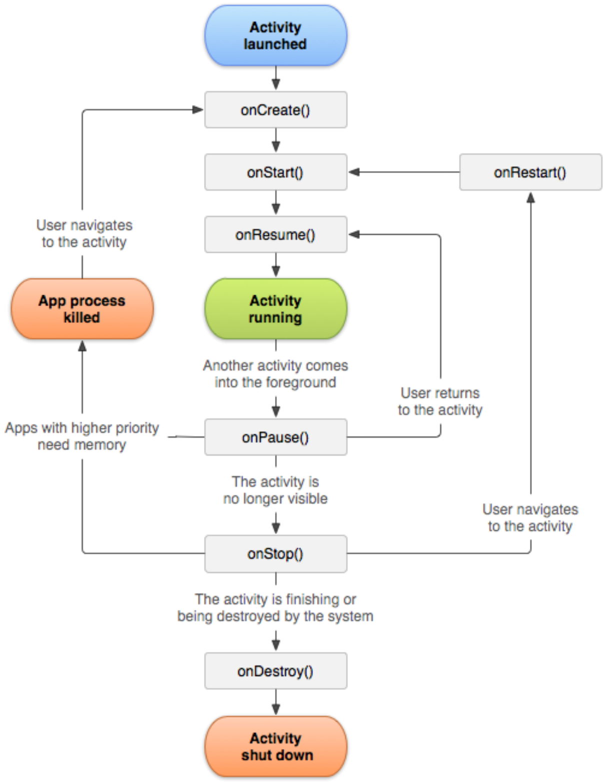


Figure 5.1 Android Activity life-cycle [108]

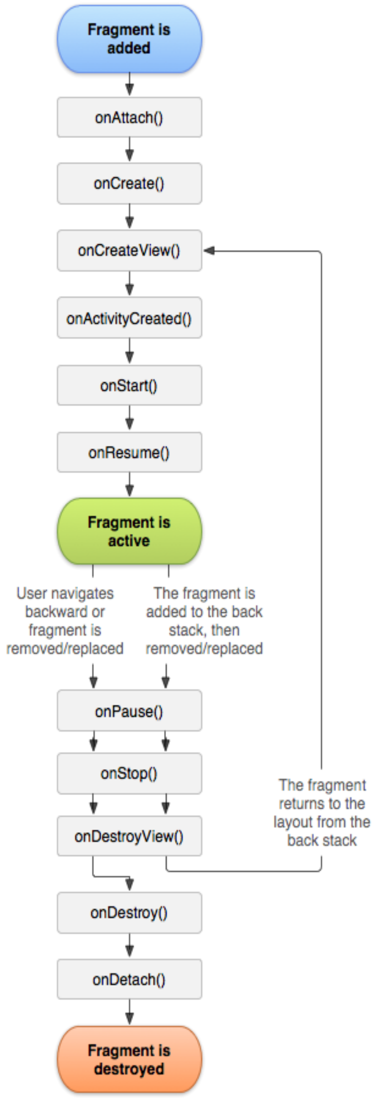


Figure 5.2 Android Fragment life-cycle [109]

Every Application consists of AndroidManifest file. It names the Java package for the application, describes the components of the applications (activities, services, broadcast receivers and content providers), declares the permissions to access parts of API and interact with other applications, states the libraries linked to the application and minimum level of Android API to work.

At the end, the Android build system compiles app resources and source code, and packages them into APKs where you can test, deploy, sign, and distribute.

5.4 General Architecture of the Overall System

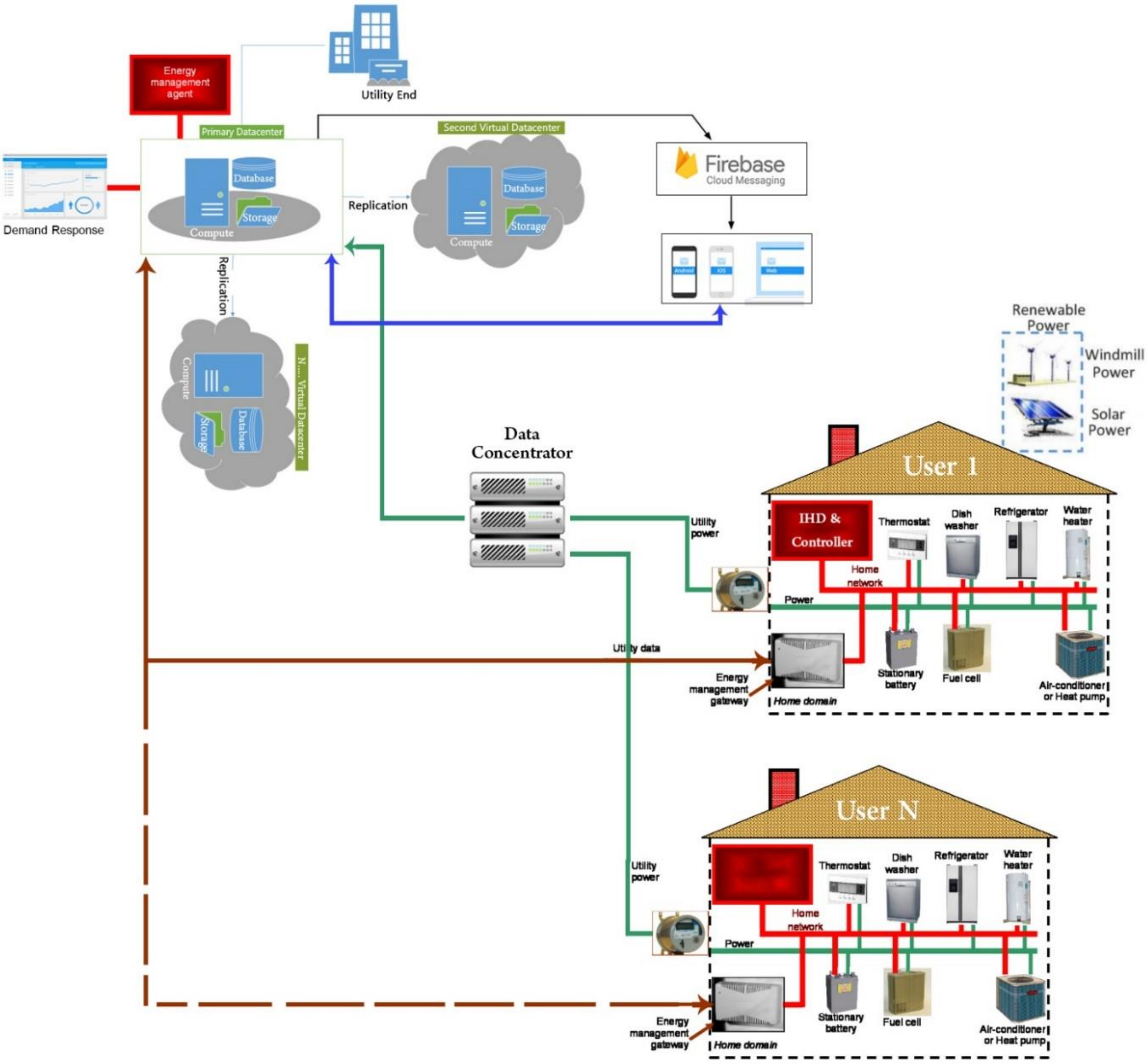


Figure 5.3 System General Architecture

Figure 5.3 shows the basic architecture of the proposed system. Each house contains a smart meter, mobile application, IHD, controllers, gateway and smart outlets (or smart appliances). Consumption data produced by each house in a neighborhood is collected through a concentrator via a local area network in a 15 minute or infrequently as daily, and then forwarded via wide area network to the cloud for storage, management and billing. Cloud architecture is used for the reasons mentioned in section 2.6.1. The major components of this architecture are illustrated below:

Utility End: Based on price-based-programs involved, utility sends price signals to energy management agent inside CC Server to decide appropriate times to operate devices.

Smart Meter: records consumption of electric energy in intervals of an hour or less and communicates that information back to the CC server for monitoring, billing and storage, as well as receiving a DR signal for pricing information from utility company in almost real time.

Cloud Server: represents central nervous system for our architecture, it is a cloud computing server which handles variety of functions, from authentication, sending consumption data for monitoring, comparison and competition, pushing demand response requests, sending general or tailored tips and handling home energy management agent.

Smart Outlets: Smart Outlet reports appliance-specific power usage to CC Server for energy monitoring, management, and storage.

Firebase cloud messaging: FCM is a cross-platform messaging solution that lets utility deliver demand response request to client apps, providing a precious opportunity to drive user reengagement and retention at no cost.

Mobile Application: requests consumption data from CC server for monitoring consumption, comparison and completion. Also, it allows goal setting and monitoring, setting preferences and scheduling devices.

IHD & Controller: Resides within house, it stores management/control information received from CC Server, and enables monitor / control features.

Gateway: sends periodically appliance-specific data captured by smart outlet to CC Server. A Two-way communication gateway enables utility to issue load-control signal to remotely control household appliances through home controller.

Smart Appliance: an equipment that uses wireless technology to receive real time data from controller to modulate their operation.

5.5 Block Diagram of the Overall System

System components are shown in Figure 5.4. It displays where different information's are retrieved from. As seen, the mobile app is very dependent on external data sources. In addition, all the functionalities and storage are migrated to a server called "Cloud Computing server", thus, the running cost of computation intensive functionalities are reduced, and the storage capacity constraints of such resource limited devices are overcome.

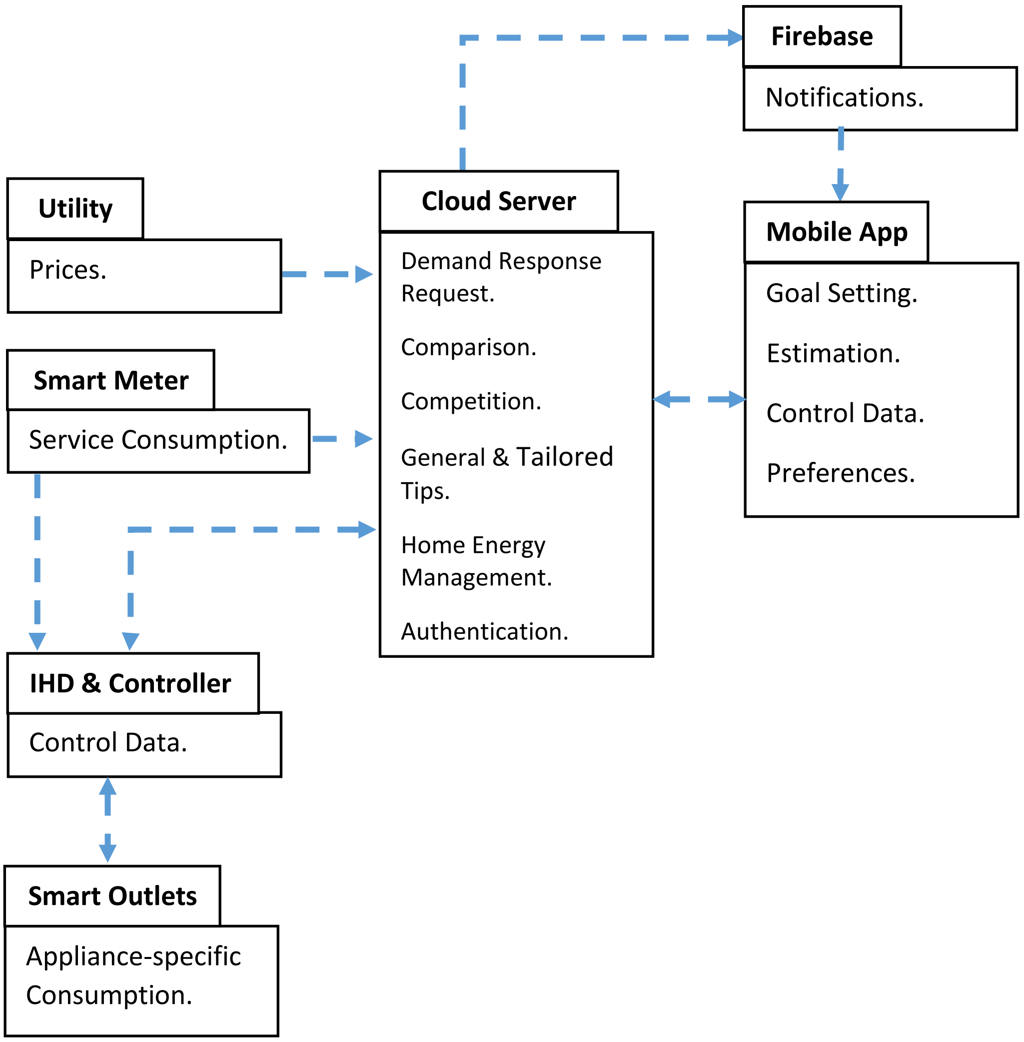


Figure 5.4 System Components- Block Diagram

5.6 UML Deployment Diagram of the Overall System

The main components of the total system are also represented using Deployment diagrams in Figure 5.5. Deployment diagrams are used as to visualize the topology of hardware used in system implementations and the software artifacts realized on them. In this thesis, we dealed with four components: mobile application realized in the form of XML layout files and java code, cloud server containg RESTful web services , a MySQL database server, and Firebase cloud messaging connection servers provided by Google, which take messages from the CC server and send them to a client app running on a device.

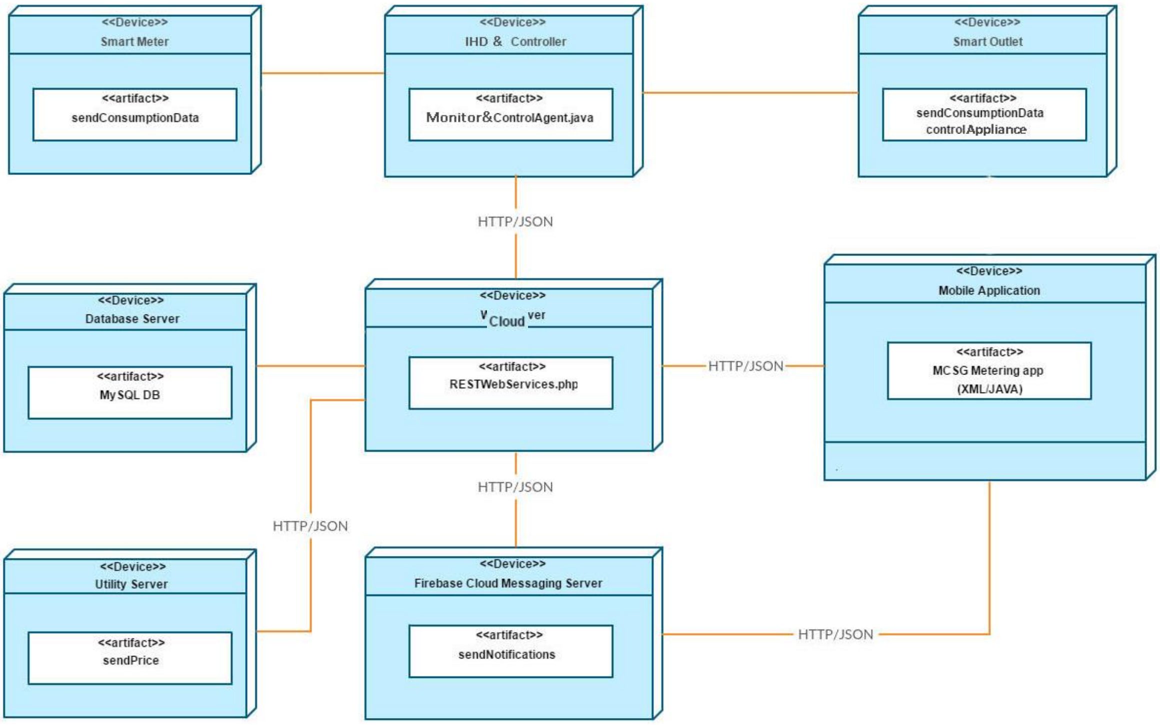


Figure 5.5 Deployment diagram of overall system

5.7 UML Sequence Diagram of the Overall System

Scenarios describe "sequences of interactions between objects and between processes" [81]. In this section, we have created a typical scenario that the user may follow with the application when he is encountered with a notification notifying him about a peak usage in his home, and designed a corresponding sequence diagram that shows the interaction between different actors within the system based on each client request. The steps in the scenario are listed below and depicted in Figure 5.6.

Peak usage scenario

- A mobile app notifies a user about a peak usage in his home.
- The user decided to check his hourly consumption for the whole day to get a general overview about his consumption.
- He also decided to check appliance-specific consumption data to indicate which appliance contribute to this peak usage.
- After some analysis, he discovered that the space heater was consuming more than any other device during the past hour.
- So, he decided to monitor its instantaneous power to determine if it was still turned on.
- Through its real-time usage data, the space heater was still turned on, so he decided to remotely control and turn it off using the app.
- The app afterward stated that the device was successfully turned off.
- At that moment, he decided to check the effect of his action on the total instantaneous power (real time consumption) of his house.
- Indeed, it was reduced.

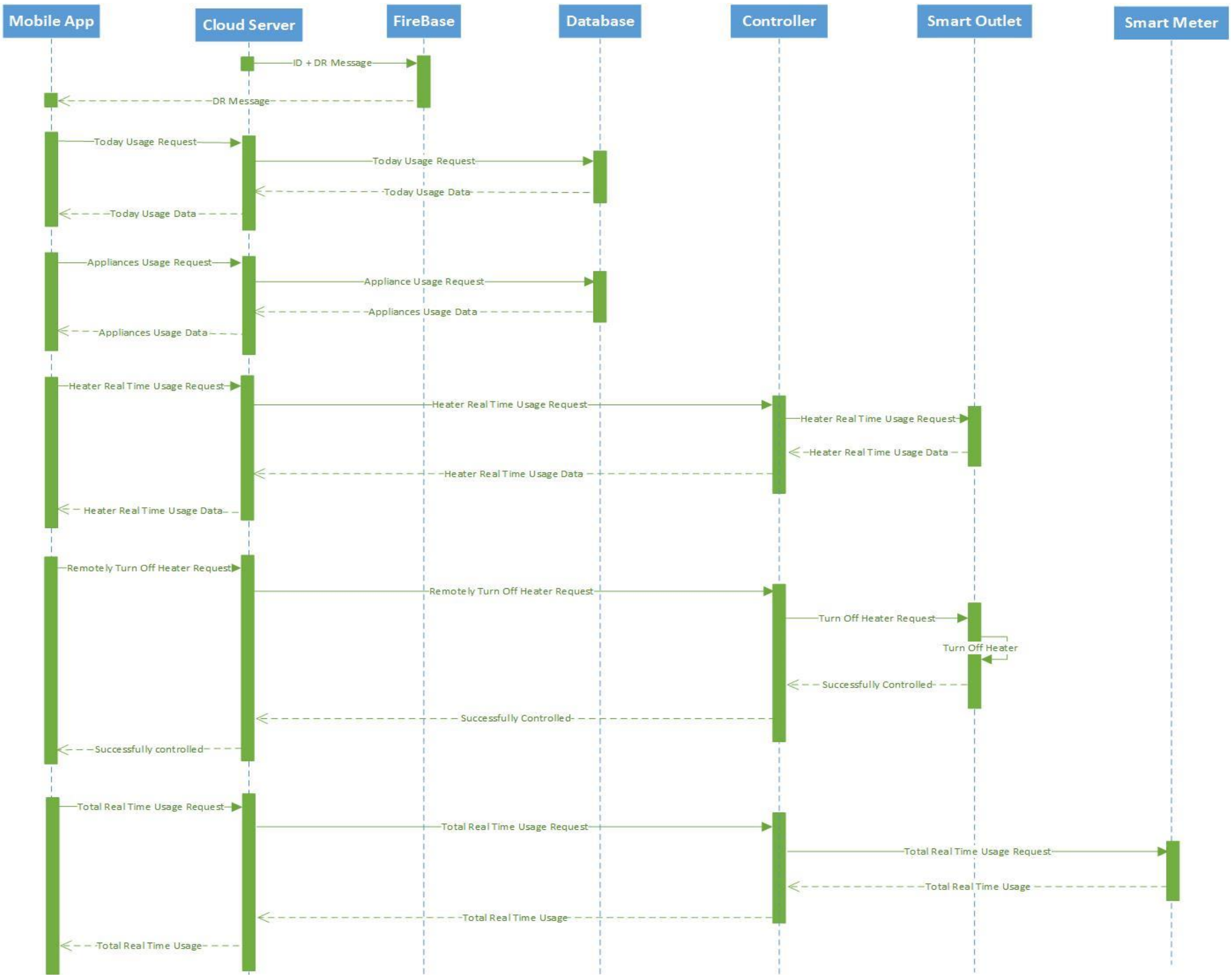


Figure 5.6 Scenario based sequence diagram

5.8 UML USE Case Diagram of Mobile App and CC Server

Use case diagram in Figure 5.7 shows a set of functions (use cases) that the mobile application and cloud computing server should perform in collaboration with external users of the system (actors). Each piece of functionality is marked with the functional requirement to which it belongs[10].

