Imperial College London

2nd year group project

Interim Report

GLOW

The smart thermostat

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Contents

Abstract

This report details the first stages of the design of the GLOW smart thermostat. The aim is to present the reasons behind the project and explain design and component choices. This includes possible challenges and an outline of the next stages.

1. Introduction

Between 2004 and 2014, the price per unit of both gas and electricity increased respectively by 115% and 63%. Heating is by far the biggest factor in household energy use in the UK and consequently it accounts for 53% of the total expense for gas and electricity. However the large majority of heating systems fails to display data on accurate temperature measurements and financial and energy expenditure. This information could be of particular interest to the user taking into account that a single degree Celsius could make a difference of 10% in heating costs (OVO Energy, n.d.). The aim of the project is to design a "Smart" Thermostat, to provide householders with live feedback on power usage and expenses. The proposed device would leverage on both economic and social aspects in order to enhance the user experience and at the same time benefit the environment. The group has named the device GLOW.

1.1 Situation

The "Internet of Things" is currently a rising star in the electronics world; it is an expression that encompasses intelligent or smart devices connected in some way to the Internet, forming a bigger cohort of devices that communicate with one another to offer more advanced functions compared to "normal" devices. Everything from phones to fridges has gone through the "smart" filter, i.e., they all have been designed with special features that serve concurrently to make the life of their user easier. Some implementations of smart thermostats are already on the market, but generally lack of the most peculiar characteristics of smart devices. Their main function in fact usually consists in enabling the user to control the product through its touchscreen or via an application. Nevertheless, no device on the market offers user personalisation nor has any "social" aspects. This is where the implementation of what the group believes to be a smart thermostat comes in.

GLOW will likely be midway between current thermostats and the "blue sky vision" for the project. GLOW will employ a screen, will involve online functionalities and will tie into the forms of technology the users already own: mobile phones and computers. The "blue sky vision" will probably relinquish the display and solely be controlled by the user through a portable device and possibly, looking at even further evolutions, even through an advanced form of automation.

1.2 Project Definition

The proposed implementation of the smart house thermostat revolves around the user, as seen by the target features. The device will need to be extremely intuitive, requiring only a minor learning curve even for the least proficient in using new technologies. It should display relevant information in a concise and easily accessible way, while providing advanced features. As the nature of a thermostat is not a device that the user will check very often, a system to encourage monitoring the energy spending should be designed.

While outlining the project, the first objective was to provide live feedback on energy consumption and cost to the user. This would be mostly practical for the user and would not necessarily lead to lower energy usage for the households, except when heating needs to be lowered due to financial constraints. When users have sufficient disposable income, the trend is usually to heat more of the house for longer, in particular in buildings with central heating. An average centrally-heated home requires about double as much energy for space heating as a similar home with heating only in the living room (Palmer & Copper, 2013). For the project to have a broader environmental impact therefore, social element needs to be taken into account, exploiting social influence to encourage the user to behave in a more environmentally conscious way and consequently reduce wastage by turning the heating down when not necessary.

1.3 Design Criteria

From our Product Design Specification (PDS), found in Appendix A, the following elements are the most crucial and relevant for the current stage of the project:

These elements define the essential functionalities of GLOW.

Performance (PDS 1) - In addition to the functionalities of a standard thermostat, the product will provide additional data and settings to encourage positive behavioural changes in users that will reduce energy used for heating. It will also have a low energy consumption.

Environment (PDS 2) and Customer (PDS 11) – The device is suitable only for residents living in properties that use the energy grid. The prototype will be designed for use in the United Kingdom only. However, its functionalities may be used in and adapted to other countries as well.

Being a feasibility study, testing is of great importance.

Testing (PDS 21) – The prototype will be tested in London. It is fundamental to ensure that the product meets the safety requirements (PDS 24). Further testing focused on behavioural change could be carried out, including simulated power savings to assess the viability of our product.

These elements provide additional factors to consider.

Target Product Cost (PDS 5) - The device should aim to pay back for itself over the course of its life. Thus, it cannot be too expensive and should preferably be more cost-effective (including installation) than the other “smart thermostats” on the market. Current prototype cost target: £80 to £120.

