

Power Down: Analyzing effectiveness of different feedback techniques towards reducing energy consumption for dormitory residents.

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Keywords: Feedback techniques, Energy reduction, Dormitory residents, Smart Electricity Meters , Raspberry Pi Controller , Statistical Analysis.

Certificate

This is to certify that the thesis titled “**Power Down: Analyzing effectiveness of different feedback techniques towards reducing energy consumption for dormitory residents**” submitted by **Deepika** for the partial fulfillment of the requirements for the degree of *Master of Technology in Computer Science & Engineering* is a record of the bonafide work carried out by her under guidance and supervision in the Mobile and Ubiquitous Computing group at Indraprastha Institute of Information Technology, Delhi. This work has not been submitted anywhere else for the reward of any other degree.

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Abstract

Energy has become basis of human life today. Practically, we rely on energy for everything we do every single day. As a result, the rate of consumption of energy has increased manifold and thereby has become a global problem. Recent research work has explored solutions to address the problem of increased energy consumption by providing efficient feedback about consumption patterns to individuals so as to motivate them to alter the activities performed as personal choices within the built environment. Prior studies indicate that University Residential environment provide an excellent venue to explore different feedback mechanisms for energy consumption. However, majority of the studies, typically done in the developed world, have conducted competitions as approach to study and alter the behavior of Dormitory residents.

Our work contributes to the understanding of feedback mechanisms, in a developing economy, through ten week study that we term as “Power Down”. The goal of the study was to analyze how different approaches influence and alter the behavior of dormitory residents to reduce energy consumption in a university residential settings.

The study involved five different phases, each spanning a duration of 2 weeks

- **Phase-1:** General Awareness
- **Phase-2:** Comparing individual and generalized feedback
- **Phase-3:** Online Feedback
- **Phase-4:** Competition Phase
- **Phase-5:** Post-Competition Phase.

During each phase, real time energy consumption data was collected for the participating group of students using electricity meters installed at the wing level. We believe this is the first such study, done in the context of developing country, that performs in-depth assessment of effectiveness of different feedback approaches towards motivating the dormitory residents in reducing their energy consumption.

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Chapter 1

Introduction

1.1 Background

Today, the world is in the grip of energy crisis. Over the past few decades, there has been significant increase in Energy Consumption with India contributing to this global increase in major way. India became the fifth largest energy consumer in the world in 2006, emitting 4.4% of Global Carbon emissions [8]. According to Global Energy Statistical yearbook 2013, India recorded the highest Energy consumption increase in 2012 amongst the BRICS countries with an increase of 5.1% [19].

This steady increase can be partially attributed to human activities mainly inside the built environment. According to International Energy Agency, the building sector accounts for the largest share(47%) of India's Energy Use in 2005 with residential settings accounting for this major 93% of total building Energy Use [10]. Also, recent studies have estimated that Residential Energy Consumption can be reduced by 22-30% within next 5-8 years purely through Behavioral changes. Thus, modifying human behavior is very important to bring about this reduce in Global Energy Consumption. Previous studies have demonstrated that in residential settings 50% of Energy Use depends on lifestyle choices while the balance depends on physical characteristics of buildings and building equipments [17].

Motivating individuals to change their Energy Consumption behavior has been an active area of research in both Residential and Commercial Settings. Much of the work has focused on residential settings wherein individuals who directly consume the resource pay for it. On the other hand, in commercial settings, employees share the resources and organization pay for it, resulting in minimal participation by employees towards Energy Conservation. Between Residential and commercial setting (Example: University Dorms) wherein though people share the resources (similar to commercial settings), but have to pay for it (similar to residential settings). One of the most interesting aspect of the University Dorm Setting is that Electricity Bill is equally split among the students sharing the dormitory in spite of unequal consumption of dorm-mates.

Also prior studies indicate that substantial percentage of total campus resource use takes place within the dormitories. For Example: In 2004, the per-student consumption of resources in building at Oberlin College included 8000 Kwh of Electricity [15]. Also students inside the dormitories have a high degree of control over personal choices like to switch off the Lights when they leave the room or unplug the charges when not in use. Also, students exhibit a high level of concern for environmental problems. Thus college dormitories provide an excellent venue for conservation measure.

From past research, it has been observed that there are three interrelated factors that are necessary to stimulate occupants to exhibit practices that conserve resources :Knowledge, motivation and Control [11]. However these factors may vary in dormitories in comparison to other residential settings as there is no direct financial incentive to reduce financial incentive to reduce Energy Consumption as they pay equally regardless of how they consume. A major challenge for people, who are willing to conserve energy and reduce carbon emissions in their residential units, is the lack of intuitive and persuasive information/feedback about their energy consumption [9]. This is particularly true for College Students inside the dormitories as their consumption is typically hidden to them. So if dorm occupants are made aware of the magnitude of their energy use, they may feel motivated to conserve. Now the question comes, how to make the dorm-residents aware and motivate them to consume less. This is where the concept of feedback comes into play. Feedback has been proved to be an effective strategy to reduce household energy use [1]. The survey of 20 studies finds that, on average, the introduction of a direct and continuous (real-time) feedback system leads to reduction of energy usage ranging from 5%15% or even more [6].

So a potential approach which aims at altering human behavior is providing the occupants with feedback about their consumption. An Average reduction of 7.4% in consumption has been observed when occupants were provided with feedback about their consumption [7]. A comprehensive review of 38 studies of household energy use conducted over last 25 years concluded that information feedback on rates of consumption provided to building occupants can increase awareness and motivate decreased energy use.

1.2 Related Work

The work presented in this report belongs to the area of reducing Energy Consumption within University residential Settings. This section presents some of the related work in area to the experiment presented in this report.

There have been several studies in the past analyzing the effect of feedback in different forms in University Residential Settings. In 2004, tufts University, USA conducted a pilot study to reduce electricity use where Dormitory residents were exposed to an educational program only, while residents of the experimental dorm were exposed to the same educational program as well as a social marketing campaign with no real time feedback data [13]. Also in 2009, University of Michigan adopted a multi-method approach including focus groups, behavioral observations, environmental measures, and web surveys as an effort to analyze the effect of different approaches to reduce consumption [12].

More Recently researchers have started deploying technologies to study their influence on energy consumption behavior in University Dorm settings. Most of these research [5], deploy energy monitoring technologies in dorm settings and provide web based feedback to the students. Also, Eco-Feedback, Social Incentives, data visualization have been employed before in various settings [2] and significant reduction of about 16.2% in daytime and 10% during nighttime has been observed signifying the effect of feedback.

Besides these, main focus of reducing resource using feedback have focused on organizing Dorm Energy Competitions. Energy Competitions on college campuses involve dormitory occupants, residence halls competing to see which buildings can use least energy over time. The most basic type of energy competition website displays energy data which is updated manually on a periodic basis(such as weekly). The Wellesley College Green Cup [16] is an example of this type of competition.

Petersen et al. [15] describe their experiences deploying a real time feedback system in an Oberlin College dorm energy competition in 2005. It compared the effect of data resolution in conservation behavior, and found that dorms receiving real-time high resolution feedback were more effective at conservation, reducing their electricity consumption by 55% compared to 31% for low resolution dorms. Brewer R.S.et al. [3] also conducted a Dorm Energy Competition Focused on Sustainable Behavior Change and Energy Literacy. They used a personalized homepage where students can complete tasks designed to increase energy literacy. In 2008, Odom W.et al. [14] provides Students in 10 dormitories with feedback primarily through the Energy Challenge website, updates were sent to students via a Facebook group and email. The competition resulted in an estimated combined avoidance of 33,008 kilowatt hours(KWh) of electricity and 724,322 gallons of water compared to baseline consumption of the previous three years.

There have also been several studies in University Residential settings, all typically in developed world, especially USA [15] where most of these studies aim at organizing Dorm Energy Competition. In dorm settings, there have been no sustainability-related studies in developing regions. Hence, we deployed an energy monitoring system in boys and girls dorm in an Indian University, and conducted a series of study to understand the impact of different kinds of feedback on energy consumption behavior.

Chapter 2

Research Contribution

In context to closely related work, this report makes the following contributions :

- We conducted a ten week Study named **POWER DOWN** in College dormitories of Indraprastha Institute of Information Technology (IIIT-Delhi) with total of 432 participants. The study derived its name as Power Down in significance to its aim of reducing the Power Consumption within the College dormitories. The study was conducted in both Girls and Boys dormitories. The main goal of the study was to assess the effectiveness of different approaches adopted and to analyze which approach works best to motivate in modifying the occupants behavior.
- The work presented in this report is the first research study in India to analyze the effect of different types of feedback in the direction of reducing energy consumption in University Residential settings aiming at altering the behavior of the occupants by providing feedback about their consumption. While there has been significant work in this area in many developed countries, but this initiative to study the effect of different approaches adopted using awareness, daily feedback, weekly feedback, real time web based feedback, competition within the dormitories offers a fresh perspective and a novel contribution in this area of research.
- We conduct Statistical analysis on the consumption data of the occupants to test the effectiveness of the approaches adopted. We present in detail about each discriminatory approach adopted and statistical analysis to demonstrate its impact.

Chapter 3

System Design

3.1 Overview

As part of the energy Conservation Drive, the IIIT-Delhi installed Smart Electricity Meters that are able to collect Energy Consumption information of its occupant for every wing within Girls and Boys Dormitories. From more than 50 such meters installed, about 1.5 million data points are being collected every day. Two Smart Meters in each wing of Girls Dormitory and two-three in each wing of Boys Dormitory (depending on the size of the wing) were deployed in the campus. Every Smart Meter measures raw power supply and backup power supply of the wing and this data is being collected every 30 seconds. These data points being collected contains the occupant's consumption information.

Power Down uses this data being collected using Smart Meters to display the consumption information to its occupants in various forms as specified in Chapter 4.

3.2 System Architecture

This Section provides with brief knowledge of the architecture behind how data is being collected and how it is being made available to the users.

As specified in the above section, Smart Meters were deployed in every wing of both Boys and Girls Dormitory of the campus. These smart meter measures data in the form of raw power supply and backup power supply and this data is being collected every 30 seconds. Multiple of such meters were connected over common RS485 bus and data was being pulled using Raspberry pi controller(with a Modbus to USB converted connected with it), where Raspberry pi are low cost single board computers used for data collection. To expose this collected data pulled via Raspberry pi controller, sMAP platform plays the entire role. Figure 3.1 represents simple data flow path from dormitories to occupants.

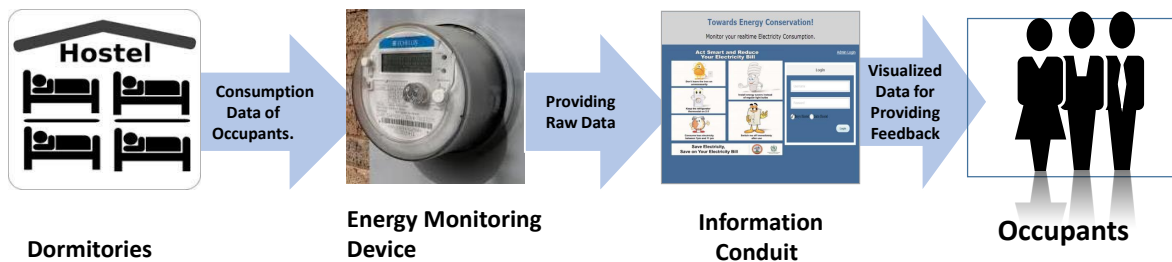


Figure 3.1: Simple data flow representing how occupants receive Feedback.

3.2.1 sMAP(Simple Measurement and Actuation Profile)

Definition

To display the collected data, our system use sMAP Platform.

sMAP or Simple Measurement and Actuation Profile is a specification for a protocol which easily and quickly exposes and publishes time-series data from a wide variety of sensors.

The sMAP provides the following utility [4]:

1. A specification for transmitting data and describing its contents
2. Set of free and open drivers to communicate with various devices using protocols
3. Tools for building, organizing, and querying large repositories of data.

This subsection provides the concept on how sMAP works to display the collected data. sMAP architecture consists of three main components:

- **sMap Sources:** sMap sources are designed to communicate with existing devices and expose their readings/values to the system. It contains one or more drivers which contains code to communicate with sources of data. sMap sources typically act as feeders for the sMap Archiver. In our System, sMap sources is installed on Raspberry Pi, which communicates with existing Smart Meters, and relay the information obtained to the sMap Archiver for storage.
- **sMap Archiver:**The sMap Archiver is a service which acts as a data-store for all the information provided by sMAP sources. It manages very large volumes of data efficiently and supports all the standard functions that databases offer such as altering, deletion and querying on the stored data.
- **Applications on top of the sMap Archiver:**Applications are built on top of sMAP Archiver and make use of the data stored in sMAP Archiver to built attractive application.

The real time web based feedback designed as part of our study to provide real time consumption

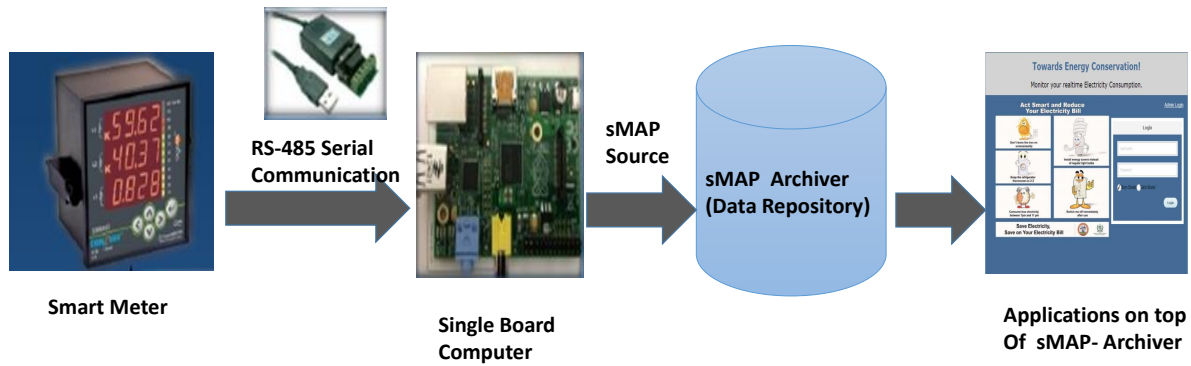


Figure 3.2: System Architecture representing how data is made available for visualization using sMAP Platform in IIIT-Delhi.

feedback to its occupants was also based on above sMAP platform principle. sMap source were installed on Raspberry Pi, which communicates with existing Smart Meters, and provide the information obtained to the sMap Archiver for storage. The Web application was then build on top of sMAP archiver which queries the desired data from sMAP archiver without bearing any direct connection with the sources and provides attractive visualizations to its users. Figure 3.2 provides the brief of System Architecture discussed above.