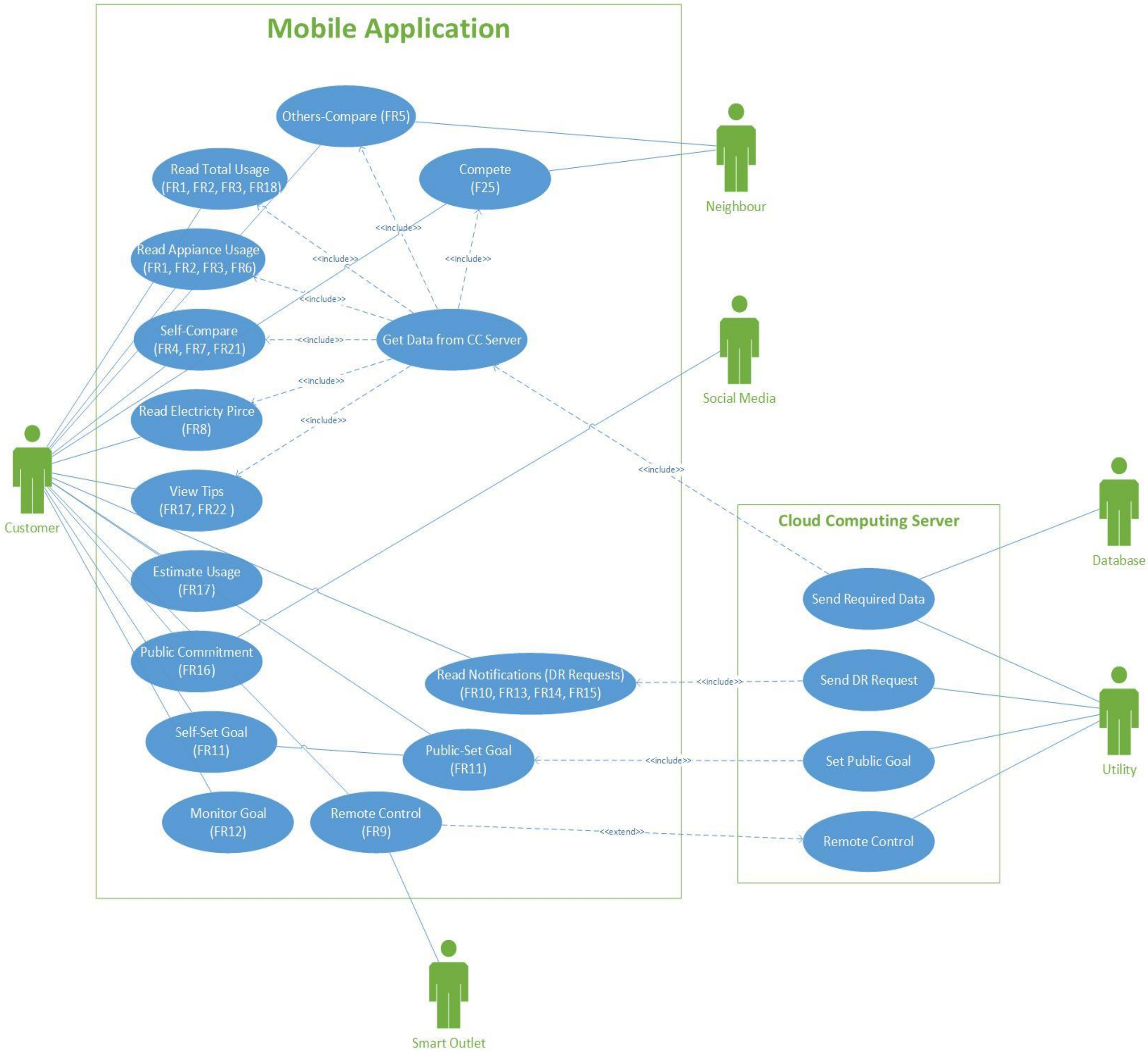


Figure 5.7 Use-case diagram of the proposed mobile app and CC server

[10] Refer to chapter 4 for more information about functionalities mentioned in Figure 19.

5.9 Hierarchical Structure of MCSG Metering Application

In this section, functionalities[11] that the mobile application should perform are categorized hierarchically as shown in Figure 5.8.

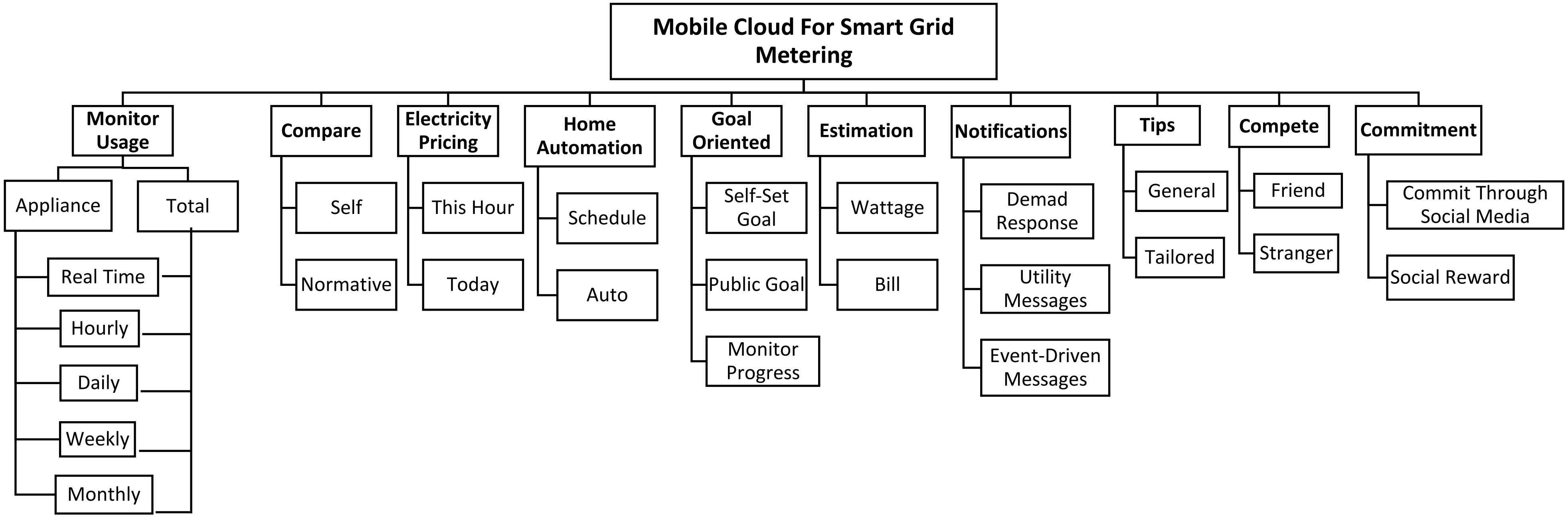


Figure 5.8 Hierarchical Structure of MCSG Metering Application

[11] Refer to chapter 4 for more information about functionalities mentioned in Figure 20.

5.10 UML Class Diagram for MCSG Metering Application

Class Diagram is a conceptual/domain modeling and detailed design modeling. Figure 5.9 describes the relationships between classes, objects, attributes, and operations within our proposed system.

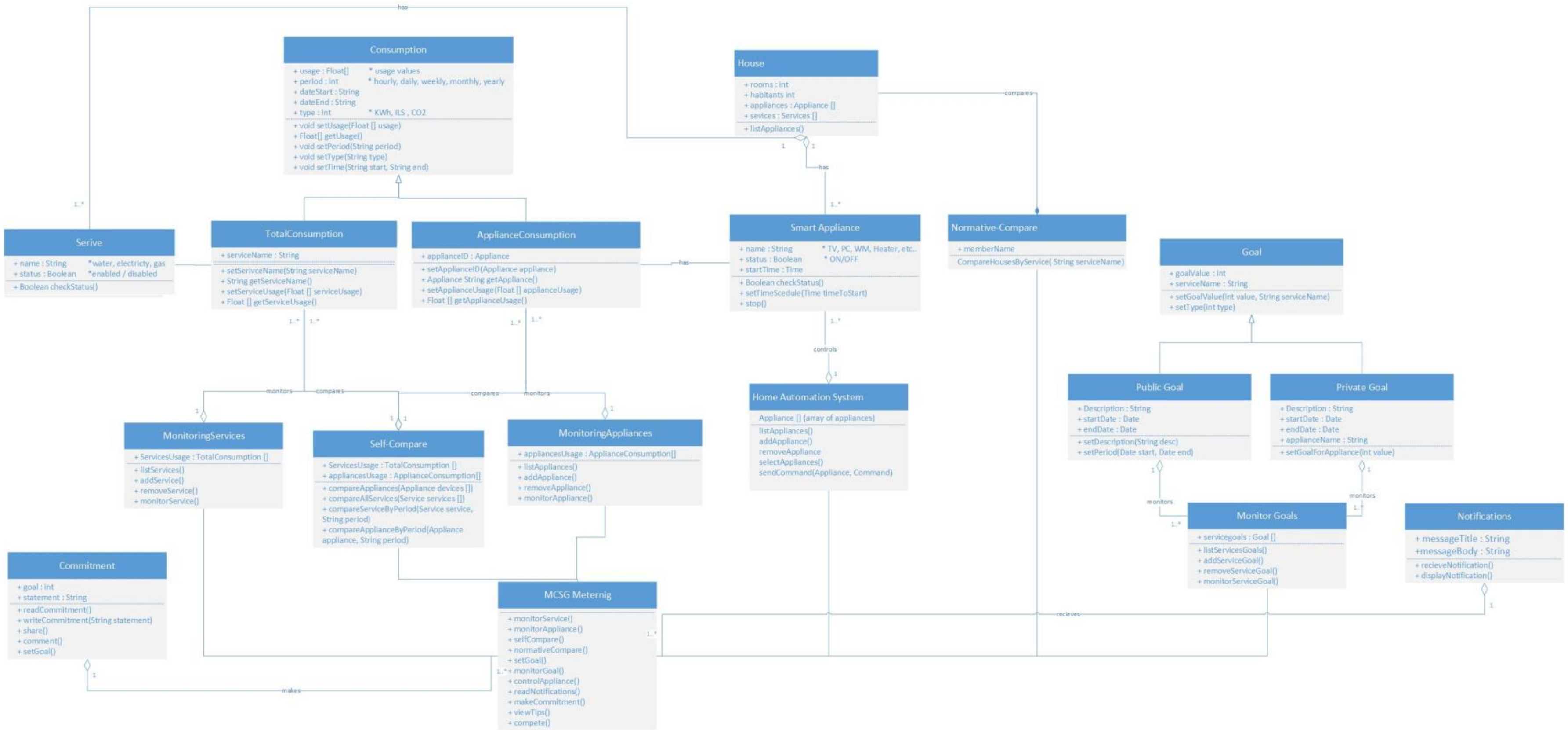


Figure 5.9 UML Class Diagram for MCSG Metering Application

5.11 Designing the User Interface

We have followed the User-Centered Design (UCD) process in the design of user interface screens, utilizing a wide range of practices supporting UCD (*focus groups brainstorming, storyboarding, participatory design, rapid and iterative prototyping, and end-user evaluation*). At first, a workshop with a focus group of ten participants (representative of anticipated users who are going to use the application, in addition to a group of UI designers) was held to explore different design solutions for the mobile application. The participants' characteristics are summarized in Table 5.1. Using a brainstorming method, we were inspired with a set of new, creative ideas for the design of user interface screens. After a while, we managed to create different paper mock-ups for each required feature in the application. Then, a storyboard was created, showing the relation between user actions or inputs and system screens, as shown in Figure 5.10. The formation of these screen representation into a sequence conveyed us with further information regarding the possible structures, functionality and navigation choices available. Taking participants feedback, the design was iteratively refined until the scenario interactions were adequately captured and the participants felt comfortable with what was achieved. A final paper mock-up is derived and served as the basis for the actual implementation on the Android platform.

Characteristics of UI Design Participants		
Age	N	(%)
15-25	2	(20%)
25-35	4	(40%)
35-45	2	(20%)
45-60	2	(20%)
Gender		
Male	6	(60%)
Female	4	(40%)
Profession		
Computer Engineer	2	(20%)
Graphic Designer	1	(10%)
Teacher	2	(20%)
Salesman	1	(10%)
Secretary	1	(10%)
Pharmacist	1	(10%)
High School Student	1	(10%)
Unemployed	1	(10%)

Highest level of education		
High school	2	(20%)
College	4	(40%)
University	3	(30%)
Graduate Degree	1	(10%)
Has a smartphone		
No	0	(0%)
Yes	10	(100%)
Type of smartphone		
Android	5	(100%)
IPONE	3	(30%)
Windows Phone	2	(20%)

Table 5.1 Characteristics of User Interface Design Participants

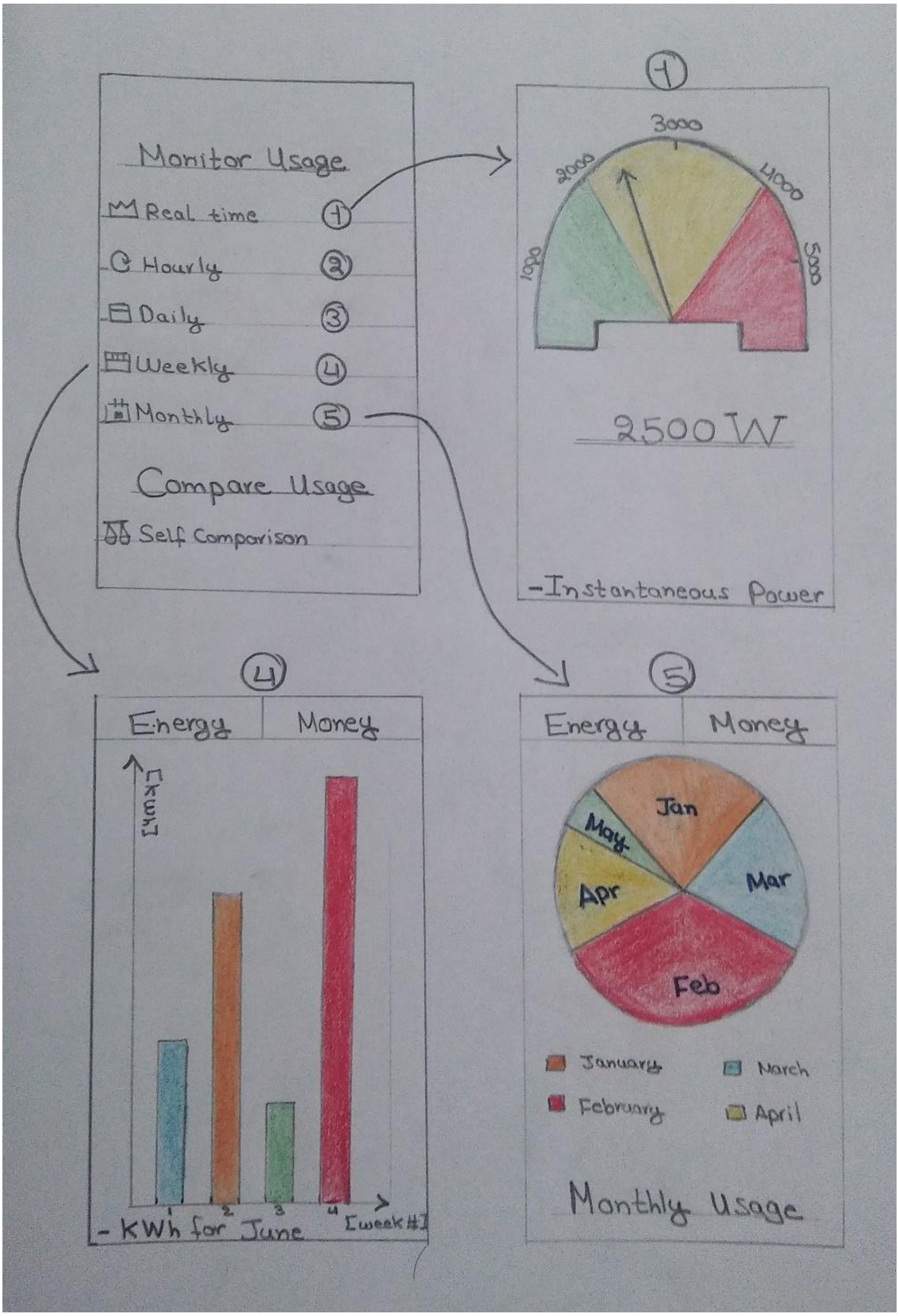


Figure 5.10 Storyboarding with different paper mockups that represent the user interfaces

CHAPTER SIX

Implementation

The development in this work has been done with what was possible with the time frame and limited access to the systems of the grid owners and electricity suppliers. Thus, a prototype with a set of functionalities rather than a full-functioning application was developed. This chapter will describe how the MCSG Metering application was implemented. First, the MCSG Metering app prototype will be described, afterword, the external libraries used will be presented, and subsequently the specific application implementation will be explained.

6.1 Prototype Description

The development process adopted an iterative prototyping, resulted in a number of prototypes:

The first prototype[12] is composed of five sections:

1) ***Monitoring Usage****:* consumers can monitor home's energy or even home's appliances in real time, and view their consumption history over hour, day, week, month or year (refer to Figure 6.4, Figure 6.5 and Figure 6.6).
2) ***Compare Usage:*** consumers can see how efficient their home is compared to a past period, e.g., last week, last month (refer to Figure 6.7 and Figure 6.8) or to others, e.g., neighbors, friends, ... etc. (refer to Figure 6.9).
3) ***Electricity Pricing:*** View charts and data of electricity prices for different tariff services, such as time-of-use and tiered pricing (refer to Figure 6.10).
4) ***Home Automation:*** consumers can access features of their home remotely via the Internet (refer to Figure 6.11).
5) ***Goal Setting****:* consumers can set and monitor a consumption target (budget), and be alerted when they are trending over it (refer to Figure 6.12).

The Final prototype implements additional features / sections to the previous one:

[12] The first prototype is the one used in the usability evaluation.

6) ***Estimation:*** consumers can see their estimated hourly/daily/monthly KWh usage and money before it arrives (refer to Figure 6.13).
7) ***Public commitment:*** consumers can commit to conserve energy to the public using social media, e.g., Facebook platform (refer to Figure 6.14).
8) ***Demand Response Requests:*** consumers are alerted with real-time demand response notifications (refer to Figure 6.15).
9) ***Inbox Messaging:*** all messages from electric utility and demand response requests are stored within the app for later preview. Consumer can also share them to social media (refer to Figure 6.16).

6.2 External Libraries

The mobile application uses a set of libraries, both for dealing with communication with external sources, and for user interface components, Appendix A.2 describes them accordingly.

6.3 MCSG Metering Application Implementation

As mentioned in the prototype description section 6.1, our prototype provides nine services to consumers. However, due to the system's complexity, huge implementation code, and the time frame for submitting this thesis, not all implementation aspects are covered and presented. Appendix A.3 discusses some important aspects regarding the implementation of the *MCSG Metering* mobile application functionalities. Three implementation phases will be discussed accordingly:

- Implementation phase one is found in Appendix A.3.1
- Implementation phase two is found in Appendix A.3.2
- Implementation phase three is found in Appendix A.3.3

6.4 Application Navigation

MCSG Metering app contains three main navigation components in order to provide an easy access to all application screens:

1) The **NavigationDrawer** expands from the left edge of the screen and overlays the content area when the user swipes from left edge or touches the navigation drawer indicator in the ActionBar. The main benefit of using it is that it allows users to switch to the app's most important screens from anywhere in the app. In our application, the NavigationDrawer shown in Figure 6.1 displays a list of nineteenth navigation options, subdivided into 7 main sections, according to the main screens mentioned in the next section.

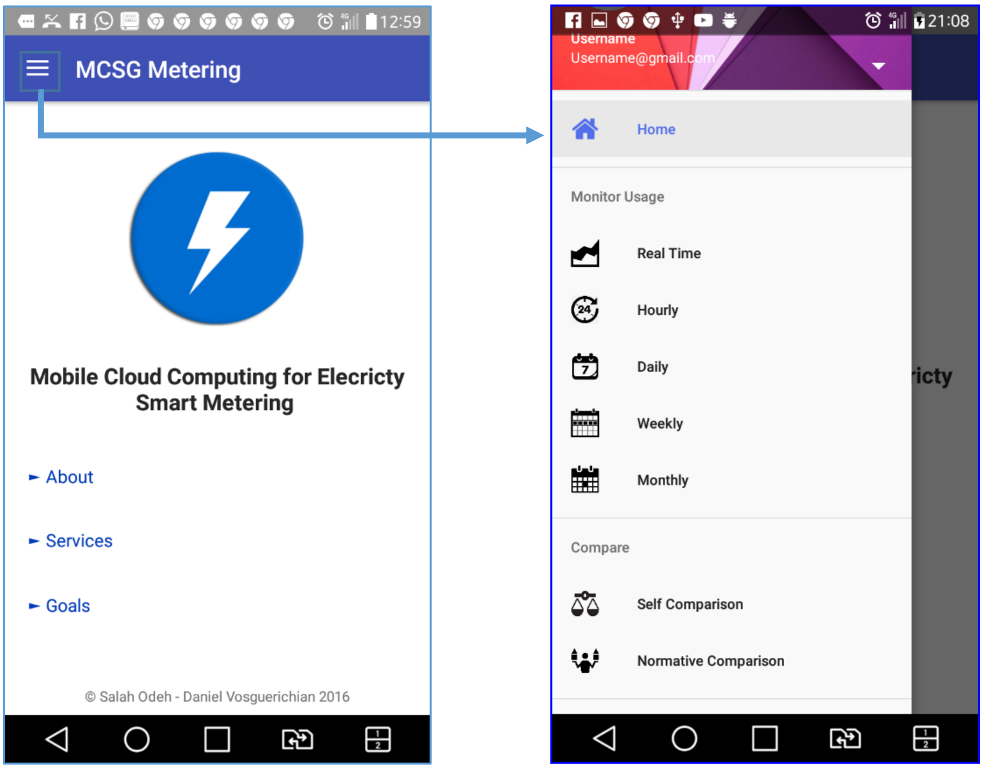


Figure 6.1 NavigationDrawer in MCSG Metering Application

2) **Tabs** provides an easy switch between sibling views on the same screen. In our application, we used tabs to switch between energy and money chart representations, as shown in Figure 6.2.

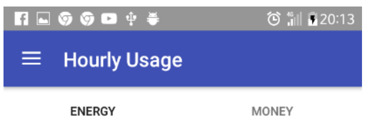


Figure 6.2 Android Tabs in MCSG Metering Application

3) **ActionBar** contains a popup menu that displays a list of navigation options in a vertical list, as shown in Figure 6.3**.**

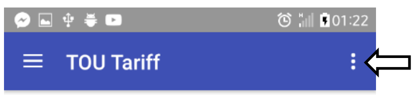


Figure 6.3 ActionBar Menu in MCSG Metering Application

6.5 Main Application Screens

Applications' Screens are all described in this section, along with the functional requirements fulfilled by each screen.

User-Interface Screens		Functional Requirements																	
		F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19 - F25
Section One: Monitoring Usage	*Real Time*	X																		Not implemented
	Hourly		X	X	X															
	Daily		X	X	X															
	Weekly		X	X	X															
	Monthly		X	X	X															
	Time-Of-Use			X	X														X	
Section Two: Compare	*Self- Daily*			X	X															
	Self-Weekly			X	X															
	Self-Monthly			X	X															
	Norm- Compare					X									X	X				
Section Three: Electricity Pricing	*This Hour Price*								X											
	Today's Prices								X											
Section Four: Home Auto	*Monitor Device*			X	X		X	X												

	Schedule Device						X			X	X									
Section Six: Tailored Information	**Estimate Wattage**			X														X		
	Estimate Bill			X														X		
Section Seven: Others	**Public Commitment**																X			
Section Eight: Real-Time *Notifications*	**Utility/Event-Driven /Demand Response Requests**													X	X	X				
Section Nine: Inbox-Message	**Inbox**													X	X	X				

Table 6.1 Functional requirements fulfilled by each application's screen

As we can notice from Table 6.1, it was not feasible to implement all the functional requirement specified in Chapter 4. First of all, it is not possible without a full access to the JDECO Company's systems. Secondly, consumption values from JDECO were anonymous, and a full implementation would require connecting to specific consumers and present them their personal information. Thirdly, the application would require access to smart equipment capable of communicating with the application. Finally, for the reasons mentioned previously in this Chapter.

6.6 Application Screen Flow

The screen flow from the NavigationDrawer to the main screens is dispayed in Figure 6.4 till Figure 6.16, categorized by the sections intorduced in the prototye description in 6.1.