Maintenance (PDS 4) – The product has to be designed such that software can be periodically and automatically updated via the Internet. Ideally, the hardware will not need repair or replacement during the product’s life in service (PDS 3).

As a “smart” product, ease of use and appearance are also significant factors.

Ergonomics (PDS 17) – The product will be easy to use in order to be appealing to a wide range of customers from all age groups and backgrounds.

Aesthetics, Appearance and Finish (PDS 16) - The device should be compact and professional looking. Its interface should be neat and uncluttered, presenting information in clear and readable manner.

2. Concept Design

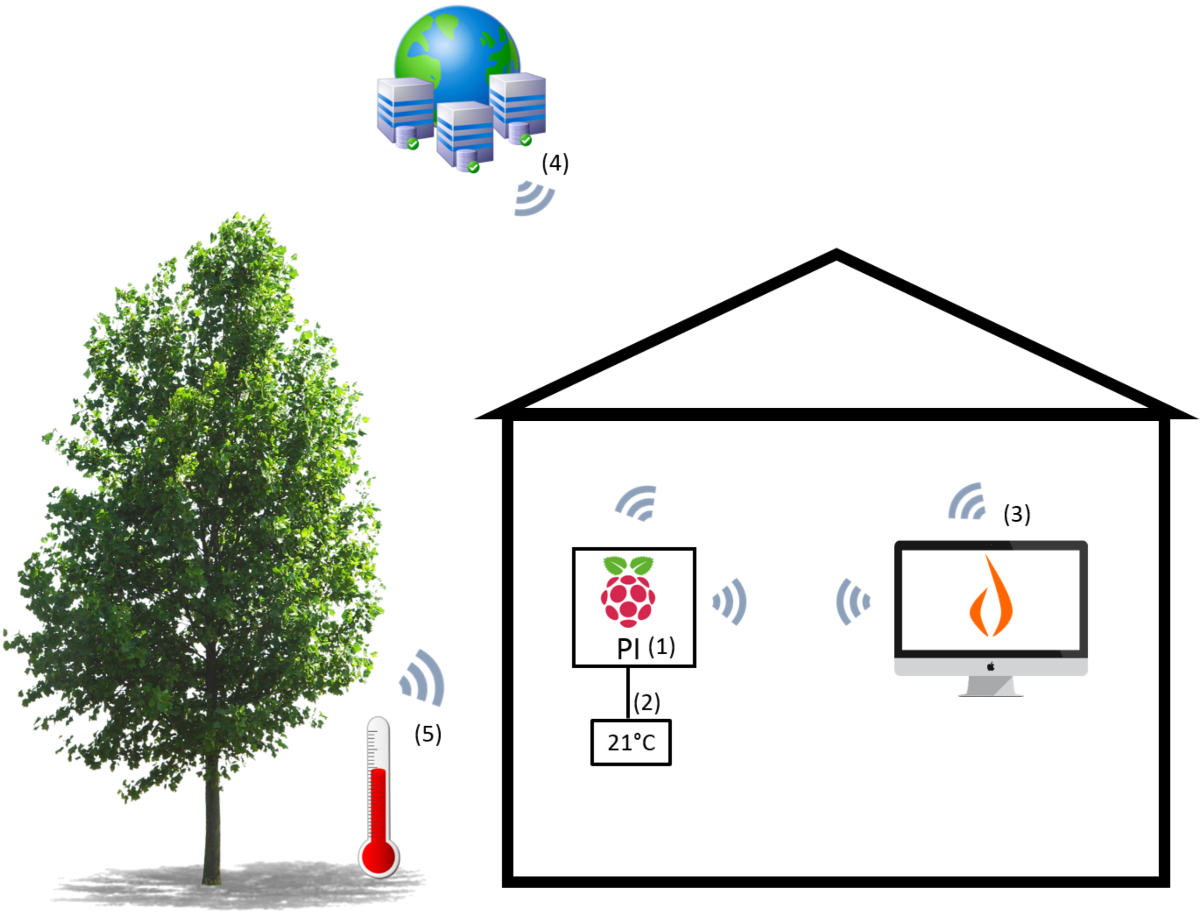

Figure 1: Overview of GLOW project

(1) Raspberry Pi - the "brain" of the device.