Chapter 4

Study Design

This section presents in detail what were different phases involved in the study and presents in detail different methods adopted during its each phase. The aim of our study was to assess users behavior when provided with different type of feedback, to analyze the effectiveness of each phase and to further apply the best methodology/approach in future technology solutions.

4.1 Participants

Total 432 participants (64.2% Male, 35.8% Female) were part of the study. Table 4.1 specifies the demography of the participants in brief.

	Number of Participants	Course Pursuing				Occupancy	
		B-Tech	M-Tech	PhD	RA	Single	Shared
Male	277	199	48	22	8	77	78
Female	155	103	34	16	2	133	144

Table 4.1: Participants Demography

4.2 Grouping

The Study targets occupants of both Girls and Boys Dormitories of the campus with total of 432 participants from which Boys constituted total of 277 participants and Girls constituted total of 155 participants.98.9% Boys with respect to Entire Boys Dormitory and 97.4% of Girls with respect to Entire Girls Dormitory participated. Rest 1.1% Boys and 2.6% Girls were not part of the study as they had their rooms on Ground Floor which also included Common Room, Warden Room, Room for other services such as Iron. So to maintain consistency with all groups under study,occupants of Ground floor of each of the dormitory were excluded as part of the study.

The data is being collected through the smart meters at wing level, so the participants were divided into total of 18 groups. Each group constituted some number of rooms based on meters installation with each group constituting one or more wings. Out of 18 groups, 10 groups formed part of Boys Dormitory and rest 8 groups as part of Girls Dormitory.

Each group within the Girls and Boys Dormitory was assigned with a unique name to represent with. The unique naming convention was followed to represent a particular group. the Unique Naming Convention:

- (i) The First Letter of the Group indicates whether the particular group belonged to Boys or Girls Hostel with G indicating Girls Hostel
B indicating Boys Hostel.
- (ii) The next two letters indicates the wings in particular group. Note that for some of the groups of the girls hostel based on meter installation, these two letters may include only part of a particular wing also.
- (iii) The Next numeral indicates the floor of the Hostel. For Example: Group G_AB1 indicates Girls Hostel, AB Wing ,First Floor.

The Table 4.2 and Table 4.3 specifies the information about groups within Boys and Girls Dormitories in brief.

4.3 Methodology

The entire power down study was of three months time period with its Onset from third week of January till third week of April. The study mainly involved five phases each of 2 weeks combined with an initial Baseline Phase, also termed as Energy Monitoring phase for analysis purposes.

For Study purposes, we have taken following conditions into account:

1. Baseline Phase(20th Jan, 2014 - 2nd Feb, 2014):This is also called Phase 0. Time duration of this phase was 2 weeks. This phase started from third week of January and it continued till the end of January. Before the actual beginning of the study, we have taken into account an Initial Phase or Phase 0 called Baseline Phase for analysis purposes. It was named as Energy Monitoring Phase. In this phase, without giving occupants any information about the study, we were collecting data of the occupants to get the consumption data for each of the group. This data was being collected to monitor the energy consumption of the occupants prior to the study. Data was also being collected so that we have data to compare and to assess if study lead to any change in consumption pattern of the occupants or not. This phase comprised of just collecting the occupant's data prior to the study.

2. Baseline Group: One group each from Boys and Girls dormitory were not provided with any type of feedback throughout the study and were considered as baseline groups. The Baseline

Group Name	No. of Occupants Participants	No. of Meters measuring consumption	Course Pursuing	Occupancy
B_A1	22	2	PhD-0 M Tech-0 B Tech-22	Triple-0 Double-11 Single-0
B_A2	22	2	PhD-0 M Tech-1 B Tech-20 RA-1	Triple-0 Double-11 Single-0
B_A3	22	2	PhD-0 M Tech-1 B Tech-20	Triple-0 Double-11 Single-0
B_A4	22	2	PhD-0 M Tech-0 B Tech-22	Triple-0 Double-11 Single-0
B_A5	24	2	PhD-0 M Tech-0 B Tech-24	Triple-0 Double-11 Single-0
B_A6	21	2	PhD-0 M Tech-0 B Tech-17 RA-1	Triple-0 Double-11 Single-0
B_BC1	35	3	PhD-10 M Tech-3 B Tech-22	Triple-0 Double-0 Single-36
B_BC2	36	3	PhD-10 M Tech-1 B Tech-24 RA-1	Triple-0 Double-0 Single-36
B_BC3	36	3	PhD-1 M Tech-9 B Tech-26	Triple-0 Double-0 Single-36
B_BC4	34	3	PhD-1 M Tech-12 B Tech-20 RA-1	Triple-0 Double-0 Single-36

Table 4.2: Participants Grouping in Boys Dormitory.

groups were nothing but groups to account for weather differences as the study proceeds. For some of the analysis, this group was taken for comparison with rest of the groups in a particular phase to study the effect of the method adopted during that phase. Following are the Baseline group from each dormitory.

Girls Dormitory : Group G_BC1 (Baseline Group) Boys Dormitory : Group B_A1 (Baseline Group)

Influence on Baseline Group From study perspective, to control any influence on baseline group, it was ensured that baseline group was not part of any awareness drive being conducted during the study. No study related emails or no invitations for any group discussions or questionnaire sessions were sent to any member of the baseline group, no posters were displayed in

Group Name	No. of Occupants Participants	No. of Meters measuring consumption	Course Pursuing	Occupancy
G_AB1	18	2	PhD-7 M Tech-11 B Tech-0	Triple-1 Double-0 Single-15
G_BC1	17	2	PhD-0 M Tech-7 B Tech-0	Triple-1 Double-0 Single-15
G_AB2	18	2	PhD-8 M Tech-3 B Tech-7	Triple-0 Double-0 Single-18
G_BC2	18	2	PhD-0 M Tech-0 B Tech-18	Triple-0 Double-0 Single-18
G_AB3	24	2	PhD-0 M Tech-9 B Tech-15	Triple-6 Double-0 Single-6
G_BC3	24	2	PhD-0 M Tech-3 B Tech-21 RA-1	Triple-6 Double-0 Single-6
G_A4	18	2	PhD-0 M Tech-1 B Tech-16 RA-1	Triple-6 Double-0 Single-0
G_C4	18	2	PhD-0 M Tech-1 B Tech-16 RA-1	Triple-6 Double-0 Single-0

Table 4.3: Participants Grouping in Girls Dormitory.

the area to the baseline group. There may have been peer influence or influence of posters inside the campus providing them an idea about the study which will remain part of the limitation of this work.

3. Use of other sources for disseminating information Other sources like social media were not used during the study for any purpose. Social media sources like Facebook was not used for providing any kind of awareness or for providing any kind of update related to the study so as to eliminate the biasness if caused due to any external online source on the participants. The online approach adopted for awareness during the study included only the formal emails and public website.

The Power Down has its following Five Phases with each phase of 2 week duration:

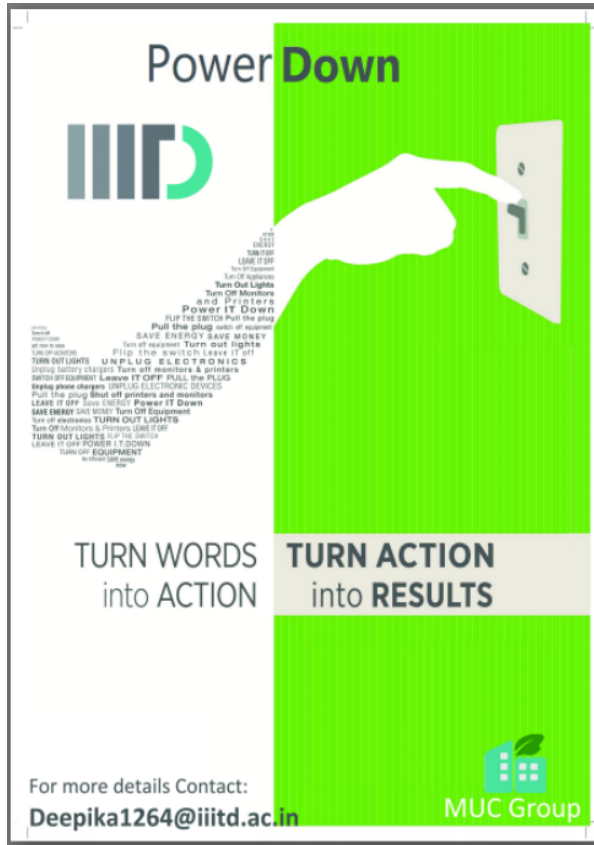
4.3.1 First Phase (General Awareness)

Time Period: First week of February-Mid of February. (3rd Feb, 2014 -16th Feb, 2014)

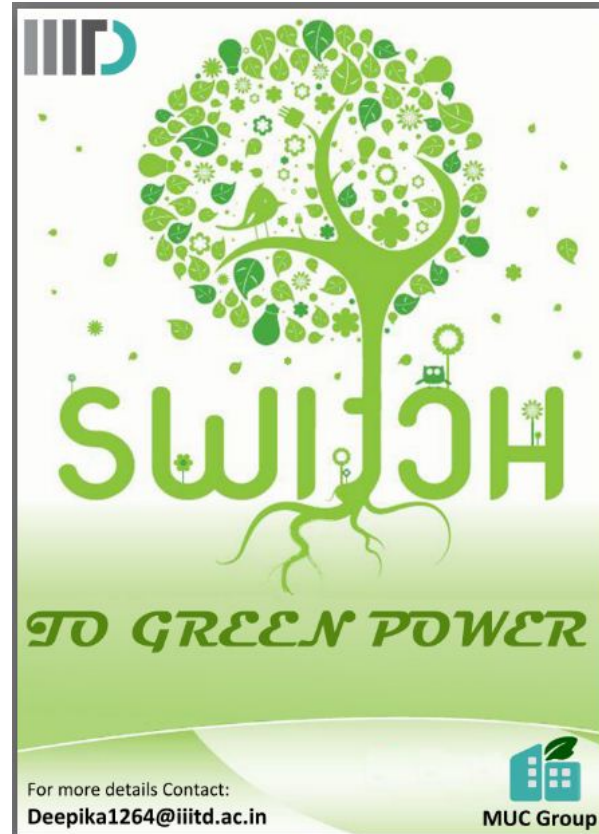
Aim: The Main aim of this phase was to encourage and motivate students to reduce consumption through awareness. For this, buzz and awareness was done at large scale. Below subsection Means Used, defines in detail, the methods adopted during the First phase to create awareness among the occupants.

Methods Adopted:

a) **Posters:** Awareness through Posters was the most applied approach in this phase. Posters were pasted at every noticeable places inside the dormitories. Washrooms, Lifts, Labs, Library, Canteen, Mess halls, Entrance doors were the most targeted area for the same. To create a big impact three big roll outs were designed and were placed at the Entrance of Hostel, Academic Area and Canteen. Figure 4.1 presents some of the posters that formed part of this drive.



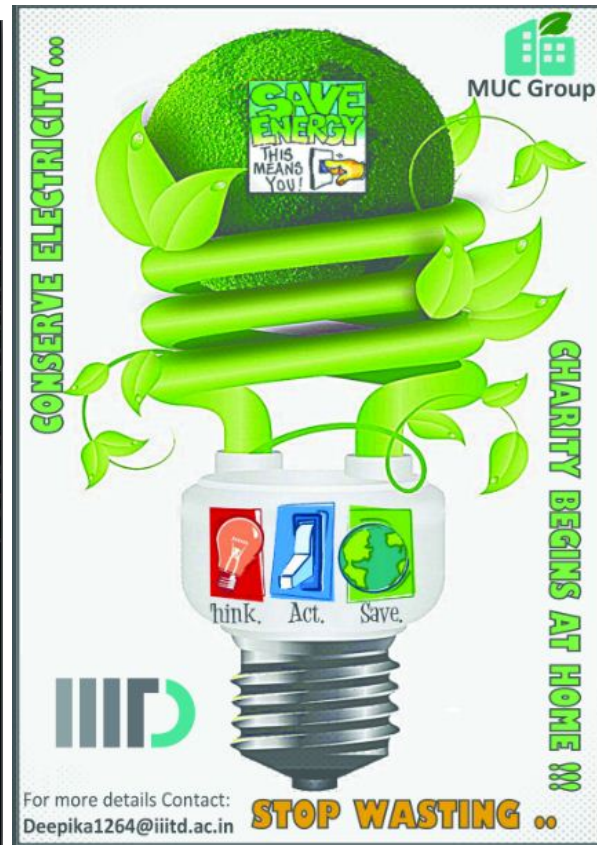
(a) Poster 1



(b) Poster 2



(c) Poster 3



(d) Poster 4

Figure 4.1: (a), (b), (c), (d) in the above Figure represents different Posters provided in First Phase of the Study.

b) Addressing: Awareness through public addressing was another adopted approach of this phase. Addressing were held in classrooms, Mess halls, Canteen, Dormitories. Door to Door visit to occupant's room to explain them about the study, overall aim of the study, means through which they can conserve energy formed part of this Public Addressing Method Adopted. Also, the meeting was scheduled in the common room of each of the dormitories for answering to queries of the occupants about which they were notified through mail. Group Discussions, Personal Addressing, Public addressing formed part of this approach.

c) Online: In this phase students were informed via mails about the Power Down Conservation Drive. They were informed that if they consume less they will be billed less. Through mails, occupants were informed about the overall aim of the study, they were provided with the link to Power down Website where in students can get detailed information about the study. Why to SAVE, How to SAVE were another answered questions through this. On this Website, a page was created where student can post his query if any. Figure 4.2, Figure 4.3 presents screen shots of the website designed for the study.