Section One: Monitoring Usage

- ***Real Time*** interface (Functional Requirments : **F1**)
- ***Hourly*** usage interface: (Functional Requirments : **F2, F3, F4**)

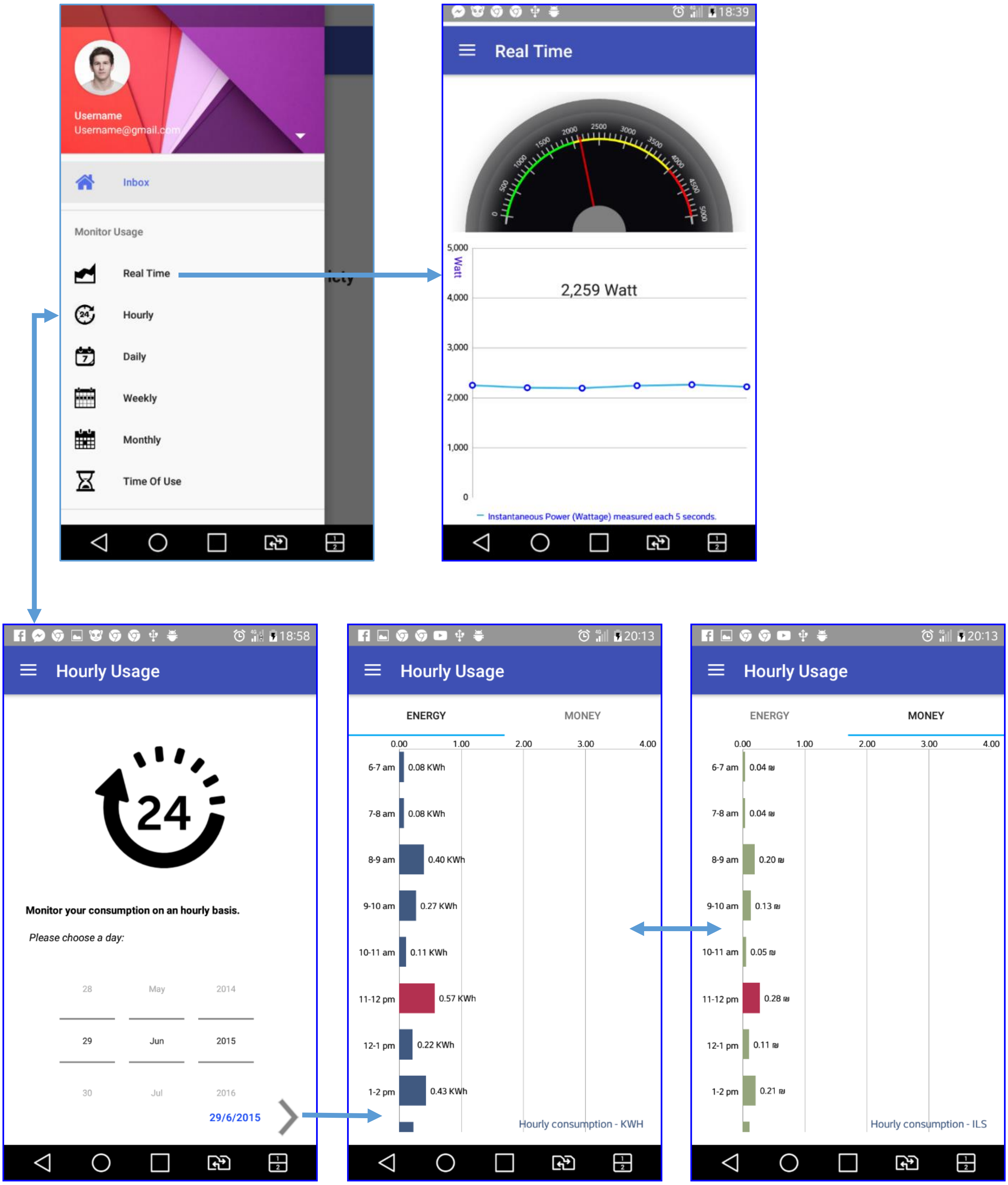


Figure 6.4 Real time and hourly usage interfaces

- ***Daily*** and ***Weekly*** usage interfaces: (Functional Requirments : **F2, F3, F4**)

Figure 6.5 Daily and weekly usage interfaces

- ***Monthly*** usage interfaces: (Functional Requirments : **F2, F3, F4**)
- ***Time-Of-Use*** usage: (Functional Requirments : **F3**, **F4**, **F18**)

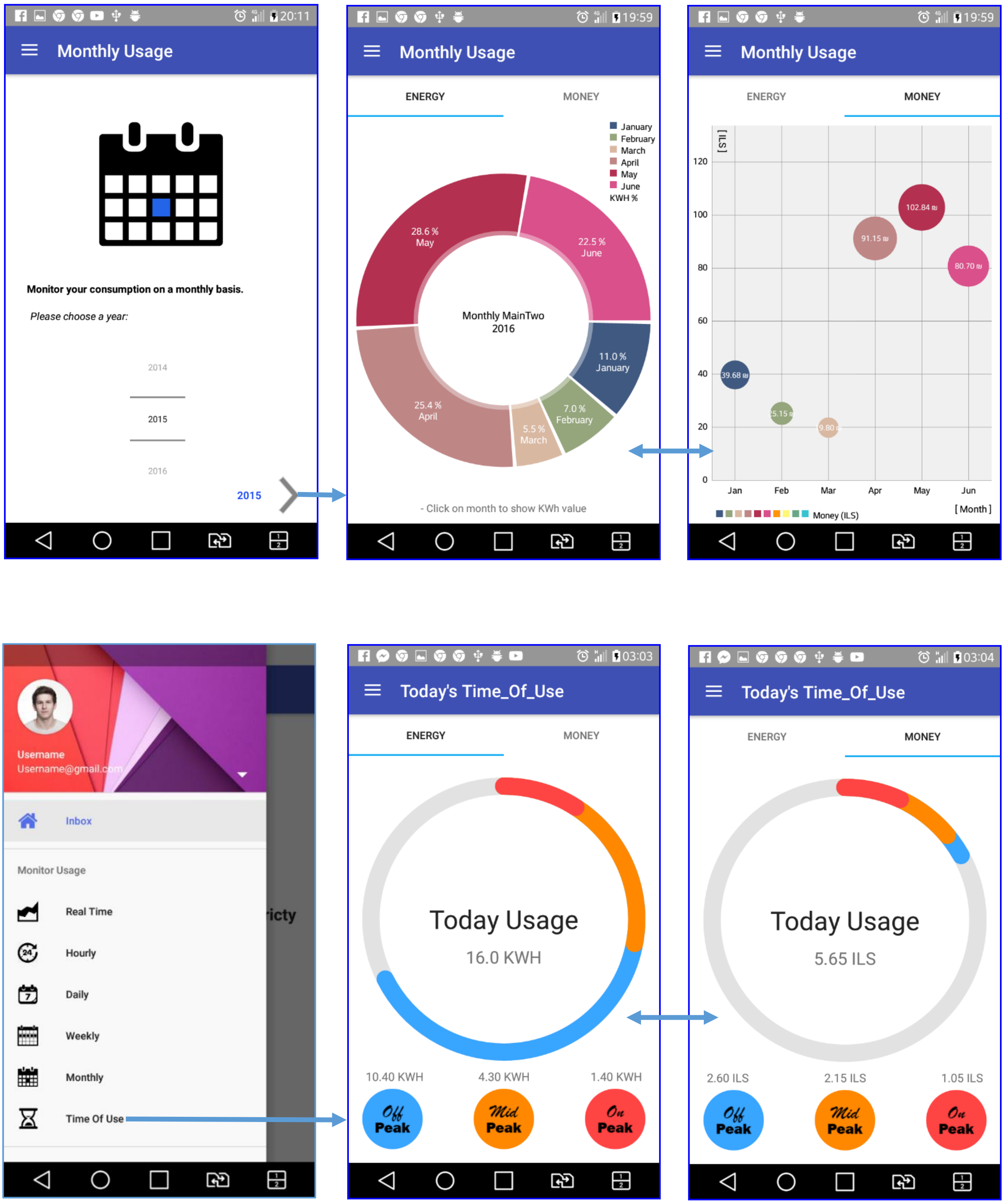


Figure 6.6 Monthly and time-of-use usage interfaces

Section Two: Compare Usage

- ***Self-Comparison*** and ***Daily Usage Comparison*** interfaces: (Functional Requirments: **F3**, **F4**)

Figure 6.7 Self-comparison and daily usage comparison interfaces

- ***Weekly Usage*** comparison and ***Monthly Usage*** comparison interfaces: (Functional Requirments: **F3**, **F4**)

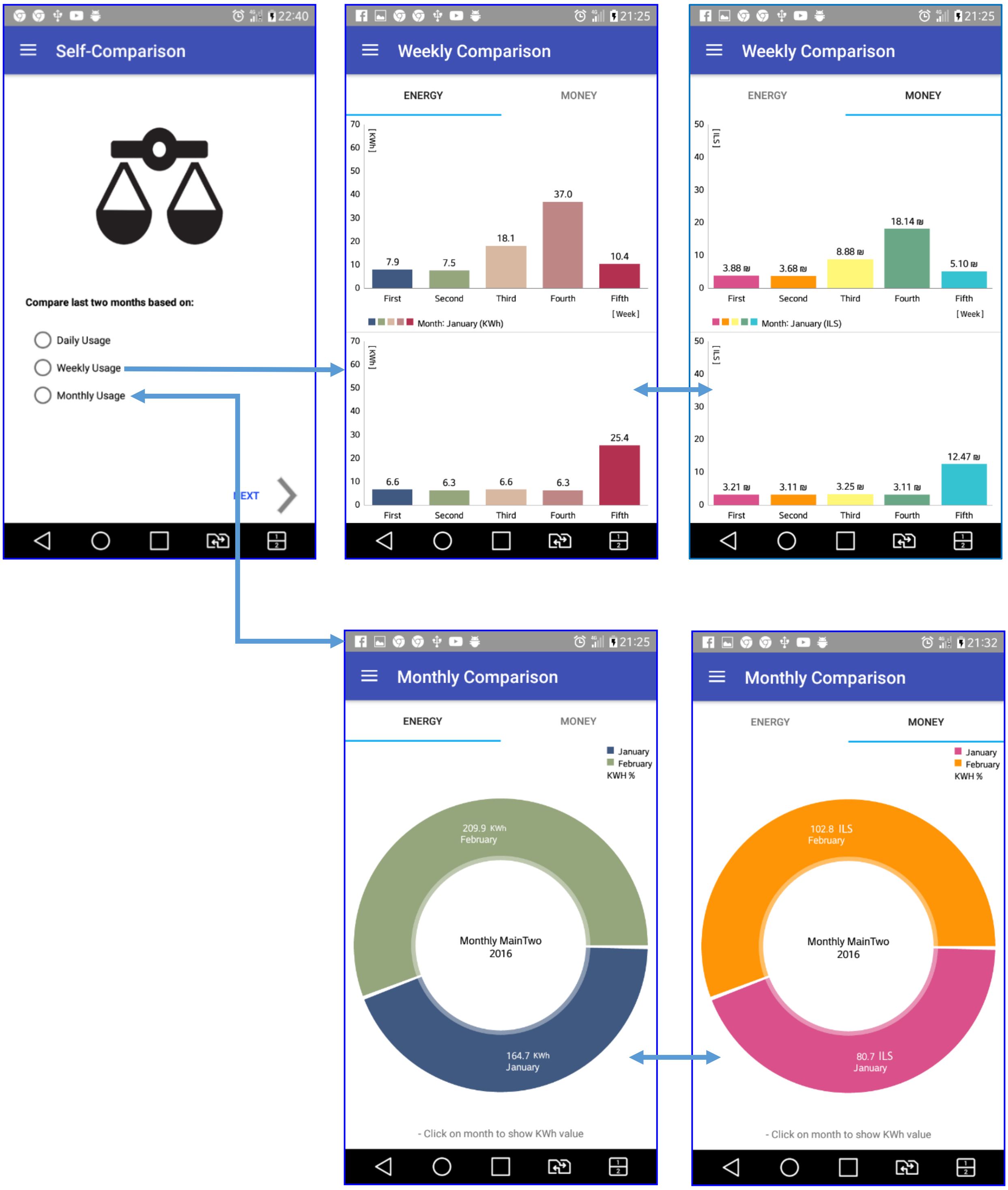


Figure 6.8 Weekly usage comparison and monthly usage comparison interfaces

- ***Normative Comparison*** interfaces***:*** (Functional Requirments: **F5, F14, F15**)

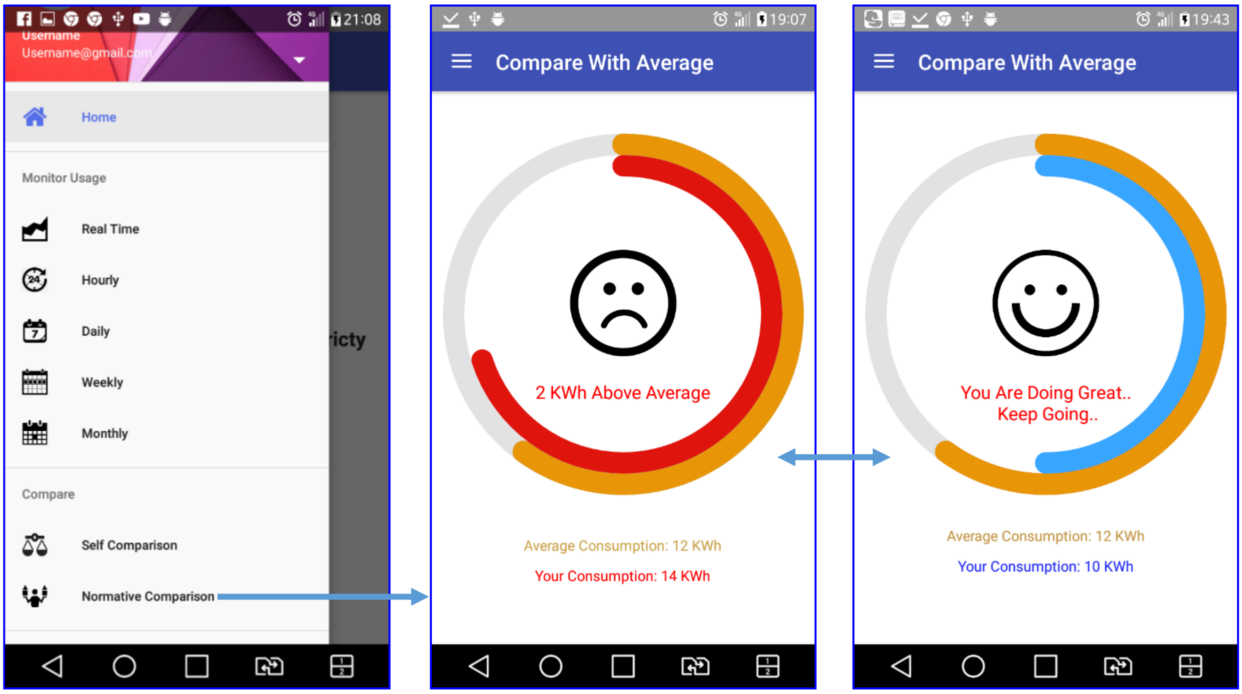


Figure 6.9 Normative comparison interfaces

Section Three: Electricity Pricing

- ***This Hour Price*** and ***Today's Prices*** interfaces: (Functional Requirments: **F8**)

Figure 6.10 This-hour price and today's prices interfaces

Section Four: Home Automation

- ***Monitor Device*** and ***Schedule Device*** interfaces: (Functional Requirments: **F3**, **F6**, **F7**, **F9**, **F10**)

Figure 6.11 Monitor device and schedule device interfaces

Section Five: Goal Oriented

Set A Target and ***Monitor Target*** interfaces: (Functional Requirments: **F11**, **F12**)

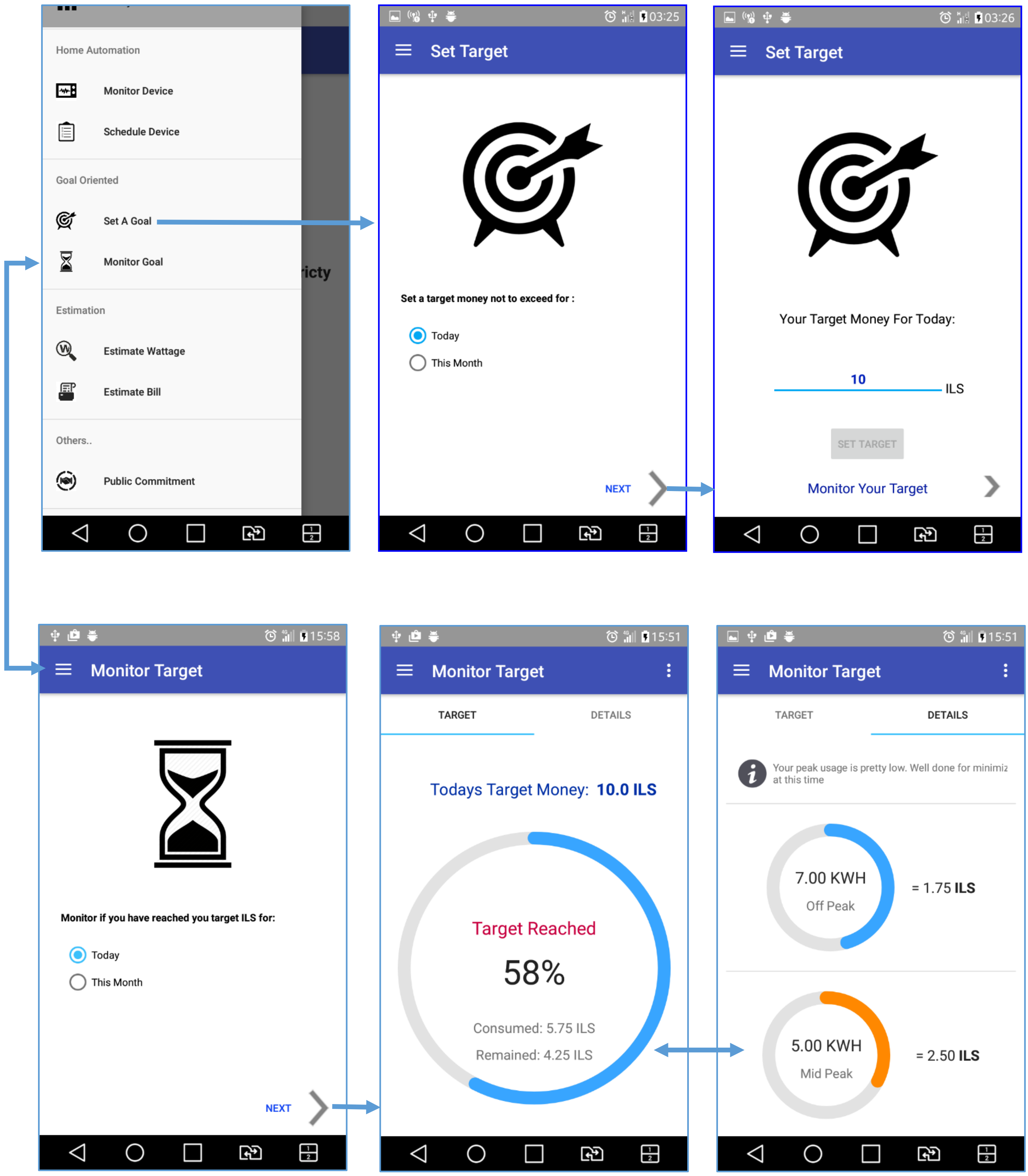


Figure 6.12 Set a target and monitor target interfaces

Section Six: Estimation / Tailored Information

- **Estimate Wattage** and **Estimate Bill** interfaces: (Functional Requirments: **F17**)

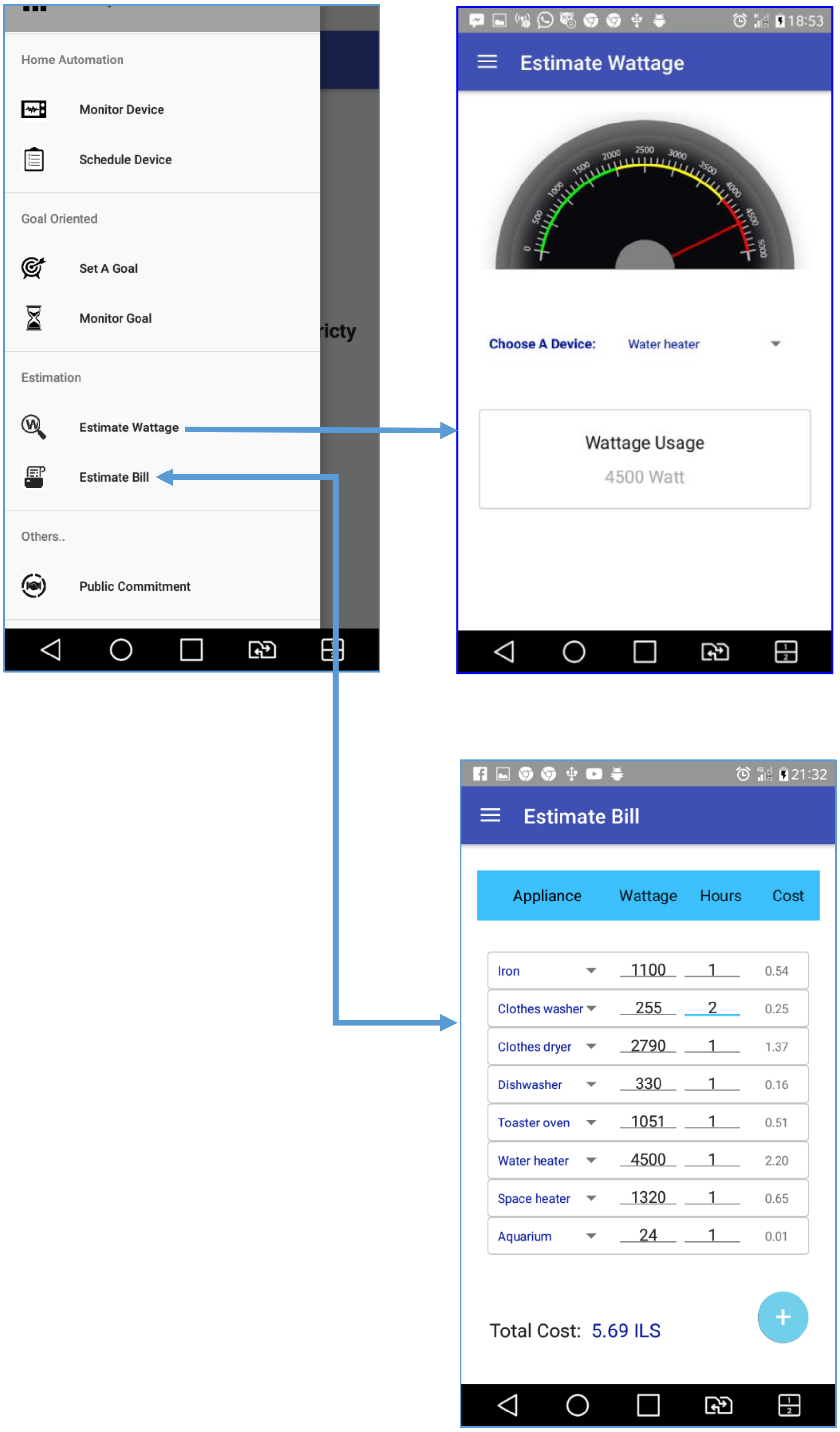


Figure 6.13 Estimate wattage and estimate bill interfaces

- **<u>Section Seven: Others / Public Commitment</u>** (Functional Requirments: **F16**)