(2) Temperature Sensor - measures the room's temperature and sends it to the Raspberry Pi.

(3) Website - linked to the database.

(4) Database - store user profile information.

(5) Outside temperature fetched by the Raspberry Pi from the internet.

2.1 Screen and Interface hardware

The main design philosophy followed in this project is to make the interface (software and hardware) both intuitive and ergonomic as the device should be easy to use by any member of the target audience regardless of technical background. This directly ties in to sections 16 and 17 of the PDS (aesthetics, appearance, and finish and ergonomics).

Choosing a Raspberry Pi as the "brain" of GLOW was agreed upon since the very first stages as the most suitable option for the project: it offers an easily adaptable Linux environment, a wide variety of I/O ports and the inbuilt capability to access the Internet. Most importantly, it is a compact and affordable computer with dimensions comparable to a thermostat. However, choosing the hardware that the customer would be interacting with was not as straightforward. First concepts included a common configuration with a small screen and auxiliary buttons. The inconvenient ergonomics, complexity to configure and the lack of flexibility for functionalities quickly led to dismissing this initial idea. A touch screen appeared to be the ideal platform for the user to interact with the thermostat. It can be easily connected and configured to work with the Raspberry Pi and allows great flexibility to implement a large, complete and intuitive user interface (UI). A large screen size was chosen for this purpose, in order to include as much information as possible on the home screen in the clearest way: temperature data, financial costs and environmental and energy saving data. The screen chosen is the 7'' Raspberry Pi Touchscreen Display (£40) which is built only for Raspberry Pi usage, easing the configuration and most importantly making the device more reliable.

2.2 The temperature sensor

As the main purpose of the product is to provide the user with real time detailed information on energy usage, it is of fundamental importance to implement a good temperature sensing system.

The system has to meet very specific requirements:

- Accuracy to at least half a centigrade degree
- Easy communication with the Raspberry Pi device
- Low power usage
- Small dimensions in order to fit in the product's case
- Durability and resilience
- Low cost and easily available

The GPIO (PrivateEyePi, n.d.) of the Raspberry Pi does not have any ADC system in it. Using an analogue device with an analogue to digital converter chip was initially considered, but subsequent study on its feasibility proved it to be an unnecessary complication. A digital temperature sensor was instead chosen. The most common choice for this kind of applications is the Dallas DS18B20. It is extremely affordable, easy to use and its accuracy is of +/- 0.5° over a range from -10° to +85° Celsius. It provides 9-bit to 12-bit measurements over a 1-wire bus (Maxim Integrated, 2008), which means that it only needs a data line, VCC and a ground to communicate with the Raspberry Pi. The thermometer also has a user programmable alarm function with upper and lower trigger points, which could be exploited by the final product. For further information please refer to the data-sheet in the Appendix D.

In order to interface with the Raspberry Pi, only one 4K7 resistor is needed, that acts as a pull-up resistor. This makes the component particularly fitting for the previously mentioned constraints, since the final circuit will be easy to implement and definitely small enough to be contained in the case of the device. The circuit is as shown:

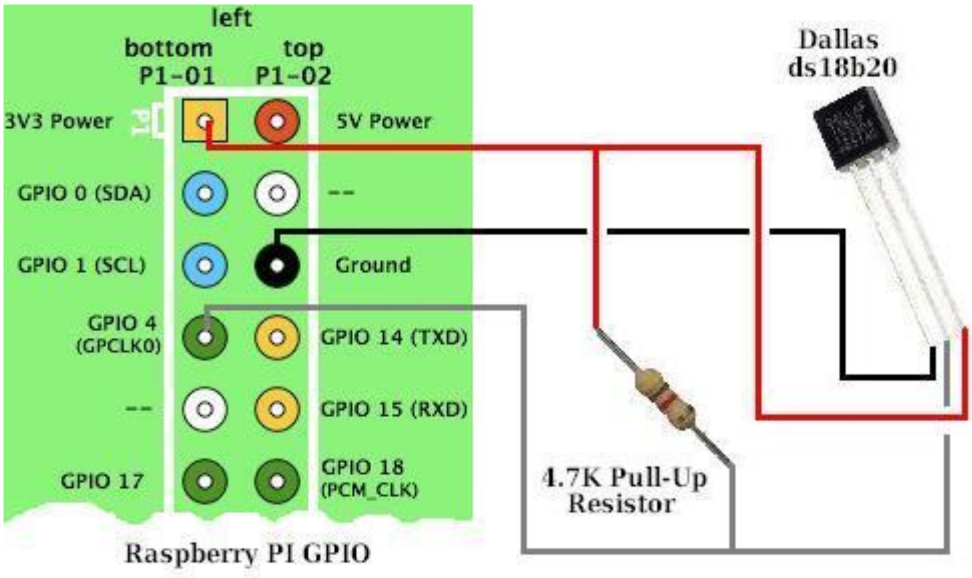

Figure 2: Temperature Sensor Circuit (REUK, 2006)

2.3 Powering the device

The device will be powered by a typical 2A output mains (110v-240v) to USB (5v) converter such as the type used to charge mobile phones or tablets. In case the user decided to use an Ethernet connection over Wi-Fi, it will be possible to use PoE (Power over Ethernet), saving on the amount of wiring required. While commercial thermostats use “power stealing” (“stealing” power from the heating control cables in order to recharge their integrated batteries), this would probably not be sufficient to power the device, requiring the use of an external adapter for safe measure.

2.4 The user interface

After having reconfirmed the choice of using a Raspberry Pi computer, as stated in the project proposal, the designing tasks focused on the software and interface. The design had to be not only functional and ergonomic, but also meet the criteria set out in the proposal of being “smart”.

The first stage consisted of coming up with concept designs for the interface. This was done before confirming any peripherals for the device, as their choice would be based on the interface design itself. Working with software rather than hardware offered the advantage to start almost immediately once a first concept design had been agreed upon, progressively modifying the code as the designs were refined.

[Appendix 8.2.1] The first initial concepts focused on providing the user with all the information that were considered significant, including a list of settings and price comparisons. A touchscreen rather than physical buttons was chosen having compared different possibilities for the hardware peripheral. This allowed the interface to lay out information and controls more widely, since condensing information into one window would have made the device less practical to use and read. The next stage concentrated onto spreading the information out to suit a touchscreen type product.

[Appendix 8.2.2] After considering the input method, the concept design was improved further, attempting to position elements more sparsely on a page. In order to bring forward more developed and eventually final design ideas, it was required to test the interfaces on the hardware in order to better understand how usable they are and how they appear in reality.

Having decided upon hardware and come up with some basic concepts, it had to be ensured that these concepts were feasible. Due to the lack of experience of group members with building GUIs, some more practice in the area was needed before further improving the concepts. After discussion, it was chosen to program the software in Python: it is included with the default Raspberry Pi operating system, it is powerful and good at processing data, and there are many GUI libraries to work with it. It was decided upon Tkinter (wiki.python.org, 2014), the "most commonly used" library for GUIs in Python, included with several of the installs for Python. Learning how to use it will help improving the concepts towards the final design [Appendix 8.2.3].

2.5 Cost

The product is very feasible to build, due in part to the hardware used. Both the Raspberry Pi and the Raspberry Pi screen are prebuilt components that become fully functional after minimal user input, such as installing the operating system and any libraries needed for the software. Due to the flexibility of prototyping using programming, building a working prototype is an achievable goal. The price of the prototype, depending on final component choices, will be in the range of £80 to £120. The price for a hypothetical industrial production however would be much lower, as the components used were bought at individual prices and the higher end Raspberry Pi was chosen. This choice is supported by the need to ensure that the software built would run on the hardware. After achieving a final version of the software, the specifications that the device needs to run could be further tested and this could lead to a different controller being used.

2.6 Website

The GLOW website [Appendix C] constitutes an important module of the product. Not only will it be a platform used to show and explain the product in a simple and concise way to potential customers, it will also include a member's only area that will enable users to customize their profile online by changing their settings, as modifying parameters directly on the device might be inconvenient for some users. The website uses HTML, CSS, JavaScript as well as PHP scripts to read and write data to/from a database. This database will also interact with the thermostat device.