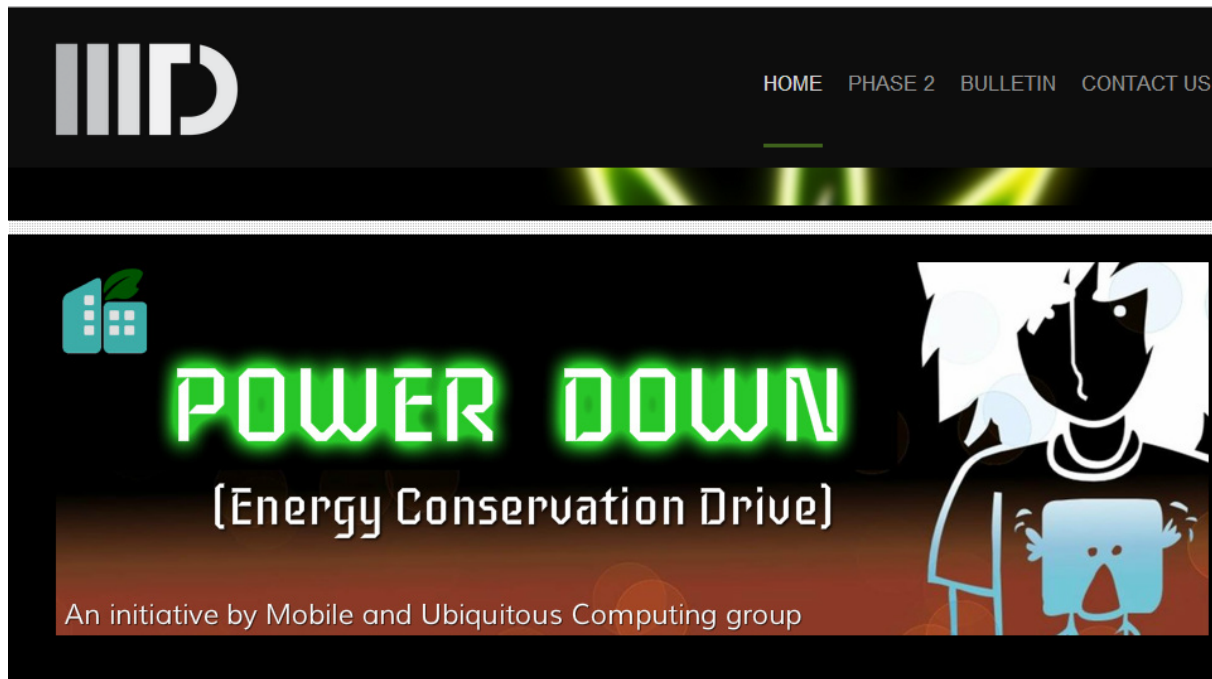


Figure 4.2: Screenshot of IIT-Delhi Power Down Public Website Logo .



Figure 4.3: Screenshot of IIIT-Delhi Power Down Public Website Home Page.

Students of Baseline Group were aware about the Power Down conservation drive only through posters or Roll outs placed at public locations like Mess Halls, Canteen Area. But no posters were made available to them in their specific wing area. No details about the study was provided to them. Neither they were part of any addressing nor they were part of any Online means being used for awareness.

4.3.2 Second Phase (Different Information based feedback)

With end of the first phase, started the second phase where participants were provided with different types of information feedback.

Time Period: Mid-February - Beginning of March 2014. (17th Feb, 2014 - 2nd Mar, 2014)

Aim: The main aim of this phase was to analyze the influence of each type of feedback mechanism adopted and to study what is the most effective approach that should be adopted to provide feedback to the occupants and to study gender based comparisons if any.

Methods Adopted:

In each boys and girls dormitory, occupants were divided into six different type of clusters with each cluster being provided with different type of information about their feedback. These clusters contained one or more than one group into them. The aim of this clustering was to see what type of feedback mechanism works best for both Boys and Girls. At the beginning of the phase, all the groups were informed about the onset of second phase and to which cluster category the group belongs to through mail and the same was updated on the public website for more clarification.

Cluster	Course Pursuing	Occupancy	
		Boys	Girls
No Awareness, No Feedback	No feedback information was provided to the participants of this Cluster. It Includes groups who were not the part of any awareness in the First Phase	B_A1 Baseline Group	G_BC1 Baseline Group
Awareness, No Feedback	No feedback information was provided to the participants of this Cluster. It Includes groups who were part of awareness in the First Phase but not getting any feedback in this phase.	B_A6	G_C4
Daily Paper Based Feedback	Feedback about consumption provided on A4 sized paper was slipped into rooms daily.	B_BC2,B_A3	G_BC3,G_AB2
Weekly Paper, Based Feedback	Feedback about consumption is provided on weekly basis through A4 sized paper slipped into occupants room.	B_BC1,B_A2	G_AB3
Daily Public Poster Based Feedback	Feedback about consumption is provided on an A3 sized poster paper on daily basis displayed at most visible location of the groups area.	B_BC3,B_A4	G_A4
Online Feedback	Feedback is provided to this Group in the form of Online Portal where after Login, occupants can check their groups consumption	B_BC4,B_A5	G_AB1,G_BC2

Table 4.4: Different Feedback Clusters Information and Grouping during Second Phase of the Study.

Following are the cluster categories:

i) No Awareness and No Feedback: This Cluster contained groups which were not provided with any kind of awareness in the First phase of the study and neither were provided with any kind of feedback about their consumption in this phase. Baseline Group from both Boys and Girls Dormitory formed part of this cluster.

ii) Awareness and No Feedback: This cluster constituted groups who were part of awareness drive in the first phase but were not provided with any kind of Feedback about the consumption

in this phase. One group each from Boys and Girls Dormitory formed part of this cluster category. This cluster was designed to see the effect of awareness and also to have comparison within different clusters.

iii) Daily Paper Based Feedback: To this cluster, feedback about the entire consumption of their group was provided on daily basis for two weeks. The paper feedback had the information about the consumption of the occupant's group to which they belonged to and included the daily power consumption of the group in Energy units (Kwh) as well as its equivalent cost consumption. The printed paper also provided comparison with lowest, average and highest consumption groups within each dormitory on daily basis. The Feedback was provided in the form of A4 size paper printed daily and slid through the room door of all participant belonging to that cluster at the end of the day. Figure 4.4a contains the view of Daily Paper Based Feedback provided to the occupants. This Feedback report was generated through the Real Feedback System discussed in Chapter Study Design.

iv) Weekly Paper Based Feedback: Similar to the daily paper based feedback, to this cluster the similar information about the consumption as well as comparison with lowest, average and highest consumption groups was provided on weekly basis. The Feedback included energy consumption of the group in Energy Units(Kwh) and its equivalent cost consumption. Since this phase was of 2 weeks, the feedback was provided at the onset, middle and at the end of this phase. The Feedback to this cluster was also provided in the form of A4 size paper printed on weekly basis and the same was slid through the door of the occupant on weekly basis This cluster constituted one group from girls dormitory and two groups from boys dormitory because of the difference in number of participants within girls and boys dormitories. Figure 4.5 provides with the view of Weekly feedback that was provided to the occupants.

v) Daily Public Poster Based Feedback: This was another feedback mechanism in which the consumption of the group within the cluster in comparison to lowest, average and highest consumption groups of the dormitory was displayed through posters outside the wing. This feedback category also gets the similar information as provided to the occupants of cluster belonging to Daily Paper based feedback and Weekly Paper Based feedback with difference being that the similar information was made available to them in the form of Posters displayed at the most visible locations of each group of this cluster on daily basis. The Posters were of A3 size and around 2-3 posters were displayed for each group within the cluster. Because of the difference in number of boys and girls participants, this cluster category constituted one group from girls dormitory and two groups from boys dormitory. Figure 4.4b provides with the view of Public Poster feedback that was provided to the occupants.

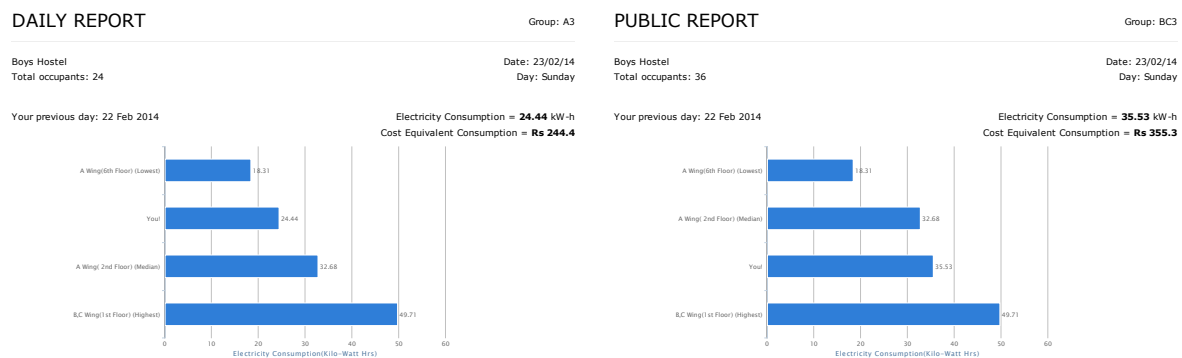
vi) Online Feedback: This cluster was provided with feedback about the consumption in the form of Online Portal(Web Feedback System) as discussed in Chapter System Design. It provided occupant's with information about the consumption of the group as well as had comparison tab which displayed consumption with lowest, average and highest consumption groups. Similar information as provided to other clusters was displayed through the portal. For each group belonging to this cluster, Login Ids and passwords were assigned and same was

provided to the occupants of this cluster through mail . This cluster constituted two groups from each of the Dormitory.

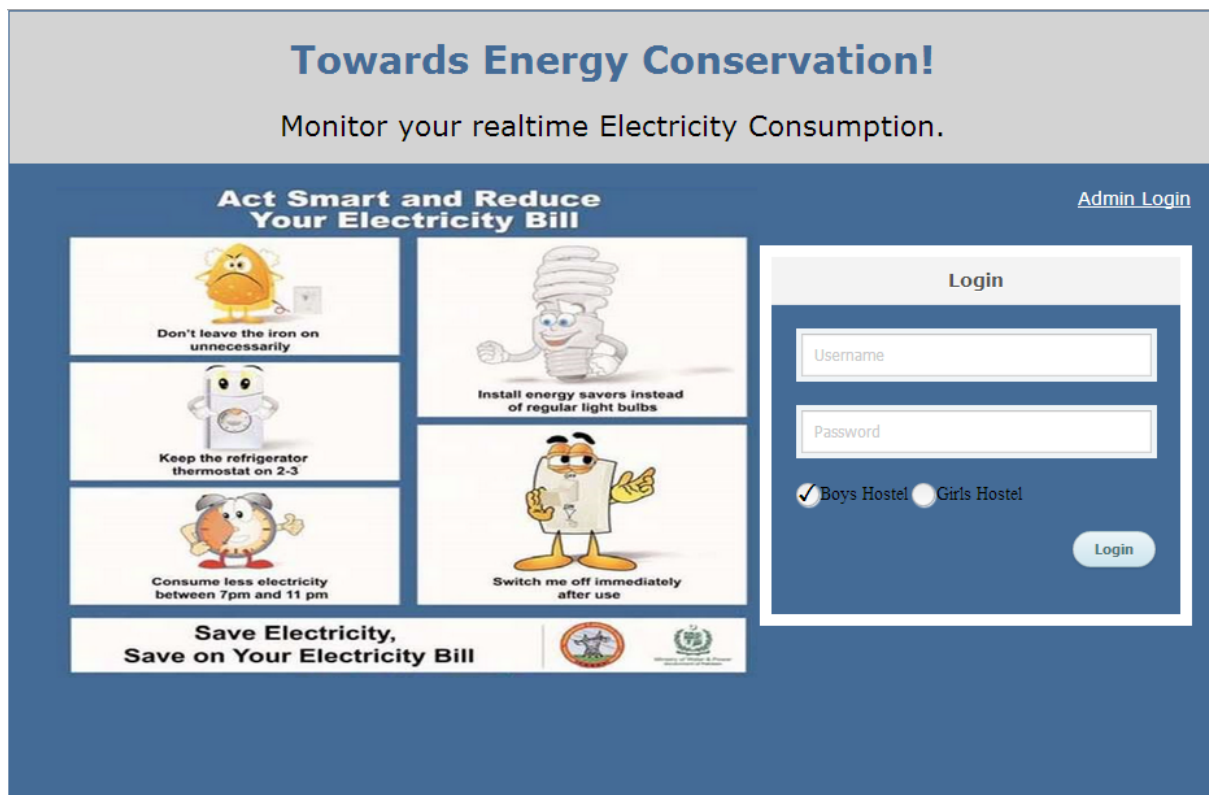
Figure 4.4c provides with screen shots of the Online System that was provided to occupants of this group.

Besides this, the public website was updated with more information about the second phase, about different clusters within this phase, Groups that were part of each cluster.

Table 4.4 provides the summary of Clusters of this phase and groups that formed part of this cluster each from Boys and Girls Dormitory.



(a) Daily Report provided to Daily Paper Based Feedback Cluster. (b) Public Report provided to Daily Public Poster Based Feedback Cluster.



(c) Screenshot of Real Time Feedback System Feedback System Home Page provided to Online Feedback Cluster.