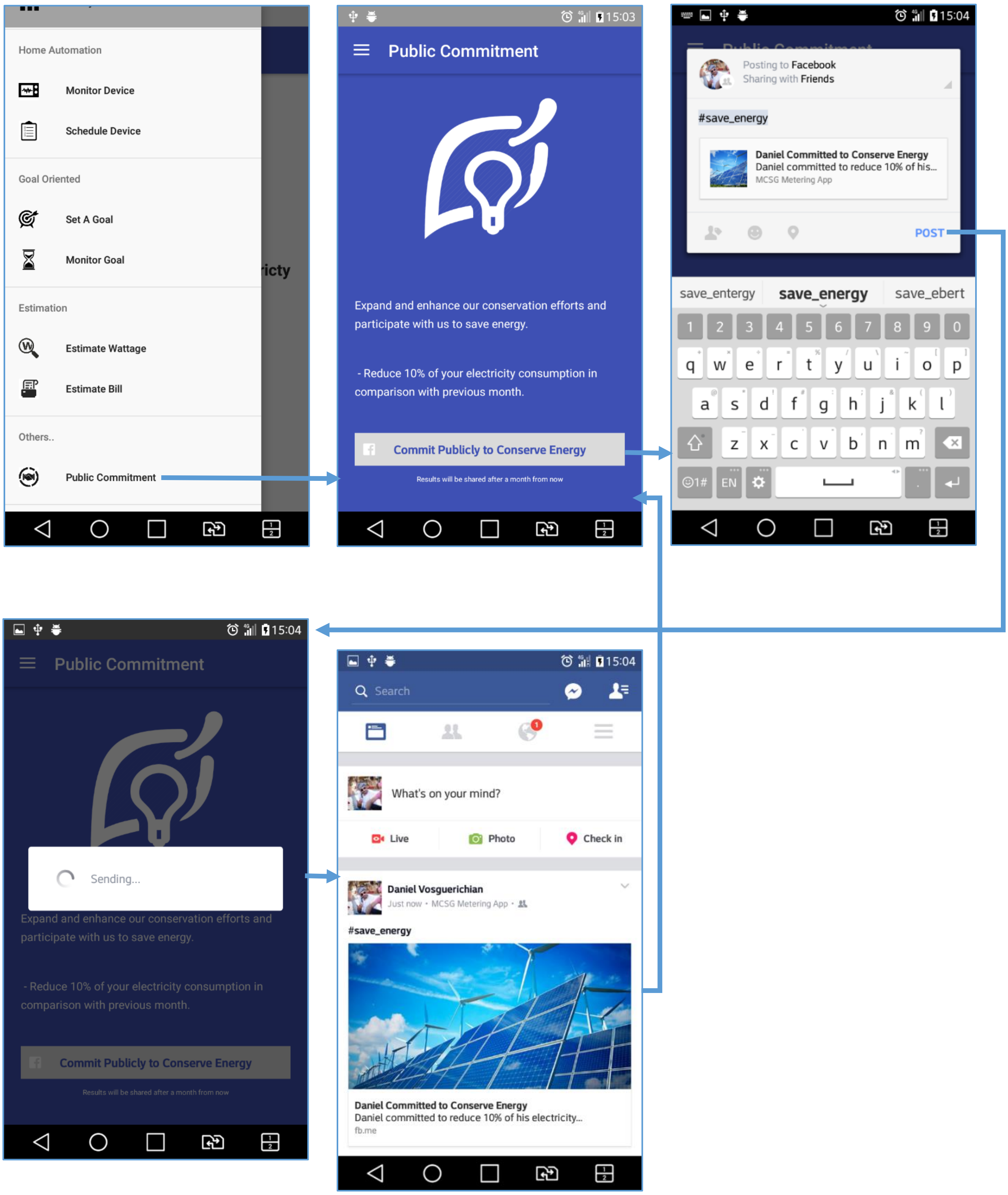


Figure 6.14 Public commitment interfaces

Section Eight: Real-Time Notifications: Utility/Event-Driven/Demand Response Messages (Functional requirements: F13)

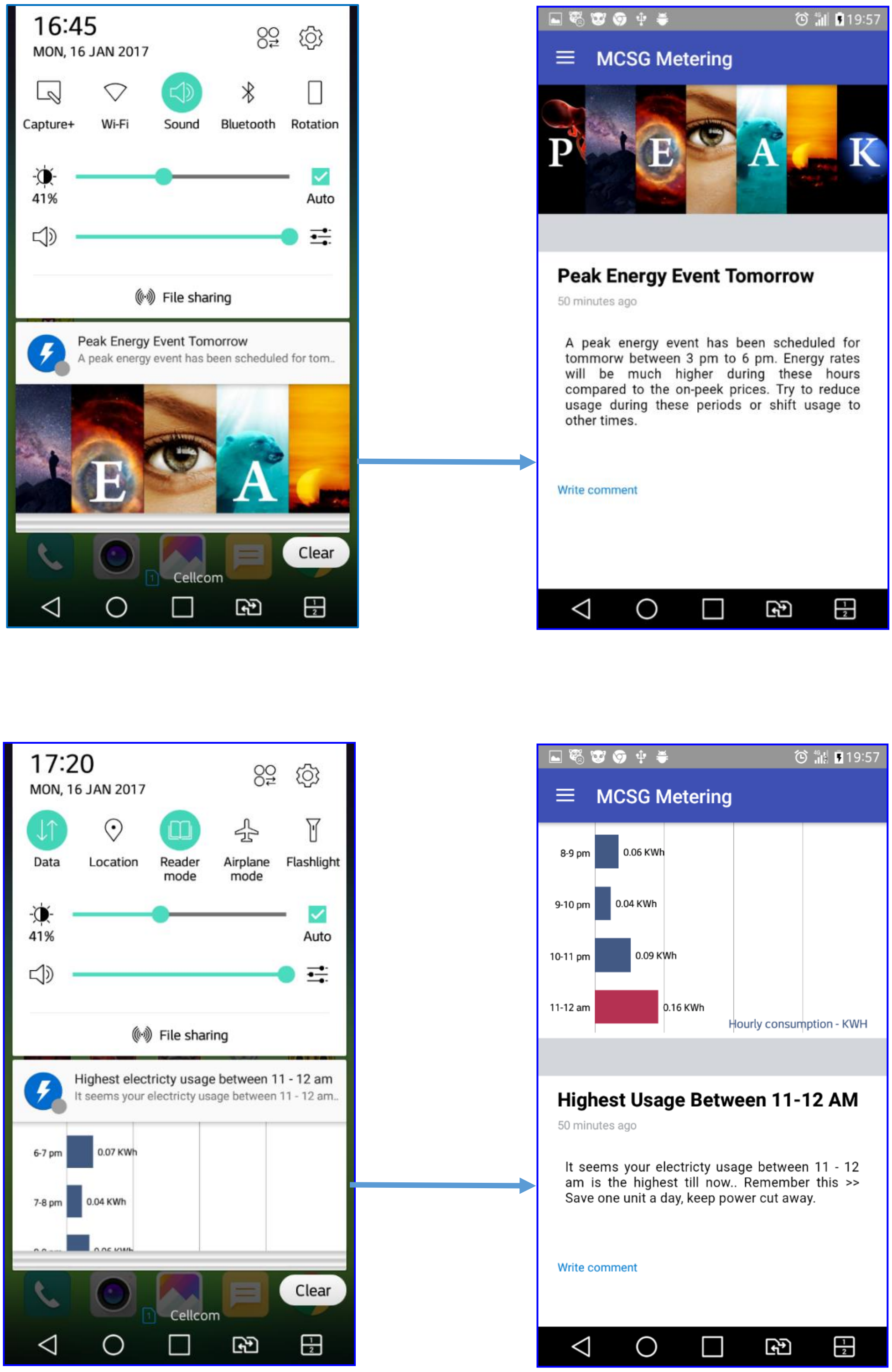


Figure 6.15 Demand response requests interfaces

Section Nine: Inbox Messages (Functional requirements: F13)

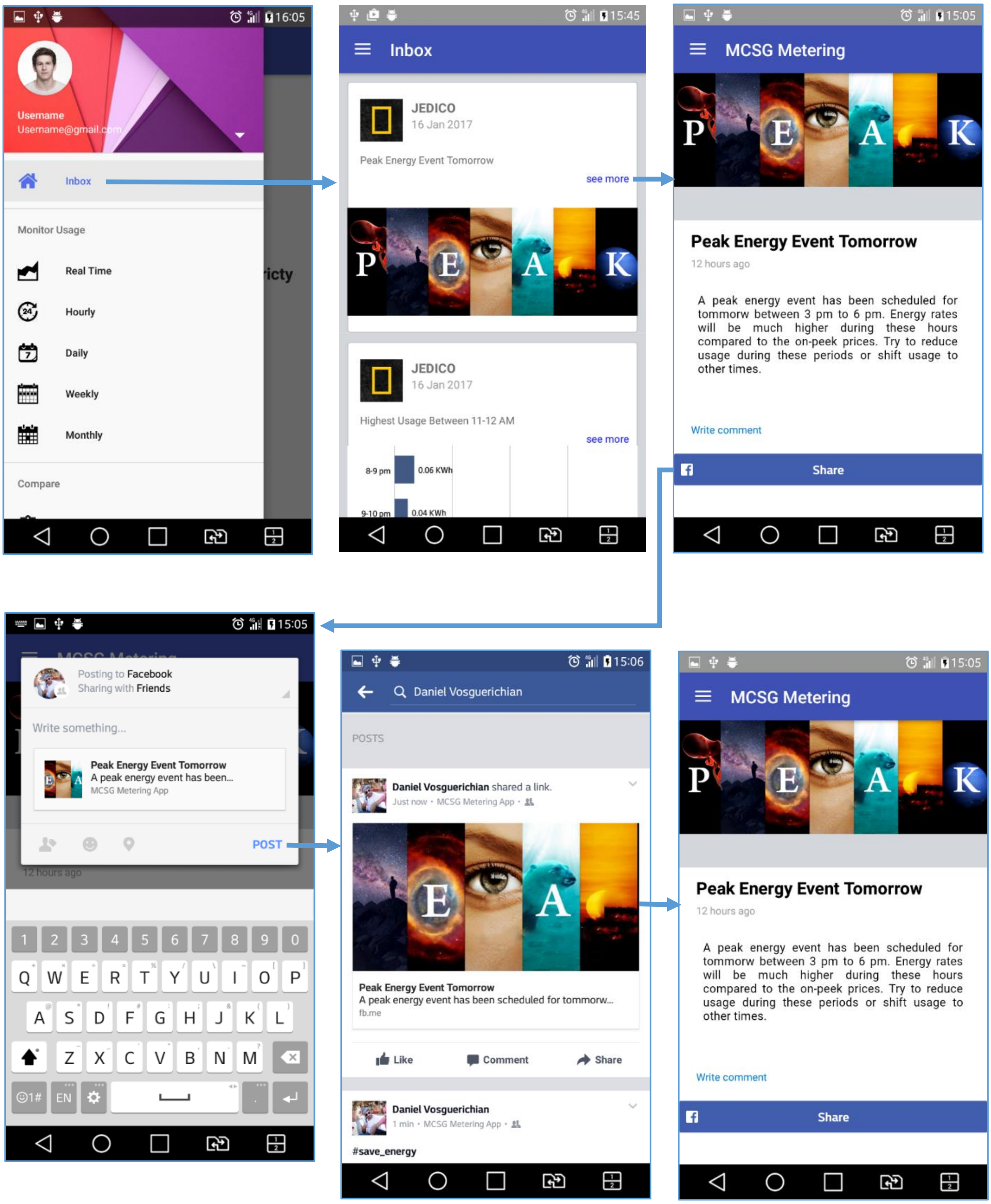


Figure 6.16 Messaging inbox interfaces

CHAPTER SEVEN

Usability Results

This chapter present the evaluation of the MCSG Metering application. Since design and development in this work have been done with what was possible with the time frame and limited access to the systems of the grid owners and/or electricity suppliers, hence the user evaluations investigate a prototype with a set of functionalities and concepts rather than a full-functioning application in natural settings. The main goal for the prototype evaluation is to measure its usability in terms of ease of use, ease of learning, and resistance to errors.

7.1 Usability Testing Participants' Characteristics

The usability testing involved seven participants (7 regular people from various professions and educational levels; 4 males, 3 females; the majority of participants owned a smartphone of Android operating system and uses their smartphones at least on a daily basis. Table 7.1 summarizes participants' characteristics.

Participants' Characteristics		
Age	N	(%)
15-25	1	(14%)
25-35	2	(29%)
35-45	2	(29%)
45-60	2	(29%)
Gender		
Male	4	(57%)
Female	3	(43%)
Profession		
Nurse	1	(14%)
Teacher	1	(14%)
Salesman	1	(14%)
Secretary	1	(14%)
Carpenter	1	(14%)
Pharmacist	1	(14%)
High School Student	1	(14%)

Highest level of education		
High school	2	(29%)
College	2	(40%)
University	2	(30%)
Graduate Degree	1	(10%)
Has a smartphone		
No	0	(0%)
Yes	7	(100%)
Type of smartphone		
Android	7	(100%)
IPONE	2	(29%)
Windows Phone	1	(14%)
Use smartphone		
Daily	6	(86%)
Weekly	1	(14%)
Monthly	0	(0%)
Rarely	0	(0%)

Table 7.1 Usability Testing Participants' Characteristics

7.2 Usability Test Execution

I have prepared sixteen task - scenarios (presented in Appendix B.2), including 19 main tasks (presented in Appendix B.3) that represents the majority of intended functionality from the first prototype. A task-scenario describes what the test user is trying to achieve by providing some context and the necessary details to accomplish the goal, this is very important to reduce the test's artificiality, making the conditions in which the usability testing is performed more reasonable and realistic. One expert and seven regular participants who passed the criteria mentioned in 3.3.5.1, have been recruited in the first test session, with an intention to continuo usability testing iterations until we fulfill the desired goals of usability testing.

In the first usability iteration, the same introduction about the system was read to each participant. In order to evaluate each task independently and reduce familiarity or learning curve effects caused by knowledge gained from previous tasks that can make later tasks easier, participants asked to randomly choose a task from a pool of tasks.

Participants were continuously encouraged to "Think Aloud", that is, simply verbalizing their thoughts, feelings, opinions as they move through the user interface, this can give us important qualitative data about their perceived usability of system. A video recorded the participant's actions, workflow and their talks while performing tasks during usability session.

After each task, a user was asked to fill a Single-Ease question (SEQ) to measure the perceived usability satisfaction, and a small talk was conducted to get the suggestions on how to improve the task (refer to Appendix B.4). At the end of the test, each participant was asked to fill in SUS questionnaire mentioned in Appendix B.6, answer some questions mentioned in Appendix B.5 and write their general comments about the system.

Recorded video was replayed for each participant, performance metrics discussed earlier with other qualitative data were noted and analyzed.

The steps followed in the usability testing is summarized in Figure 7.1.

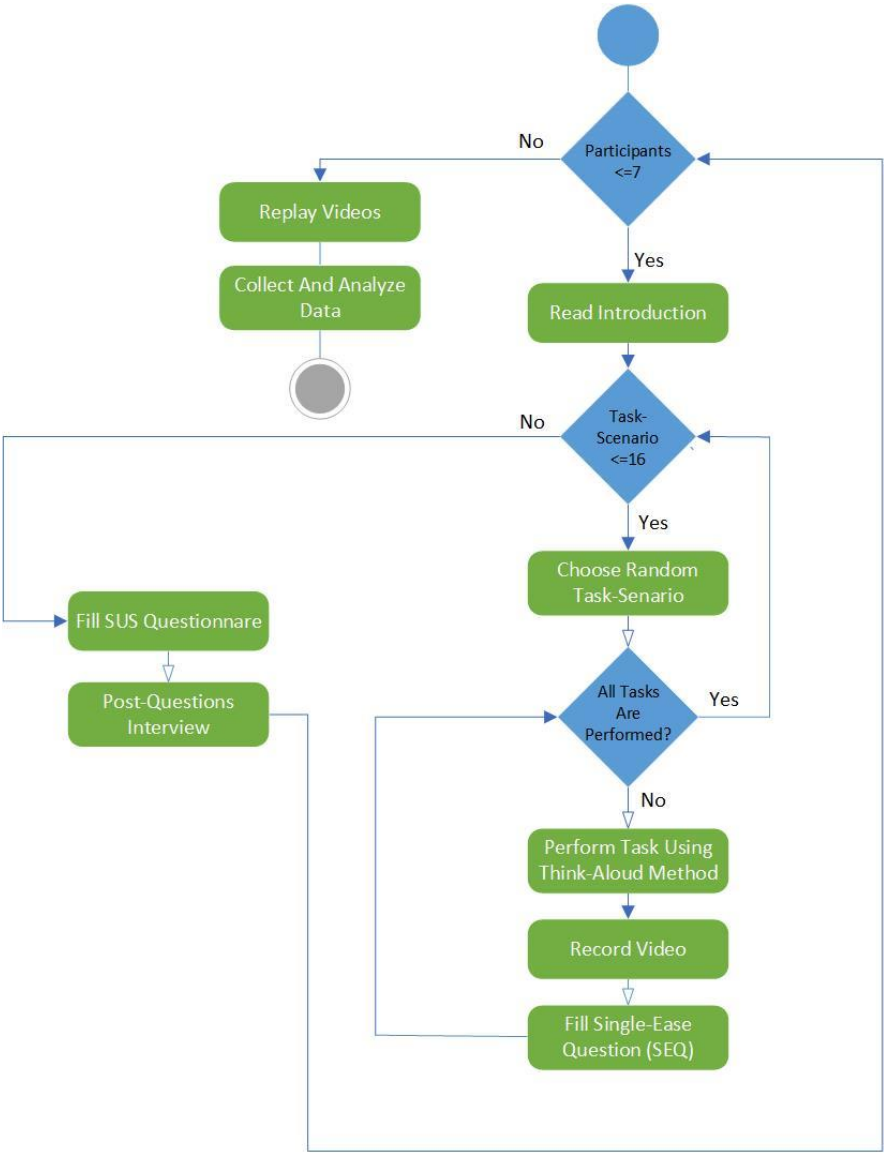


Figure 7.1 Usability Testing Execution

Our plan is to test the prototype in multiple iterations until we reach to an acceptable usability results (performance objectives defined in 3.3.5.3). With the aid of participants of usability session and based on their test outcomes, our ultimate goal is to make the mobile application continuously better and more intuitive. Thus, ensuring that the user has positive usage experience and satisfied with the ease of product.

Hint: All martials used in our usability testing are included in Appendix B.

7.3 The Various Considered Measures

In each usability test, the following performance metrics were collected after each performed task:

1) Success rate - If a user completed a task successfully or not.
2) User encountered errors per-scenario basis.
3) The time it takes for a user to complete a task.
4) Perceived usability of a task (Task-level Satisfaction).

in addition, the following qualitative data are collected:

1) Participant spoken or written feelings.
2) Problems encountered by the participants.
3) Comments/suggestions.
4) User preferences.
5) Answers to non – numerical questions.
6) Recorded difficulties faced by participants.
7) Facial and body expression during test.
8) Positive feedback which reflects aspects that worked well in a product.

7.4 Tasks' Performance Metrics Results

This section presents the quantitative results (test task results) from conducting usability tests with seven regular participants and one expert user. The results are plotted in (Figures 7.2 - Figure 7.4) and are analyzed in the next section.

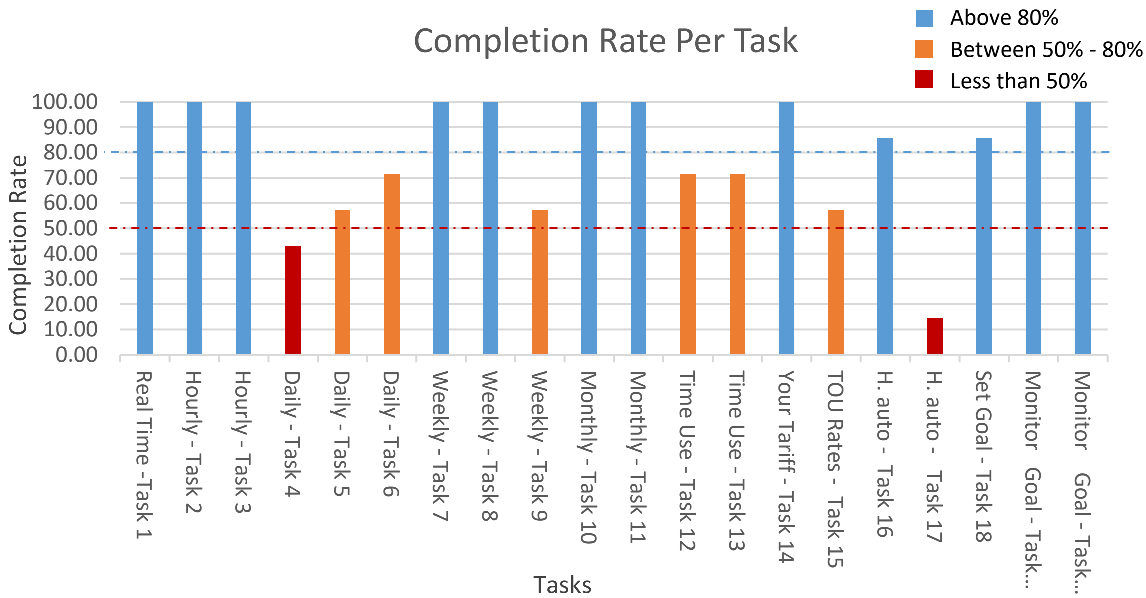


Figure 7.2 Usability testing results - Task's completion rate

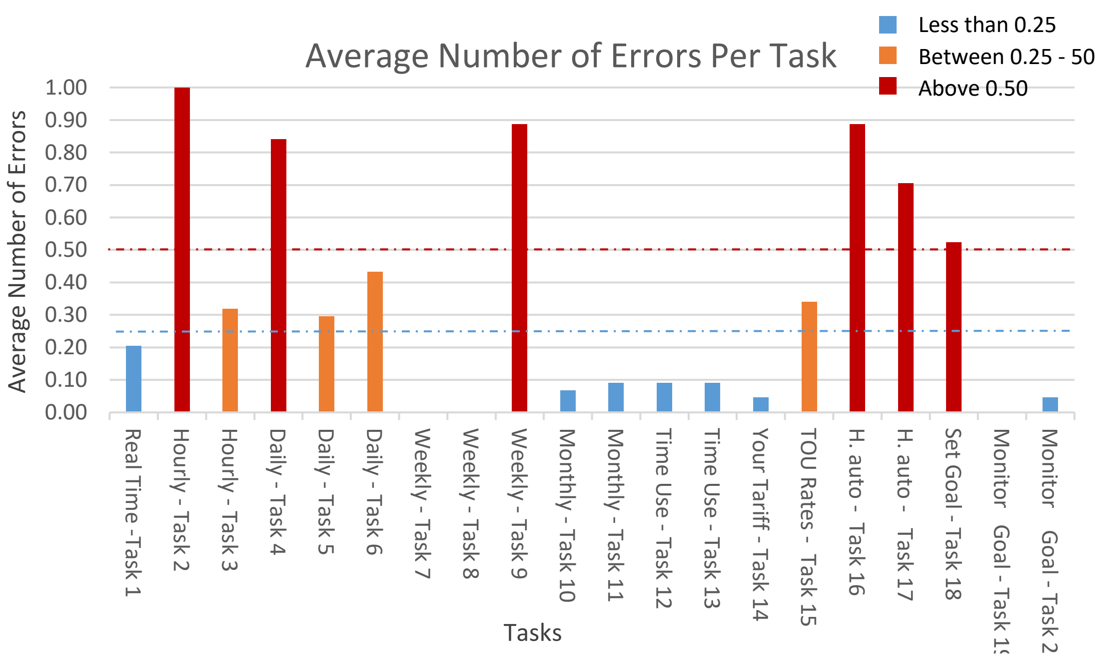


Figure 7.3 Usability testing results - Average number of errors per task

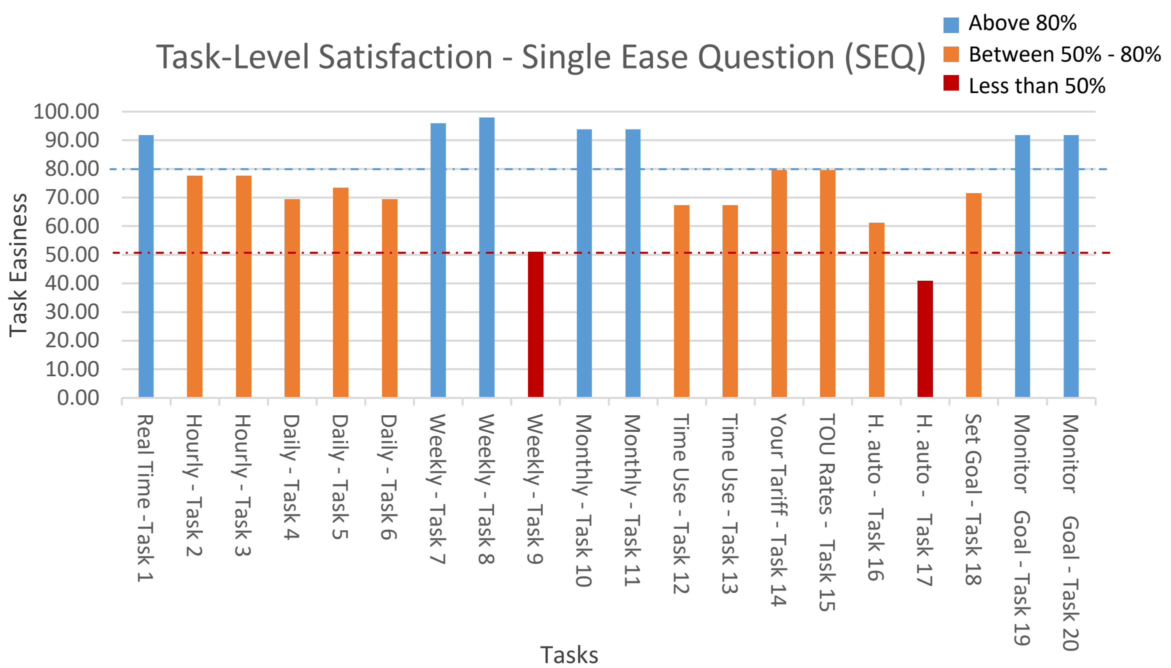


Figure 7.5 Usability testing results - Task-level satisfaction

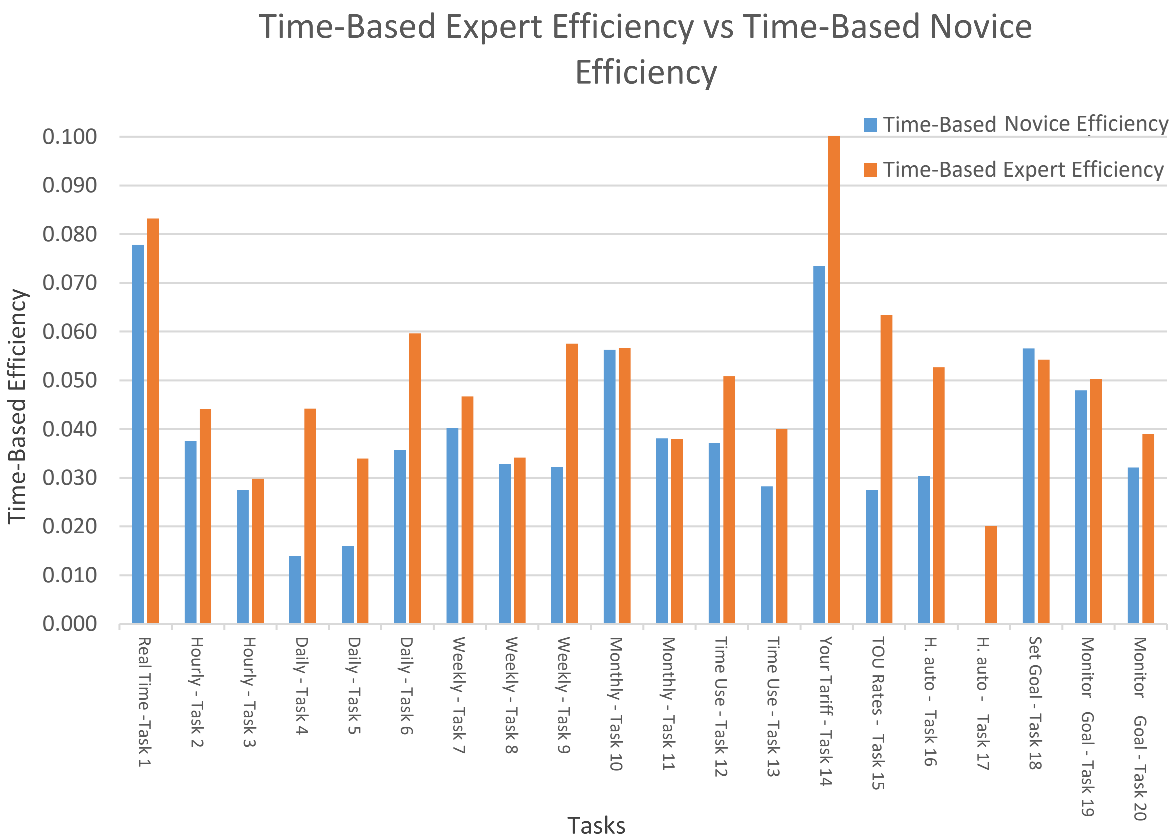


Figure 7.4 Usability testing results - Time-based expert efficiency vs time-based novice efficiency

7.5 Usability Results Findings

Findings from test task results mentioned previously with the qualitative findings regarding usability will be discussed in a clear and systematic way.

Task 2,3

Even though task two has 100% completion rate (Figure 7.2), it has received the most error rate with high error frequencies (Figure 7.3).

Bar chart was not clickable, some participant kept clicking on same bar on the bar chart more than five times, as if they want it to show something, some argued "I was hoping that values would appear in a toast after clicking on the bar chart". Observing the same error repeated five times versus one time better describes the poor usage experience, which creates significant delay and frustration.

In addition, the majority of participants were scrolling the interface downwards instead of upwards as a first action after entering the interface.

Moreover, three users were confused with values above bars, "At first, I couldn’t figure out what the values represent. It took me a considerable time to see the statement at the bottom "Hourly consumption KWH", it was hardly seen and written in a small size, I would recommend to mention KWH unit or money unit beside values".

Most notable among the findings in this task was the realization that users’ subjective satisfaction is at odds with performance metrics. Even with high error rate, most of participants were fairly satisfied with the easiness of task with 78% average task satisfaction (Figure 7.5), justifying their scores that the encountered problems have minor effect on usability, but an enhancement would improve user experience significantly.

Task 4,5

Task four received the third most error rate with an average of 0.84 (Figure 7.3), notable finding here that errors encountered in this task had a direct relation with task failure, with a result of 43% completion rate (Figure 7.2).

While condensing all days in one small screen size can give a better visualization of overall consumption in a month, this led to several human errors, such as slips caused by the small space between values, i.e., users were trying to reference a specific point on a chart, but unintentionally referenced another point due to narrow space between daily points. More than 50% failed in this task by reading wrong values due to slips.

For more than 40% of participants, encountered slips created additional delay and frustration for task completion, where it took more than one click to reference the right point on the curve.

Slips in this situation can be considered as severe and serious usability problem that cause a task failure and delay user significantly, and thus need to be addressed.

Since we cannot eliminate "flat fingers", such slips give us a good indication to reduce the amount of data shown (i.e., showing some days in one view with an added functionality like scrolling to view the remaining days, and increasing the size of clickable points on the curve would prevent such unintended human errors.

Two participants mentioned that "adding additional chart showing daily data separately (bar chart) would be an added value to the system".

Also, some participants encountered errors related to tab swapping functionality in android, i.e., while a chart in a zoom-in mode, users where frustrated and irritated by the tab swapping functionality when their intention was to scroll the chart. They suggest that while chart in zoom-in mode, the app should disable the Tab swapping.

Task 7, 8, 1, 11, 19, 20

Tasks (7, 8 - Weekly Monitoring), (10, 11 – Monthly Monitoring), (19,20 – Monitor Goal) received 100% completion rate (Figure 7.2), minimum or no error rate (Figure 7.3), and a very high task satisfaction above 90% (Figure 7.5). They justified their scores on the basis of the fun, entertainment, interactivity and attractiveness an animated chart brings. Many participants stated "Easiness of such an application comes from the graphical representation in use, presenting consumption values with charts is very intuitive since our brains process visual information much faster than textual information".

Task 14

Even though task fourteen received a very minimum error rate (Figure 7.3), most of participants complained about the terminology used in main menu - "Your Tariff", they argued that it was not clear, does not represent functionality in use, and even misleading term. Some participants argued that they figured out how to complete the task from the terms used in scenario, otherwise, they would fail, this could clarify the reason for high completion rate (Figure 7.2). The majority had suggested the term "This hour price" as a simple, obvious term that is easy to figure out for novice users.

Task 15

Task fifteen received same comments about the terminology used in main menu, but this time it had a high impact on task failure and low completion rate (Figure 7.2), one argued "I was confused by the terminology used in main item "TOU Rates", not clear what it means! I think "Today prices" would be sufficient to reflect time-of-use prices for today and would be very clear to figure out, especially by novice user who does not have any knowledge about Time_Of_Use concepts and abbreviations".

The same slips encountered in task four were observed here, it is pretty clear that charts with condensed data should be expanded on multiple views by adding scrolling functionalities.

Task 9, 6

Task 9, 6, received low completion rate (Figure 7.2), low task satisfaction (Figure 7.5), majority of participants complained about location of menu item, they were hidden and difficult for first time users to figure its place, some managed to complete the task by the previous knowledge gained from previous tasks, they argued that comparison functionalities should be contained in a separate menu section called "Compare".

Task 18

Even though majority of participant completed the task successfully (Figure 7.2), task satisfaction was 71% (Figure 7.5), most users waited a considerable time after the task completion, they said "What's Next!". Some users were clicking multiple times on "set target" button waiting for an action. They suggested that a feedback should appear telling them that they have successfully completed the task, or monitoring interface should appear.

Task 17

Received the lowest completion rate 14% (Figure 7.2), second highest error rate 0.89 (Figure 7.3), and lowest task satisfaction (Figure 7.5). One notable finding was with the workflow they followed to perform their task which was totally different than intended workflow by the application developer.

Even though most users reached to the right interface, most users started by clicking on the "ON-OFF switch" button, some have clicked it more than five times before discovering the schedule link. After setting a time to a device schedule, most user didn’t finalize their task by turning the switch button ON and though that the task was finished. Our goal in the next prototype is to follow user's workflow to handle the task and see how this approach will prevent errors and user confusion.

In addition, there were minor usability issues with the application, i.e., small text and value size, small space between bars, some axis titles and chart legends were missing, axis values were continuously changing based on the represented data, and thus, there is no fixed reference values for accurate comparison.

Figure 7.4 shows the descriptive result of the average time taken for tasks completion by expert and novice users. The majority of tasks showed comparable results which assures the easiness of those tasks. An exception goes to tasks 4, 5, 6, 9, 14, 15, 16, 17 for the reasons mentioned in the previous discussion.

7.6 SUS Findings

Our usability testing was designed with an SUS feedback at the end of each session. The results in Table 7.2 were evaluated and calculated using the SUS scoring scale described in Appendix B.7. The Participants scored our interactive application as 84.6, according to the ranking grade of SUS score, our system gets an A, an excellent result but with potential of improvement.

		Strongly Disagree				Strongly Agree
		1	**2**	**3**	**4**	**5**
1.	I think that I would like to use this system frequently.			**1**	**1**	**5**
2.	I found the system unnecessarily complex.	**4**	**2**	**1**		
3.	I thought the system was easy to use.			**1**	**2**	**4**
4.	I think that I would need the support of a technical person to be able to use this system.	**5**	**1**	**1**		
5.	I found the various functions in this system were well integrated.			**2**	**2**	**3**
6.	I thought there was too much inconsistency in this system.	**4**	**3**			
7.	I would imagine that most people would learn to use this system very quickly.			**1**	**3**	**3**
8.	I found the system very cumbersome to use.	**6**	**1**			
9.	I felt very confident using the system.				**1**	**6**
10.	I needed to learn a lot of things before I could get going with this system.	**2**	**5**			

Table 7.2 Cumulative SUS results

Major findings from SUS:

1- 86% of participant strongly agree or agreed that the system was ease to use.
2- 86% strongly disagree that the system is very cumbersome to use.
3- 86% strongly disagree or disagree that they need the support of a technical person to be able to use this system.

4- 86% of participant strongly disagree or disagree to the statement 10, with a notice that people should have the basic knowledge on Time-of-use concepts and terms in order to efficiently use the system, since this application will be used by a wide spectrum of people. They suggested hints to be introduced in the system illustrating TOU terms "on-peak, mid-peak and off-peak".
5- 86% strongly agree or agree that most people would learn to use this system very quickly.
6- 71% strongly agree or agree that various functions in this system were well integrated.
7- 100% strongly agree or agree that they are very confident using this system.
8- 86% strongly agree or agree that they would like to use this system frequently. Most participant argued that such an easy to use mobile application with the provided functionality will indeed increase consumption awareness and motivate consumers behavioral change (reduce their usage or shift to off-peak demand), also electricity will be more fun, engaging and a rewarding process. " For the first time in my life, I can monitor my electricity usage, which let me take smart decisions to reduce my consumption, and thus reduce my bills. Since I am environment-friendly person, I can now monitor the best time to turn on my devices".
9- 57% strongly disagree and 43% disagree that there was too much inconsistency in this system.
10- Results by the statements (4, 7, 10) confirm that the non-functional requirement "Learnability" is fulfilled by the application.
11- Results by the statements (3, 8) confirm that the non-functional requirement "Usability" is fulfilled by the application.

7.7 Final Remarks

Based on the previous results, the following tasks (2, 3, 4, 5, 6, 9, 12, 13, 14, 15, 16, 17) failed to fulfill the performance objectives mentioned in 3.3.5.3, and were chosen for a second usability iteration.

In this aspect, while all the stated functionalities are modified based on the previous usability testing results, we were totally satisfied with the achievements from the first usability testing within this thesis scope, with the aim to hold further usability iterations for future work. However, the same participants of previous usability testing were shown the new version of the MCSG Metering application and a feedback has been recorded and analyzed.

In this stage, participants have expressed a positive feedback about the updated system design and usability, some of their feedback are included here:

- Transparent menu - menu items made the navigation very easy and intuitive. Menu items are simple, user friendly, obvious and easy to figure out. All Related items where categorized well.
- Context indication - I always know where I am all the time (navigational feedback).
- Presentation of values with charts is very intuitive since our brains process visual information much faster than a textual information.
- Consistent look and feel across interfaces.
- Familiarity and consistency of design reduced my learning curve to effectively use the application.
- Interactive design and animation made the app experience more engaging and dynamic.
- Simple and clean design constructed seamless experience.

CHAPTER EIGHT

Discussion and Conclusion

The research has been guided by two major questions:

- *What motivates energy consumption behavior?*
- And *what kind of information needed in a mobile environment to motivate behavioral change towards sustainability?*

Human behavior and behavioral change models introduced in chapter 2 were necessary to understand the theoretical underpinnings of energy use behavior, and advance our knowledge of how to build a technology based solutions that promotes sustainability. The discovered motivations behind energy behavior are several and diverse, they totally fit the majority of people who are interested and motivated by different things.

In this study, we took both perspectives of customers and their counter stakeholders, such as grid owners and electricity suppliers when we built the mobile application. Both provided us with different motivations and requirements. This diversity in requirements has led in contradiction in some aspects, for example, the objective of residential customers is how to reduce their overall consumption in order to see a reduction in their billing cost, while the business-oriented stakeholders may be more interested on load control, where they want to match demand with the available supply. Thus, it is difficult to build an application that fits all.

The proposed MCSG Metering application was implemented to fulfill these motivations and needs. The mobile application provides different levels of detail and timeliness of information, from a real-time information to patterns over a longer period of time, thus, succeeding to achieve consumers desire to have an intelligent system that provides oversight, predictability and raise awareness of electricity consumption.

The advantage of MCSG Metering application is that it was built on a purely scientific basis in term of promoting behavioral change towards pro- environmental behaviour, in contrast to the In-Home-Displays (IHD) available in market, that are built on a commercial basis only, and where some of them has been scientifically proven to yield an increase in the consumption pattern, a concept called boomering effects or take-back effects.

Since the MCSG Metering application has been introduced to deal with diverse users as possible, as people of all genders, educational levels, professions are expected to use it, the application has been tested in regards to its usability. With seven regular test users and one expert user, remarkable findings has been discovered in the first iteration of usability testing that led to further improvement. Within the thesis scope, we were satisfied with what was achieved from the first iteration and hold further usability iterations for future work, however, the second prototype has received very good feedback, the majority of test users were very positive towards using such system and excited that the technology will benefit them in the real life. Almost all of the functionalities were appreciated by one or more participants, but other requirements have been suggested along the way.

CHAPTER NINE

Future Work

There are many directions for future work, stated here briefly.

First Plan: to execute a second usability iteration for the tasks that failed to succeed the following performance objectives:

- Task level satisfaction above 80%.
- Average error rate below 0.5.
- Completion rate above 80%.
- Time based novice efficiency above 60% of time based expert efficiency.

The goal is to address the following question: Are the problems identified in the previous iteration of testing are still encountered in this iteration?

Second Plan: to investigate the adoption and acceptance of the proposed mobile application. Acceptance testing can be conducted using two approaches, qualitative or quantitative method. The quantitative study can be conducted using a validated measurement instrument proposed in [82], which is a questionnaire consisting of questions related to each of the six constructs in the Mobile Acceptance Testing Model.

Third Plan: to examine the following interventions (real time feedback, historical feedback, self-comparison, normative-comparison, electricity prices, tailored information, demand response notification, group and individual goal setting, public commitment, automation, etc.) implemented in MCSG Metering mobile application (individually or in combination) through a field study on a large number of participants, if they would result in:

- Change in energy related behaviors
- Change in energy use.
- Change in knowledge and attitude.
- Long term effectiveness "habit formation".

Our primary focus also is to clarify the extent to which this impact is based on the design and whether mobility of the device impact its overall effectiveness.

References

[1] P. Nejat, F. Jomehzadeh, M. M. Taheri, M. Gohari, M. Z. Abd and Majid, "A global review of energy consumption, CO2 emissions and policy in the residential sector (with an overview of the top ten CO2 emitting countries)," *Renewable and Sustainable Energy Reviews 43,* p. 843–862, 2015.

[2] S. UGARTE, B. v. der REE, M. VOOGT, W. EICHHAMMER, J. A. ORDOÑEZ, M. REUTER, B. SCHLOMANN, P. LLORET and R. VILLAFÁFILA, "Energy Efficiency for Low-Income Households," European Parliament's Committee on Industry, Research and Energy (ITRE)., November 2016.

[3] S. Yang and K. Zhou, "Understanding household energy consumption behavior: The contribution of energy big data analytics," *Renewable and Sustainable Energy Reviews 56,* p. 810–819, 2016.

[4] "Potensial- og barrierestudie. Energieffektivisering i norske bygg.," Enova, Norway, 2012.

[5] C. Fischer, "Feedback on household electricity consumption: a tool for saving energy?," *Energy Efficiency: Springer Science + Business Media,* p. 1:79–104, 6 May 2008.

[6] T. Rothengatter, W. Abrahamse, S. Linda and C. Vlek, "A review of intervention studies aimed at household energy conservation," *Journal of Environmental Psychology Volume 25, Issue 3,* p. Pages 273–291, September 2005.

[7] S. Darby, "The Effectiveness of Feedback on Energy Consumption: A Review for Defra of the Literature on Metering, Billing and Direct Displays," Environmental Change Institute, University of Oxford, 2006.

[8] J. A. “. Laitner, K. Ehrhardt-Martinez and K. . A. Donnelly, "Advanced Metering Initiatives and Residential Feedback Programs: A Meta-Review for Household Electricity-Saving Opportunities.," American Council for an Energy-Efficient Economy, Washington, 2010.

[9] " Global Smart Grid Report- Market Research," NRGExpert, 2011.

[10] W. H. Chin, Z. Fan, P. Kulkarni, S. Gormus, C. Efthymiou, G. Kalogridis, M. Sooriyabandara, Z. Zhu and S. Lambotharan, "Smart Grid Communications: Overview of Research Challenges, Solutions, and Standardization Activities," in *IEEE Communications Surveys and Tutorials*, 15 Dec 2011.

[11] G. P. Hancke, ,. V. C. Gungor, D. Sahin, T. Kocak, S. Ergut, C. Buccella and C. Cecati, "A Survey on Smart Grid Potential Applications and Communication Requirements," *IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS, VOL. 9, NO. 1,* 2013.

[12] M. Liserre, T. Sauter and J. Y. Hung, "Future Energy Systems: Integrating Renewable Energy Sources into the Smart Power Grid Through Industrial Electronics," in *IEEE Industrial Electronics Magazine (Volume: 4, Issue: 1)*, March 2010.