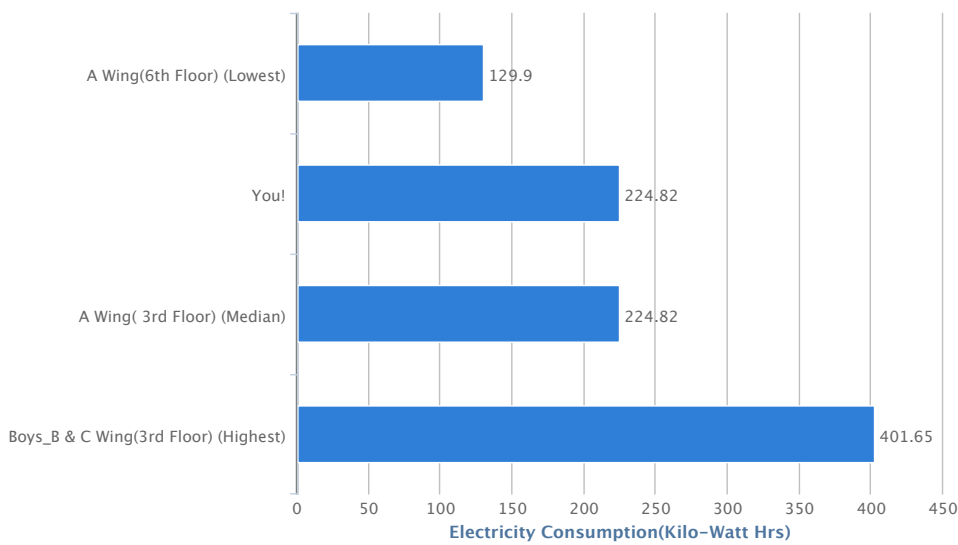
WEEKLY REPORT

Group: A3

Boys Hostel
Total occupants: 24

Date: 24/02/14
Day: Monday

Your previous week: 17 Feb to 24 Feb 2014 Electricity Consumption = **224.82** kW-h
Cost Equivalent Consumption = **Rs 2248.2**



YOUR DAILY CONSUMPTION FOR PREVIOUS WEEK

Monday
39.3 kW-h

Tuesday
40.67 kW-h

Wednesday
32.65 kW-h

Thursday
31.06 kW-h

Friday
29.92 kW-h

Saturday
24.46 kW-h

Figure 4.5: Weekly Report provided to Weekly Paper Based Feedback Cluster.

4.3.3 Third Phase (Online Feedback)

Time Period: First week of February - Mid of February(3rd Mar-16th Mar, 2014)

Aim: The main aim of this phase was to analyze the behavior of participants when provided with real time web based feedback without any incentives.

Methods Adopted: This phase was also of duration of two weeks. Occupants of this phase were provided with Real time Feedback system where the occupant can view their groups last 24 hours consumption, any particular day consumption or entire week consumption. The Participant can view this consumption by Login into the portal who's username and password were provided to the occupants through mail. The participant can also compare its consumption with rest of the groups on 24 hours or any day or any week basis. In this phase, all the groups were taken together irrespective of the dormitory. The occupants were informed about this phase through mail and same was updated on the Public Website. Changes were made to the system so that there is consistency between the groups who were provided with feedback system in the second phase and who were not. This Phase was also targeted to maintain equal level of consistency between all the groups before the next phase, that is Competition Phase Starts. Figure 4.6 shows screen shots of the Online System used during this phase. The main aim of this phase was to see the effect of real time feedback on the occupants.

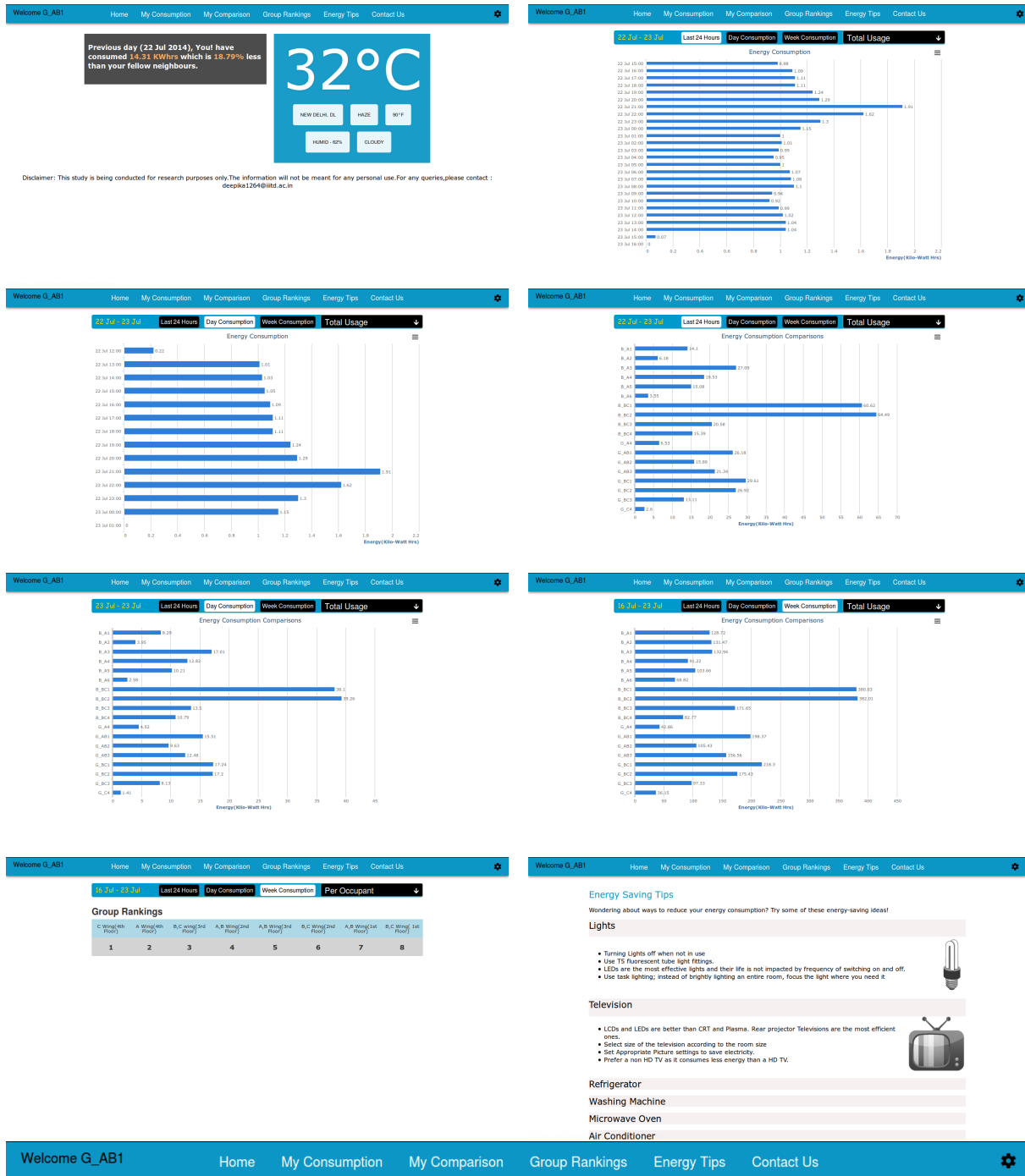


Figure 4.6: Screenshots of different Pages of Real Time Feedback System provided during Third Phase of the Study .

4.3.4 Fourth Phase (Competition Phase)

Time Period: Third week of March - First week of April(17th March to 6th April, 2014)

Aim: The main aim of this phase was to analyze the difference in consumption between the third and the fourth phase, that is competition spirit motivates occupants to consume less or not. Another goal of this phase was to see if incentive can be reason for motivation among the students for reduction or not.

Methods Adopted

This Phase started with a gap of one week between the third and the fourth phase as the institute was closed on account of Holi break with almost very less population of participants. The main target of this phase was the competition **Power down Challenge: Battle of Dorms**. All the groups were competing against each other. The top three teams at the end of this phase will be provided with Incentives, in our case a Burger Party to the top three groups.

The participants of this phase were provided with consumption about their group's feedback in similar way as was provided in the third phase with a difference that the groups were also ranked in order of their consumption with lowest consumption group as Rank 1 and highest as Last Rank so that they can clearly figure out where they stand amongst all the groups at any time they Login. This phase started with creating buzz among the participants about the challenge and about the incentive that the top three teams will be provided with the Burger Party. Login of the portal was same for both third and fourth phase.

The Public website was also updated through the information about this Phase. Figure 4.2 shows screen shot of the website provided to the occupants. The Students were informed about this phase, its motive and incentives through a Poster. Figure 4.7 shows the poster provided to the occupants for better information.



Figure 4.7: Poster provided to Inform students about the Competition Phase.

4.3.5 Fifth Phase (Post-Competition Phase)

Time Period: Second week of April - Third week of April(7th April to 20th April, 2014)

Aim: The main aim of this phase was to analyze if study made any difference in continuing the conservation behavior if followed by the occupants during the earlier phases of the study.

Methods Adopted

This Phase did not informed the occupants about the start of this phase but they were notified about the finishing of the competition phase. Real-Time Feedback system was still accessible to the occupants but they were not explicitly informed about this phase. This Phase was monitoring the consumption of the occupants to see if the reduction if any happened during the study continues to happen. In a way to assess if they still were motivated to consume less and follow

the conservation practices if any adopted during the study.

The Power Down Study had these main Five phases with Baseline Phase.

Figure 4.8 shows the Time line Diagram of the Power Down Study to provide the summary of different phases of the study in brief.

4.4 Data-analysis

Analysis is truly based on the data collected during different phases of the study with the help of Smart Meters. This data is being collected every 30 seconds and can be queried for analysis purposes over LAN.

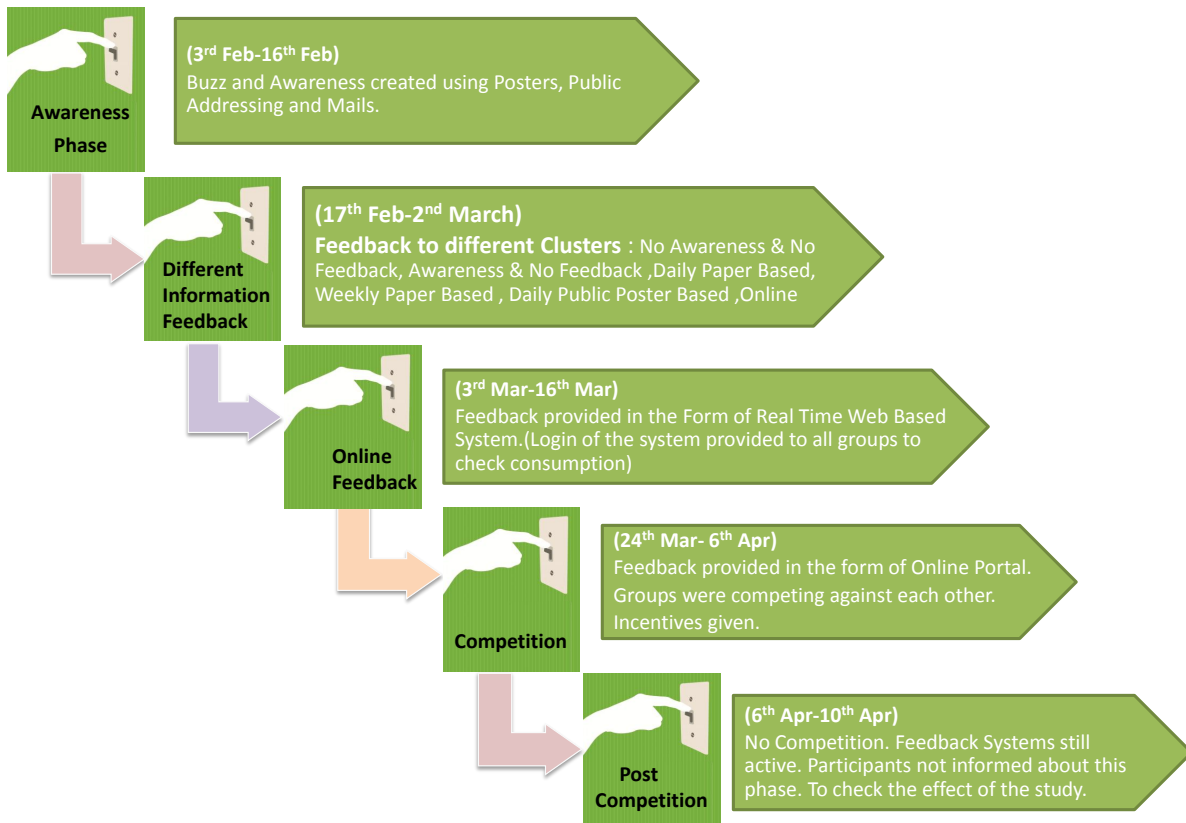


Figure 4.8: Power Down Study - Timeline Diagram.

Chapter 5

Results

The following Chapter discusses the results for the study. The results are entirely based on the empirical and statistical analysis of the data collected. This Chapter also discusses the results of the Survey conducted for the participants.

5.1 Gender Based Comparison(Boys Vs. Girls)

This section analyzes the Gender Based difference in Energy Consumption pattern during different phases of the study. The data has been collected and analyzed for both Boys and Girls. Due to difference in number of Boys and Girls participants, the per occupant consumption has been used for comparison purposes. The same has been obtained by normalizing the total consumption for both Boys and Girls dormitories for each of the phases by the number of participants in each dormitory.

Figure 5.1 compares per occupant consumption of Boys and Girls (in Kwh) during different phases of the study. It clearly shows that per occupant consumption of Girls was lower than Boys in all the phases including the Baseline phase, showing that Girls in general were energy conscious in comparison to Boys even before the study.

Statistical analysis for the same has also been done using Independent t-test showing that for each of the phases, per female energy consumption (on an hourly rate) is significantly lower than per male consumption. table 5.1 shows statistical analysis results for different phases with $p < 0.01$.