[13] M. Khanna, W. Wang and Y. Xu, "A survey on the communication architectures in smart grid," in *Computer Networks, Volume 55, Issue 15*, 27 October 2011.

[14] X. Fang, S. Misra, G. Xue and D. Yang, "Smart Grid – The New and Improved Power Grid: A Survey," in *IEEE COMMUNICATIONS SURVEYS & TUTORIALS, VOL. 14, NO. 4*, FOURTH QUARTER 2012.

[15] "U.S. Department of Energy," [Online]. Available: https://energy.gov/oe/services/technology-development/smart-grid. [Accessed 10 6 2016].

[16] D. Geelen, A. Reinders and D. Keyson, "Empowering the end-user in smart grids: Recommendations for the design of products and services," *Elsevier*, 2013.

[17] "NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 3.0," *National Institute of Standards Technology*, September 2014.

[18] A. Mahmood, N. Javaid and S. Razzaq, "A review of wireless communications for smart grid," *Renewable and Sustainable Energy Reviews*, p. 41 p. 248–260, 2015.

[19] K. Raahemifar, R. R. Mohassel, A. Fung and F. Mohammadi, "A survey on Advanced Metering Infrastructure," *Electrical Power and Energy Systems 63*, p. p. 473–484, 2014.

[20] United States Department of Energy, "Smart Grid System Report," Department of Energy, Washington, DC, 2014.

[21] Areias and M. Os´orio, "SCADA IN A CLOUD-BASED ARCHITECTURE," *MESTRADO EM SEGURANC¸A INFORMA´ TICA*, 2013.

[22] M. Kuzlu, M. Pipattanasomporn and S. Rahman, "Survey Paper: Communication network requirements for major smart grid," *Elsevier*, p. Computer Networks 67 p. 74–88, 2014.

[23] P. Siano, "Demand response and smart grids—A survey," *Renewable and Sustainable Energy Reviews 30 - Elsevier*, p. p. 461–478, February, 2014.

[24] THE EUROPEAN PARLIAMENT AND THE COUNCIL OF UNION , "DIRECTIVE 2012/27/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC," *Official Journal of the European Union*, pp. 1-315, 2012.

[25] E. COMMISSION, "COMMISSION RECOMMENDATION of 9 March 2012 on preparations for the roll-out of smart metering systems," *Official Journal of the European Union*, pp. 1-74, 2012.

[26] A. Hafeez, N. . H. Kandil, . B. Al-Omar, . T. Landolsi and . A. R. Al-Ali, "Smart Home Area Networks Protocols within the Smart Grid Context," *Journal of*

Communications - Engineering and Technology Publishing, vol. 9, no. 9, pp. 665-671, September 2014.

[27] N. Silva-Send, W. P. Schultz, M. Estrada, J. Schmitt and R. Sokoloski, "Using in-home displays to provide smart meter feedback about household electricity consumption: A randomized control trial comparing kilowatts, cost, and social norms," *Elsevier - Energy xxx,* pp. p. 1-8, 2015.

[28] N. Strother and B. Lockhart, "Smart Meters. Smart Electric Meters, Advanced Metering Infrastructure, and Meter Communications: Global Market Analysis and Forecasts;," *Navigant Research: Boulder, CO, USA,* 2014.

[29] Itziar, N. Uribe-Pérez, L. Hernández, Angulo and D. de la Vega, "State of the Art and Trends Review of Smart Metering in Electricity Grids," *mdpi - Appl. Sci. 6, 68;,* pp. 1-24, 2016.

[30] D. York and M. Kushler,, "Exploring the Relationship Between Demand Response and Energy Efficiency: Between Demand Response and Energy Efficiency:," *American Council for an Energy-Efficient Economy,* pp. 1-90, 2005.

[31] Paul, C. Gerald and T. Gardner, "The Short List: The Most Effective Actions U.S. Households Can Take to Curb Climate Change," *Environment science and policy for sustainable devepoment,* SEPTEMBER/OCTOBER 2008.

[32] M.-I. Alizadeh and J. Aghaei, "Demand response in smart electricity grids equipped with renewable energy sources: A review," *Elsevier - Renewable and Sustainable Energy Reviews 18,* p. 64–72, (2013).

[33] R. K. Jain, Building Eco-Informatics: Examining the Dynamics of Eco-Feedback Design and Peer Networks to Achieve Sustainable Reductions in Energy Consumption, United States: ProQuest, 2013.

[34] E. Matthies, "How can psychologists improve their outreach towards practitioners? A suggestion for a new, integintegrative model of environmentally sound everyday practice.," in *Umweltpsychologie*, 2005.

[35] E. Geller, " The challenge of increasing proenvironmental behavior.," in *Handbook of Environmental Psychology*, New York, 2002.

[36] B. Fogg, "A Behavior Model for Persuasive Design," in *Proceedings of the 4th International Conference on Persuasive Technology*, Claremont, California, USA, April 26 - 29, 2009 .

[37] R. Yun, P. Scupelli, A. Aziz and V. Loftness, "Sustainability in the Workplace: Nine Intervention Techniques for Behavior Change," in *S. Berkovsky and J. Freyne (Eds.): PERSUASIVE 2013, LNCS 7822,,* 2013.

[38] B. Fogg , "Persuasive Computers: Perspectives and Research Directions," *CHI 98,* pp. 18-23.

[39] Oinas-Kukkonen and Harjumaa, "Towards Deeper Understanding of Persuasion in Software and Information Systems.," in *Proceedings of The First International*

Conference on Advances in Human-Computer Interaction (ACHI 2008), Sainte Luce, Martinique,, February 10-15 (2008).

[40] H. Oinas-Kukkonen and M. Harjumaa, "A Systematic Framework for Designing and Evaluating Persuasive Systems.," in *International Conference on Persuasive Technology*, Berlin, Heidelberg, 2008.

[41] B. J. Fogg, "Persuasive Technology: Using Computers to Change What We Think and Do (Interactive Technologies)," 30 December 2002.

[42] W. Abrahamse, L. Steg, C. Vlek and T. Rothengatter, "The effect of tailored information, goal setting, and tailored feedback on household energy use, energy-related behaviors, and behavioral antecedents," *Journal of Environmental Psychology, Volume 27, Issue 4,*, p. 265–276, December 2007.

[43] G. Wood and M. Newborough, "“Energy-Use Information mation Transfer for Intelligent Homes: Enabling Energy Conservation with Central and Local Displays," *Energy and Buildings,* vol. 39, no. 4, p. 495–503, 2007.

[44] J. Froehlich, "Promoting Energy Efficient Behaviors in the Home through Feedback: The Role of Human-Computer Interaction," in *HCIC 2009*, 2009.

[45] M. E. ,. J. S. ,. R. S. P. Wesley Schultz, "Using in-home displays to provide smart meter feedback about household electricity consumption: A randomized control trial comparing kilowatts, cost, and social norms," *Elsevier,* pp. 1-8, 2015.

[46] P. a. G. T. Mell, "The NIST definition of cloud computing, recommendations of the National Institute of Standards and Technology, Special Publication 800-145," NIST, 2011.

[47] A. u. R. Khan, M. Othman, S. A. Madani and S. U. Khan, "A Survey of Mobile Cloud Computing Application Models," *IEEE COMMUNICATIONS SURVEYS & TUTORIALS,* vol. 16, no. 1, pp. 393 - 413, 2014.

[48] T. D. Hoang, C. Lee, D. Niyato and P. Wang, "RESEARCH ARTICLE - A survey of mobile cloud computing: architecture, applications, and approaches," *WIRELESS COMMUNICATIONS AND MOBILE COMPUTING,* vol. 13, p. 1587–1611, 2013.

[49] W.-T. Tsai, R.-S. Chang, J. Gao, V. Gruhn, J. He and G. Roussos, "Mobile Cloud Computing Research – Issues, Challenges, and Needs," in *2013 IEEE Seventh International Symposium on Service-Oriented System Engineering*, 2013.

[50] Bose, S. Debabrata and Rajesh, "A Mobile Cloud Computing Architecture with Easy Resource Sharing," *International Journal of Current Engineering and Technology,* vol. 4, no. 3, pp. 1249 - 1254, 2014.

[51] A. R. Hevner, S. T. March, J. P. Ram and Sudha, "Design Science in Information Systems Research.," *MIS Quarterly,* p. 28(1):75–105, 2004.

[52] S. Gregor and A. . R. Hevner, "POSITIONING AND PRESENTING DESIGN SCIENCE RESEARCH FOR MAXIMUM IMPACT," *MIS Quarterly,* vol. Vol. 37, no. No. 2, pp. 337-355, June 2013.

[53] E.-O. Baek, K. Cagiltay, E. Boling and T. Frick, "User-Centered Design and Development," *Handbook of research on educational communications and technology. Mahwah: Lawrence Erlbaum Associates;*, pp. 659 - 670, 2007.

[54] International Organization for Standardization, "Human centred design for interactive systems," *Ergonomics of human system interaction-Part 210,* 2008.

[55] A. Idri, K. Moumane and A. Alain, "On the Use of Software Quality Standard ISO/IEC 9126 in Mobile Environments," in *20th APSEC conference*, Bangkok, December 2013.

[56] A. Abran, K. Moumane and A. Idri , "Usability evaluation of mobile applications using ISO 9241 and ISO 25062 standards," *Moumane et al. SpringerPlus*, 2016.

[57] A. M. Kim L, "Web design issues when searching for information in a small screen display," in *Proceedings of the 19th annual international conference on computer documentation*, Sante Fe, New Mexico, USA, 2001.

[58] F. Research., "“How Mature Is Your Mobile Strategy?”," May 2011. [Online]. Available: http://blogs.forrester.com/thomas_ husson/10-.

[59] Deloitte, "“So Many Apps – So Little to Download”," 20 Augest 2012.. [Online]. Available: http://www.mondaq.com/x/192692/IT+internet/.

[60] International Organization for Standardization, "Ergonomic requirements for office work with visual display terminals (VDTs) Part 11 Guidance on usability," in *International standard, 9241-11*, Geneve, 1998.

[61] S. Harker, N. Bevan and J. Carter, "ISO 9241-11 revised: What have we learnt about usability since 1998?," *M. Kurosu (ed.): HumaComputer Interaction, Part 1, HCII,* pp. 143-151,, 2015.

[62] J. NIELSEN, "Usability 101: Introduction to Usability," Nielsen Norman Group, 4 January 2012. [Online]. Available: https://www.nngroup.com/articles/usability-101-introduction-to-usability/. [Accessed 4 February 2017].

[63] P. J, A guide to usability: human factors in computing., Boston: Addison Wesley, The Open University, 1993.

[64] A. Kaikkonen, A. Kekäläinen, M. Cankar, T. Kallio and . A. Kankainen, "Usability testing of mobile applications: a comparison between laboratory and field testing.," *J Usability Study,* p. 1:4–16, 2005.

[65] Black and W. Spencer, "Current Practices for Product Usability Testing in Web and Mobile Applications," in *Honors Theses. Paper 226*, Spring 2015.

[66] T. Landauer and J. Nielsen, "A mathematical model of the finding of usability problems," in *In Proceedings of the INTERACT ‘93 and CHI ‘93 conference on human factors in computing systems*, ACM: Amsterdam, The Netherlands;, 1993.

[67] J. NIELSEN, "Usability Metrics," Nielsen Norman Group, 21 January 2001. [Online]. Available: https://www.nngroup.com/articles/usability-metrics/. [Accessed 4 February 2017].

[68] J. Sauro, "RATING THE SEVERITY OF USABILITY PROBLEMS," 2013 July 30. [Online]. Available: http://measuringu.com/rating-severity/. [Accessed 4 February 2017].

[69] C. ROHRER, "When to Use Which User-Experience Research Methods," Nielsen Norman Group, 12 October 2014. [Online]. Available: https://www.nngroup.com/articles/which-ux-research-methods/. [Accessed 4 February 2017].

[70] J. Sauro and J. S. Dumas, "Comparison of Three One-Question, Post-Task Usability Questionnaires," in *CHI 2009*, Boston, Massachusetts, USA, April 4–9 (2009).

[71] B. J, "SUS: a “quick and dirty” usability scale," *In Jordan PW, et al., eds. Usability Evaluation in Industry. London; Bristol: Taylor & Francis;*, p. 189–194, 1996.

[72] A. Bangor, P. Kortum and J. Miller, "Determining what individual SUS scores mean: adding an adjective rating scale.," *J Usability Stud,* p. 4(3):114–123, 2009.

[73] T. Porter and D. R. Miller, "Investigating The Three-Click Rule: A Pilot Study," in *Proceedings of the Eleventh Midwest Association for Information Systems Conference*, , Milwaukee, Wisconsin,, May 19-20, 2016.

[74] J. Sauro, "10 BENCHMARKS FOR USER EXPERIENCE METRICS," measuringu, 16 October 2012. [Online]. Available: https://measuringu.com/ux-benchmarks/. [Accessed 15 May 2016].

[75] J. Nielsen, Usability Engineering, Boston: Academic Press, January 1, 1993.

[76] P. Piejko, "16 mobile market statistics you should know in 2016," 12 April 2016. [Online]. Available: https://deviceatlas.com/blog/16-mobile-market-statistics-you-should-know-2016. [Accessed 21 February 2017].

[77] statista, "Statistics and facts about Smartphones," [Online]. Available: https://www.statista.com/topics/840/smartphones/. [Accessed 21 February 2017].

[78] statcounter, "Mobile internet usage over desktop internet usage," [Online]. Available: http://gs.statcounter.com/press/mobile-internet-usage. [Accessed 22 February 2017].

[79] "Apps Permissions in the Google Play Store," Pew Research Center, US, 2015.

[80] the International Data Corporation (IDC), "Worldwide Quarterly Mobile Phone Tracker," [Online]. Available: http://www.idc.com/tracker/showproductinfo.jsp?prod_id=37. [Accessed 22 February 2017].

[81] P. Kruchten, "Architectural Blueprints," in *The "4+1" View Model of Software*, IEEE Software, 1995, p. 12(6):42–50.

[82] S. Gaoa, J. Krogstieb and K. Siauc, "Adoption of mobile information services: An empirical study," *IOS Press - Mobile Information Systems,* vol. 10, no. 2, p. 147–171, 2014.

[83] IBM, Integrated Web Services Server Administration and Programming Guide, IBM Corporation, First Edition (August 2016).

[84] "Difference between SOAP and REST web services in java," [Online]. Available: http://www.java2blog.com/2016/06/difference-between-soap-and-rest-web-services.html. [Accessed 15 2 2017].

[85] T. Point, Web services - Web application components, Tutorials Point (I) Pvt. Ltd. , 2015.

[86] A. M. Gamaleldin, Development and Deployment of REST Web Services in JAVA | Tutorial / An example for Android-based clients, Software Engineering Competence Center , 2013.

[87] Q. . Z. Sheng, X. Qiao, A. . V. Vasilakos, C. Szabo, S. Bourne and X. Xu, "Web services composition: A decade's overview," *Elsevier,* pp. 218-238, 2014.

[88] L. Richardson, M. Amundsen and . S. Ruby, Restful Web API, United States of America: O'Reilly Media, Inc., 2013.

[89] A. Ranebennur, DEVELOPING GOOGLE ANDROID APPLICATION USING RESTFUL WEB SERVICES, USA: Thesis- San Diego State University, 2014.

[90] "Firebase," google, [Online]. Available: https://firebase.google.com/features/. [Accessed 31 3 2017].

[91] "Firebase Cloud Messaging," [Online]. Available: https://firebase.google.com/docs/cloud-messaging/. [Accessed 31 3 2017].

[92] "FCM Messaging," google, [Online]. Available: https://firebase.google.com/docs/cloud-messaging/concept-options. [Accessed 31 3 2017].

[93] "MPAndroidChart," [Online]. Available: https://github.com/PhilJay/MPAndroidChart. [Accessed 31 3 2017].

[94] "Transmitting Network Data Using Volley," 17 1 2017. [Online]. Available: https://developer.android.com/training/volley/index.html.

[95] "An Introduction to Volley," 13 5 2015. [Online]. Available: https://code.tutsplus.com/tutorials/an-introduction-to-volley--cms-23800.

[96] [Online]. Available: https://github.com/luxiaoming/android-DecoView-charting.

[97] "Facebook SDK for Android," [Online]. Available: https://developers.facebook.com/docs/android/. [Accessed 31 3 2017].

[98] "App Links on Android," [Online]. Available: https://developers.facebook.com/docs/applinks/android. [Accessed 31 3 2017].

[99] "Sharing on Android," [Online]. Available: https://developers.facebook.com/docs/sharing/android. [Accessed 31 3 2017].

[100] P. W. Jordan, B. Thomas, I. . L. McClelland and B. Weerdmeester, "SUS: a "quick and dirty" usability scale.," in *Usability Evaluation In Industry,* London, Taylor and Francis, 1996, p. 189–194.

[101] B. Karimi, V. Namboodiri and M. Jadliwala, "Scalable Meter Data Collection in Smart Grids," *IEEE,* 2015.

[102] X. Fang, S. Misra, G. Xue and D. Yang, "Smart Grid – The New and Improved Power Grid: A Survey," in *IEEE Communications Surveys & Tutorials, Volume: 14, Issue: 4*, 09 December 2011.

[103] N. Bevan, J. Carter, J. Earthy, T. Geis and S. Harker, "New ISO Standards for Usability, Usability Reports and Usability Measures," *M. Kurosu (Ed.): HCI 2016,* p. 268–278, 2015.

[104] A. Pitsillides, N. Komninos and E. Philippou, "Survey in Smart Grid and Smart Home Security: Issues, Challenges and Countermeasures," *IEEE,* 2014.

[105] M. Badra, S. Zeadally, A. Pathan and C. Alcaraz, "Towards Privacy Protection in Smart Grid," *Wireless Personal Communications, vol. 73,* pp. pp. 23-50, 2012.

[106] D. Geelen, . A. Reinders and D. Keyson, "Empowering the end-user in smart grids: Recommendations for the design of products and services," *Elsevier - Energy Policy,* vol. 61, p. 151–161, October 2013.

[107] igi-global, "What is Pro-Environmental Behaviour," [Online]. Available: http://www.igi-global.com/dictionary/pro-environmental-behaviour/56188. [Accessed 15 4 2017].

[108] Google, "The Activity Lifecycle," [Online]. Available: https://developer.android.com/guide/components/activities/activity-lifecycle.html. [Accessed 6 5 2017].

[109] Google, "Fragments," [Online]. Available: https://developer.android.com/guide/components/fragments.html. [Accessed 6 5 2017].

APPENDIX A

Technical Implementation

This section describes in more detail the implementation aspects of MCSG Metering application.

A.1 Server-Side Web Services

For the mobile app to be able to extract data from remote servers, a web service has to be developed. The direct integration of the smart electricity meter to the web eases the development of applications and prototypes on top of the smart electricity meter. As described by the World Wide Web consortium, web service is a software system that provides a standard means of interoperating between software applications running on a variety of platforms and frameworks. Amongst Web Services available, the two most favored architectures are Simple Object Access Protocol (SOAP) and Representational State Transfer (REST) web services. In this section, we compare both architecture in order to reach a discussion of which one is suitable in our case.

A.1.1 SOAP Web Services

SOAP is a standard protocol to create web services, it is a protocol for exchange of information in a decentralized, distributed environment. SOAP is an object-oriented technology that codifies the use of XML as an encoding scheme for request and response parameters using HTTP as a means for transport for exchanging information between computers [83] .

An important aspect of SOAP Web Services is WSDL, stands for Web Service Description Language, an XML file that describes the technicality of how to implement a SOAP web service, including URI of web-services server, functions available, parameters and return type, etc. SOAP web services are hard to maintain as if we do any changes in WSDL, we need to create client stub again. SOAP requires more bandwidth and resources as it uses XML messages to exchange information [84] [85].

A.1.2 RESTful Web Services

REST [86] [87] [88] is an architecture style for designing networked applications. It relies on a stateless, client-server, cacheable communications protocol that uses HTTP protocol. Features of REST that make it unique from other Web services are:

1. **Unique URL mapping:** every resource is mapped to a unique URI, where a resource could be a data or functionality.
2. **Stateless architecture:** the server does not store data from client requests, which means the necessary state to handle the request is contained within the client's request itself, whether as part of the URI, query-string parameters, body, or headers. This allows us to balance the load across multiple servers which, if done correctly can negate any network performance issues.
3. **Limited action verbs:** REST uses the four verbs GET, POST, PUT and DELETE for all its communication and resource handling (post data (create and/or update), read data (e.g., make queries), and delete data, so it is lightweight and simple alternative to the complex mechanisms or protocols used in CORBA, RPC or SOAP.
4. **Standard data exchange formats:** XML and JSON (JavaScript Object Notation) are common structural forms to accomplish cross-platform and cross application solutions to meet a variety of use cases.
5. **Less Message Overhead:** Using SOAP technology, the request and response will be embedded as the "payload" inside a SOAP message, thus adds additional overhead on processing and consumes a lot of bandwidth. Unlike SOAP, REST sends Recourse URL to the server using a simpler HTTP method request, and the HTTP reply will be the raw result data - not encapsulated in a header or envelope, just the data you need directly, REST is particularly useful for limited-bandwidth devices.

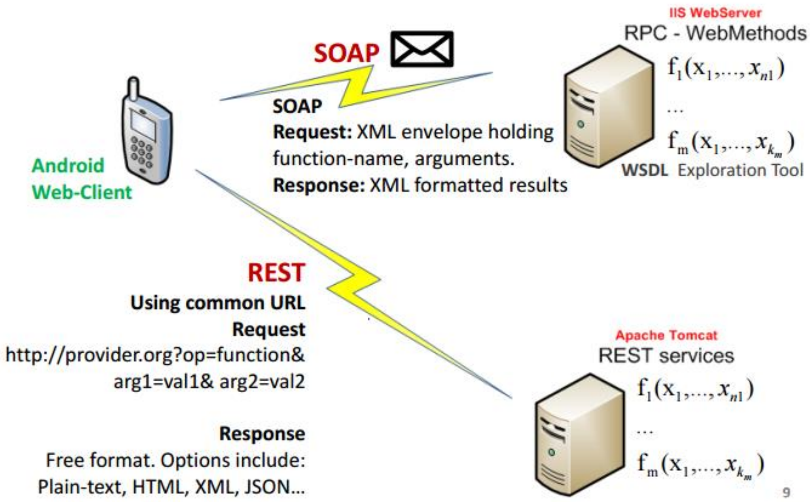


Figure A.1 Rest and SOAP web services

A.1.3 RESTful is Preferred Over SOAP

Since our application does not require the server to maintain the client's state during the transaction, as each and every request to the server would be complete and independent of each other, and since a lightweight protocol is needed, as we are dealing with a resource constraint mobile devices. Rest is definitely a candidate for the application in this thesis.