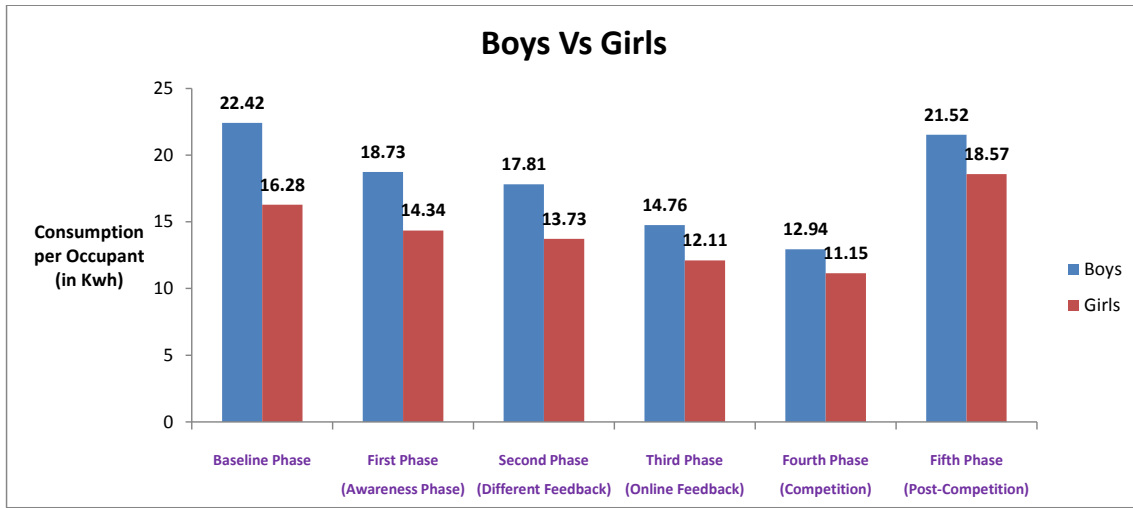


Figure 5.1: Boys and Girls per occupant consumption during different phases of the Study.

Phase	T Test Result(t5374)	Mean Difference	Mean Standard Error
Baseline Phase	27.8	18.3	0.65
Awareness Phase	23.7	13.1	0.6
Different Information Feedback	21.5	12.1	0.6
Online Feedback	15.4	7.9	0.5
Competition Phase	11.9	5.3	0.5
Post-Competition Phases	15.8	8.8	0.5

Table 5.1: Statistical Analysis showing Male per Occupant Consumption is more than Female per Occupant Consumption.

Figure 5.2 depicts difference in consumption between Boys and Girls during different phases of the study including the Baseline Phase which has been obtained by subtracting per occupant Girls consumption from per occupant Boys consumption in each phase. The data shows that the maximum difference between boys and girls consumption was during the Baseline phase depicted in Red and as the study grew this difference decreased showing the effect of the study.

This difference decreased to the minimum during the Competition Phase shown in Green with again a sudden increase in consumption during the fifth phase of the study. This decrease in difference can also be seen from the data obtained from Statistical Analysis signifying the Maximum Mean difference of 18.3 during the Baseline Phase and Minimum Mean difference of 5.3 during the Competition Phase.

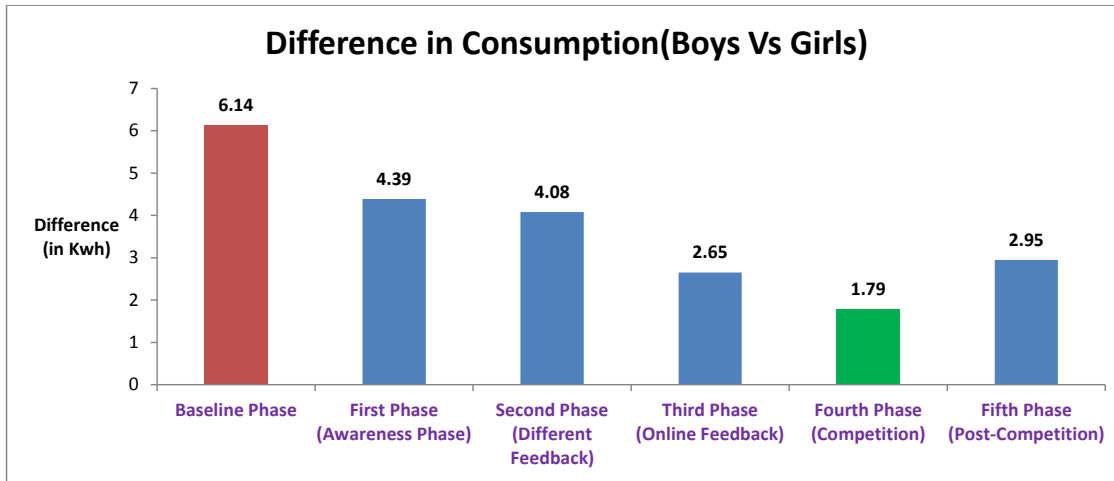


Figure 5.2: Difference(in KWH)between Boys and Girls Consumption in differnt Phases of the study.

From figure 5.1, we can see that per occupant Girls consumption was lower than boys in all phases of the study including the Baseline Phase signifying Girls were more energy conscious than boys even before the study. But when comparing the decrease in per occupant consumption from Baseline phase to Competition phase, the decrease for boys was around 9.48 Kwh (From 22.42 Kwh to 12.94Kwh) whereas for girls it was 5.13 Kwh (From 16.18 4 Kwh to 11.15 Kwh) showing that as study grew with its phases, boys got more motivated and consumed less. So Girls in general were more Energy Conscious than boys even before the study but with study, boys got more motivated and became more energy efficient than girls and hence reduced more.

The above result provides gender based comparison for all the phases involved in the study. Keeping in view that the majority population of both Boys and Girls dormitory belongs to Delhi and nearby areas so participants are likely to visit their home often during the weekends. So to analyze results better, for each phase weekday as well as weekend analysis has been performed separately. Analysis have been performed in similar way as performed for the entire phase.

5.1.1 Weekday-Weekend Analysis

Figure 5.3 and figure 5.4 compares per occupant consumption of Boys and Girls (in Kwh) during the weekdays and weekends during different phases of the study. The results are similar to the phase results as discussed in the above section. It clearly shows that per occupant consumption of Girls was lower than Boys during all phases of the study.

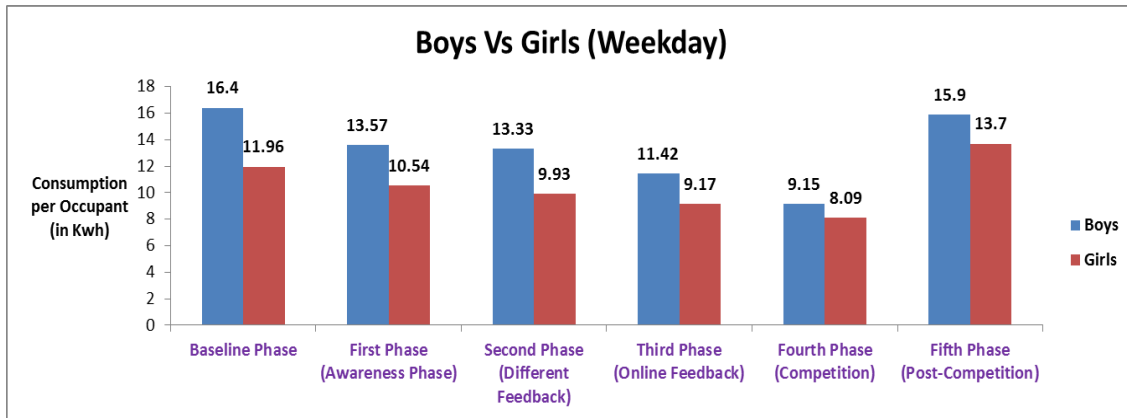


Figure 5.3: Boys and Girls per occupant Weekday consumption during different phases of the Study.

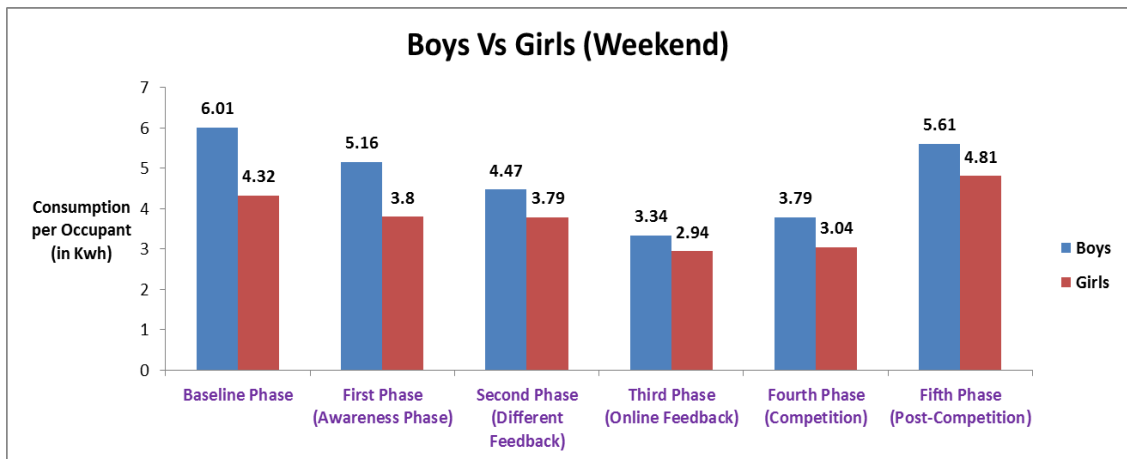


Figure 5.4: Boys and Girls per occupant Weekend consumption during different phases of the Study.

Figure 5.5 compares difference in consumption between Boys and Girls for both weekdays and weekends during different phases of the study. For both weekdays as well as weekends, figure 5.5 shows that maximum difference in consumption was observed during the Baseline phase as observed during the phase results as shown in figure 5.2. Comparing for minimum difference, results for weekday shows minimum difference between boys and girls during the Competition phase (Fourth phase) as accordance with phase results whereas weekends shows difference in results showing minimum difference during the Online Feedback Phase. The reason for this difference may be that many students would have visited their homes during this Online Feedback (third phase) weekend leading to less number of students in the hostel, as a week prior

students had Mid semester Examination and they may not have got a chance to visit their homes on the weekend before.

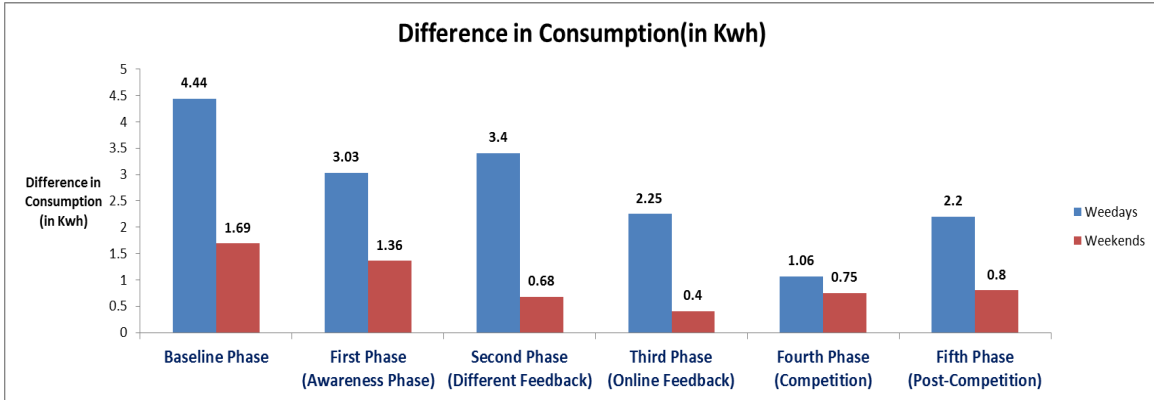


Figure 5.5: Difference(in KWH)between Boys and Girls consumption during Weekdays and Weekends in differnt Phases of the study.

5.2 Best Feedback Mechanism (Second Phase Analysis)

The second phase of the study included different types of feedback mechanisms provided to the participants. The participants were divided into six types of clusters within both the dormitories each containing some number of groups. The study provided different types of feedback mechanism in the second phase separately within each of the dormitories discussed in the Chapter Study Design. The Analysis has been done by gathering data for each of the cluster for Baseline and Second Phase then comparing the reduction for each of the cluster for this phase from the baseline phase.

Figure 5.6, figure 5.7compares the reduction of each of the clusters among Boys and Girls showing the effect of different feedback mechanisms adopted during second phase of the study.

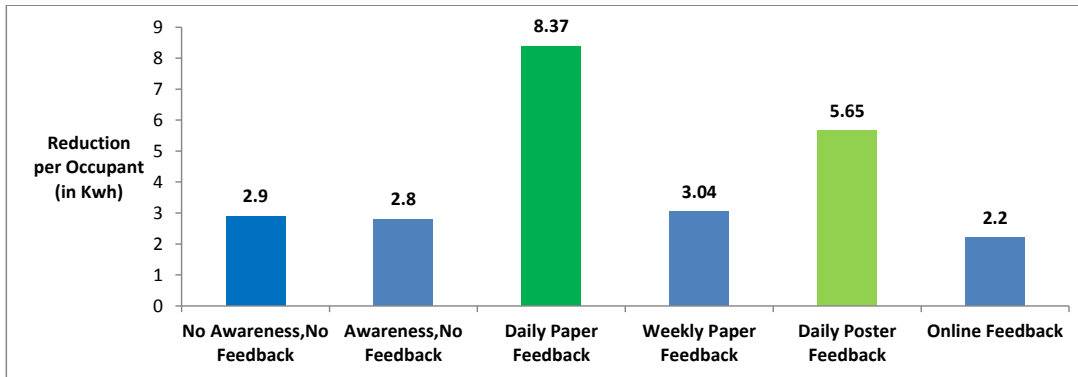


Figure 5.6: Energy Reduction Comparison (in Kwh) among different Clusters in Boys during Second Phase.

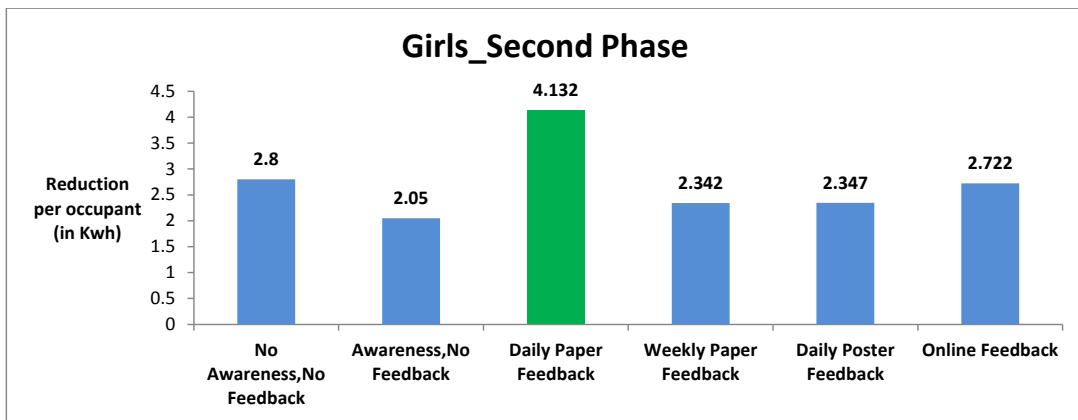


Figure 5.7: Energy Reduction Comparison (in Kwh) among different Clusters in Girls during Second Phase.