A.1.4 JSON is Preferred Over XML

JSON and XML are language independent data interchange formats. However, JSON is the candidate within the context of this thesis for the following reasons [89]:

- JSON syntax is lightweight and definitely less verbose than XML.
- XML is comparatively heavy weight with all of its start -end tags and a tree structure for representing the data. When it comes down to pure byte size, JSON can represent the same data as XML using fewer characters.
- JSON parsing is faster; XML parser software is slow and cumbersome, JSON is estimated to parse up to one hundred times faster than XML in modern browsers.
- JSON's structure is intuitive, making it easy to read and map directly to domain objects in whatever programming language is being used.

A.2 External Libraries

The mobile application uses a set of libraries, both for dealing with communication with external sources, and for user interface components, this section describes them accordingly.

A.2.1 Firebase

Firebase is a mobile platform made up of complementary free features that help mobile developers to build their apps. Firebase supports working across platforms with APIs packaged into single SDKs for iOS, Android, JavaScript and C++. Figure A.2 illustrates tools offered by Firebase mobile platform [90].

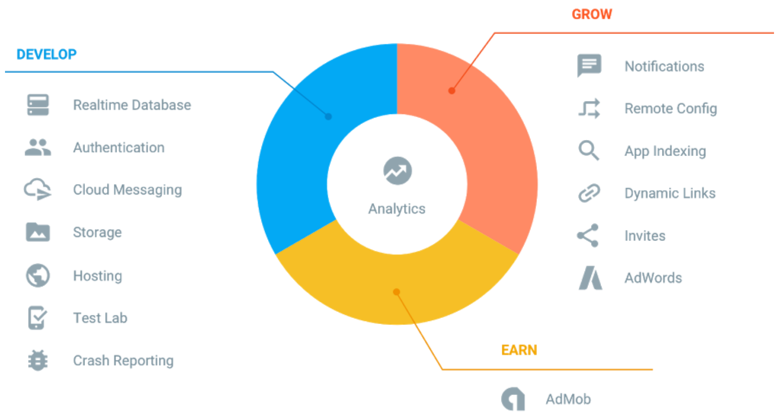


Figure A.2 Firebase mobile platform features [90].

Firebase Cloud Messaging (FCM) is a relevant feature that is implemented in our mobile solution. FCM is a cross-platform messaging solution that lets developers reliably deliver notification messages or data messages to client apps, providing a precious opportunity to drive user reengagement and retention at no cost. Key capability of FCM is its ability to distribute messages to client app in any of three ways – to single devices, to groups of devices, or to devices subscribed to topics [91]. As shown in Figure A.3 FCM implementation includes an app server that interacts with FCM via HTTP or XAMP

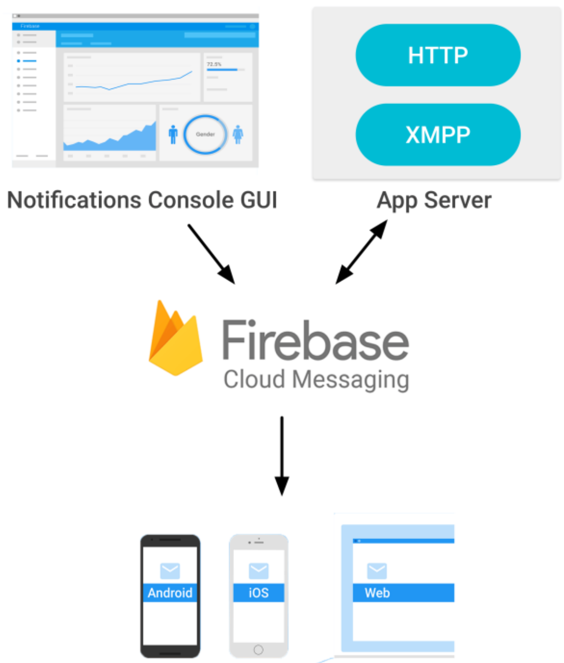


Figure A.3 Firebase Cloud Messaging Implementation [91] protocol, and a client app. An app server or the Notification console are two ways to compose and send messages to the app client [91].

We may need the following credentials for FCM implementation to work [92]:

Sender ID: A unique numerical value created when we create a Firebase project. The sender ID is used to identify each app server that can send messages to the client app.

Server key: A key that authorizes an app server for access to Google services.

Registration token: A secret ID generated by the FCM SDK for each client app instance.

A.2.2 MPAndroidChart

MPAndroidChart is an open source charting library for creating charts in Android applications. The API provides many chart types (Line chart, bar chart, pie chart, scatter chart, candle stick chart, bubble chart, Radar chart, ... etc.) that are highly customizable, interactive, and easy to create. Figure A.4 illustrates different chart types from this library [93].

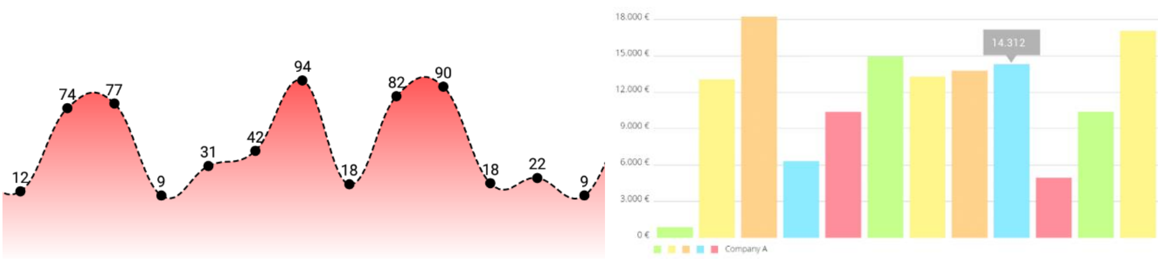


Figure A.4 MPAndroidChart charts [93]

A.2.3 Volley

Volley is an HTTP library that makes networking easier, reliable and faster for Android apps. Volley is a replacement of typically used tools that are filled with known issues and bugs, such as *java.net.HttpURLConnection* and the Apache *org.apache.http.client* . Some of the benefits offered by Volley Library: multiple concurrent network connections. Transparent disk and memory response caching with standard

HTTP cache coherence. Automatic scheduling of network requests, debugging and tracing too, powerful customization ability, etc. [94] [95]

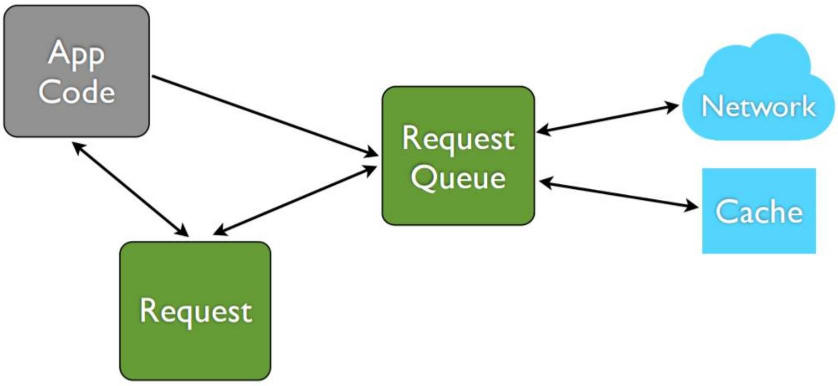


Figure A.5 How Volley Library Works [95]

A.2.4 DecoView

DecoView is a library that enables creation of configurable, animated circular charts in Android apps [96].

A.2.5 Facebook SDK for Android

It enables us to integrate our Android app with Facebook's platform. The SDK provides support for Login with Facebook authentication, sharing content to Facebook API, App links, Graph API, App Invites, and further interesting services [97]. We have used the following services in our app:

App linking: App links is an open standard to deep link to content in mobile app. When the Facebook app comes across a link that supports App Links, it will launch the mobile app version with the right information so the content can be seen immediately and quickly. If the person doesn't have the app installed, they will be redirected to the app's Google Play listing page to download the app. App links enhances user experience and drives traffic and app installs [98].

Sharing: It enables sharing contents from an Android app to Facebook Timeline. Content includes the following: links, photos, videos, multimedia, Open Graph stories, etc. [99].

A.3 Application Code

A.3.1 Implementation Phase One

In this part, steps that the client app follows when performing a specific functionality in it (monitoring daily consumption) and interaction with server-side REST API will be explained in a clear and systematic way using snipped code.

Adding Manifest.xml

For the android client to be able to communicate to a remote server, one needs an essential addition to the File, AndroidManifest.xml present in the Android project.

```
<uses-permission android:name="android.permission.INTERNET" />
```

The URL of Web Service Definition

```
private String URL_FEED = "http://mobile.SGmetering.ps/mcsg-metering/index.php?";
```

Passing Parameters through URL

The client app pass some parameters to the web server based on the client request, include: monitoring period, month and year for the required consumption data.

```
else if(item_type.equals("daily")){

    month= bundle.getInt("month_Picked");
    year=  bundle.getInt("year_Picked");

    params.put("tag", "dailymonitor");
    params.put("month",Integer.toString(month));
    params.put("year",Integer.toString(year));

}
```

Volley Request

The client app uses an jsObjRequest object to call the remote Web Service. This practice is functionally equivalent to running a background thread without blocking the main Android UI thread. The Volley class is responsible for establishing the asynchronous HTTP client-server exchange. In our work, an HTTP POST operation is invoked using the URL mentioned earlier.

```
// making fresh volley request and getting json
CustomRequest jsObjRequest = new CustomRequest(Request.Method.POST, URL_FEED, params, new
Response.Listener<JSONObject>() {

    @Override
    public void onResponse(JSONObject response) {
        VolleyLog.d("Response", "Response: " + response.toString());
        if (response != null) {
```

```
pDialog.dismiss();
parseJsonFeed(response);}
```

***Monitoring Daily Consumption* REST Web Service**

The invoked PHP method extracts its result from a MySql database (Figure A.6) based on passed parameters, calculates daily consumption in KWh and cost, and finally send an encoded JSON response to the Client app.

```
else if ($tag == 'dailymonitor') {
    $month = $_POST['month']؛                    // retrieves passed month value
    $year = $_POST['year']؛                      // retrieves passed year value
    $total=0؛                                    // total energy consumed
    $response["ldailymonitor"] = array؛()        // creates array to store KWh and money values
    $rows = array؛()
    $daynumber = 1؛
    $i=0؛
    $count=0؛
mysql_query('SET CHARACTER SET utf8') ؛
$monitor = mysql_query("SELECT * FROM `Rahbt` WHERE `Date` LIKE  CONCAT('$month','/%')  AND
`Date` LIKE  CONCAT('%/','$year','%') AND `Name`= 'SP100302308'") ؛  // MySQL query retrieves the
required data
  if ($monitor) {
      while($p = mysql_fetch_assoc($monitor)) {       // fetches one raw at a time from retrieved table
      $rows["HourlyUsage"] = $p["HourlyUsage"]؛
      $total = $total +  $rows["HourlyUsage"]؛         // calculate total energy consumed
      if($count == 0 || $count % 24 != 0){
       $rows["day".strval($daynumber)]= $rows["day".strval($daynumber)] + $rows["HourlyUsage"]؛
// calculate daily consumption (summation of hours - KWh)          }
       else {
       $rows["mday".strval($daynumber)]= $rows["day".strval($daynumber)] *0.49؛// calculates daily bill
       array_push($response["ldailymonitor"], $rows)؛
       $daynumber++؛
      $rows["day".strval($daynumber)]= $rows["day".strval($daynumber)] + $rows["HourlyUsage"]؛}
$month= $month+1؛}
       $response["total"] = $total؛
       $response["success"] = 1؛
       echo json_encode($response);} // sends JSON representation of $response array to the mobile client
```

Consumption Data stored in MySQL Database

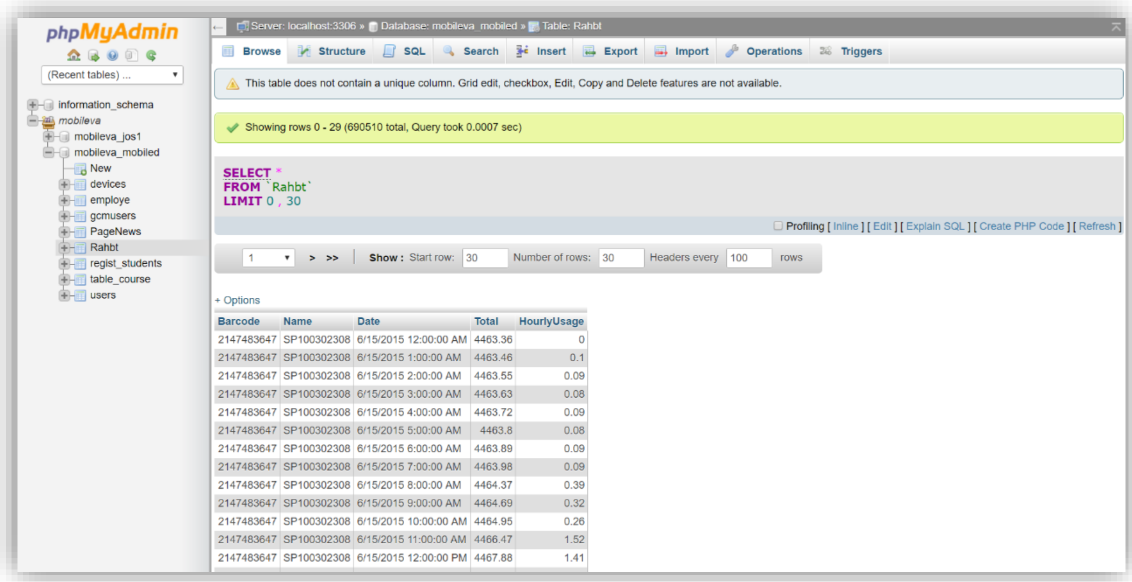


Figure A.6 Hourly consumption stored in MySQL database

HTTP Response (JSON Object):

To test HTTP Response in our case, the log running apps in Android Studio would be an option, however, this approach has several drawbacks, it is time-consuming, since in order to run a query one needs to interact with UI, fill forms, etc., in addition, log output format is usually unreadable and extra work is required to improve data representation. Postman REST Client is a Chrome extension, an HTTP client for testing web services. This extension allows us to examine server-side development apart from client side in an easy, user friendly way.

Figure A.7 shows the Postman request and response viewers for an HTTP Request mentioned earlier.

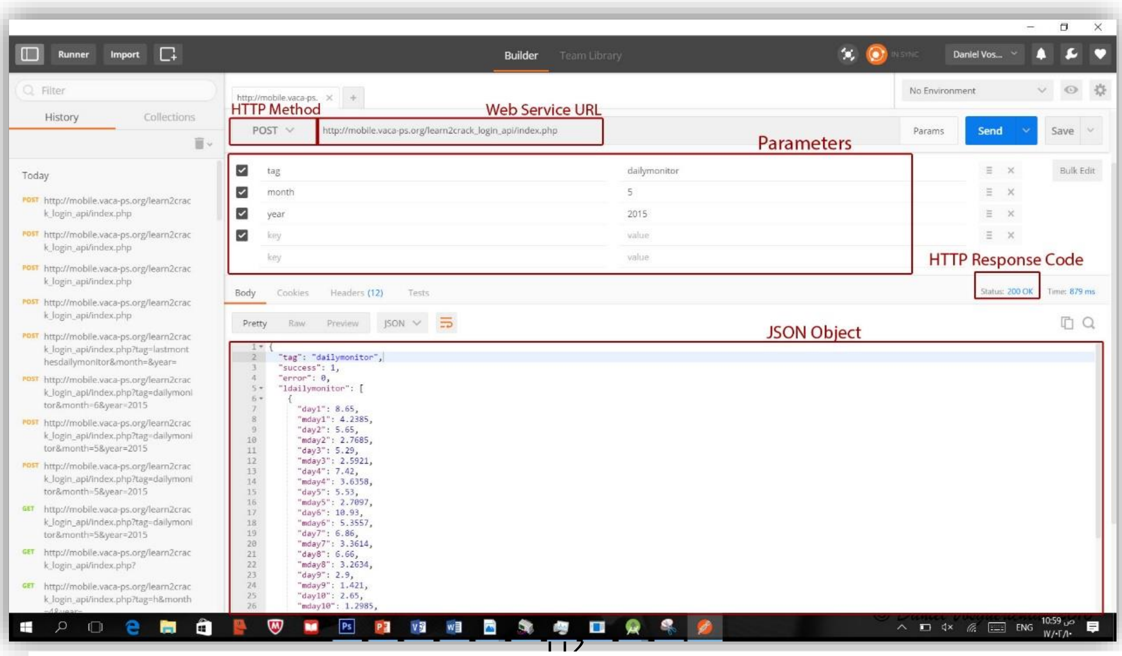


Figure A.7 HTTP request in Postman REST Client Chrome extention

Parsing JSON Response

The client app afterwards collects the JSON response string and decodes it into a Java Array using the JSON parser libraries.

```
_private void parseJsonFeed(JSONObject response) {
else if (item_type.equals("daily")){

   energy_values = new float[31];
   money_values = new float[31];

   totalE= (float)response.getDouble("total");
   totalM = totalE * (float)0.49;

      JSONArray feedArray = response.getJSONArray("ldailymonitor");

   for (int i = 0; i < feedArray.length()&& i!=31 ; i++) {
      JSONObject feedObj = (JSONObject) feedArray.get(i);

      Log.d("day"+ (i+1), Float.toString((float) feedObj.getDouble("day"+ (i+1))));
      Log.d("mday"+ (i+1), Float.toString((float) feedObj.getDouble("mday"+ (i+1))));
      energy_values [i]= (float) feedObj.getDouble("day"+ (i+1));
      money_values [i]= (float) feedObj.getDouble("mday"+ (i+1));
     }
}
```

Drawing Chart

Once JSON response is decoded, the application draws a line chart to represent retrieved data. In order to do so, we have created an XML file containing line chart widget provided by MPAndroidChart library mentioned in 0.

```
<com.github.daniel.charting.charts.LineChart
   android:id="@+id/chart2"
   android:layout_width="match_parent"
   android:layout_height="match_parent"
   android:layout_gravity="right"
   />
```

The KWh and cost data are drawn on the UI using the following code in Java.

```
private void drawChart(int count, float values[]) {

      ArrayList<String> xVals = new ArrayList<String>();
      for (int i = 1; i <= count; i++) {
         xVals.add((i) + "");              // add x-Axis values
      }

      ArrayList<Entry> yVals = new ArrayList<Entry>();
      for (int i = 0; i < values.length; i++) {
         float val = values[i];
         yVals.add(new Entry(val, i));     // add y-Axis values
      }
      // create a dataset and give it a type
      LineDataSet set1 = new LineDataSet(yVals,          Main.mMonthes[Main.month-1]);

       set1.setCircleColor(Color.BLACK);
       set1.setLineWidth(2f);
```

```
        set1.setCircleSize(5f);
        set1.setDrawCircleHole(true);
        set1.setDrawCubic(true);
        set1.setValueTextSize(10f);
        set1.setFillAlpha(90);
        set1.setDrawCircles(true);
        set1.setDrawValues(true);
        set1.setDrawCubic(true);
        set1.setFillAlpha(65);
        set1.setDrawFilled(false);

        if(type.contentEquals("energy")){
          set1.setColor(Color.RED);
        }

        else{
          set1.setValueFormatter(new MyValueFormatter1("money"));
          set1.setColor(ColorTemplate.PASTEL_COLORS[1]);
        }

  ArrayList<ILineDataSet> dataSets = new    ArrayList<ILineDataSet>();
      dataSets.add(set1); // add the datasets

      // create a data object with the datasets
      LineData data = new LineData(xVals, dataSets);

      // set data (pass data to the chart)
      mChart.setScaleMinima(4f, 1f);
      mChart.setData(data);}
```

The whole procedure can be summarized through Figure A.8.

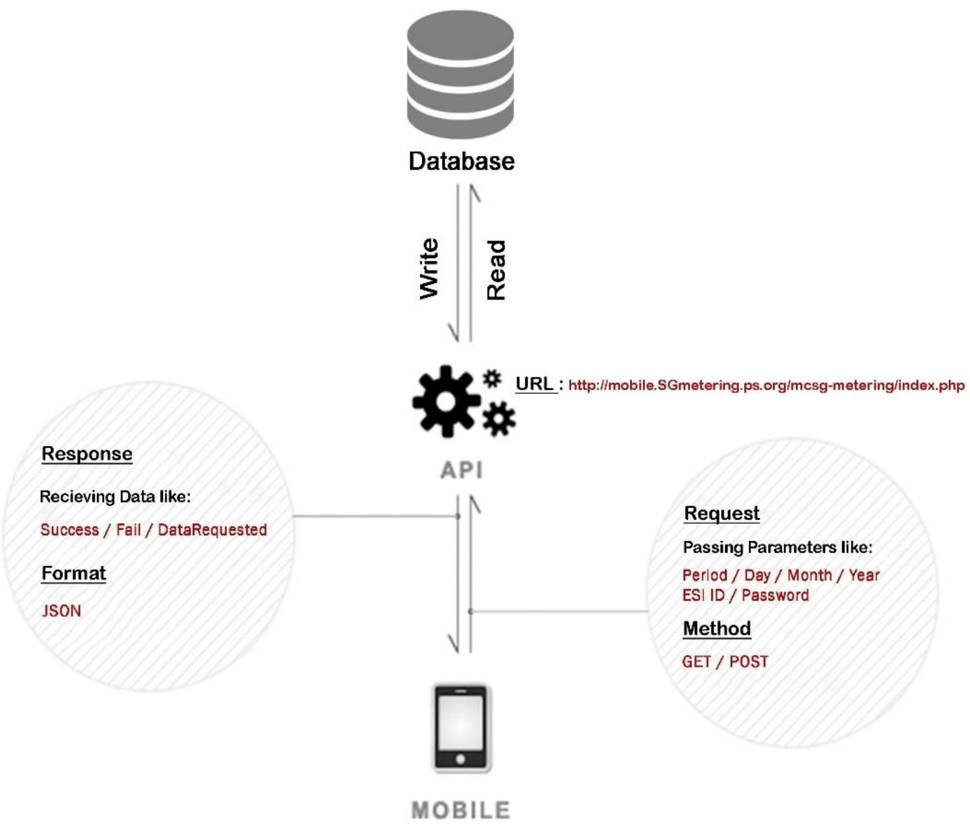


Figure A.8 Requesting consumption data using REST web service

A.3.2 Implementation Phase Two

In this part, steps that the client app follows when registering with Firebase Cloud Messaging and when receiving notifications will be explained in a clear and systematic way.

Adding Manifest.xml

For the android client to be able to receive registration tokens and notifications from FCM server, one needs an essential addition to the AndroidManifest.xml file present in the Android project.

```
<service android:name=".MyFirebaseMessagingService">
   <intent-filter>
      <action android:name="com.google.firebase.MESSAGING_EVENT"/>
   </intent-filter>
</service>
<service android:name=".FirebaseIDService">
   <intent-filter>
      <action android:name="com.google.firebase.INSTANCE_ID_EVENT"/>
   </intent-filter>
</service>
```

Register with FCM

On initial startup of the app, the FCM SDK generates a registration token for the client app instance.