Figure 5.6, Figure 5.7 shows that for both Boys and Girls, maximum reduction was when students were provided with Daily Paper Based Feedback showing that Daily Paper Based Feedback performs the best.

Girls: Daily Paper Based was the best and rests of the feedback mechanisms were comparable.

Boys: Daily Paper Based Feedback and Daily Poster Feedback were the top two best performing mechanisms while rests were comparable.

To analyze the six conditions of Phase-2 using Statistical Analysis, we conducted a 1-way

ANOVA, Table 5.2 Table 5.3 shows the results for the same.

Cluster	Mean	Standard Deviation
No Awareness, No Feedback	- 8.75	29.28
Awareness, No Feedback	-8.38	25.21
Daily Paper Based Feedback	-24.93	26.85
Weekly Paper Based Feedback	-8.95	27.73
Daily Public Poster Based Feedback	-16.83	33.51
Online Feedback	-6.77	25.7

Table 5.2: Statistical Analysis Results for Second Phase For Boys.

From table 5.2, post-hoc analysis revealed that Daily Paper Based Feedback performed the best showing the maximum reduction and Daily Public Poster Based Feedback ranked the second best feedback outperforming all other conditions significantly ($p < 0.01$) while other conditions were almost comparable.

Cluster	Mean	Standard Deviation
No Awareness, No Feedback	- 8.55	35.36
Awareness, No Feedback	-6.03	10.23
Daily Paper Based Feedback	-12.92	20.84
Weekly Paper Based Feedback	-6.9	10.85
Daily Public Poster Based Feedback	-6.99	12.47
Online Feedback	-5.2	21.26

Table 5.3: Statistical Analysis Results for Second Phase For Girls.

From table 5.3, post-hoc analysis revealed that Daily Paper Based Feedback performed the best outperforming all other conditions significantly ($p < 0.01$) while rest of the conditions were comparable.

Observing both Empirical and Statistical Analysis, Daily Paper Based Feedback proved to be the best feedback mechanism adopted for both boys and girls showing that daily if people were provided with feedback where they dont have to explicitly visit the Online System and directly they get to know about their consumption it will help in better Energy Reduction.

The Best Feedback mechanism for second phase has also been further analyzed for both weekday as well as weekend to see if their is any major difference in the results.

5.2.1 Weekday-Weekend Analysis

The second phase of the study included different types of feedback mechanisms provided to the participants. The analysis for both weekday and weekend for this phase has also been done in similar way as done for the entire phase as discussed in the above section.

Figure 5.8, figure 5.9 compares reduction during weekdays and weekends for each of the clusters among Boys and Girls, showing the effect of different feedback mechanisms adopted in the second phase of the study.

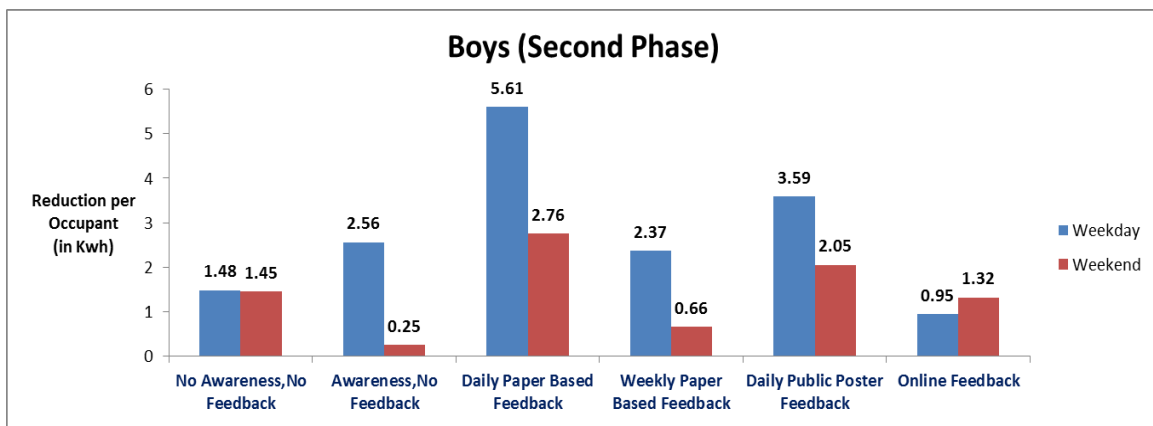


Figure 5.8: Compares Energy Reduction (in Kwh) during weekdays and weekends among different Clusters in Boys.

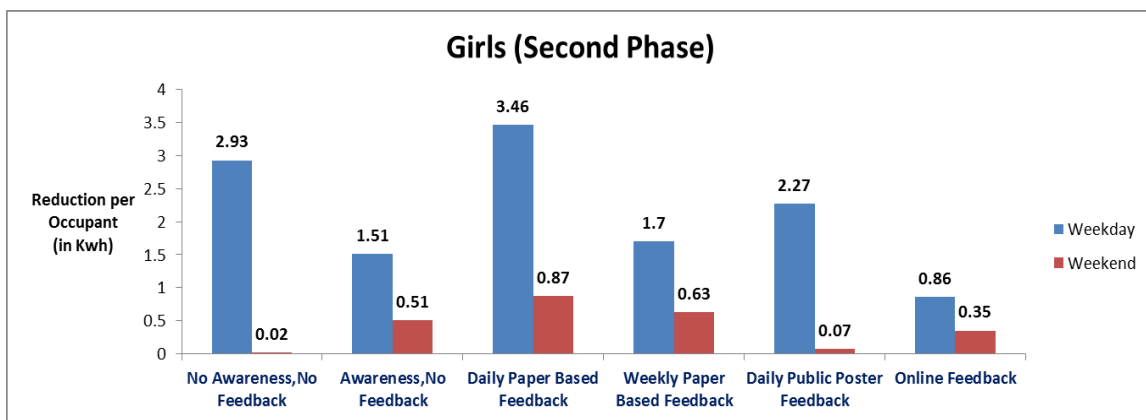


Figure 5.9: Compares Energy Reduction (in Kwh) during weekdays and weekends among different Clusters in Girls.

The results for both weekday as well as weekends are similar to the results obtained for the entire phase. Figure 5.8, figure 5.9 shows that for both Boys and Girls, maximum reduction was when students were provided with Daily Paper Based Feedback showing that Daily Paper Based Feedback performs the best as similar to the phase results.

Girls: Daily Paper Based was the best and rest of the feedback mechanisms were comparable.

Boys: Daily Paper Based Feedback and Daily Poster Feedback were the top two best performing mechanisms while rests were comparable.

Observing both Weekday as well as Weekend analysis, Daily Paper Based Feedback proved to be the best feedback mechanism adopted for both boys and girls. The pattern for the results for both weekday and weekend analysis were similar to the phase results as discussed in the above section.

5.3 Competition Phase Analysis

This section compares all the phases of the study and compares if competition along with Incentive motivates students to reduce more. Note: Since Power Down is a Timeline study, so to compare all the phases and correspondingly account for temperature differences, we have used Baseline Group.

For Analysis, the percent reduction of the Baseline Group from Baseline phase to other phases, accounts for the temperature difference for each of the phases. The Percent reduction of the baseline group for each phase was obtained and an equivalent percent reduction from the Total Baseline Consumption data provides Baseline data for each phase separately. Now Comparing each phase total consumption from its Baseline data provides the reduction for each of the Phases. Tables 5.4, 5.5 shows the percent reduction among Boys and Girls of Baseline Group from baseline phase to other phases and correspondingly the new baseline data for each phase.

Phase	total Consumption(in Wh)	Baseline Reduction of Baseline Group(in %)	New Baseline Data(in Wh)
Baseline	201844.2		
First	168641	8.67	184344.31
Second	160310.6	14.97	171628.124
Third	132880.3	23	155420.034
Fourth	116511.30	10	181659.78
Fifth	193729.60	-5.59	213127.29

Table 5.4: Data showing each phase Total Consumption, Baseline Reduction and new Baseline Data in Boys.

Phase	total Consumption(in Wh)	Baseline Reduction of Baseline Group(in %)	New Baseline Data(in Wh)
Baseline	113982.5		
First	100429.60	5.79	105952.5
Second	96133.64	7.19	104487.867
Third	84818.45	15.01	96965.13
Fourth	78067.28	19	92326.5
Fifth	130008.9	4.7	108625.32

Table 5.5: Data showing each phase Total Consumption, Baseline Reduction and new Baseline Data in Girls

From figure 5.10 and figure 5.12 for both boys and girls, Fourth Phase has the maximum reduction confirming that Feedback when combined with competition along with incentives motivates students best to conserve.

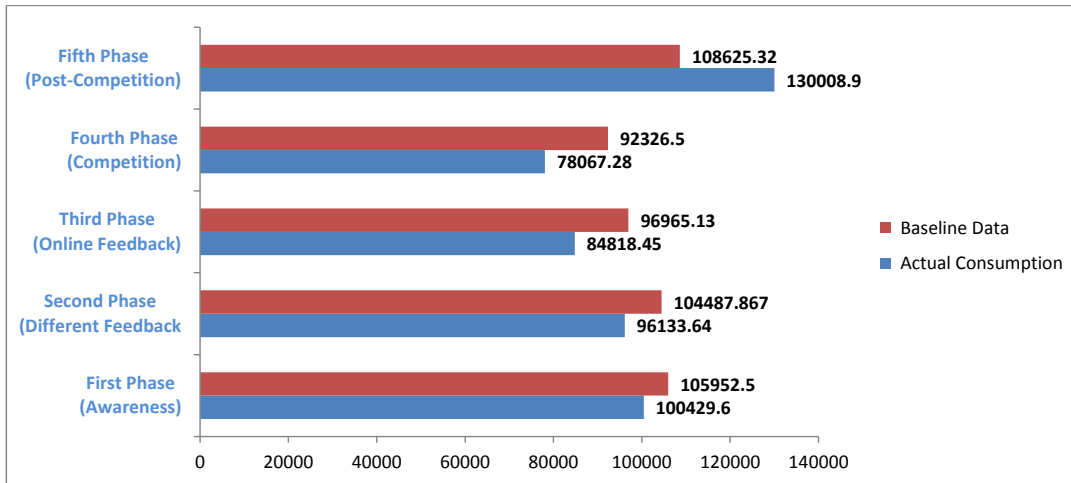


Figure 5.10: Graph comparing Each Phase Total Consumption with its corresponding Baseline Data in Girls.

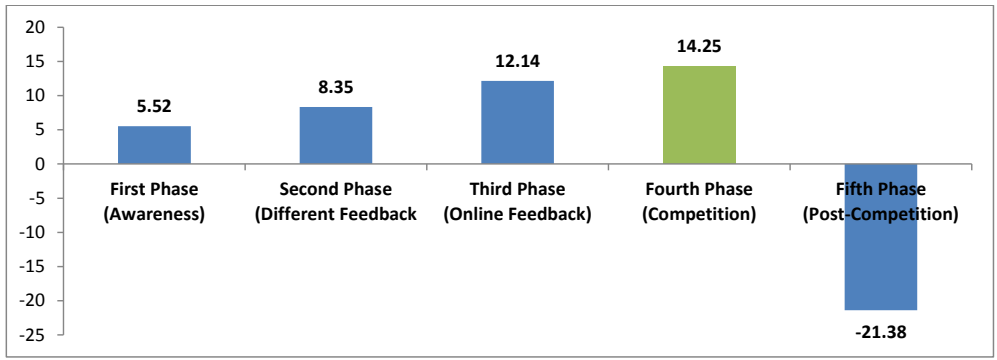


Figure 5.11: Graph represents increase or decrease in Consumption during different Phases in Girls with respect to Baseline Data.

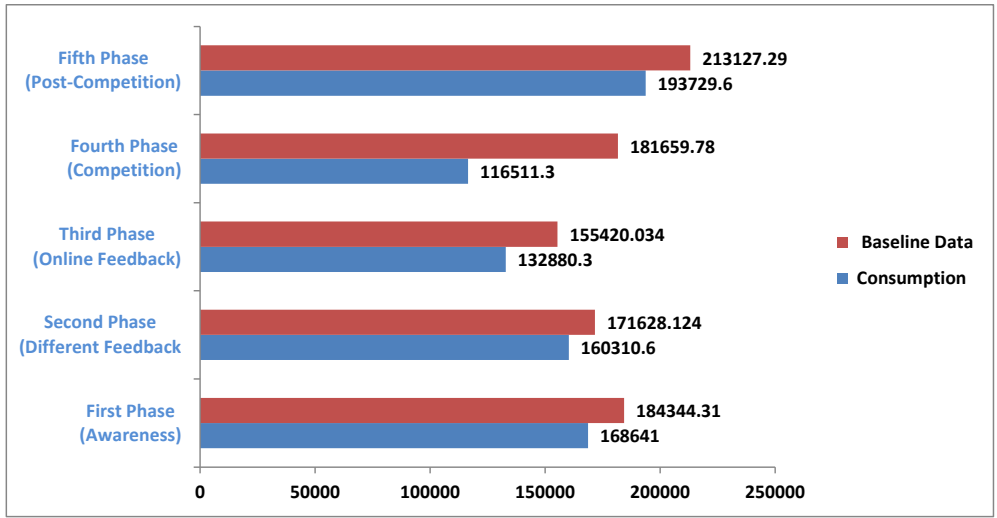


Figure 5.12: Graph comparing Each Phase Total Consumption with its corresponding Baseline Data in Boys.

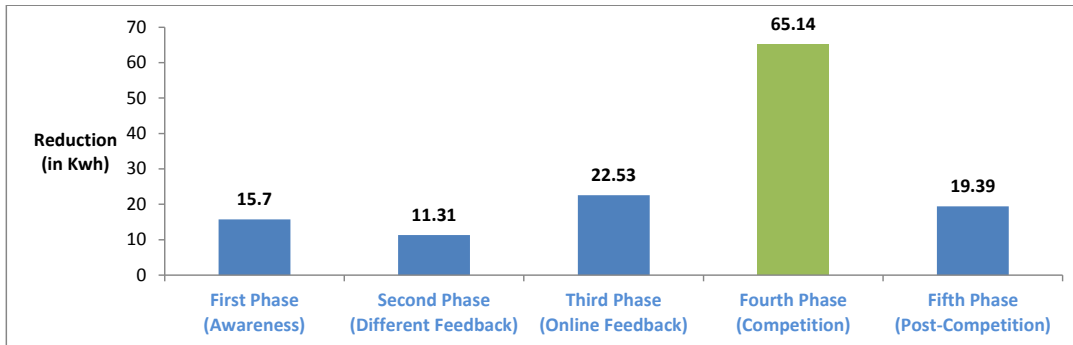


Figure 5.13: Graph represents increase or decrease in Consumption during different Phases in Boys with respect to Baseline Data.

Boys show a significant reduction during this phase showing the effect of feedback combined with Competition along with incentives. Although Girls also reduce maximum during this phase but their consumption is not very significantly different when compared with other phases.

Both weekday as well as weekend analysis have also been performed for analyzing if Competition phase had the same effect during weekdays as well as weekends.

5.3.1 Weekday-Weekend Analysis

Analysis for weekday and weekend has been performed by taking into account weekdays and weekends respectively for all the phases and then comparing the results in a similar way as performed for the entire phase in the earlier section.

Figure 5.14, figure 5.15 compares each phase total consumption with its corresponding Baseline data in Girls during weekdays and weekends respectively. Analyzing both the data for weekends and weekdays figure 5.16 has been obtained comparing each phase weekend as well as weekday consumption among Girls.

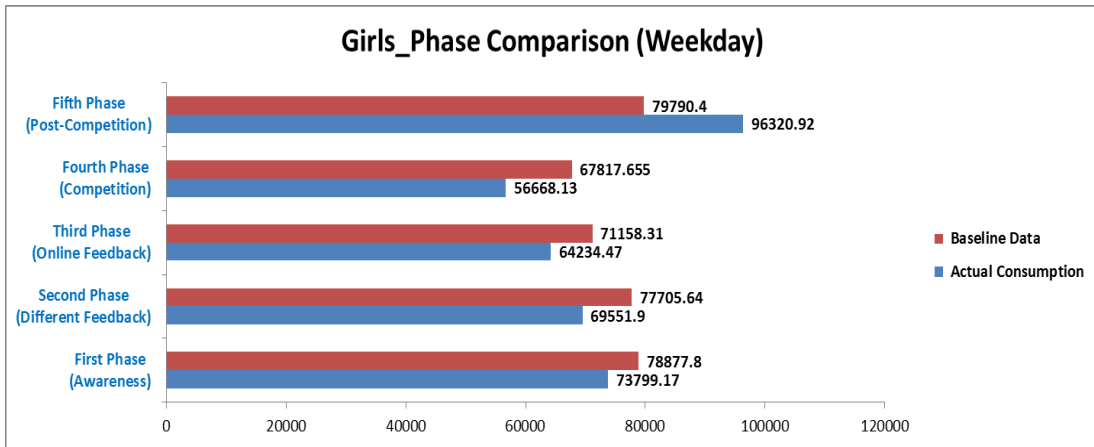


Figure 5.14: Graph comparing each Phase Total Consumption with its corresponding Baseline Data in Girls during weekdays.

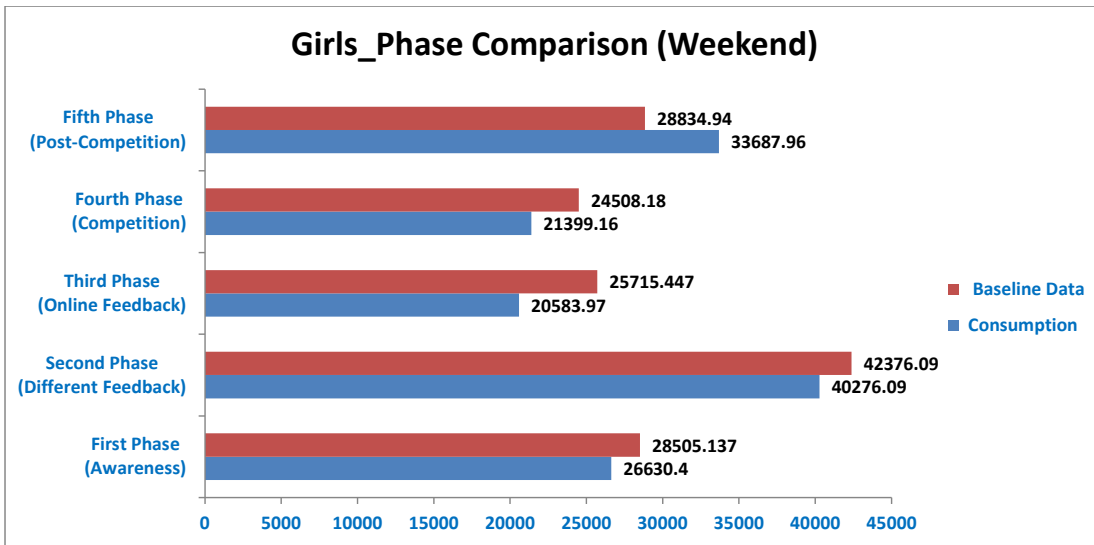


Figure 5.15: Graph comparing each phase total consumption with its corresponding Baseline Data in Girls during weekends.

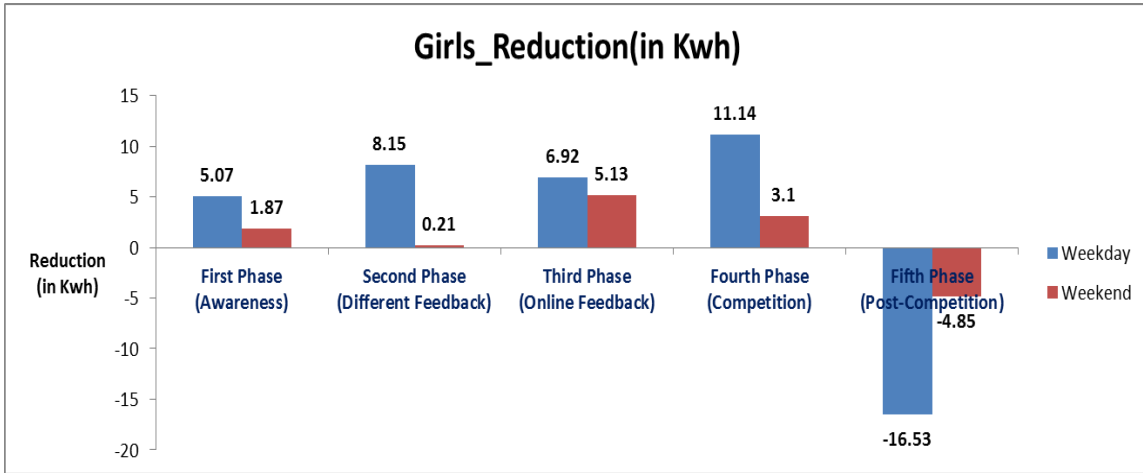


Figure 5.16: Compares weekday and weekend consumption during different phases in Girls with respect to Baseline Data.

Figure 5.16 shows that among girls, maximum reduction during weekday was obtained during the Fourth Phase (Competition Phase) as accordance with Phase results for girls whereas during weekends, maximum reduction was obtained during the Third Phase (Online Feedback) phase. Figure 5.17, figure 5.18 also compares each phase total consumption with its corresponding Baseline data in Boys during weekdays and weekends respectively. Analyzing both the data for weekends and weekdays figure 5.19 has been obtained comparing each phase weekend as well as weekday consumption among Boys.

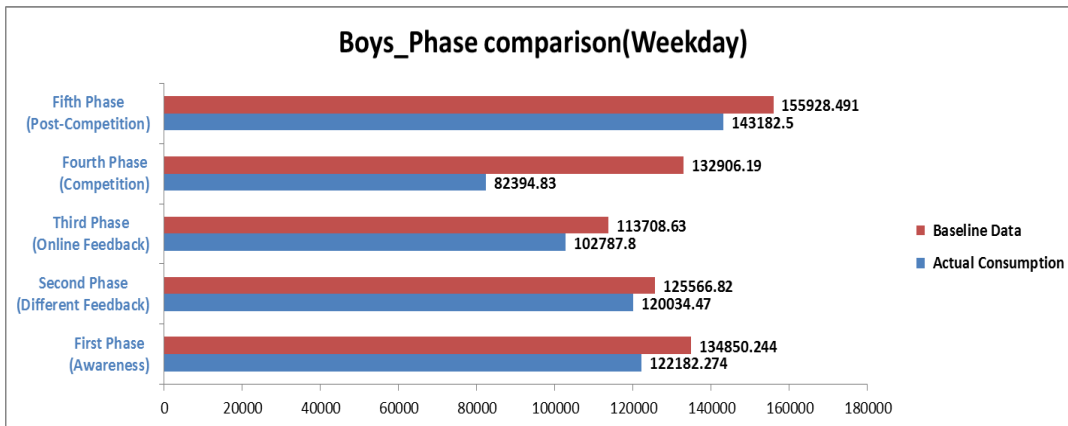


Figure 5.17: Graph comparing Each Phase Total Consumption with its corresponding Baseline Data in Boys during weekdays.

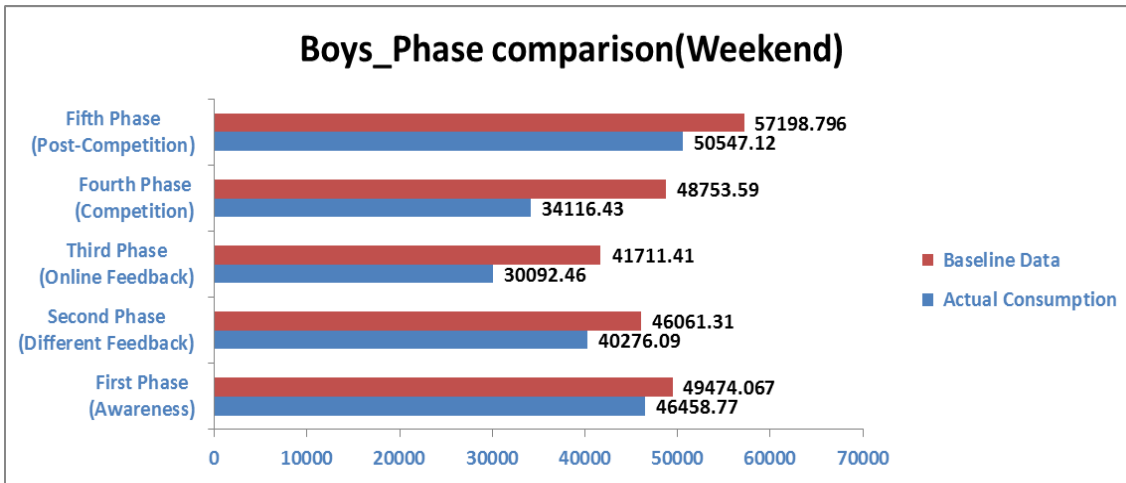


Figure 5.18: Graph comparing Each Phase Total Consumption with its corresponding Baseline Data in Boys during weekends.

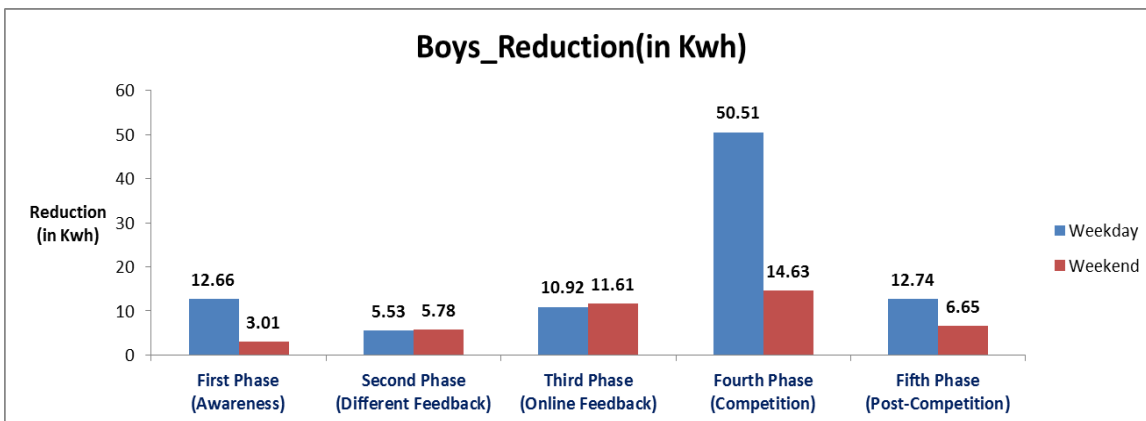


Figure 5.19: Compares weekday and weekend consumption during different phases in Boys with respect to Baseline Data.

Figure 5.19 shows that among boys, maximum reduction during weekday and weekend was obtained during the Fourth Phase(Competition Phase) as accordance with Phase results for Boys. From Figure 5.16 and figure 5.18 for both boys and girls, Fourth Phase has the maximum reduction during weekday confirming that Feedback when combined with competition along with incentives motivates students best to conserve. Boys show a significant reduction during this phase showing the effect of feedback combined with Competition along with incentives. Although Girls also reduce maximum during this phase but their consumption is not very sig-

nificantly different when compared with other phases.