Store token in a remote server

When the client app register with Firebase, FCM SDK generates a registration token for the client app instance. The onTokenRefresh callback fires whenever a new token is generated. In our case, we store the token in a remote server for later use.

```
@Override
public void onTokenRefresh() {
   // Get updated InstanceID token.
   String refreshedToken = FirebaseInstanceId.getInstance().getToken();
   Log.d("Token", "Refreshed token: " + refreshedToken);

   // TODO: Implement this method to send any registration to your app's servers.
   storeToken(refreshedToken);// store token in device's local database
   sendRegistrationToServer(refreshedToken);// store token on our sever
}

private void sendRegistrationToServer( String token) {
// making fresh volley request and getting json
CustomRequest jsObjRequest = new CustomRequest(Request.Method.POST, URL_REGISTER_DEVICE,
params, new Response.Listener<JSONObject>() {


   @Override
```

```
    public void onResponse(JSONObject response) {
        if (response != null) {
            try {
                Toast.makeText(FirebaseIDService.this, response.getString("message"),
Toast.LENGTH_LONG).show();
            } catch (JSONException e) {
                e.printStackTrace();
            }
        }}
```

Restful web service that stores tokens in MySQL database:

The invoked PHP method stores the received token in MySql database, as shown in Figure A.9.

```
//storing token in database
    public function registerDevice($esiid,$token){
        if(!$this->isEmailExist($email)){
            $stmt = $this->con->prepare("INSERT INTO devices (esiid, token) VALUES (?,?) ");
            $stmt->bind_param("ss",$esiid,$token);
            if($stmt->execute())
                return 0; //return 0 means success
            return 1; //return 1 means failure
        }else{
            return 2; //returning 2 means ESI id already exist
        }
    }
```

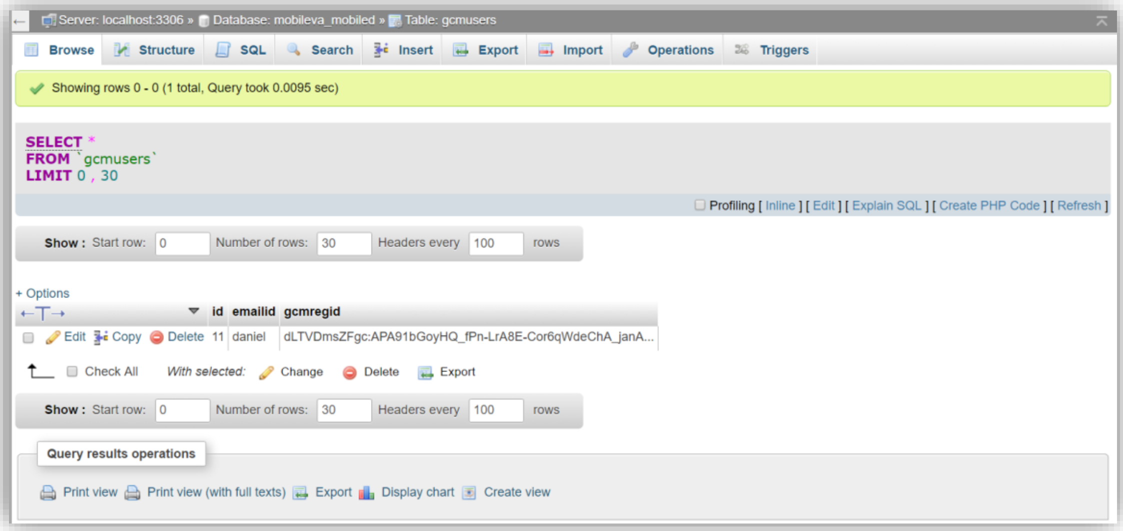


Figure A.9 FCM tokens stored in MySQL database

Push notifications to clients apps

To send a notification to a specific device or a group of devices, one way is to use FCM Notifications Console or to use a customized webpage in our web server.

Figure A.10 shows the FCM Notification Console for pushing notifications on client apps.

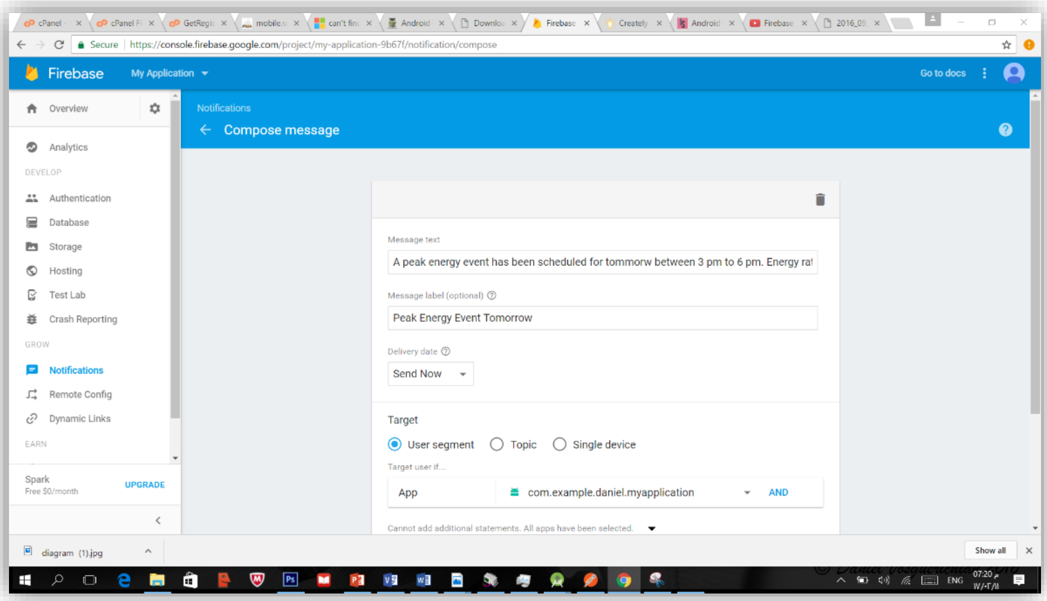


Figure A.10 FCM Notification Console

However, in our case, we have implement a restful web service that handles sending notifications to client apps:

```
if($_SERVER['REQUEST_METHOD']=='POST'){
 //retrieving the required parameters
 if(isset($_POST['title']) and isset($_POST['message']) and isset($_POST['email'])){
 //creating a new push
 $push = null;
 //first check if the push has an image with it
 if(isset($_POST['image'])){
 $push = new Push($_POST['title'], $_POST['message'], $_POST['image'] );
$db->registerNews($_POST['image'], $_POST['title'],$_POST['message']); }
else{
 //if the push don't have an image give null in place of image
 $push = new Push( $_POST['title'], $_POST['message'], null );}
 //getting the push from push object
 $mPushNotification = $push->getPush();
 //getting the token from database object
 $devicetoken = $db->getTokenByEmail($_POST['esiid']);
 //creating firebase class object
 $firebase = new Firebase();
 //sending push notification and displaying result
 echo $firebase->send($devicetoken, $mPushNotification);
```

```
 }else{
 $response['error']=true;
 $response['message']='Parameters missing'; }
}else{
 $response['error']=true;
 $response['message']='Invalid request';}
echo json_encode($response);
```

A.3.3 Implementation Phase Three

In this part, we will illustrate the implementation of public commitment functionality. A feature that allow users to commit conserving electricity in front of public using social media, especially Facebook platform.

Create Fragment and implement android Facebook share button into it

An XML file containing a fragment is created, the fragment consists of ShareButton widget, provided by Facebook SDK, and a TextView explaining the idea to the users.

```
<LinearLayout xmlns:android="http://schemas.android.com/apk/res/android"
    xmlns:app="http://schemas.android.com/apk/res-auto"
    android:orientation="vertical" android:layout_width="match_parent"
    android:weightSum="1">

<TextView
    android:text=" Expand and enhance our conservation efforts and participate with us to save
energy.
\n -   Reduce 10% of your electricity consumption in comparison with previous month."
    android:layout_width="match_parent"
    android:layout_height="wrap_content"
    android:id="@+id/textView50"
    />

<com.facebook.share.widget.ShareButton
    android:text="Commit Publicly to Conserve Energy"
    android:layout_width="match_parent"
    android:layout_height="wrap_content"
    android:id="@+id/fb_share_button"
    android:textColor="@color/about_libraries_primary" />

</LinearLayout>
```

Define Content to be shared

Facebook SDK has different classes for sharing content, in our case, we used the following code:

```
ShareLinkContent content = new ShareLinkContent.Builder()
        .setContentUrl(Uri.parse("https://fb.me/648367435365195?id=1B"))
        .setContentTitle("Daniel Committed to Conserve Energy")
        .setContentDescription("Daniel committed to reduce 10% of his electricity consumption in
```

```
comparison with previous month")
        .setImageUrl(Uri.parse("http://mobile.vaca-ps.org/images/saveelectricity.jpg"))
.build();
```

Methods being used to set Content are: *setContentTitle* method : sets the title of the content. *setImageUrl* method : sets URL of the image to be shared. *setContentDescription* method : sets the description to be shared. *setContentUrl* method : sets the URL of the page to be shared.

APPENDIX B

Usability Testing Materials

The different materials used in the usability testing are presented in this chapter.

B.1 Usability Test Plan

Time	1/1/2017 – 29/1/2017.
Duration	1 hour per person.
Devices	Android smartphone with Internet access.
Software	First prototype of MCSG Metering application.
Users	One expert and seven regular test participants.
Data collection	Notes, recording videos, SUS, SEQ, interviews.
Method	Video Recording is turned on. The introduction about MCSG metering app is read. The test user draws 16 task-scenarios, one at a time (presented in B.2). Each scenario may consist of one or more tasks (presented in B.3). The user fills SEQ after each task (presented in B.4). The user may stop if he fails to complete the task. The user fills out SUS questionnaire (presented in B.6). The user gives general comments, feedback about the system. Post-Questions and deep interview is done (presented in B.5). Video is replayed and usability testing results are noted and analyzed (presented in B.4).

Table B.1 Usability Test Plan

B.2 Task-Scenarios

<u>Scenario 1</u> - *Real Time* Menu Item - 1 Task

You are going to work, you turned off your lights, and majority of devices, but still not sure if something in on, so you decided to check how much power (KW) your house is consuming right now? What shall you conclude?

____

<u>Scenario 2</u> - *Hourly* Menu Item - 2 Tasks

We are in a winter time, and you have turned on your heater with a couple of devices for the past hour. Now, you want to see how much energy and money you have consumed for the last hour (5 – 6 pm)? What shall you do? What is the amount of KWH and ILS for this specific hour?

____

<u>Scenario 3</u> - *Daily* Menu Item - 2 Tasks

You want to monitor your usage in January for each day, what shall you do? From your observation, which day your billing cost was the highest? And what was the amount of money?

____

<u>Scenario 4</u> - *Daily* Menu Item - 1 Task

You want to compare your KWH usage for the last two months on a daily basis, from your observation, was your consumption for electricity increased or decreased?

____

<u>Scenario 5</u> - *Weekly* Menu Item - 3 Tasks

Suppose you are in the second week of May – 2015, and you want to see your total consumption for the last week. What would be your KWH and ILS values?

____

<u>Scenario 6</u> - *Weekly* Menu Item - 1 Task

In the end of January, your billing cost were high, so you decided to change your consumption behaviuor and reduce your usage. At the end of February, you want to compare your consumption for January and February based on a weekly basis to see if you have achieved your goal? After reaching to the corresponding interface, was your usage in the fifth week increased or decreased.

Scenario 7 **-** *Monthly* Menu Item - 2 Tasks

After six months of installing this product on your mobile, you want to compare your consumption based on monthly usage for 2016. In fact, you want to see how your consumption (KWH – ILS) is changing from January till the end of this month. After reaching that interface, what is the month in which your consumption – KWH **-** was the lowest? And what is the month where your bill – ILS – was the highest?

Scenario 8 - *Time of Use* Menu Item **-** 2 Tasks

You are dealing with your electricity provider based on TOU Rates, where price of each KWH usage vary depending on the time-of-day you consume electricity, usually a day is divided into three periods (off Peak, mid Peak, and on Peak periods) where you are charged (0.25 ILS / KWH, 0.50 ILS / KWH, 0.75 ILS / KWH) respectively.

Scenario 9 - *TOU Customer* Menu Item **-** 1 Task ***** *not included in usability test*

you are dealing with your electricity provider based on TOU Rates, where price of your KWH usage vary depending on the time-of-day. what should you do to enable TOU services on this application.

Scenario 10 - *Your Tariff* Menu Item **-** 1 Task ***** due to similarity, we chose one of two

- You are dealing with your contractor based on **Fixed Tariff**, what is the amount of money you pay for each KWH you use?

- You are dealing with your contractor based on **TOU Tariff**, what is the amount of money you pay for each KWH usage in this particular hour?

<u>Scenario 11</u> - *TOU Rates* Menu Item **-** 1 Task

You want to turn on your washing machine, but this hour falls in an on_peak period and the price for each KWH used would be high, so you want to know the nearest time where TOU price would be the lowest.

<u>Scenario 12</u> - *Schedule Device* Menu Item - 1 Task

Your outside home and you want to check if you have forgotten to turn off TV, what shall you do?

<u>Scenario 13</u> - *Schedule Device* Menu Item - 1 Task

You are outside home and you want to remotely schedule your washing machine to run in the nearest time where price is low, what shall you do?

<u>Scenario 14</u> - *Set Goal* Menu Item **-** 1 Task ***** due to similarity, we chose one of two

- If you are a goal oriented person and you want to set a target money for today usage to be within 10 ILS, what would you do?

- If you are a goal oriented person and you want to set a target money for monthly usage to be within 160 ILS, what would you do?

<u>Scenario 15</u> - *Monitor Goal* Menu Item **-** 1 Task ***** due to similarity, we chose one of two

- In the middle of the day and after setting a target money for today's usage, you wanted to keep track and monitor if your electricity usage has reached the target money for today, what shall you go? what is the percentage toward the target you have consumed and what is the remaining money to reach target?

- During the first week of this month (May), you have set a target money for monthly usage to be within 160 ILS. After two weeks from that time, you wanted to keep track and monitor the percentage of your electricity usage toward the target money, what shall you do? what is the percentage reached and what is the remaining money to reach target?

<u>Scenario 16</u> - *Monitor Goal* Menu Item - 1 Task ***** due to similarity, we chose one of two

-While monitoring your target money for today, you want to see the distribution of today's KWH consumption in the three periods (off peak, mid peak and on peak), what shall you do? how much KWH you have consumed in “off_Peak” period?

-While monitoring your target money for today, you want to see the distribution of monthly KWH consumption in the three periods (off peak, mid peak and on peak), what shall you do? how much KWH you have consumed in “off_Peak” period?

B.3 Usability Testing Tasks

Menu Items	**Tasks**	
Real time	1)	Find out how much power (KW) your house is consuming right now?
Hourly	2)	What is the amount of KWH consumed between 5 – 6 pm?
	3)	What is the billing cost for electricity consumed between 5 – 6 pm?
Daily	4)	Which day in January where your KWH was the highest?
	5)	What was the highest amount of money per day in January?
	6)	Based on a daily usage data, compare between last two months' usage? Was your consumption increased or decreased?
Weekly	7)	What is the total KWH consumed in the first week of February?

	8)	What is the corresponding ILS value for the first week of February?
	9)	While comparing between January and February usage on a weekly basis, was your KWH usage increased or decreased in the fifth week?
Monthly	10)	Which month in 2016 where your KWH consumption was the lowest?
	11)	Which month in 2016 where your billing cost was the highest?
Time of Use	12)	For today usage, how much KWH you have consumed in “on_Peak” period?
	13)	For today usage, how much money you would pay for usage in “on_Peak” period?
Your Tariff	14)	You are dealing with your contractor based on Fixed Tariff / TOU Rates, what is the amount of money you pay for each KWH you use?
TOU Rates	15)	What is the nearest time where TOU price is the lowest?
Home Automation	16)	What is the amount of instant power the TV Outlet is consuming now?
	17)	Try to schedule the Washing machine to work in the nearest time where TOU price is the lowest.
Set A Goal	18)	Set a target money for today to be within 10 ILS. Set a target money for this month to be within 150 ILS.
Monitor Goal	19)	What is the percentage toward the target you have consumed and what is the remaining money to reach Todays target?

		What is the percentage toward the target you have consumed and what is the remaining money to reach this month target?
	20)	For today's usage, how much KWH you have consumed in an “off_Peak” period?

Table B.2 Usability Testing Tasks

B.4 Usability Testing Results Sheet

Participant #____

<table>
<tr><td colspan="4">Scenario #</td></tr>
<tr><td>Task Success</td><td colspan="3">1 - succeed 0 - failed</td></tr>
<tr><td>Task Time</td><td colspan="2"></td><td>Task Time</td></tr>
<tr><td rowspan="6">Task Errors</td><td>Repetition</td><td colspan="2">Description</td></tr>
<tr><td></td><td colspan="2"></td></tr>
<tr><td></td><td colspan="2"></td></tr>
<tr><td></td><td colspan="2"></td></tr>
<tr><td></td><td colspan="2"></td></tr>
<tr><td></td><td colspan="2">TOTAL</td></tr>
<tr><td>Task-level satisfaction (SEQ)</td><td colspan="3">Very Difficult 1 2 3 4 5 Very Easy</td></tr>
<tr><td>Comments, Suggestions, Difficulties</td><td colspan="3"></td></tr>
</table>

Table B.3 Usability Testing Results Sheet

B.5 Interview Questions

	Post-Questions / User Impressions	**User Response**
1)	What is your overall impression to the system?	
2)	What did you like best about the system?	
3)	What did you like least about the system?	
4)	What was easy to use or understand about the system?	
5)	What was difficult to use or understand about the	
6)	If you were the mobile developer, what are the things you would do to improve the website?	
7)	Is there anything that you feel is missing on this system?	
8)	If you were to describe this application to a colleague in a sentence or two, what would you say?	

Table B.4 Interview Questions

B.6 System Usability Scale – Overall Satisfaction

		Strongly Disagree				Strongly Agree
1)	I think that I would like to use this system frequently.	1	2	3	4	5
2)	I found the system unnecessarily complex.	1	2	3	4	5
3)	I thought the system was easy to use.	1	2	3	4	5
4)	I think that I would need the support of a technical person to be able to use this system.	1	2	3	4	5
5)	I found the various functions in this system were well integrated.	1	2	3	4	5
6)	I thought there was too much inconsistency in this system.	1	2	3	4	5
7)	I would imagine that most people would learn to use this system very quickly.	1	2	3	4	5
8)	I found the system very cumbersome to use.	1	2	3	4	5
9)	I felt very confident using the system.	1	2	3	4	5
10)	I needed to learn a lot of things before I could get going with this system.	1	2	3	4	5

Table B.5 System Usability Scale – Overall Satisfaction

B.7 Calculate System Usability Scale Score

To calculate the SUS score [100]:

1) For odd numbered items, the score contribution equals (scale position – 1).
2) For even numbered items, the score contribution equals (5 - scale position).
3) Sum the 10 items scores.
4) Multiply the sum by 2.5.
5) SUS scores have a range of 0 to 100.

مقاربة المحمول السحابية المستندة لنموذج التغيير السلوكي من أجل ترشيد استهلاك الطاقة

اعداد: دانيال وليام هاكوب فوسكرجيان

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الملخص

يعتبر ترشيد استهلاك الطاقة، أحد أهم الأهداف التي يطمح اليها كل مجتمع عامة، و نظام السلطة خاصة.

ومع ظهور شبكات الكهرباء الذكية، من المتوقع أن ينتقل المستخدمون، من دورهم كمستهلكين للكهرباء فقط، لدور مساهم نشط، يشار إليهم "كمزوّد مشارك"، وهو مصطلح.. يعكس قدرة المستهلك على الحدّ من استهلاك الكهرباء، وتحويل الاستهلاك.. من فترات الذروة.. الي فترات الاستهلاك المنخفض.. وتوليد الكهرباء، والاتجار بها..

من أجل بناء تطبيق هاتف ذكي، يُعنى بترشيد استهلاك الطاقة، ويهدف إلى تعزيز السلوك المؤيد للبيئة، وتمكين المستخدمين لهذا التطبيق، لتولي دورا نشطا يسمى.. "مزود مشارك"، تبدأ الرسالة حول هذا الموضوع.. بالبحث في الدوافع.. وراء سلوك الانسان السلبي في استهلاك الكهرباء، ومن ثمّ ، تحديد المعلومات التي يمكن ادراجها في بيئة الهاتف المحمول.. لتحفيز التغيير السلوكي الايجابي للانسان في استخدامه للكهرباء.. ومن اجل ان يكون هذا التغير مستداما.

واستنادا إلى نماذج تغيير السلوك البيئي المختلفة.. والذي يتحدّث عنها علم السلوك، وكذلك دراسة المستخدمين المحتملين للنظام، تم اقتراح نموذج هجين لتغيير السلوك في استهلاك الطاقة، كما تم تحديد مجموعة من متطلبات النظام، والتي قادتنا الى تصميم وتطوير تطبيق هاتف ذكي يسمى:

Mobile Cloud for Smart Grid Metering (MCSG Metering)

وهذا الحل ، يستخدم تقنيات مختلفة.. لتشجيع السلوك المؤيد للبيئة، على سبيل المثال :– العدادات الذكية، تكنولوجيا الحوسبة السحابية، تكنولوجيا الحوسبة المتنقلة، وتكنولوجيا الاقناع، وتقنيات تغيير السلوك.

وقد تم تنفيذ عملية التصميم ، باستخدام نهج "التصميم الموجه للمستخدم" (UCD) ، والبحث العلمي في الرسالة ، اتّبع طريقة "علم التصميم" (DSRM).

وبالمقارنة مع شاشات العرض المنزلية التي تعرض فقط قياسات الطاقة اللحظية، يتضمن التطبيق.. المحفزات التالية لتغير السلوك الايجابي وهي:- رؤية مقدار الاستهلاك اللحظي للكهرباء، رؤية مقدار الاستهلاك للفترات السابقة، المقارنة الذاتية، المقارنة المعيارية (المقارنة مع الغير)، تحديد الأهداف، الالتزام امام العامة عبر مواقع التواصل الاجتماعي، الأتمتة، وغيرها.

في هذه الدراسة، تم تقييم التطبيق من حيث سهولة الاستخدام، وهو أمر ذو أهمية كبيرة عندما يتعلق الأمر ببناء أداة جذابة لإدارة الطاقة التي يتم استخدامها بشكل متكرر لفترات طويلة من قبل الفرد. وسجل المشاركون في اختبار سهولة الاستخدام لهذا التطبيق التفاعلي الرقم 84.6٪. ووفقا لدرجة التصنيف من المقياس العالمي System Usability Scale (SUS) ، حصل نظامنا على درجة A، وهي نتيجة ممتازة، مع إمكانية تحسين هذا النظام.

والرسالة سوف تصف الهيكلية، التصميم والتطبيق لِ MSCG Metering، بالاضافة الى تقديم ومناقشة نتائج تقييم سهولة استخدام البرنامج.