From the above comparison, boys show maximum reduction during the Competition phase in phase, weekday as well as weekend analysis whereas girls show maximum reduction in competition phase during weekday as well as phase analysis but for weekend analysis, maximum reduction was obtained during the Online phase. The reason for this may be less population in girls hostel during the weekend of Online phase due to Mid Semester Exams a week prior.

5.4 Survey Results

The Survey was conducted after the Competition phase to gather information about participants views about the study. Survey was conducted among 432 participants out of which 84 participants responded to the survey which constituted of 67%t Males and 33% Females.

This percentage included 73.81 % B-Tech, 21.43 % M-Tech and about 4.76 % PhD.

Below 5.20 shows the Percent response from each of the group clearly showing that from each of the Boys Group there were at least 4 responses whereas in Girls most of the girls had less than 2 responses showing lack of interest among the girls at latter part of the study.

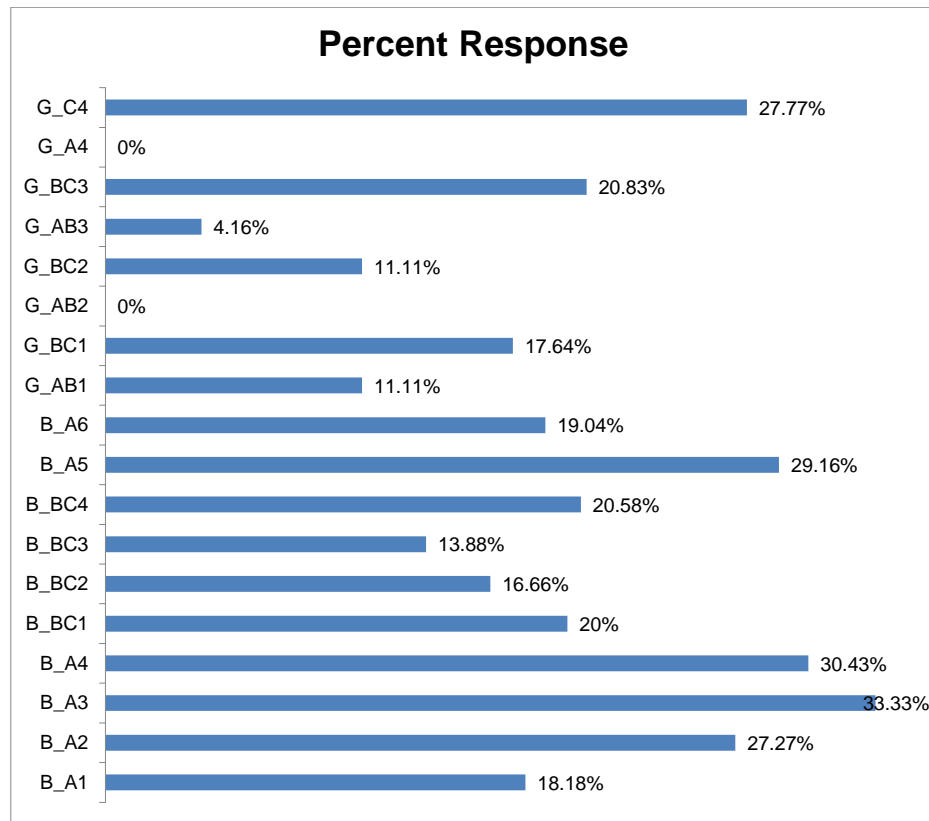


Figure 5.20: Each Group's Percentage Response to the Survey.

When asked if the Study made you aware about energy consumption or other related topics in the last few weeks, almost 88 percent of the respondents said yes, they got aware about the same and 12 percent said No which can say that yes the study was successful in creating awareness among the occupants.

Figure 5.21 shows the students response when they were asked how much they agree or disagree with the statement that Energy Conservation is an important these days and one should try to do everything one can at Home or University Level then almost 60 percent of the occupants Strongly Agree to the statement showing that students think they should try to do maximum they can for saving Energy.

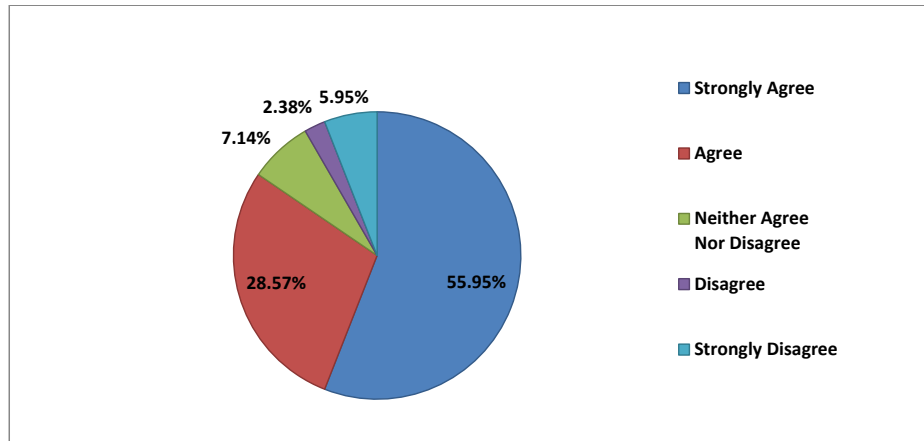


Figure 5.21: Survey Participants Percent Reponse when students were asked how much they agree or disagree with the statement that Energy Conservation is important these days and one should try to do everything one can at Home or University Level .

Students were also asked if they did put some efforts in reducing Electricity during the study. Almost 70 % responded with they had put Good amount of Effort in reducing energy consumption in the weeks of the study.

When students were asked the strategies adopted to conserve electricity during the study, almost 70 % of the occupants always turned off the lights when they leave their room with other followed practice to turn off the Inactive Electronic Devices at the end of the day or when they leave their room with maximum never followed practice to turn off the geyser in the bathroom. Figure 5.22 shows the practices they followed Always, Very Often, Sometimes and Never.

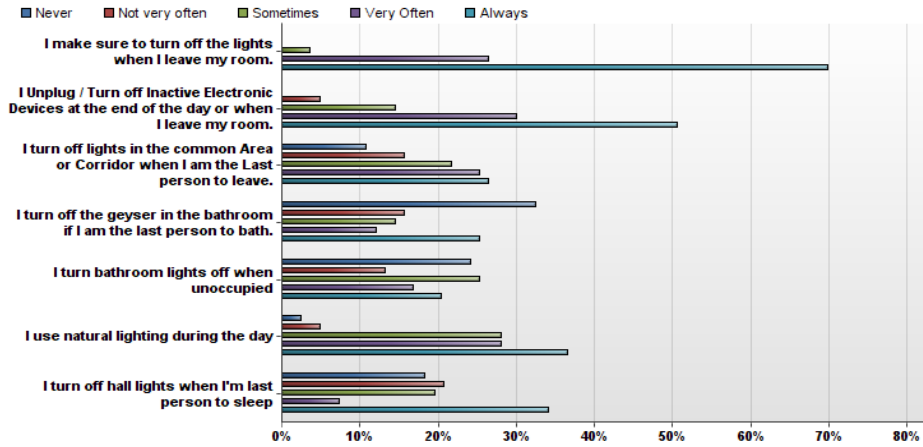


Figure 5.22: Different Practices adopted during the study to Conserve Electricity.

Figure 5.23 also show results when students asked the best way that will help in maximum reduction. Participants feel that self-motivation works best and then if they will be provided with information through mail that will be another mechanism that can help in better reduction.

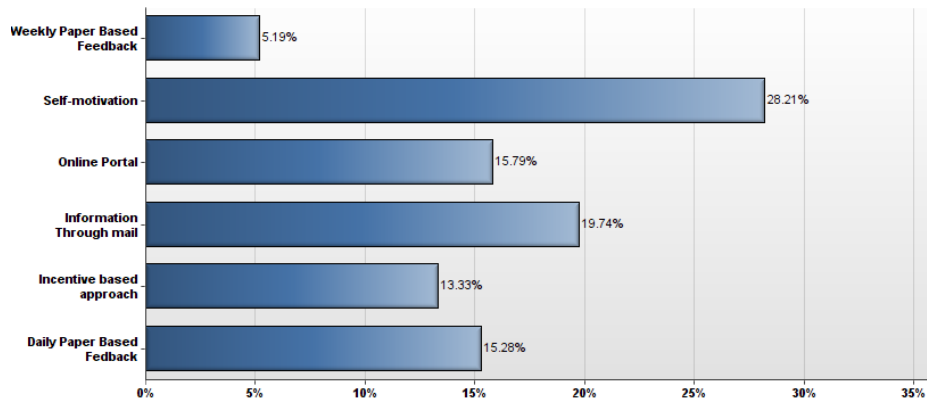


Figure 5.23: Students views on the best ways that will help in Maximum Reduction.

Figure 5.24 shows the statistics of when Students were asked if they checked Online System to check the consumption, about 37 percent responded that they do have sometimes checked the system whereas about 23 percent responded that they never checked the Online feedback system showing lack of interest and motivation to conserve.

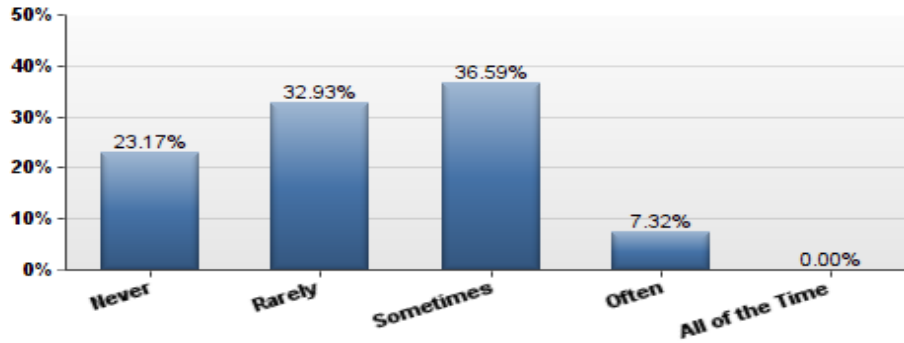


Figure 5.24: Statistics showing student's frequency of checking the Online System .

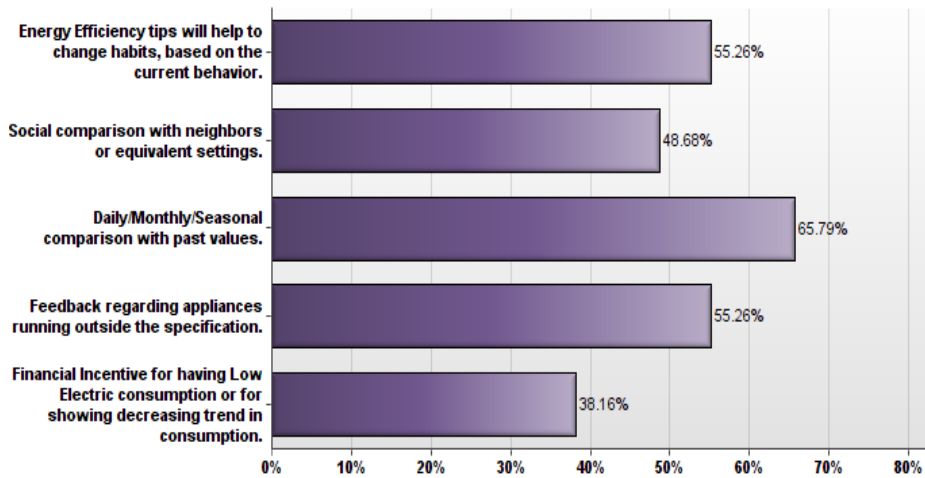


Figure 5.25: Responses showing the mechanisms that they think can help in better Energy Reduction.

Figure 5.25 shows the responses when students were asked to rate the mechanisms which they think can help in better Energy Reduction. Almost 66 percent people feel if they will be provided with Self Comparison it will help better to save whereas financial Incentive was the least preferred mechanisms. Participants when asked if they get information about how much money they saved from the previous weeks will that be helpful, almost 95 percent occupants said yes equivalent savings will be more useful rather than providing with information about equivalent cost consumption.

Chapter 6

Conclusions

A watt saved is more than a watt produced. While several prior studies have looked into providing efficient and accurate energy consumption feedback as an effective technique to achieve reduction in energy consumption, no such study has been done in the Indian context. Understanding this influence in the Indian context is important since the energy environment in the developing countries such as India is very different from that in the developed countries such as the USA in terms of types of appliances used, demand-supply gap, socio-economic and cultural parity and pricing of electricity.

In this research, that we term as Power Down, we take a university dorm setting and performed a 10 week long study, spanning 5 different phases, to better understand the influence of different feedback mechanisms across different genders towards motivating energy conservation behavior. We observed that while females were more energy conscious than males, feedback resulted in higher motivation towards energy conservation in males than in females. Such an observation calls for developing suitable feedback approaches, keeping in mind the gender of the audience so as to result in most effective conservation behavior.

Amongst different feedback approaches, daily paper based feedback was observed to be most effective. Such a mechanism, does not require any additional effort (like logging onto an online portal) by the user and provides feedback over the immediate past thus resulting in most impact. When the participants were surveyed, majority of them acknowledged that daily email based feedback will also be very effective. While email also requires online access, the audience for our study (university students) usually check their email at least once a day. As a result, no special effort is required to access the feedback information.

When comparing different study phases, competition phase resulted in most reduction for both females and males. This further corroborates the finding from previous studies that competition spirit, along with incentives, are jointly useful to provide the most effective motivation. Males,

known to show more competitive behavior, demonstrated higher reduction in energy consumption than females, during this phase.

While our study was limited to university students, we believe that the inferences drawn can potentially have a wider applicability to a broad set of users. In the future, we plan to extend a similar study to residential apartments to better understand the generalizability of our results.

Chapter 7

Limitations of the Work

Following are the limitations of the work:

- Influence of any external factors on any of the participant during the study was neither monitored nor was controlled. The results obtained through analysis did not take into account effect of any such factors if adopted during the study. The influence may have lead to variation in results but will remain part of limitation of this work.
- Peer or any external factors like Roll outs inside the campus may have influenced the members of the baseline group, providing them an idea about the ongoing energy conservation drive inside the campus. Elimination of such factors will remain part of limitation of this work.

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