3. Discussion

The main purpose of the interface is to convey real-time information about energy usage, stimulating the users to adopt a more environmental friendly behaviour. The immediacy of feedback has been proven to be one of the most effective ways to encourage user awareness of their energy consumption, producing savings of up to 10% (Houwelingen, et al., 1989). Real-time feedback in fact empowers the users with the control over the heating system in their houses. Moreover, allowing users to simulate the effects of adjusting temperature setting of the heater, the smart thermostat could help users to learn how their settings affects energy consumption and subsequently expenses (Nowak, et al., 2014).

Nevertheless, real-time feedback alone is not sufficient to motivate energy saving. Energy consumption in kilowatts is far too abstract an information for the average user. Even with exact and accurate data on energy consumption, the users may have little understanding of the amount of energy (Palmer & Copper, 2013). Thus, it was decided to relate the energy consumption to events that householders are more familiar with. For example, instead of telling them that they have saved 1kw of energy, the thermostat will show that the equivalent amount of energy can keep a light bulb on for 20 hours. The data is this way more tangible and relatable for users. They could appreciate how much energy they are saving and how this energy could be put to other uses.

Furthermore, the smart thermostat analyses the user profile and sets up a virtual community for users with similar background. Research has shown that people are often more willing to take any pro-environmental actions if others are contributing. Knowing that they belong to an environmental friendly community and seeing the average consumption of this community motivates them to keep up with their peers. Comparing one's progress with others has in fact long been known to be a key determinant for people's actions (Palmer & Copper, 2013). The smart thermostat would allow the users to choose whether they wish to make their data public. It has been proven that commitment made in public encourages long-lasting changes in one's energy saving behaviour (Nowak, et al., 2014).

The main reason for including user profiling is that users have different behaviours according to their age, financial and social standings. A student would not necessarily have the same needs and habits as a retiree, therefore the displayed information would have to change. The shown data will need to be specifically tailored to the current user; for this reason, it will be necessary to develop specific profiles for the device in order to provide highly personalised feedback. In conclusion, the thermostat could record users' usage and behaviour data anonymously, building a database used to present comparative statistics to the user. This feature will also tie into the website, as previously discussed.

4. Challenges

The project GLOW, as presented, is primarily based on software. Although this will represent a positive factor in reducing testing time due to the flexibility of programming, writing the code itself is a very complex and time consuming task. Time constraints will therefore play a substantial role in achieving a software working to an acceptable standard. In order to tackle this limitation, good time management and fair sharing of the workload will be extremely significant. A Gantt chart will be used to facilitate this task.

A more abstract, but nonetheless essential, obstacle to consider, is making the product appealing to the potential users. While the project was originally designed as an aid to more financially sustainable choices for students, it is at this stage necessary to promote its use to a much broader and varied target audience. The marketing and advertising will therefore focus on the great impact that the use of the device could have on the environment, highlighting the features that make GLOW better than the competition on the market; this will be further developed in the next stages.

5. Conclusion

Through the first term, from the idea proposal to the interim report, the project was undergoing constant modification. Indeed, after the numerous group meetings and discussions with the project supervisor new ideas in order to improve the GLOW project were often brought forward. The most important features of the thermostat however remained the same: a smart device that could adapt itself not only to individual households but also to different user profiles. Therefore, the focus was on how to enhance the connection between GLOW's performance and the user characteristics through different features such as interface and design, as presented in this report.

To conclude, thanks to the preparation thus far, it is now possible to start working on the next stages of the project.

6. Future Work

Having designed and obtained a prototype version for the device's interface, and keeping in mind all the various functionalities that need to be implemented, the second part of the academic year will be devoted to practically realising these concepts. Regarding the hardware deliverable, the temperature sensor will take up most of the work, as it is the only circuitry involved in the system, along with the Raspberry Pi.

As far as software is concerned, there are multiple deliverables: the main interface and the website. Three key elements need to be developed: statistics, live prices through thermo-physical calculation, prioritizing and managing displayed data. This leads to the second stage of development, which consists of connecting the device to the Internet and collecting relevant data required for the functionalities; these include energy prices and user settings set up on the website. The third part of software implementation is designing the website, which will play a major role in the GLOW project. Adding to the description of the project, the site will include a restricted member's area that will allow the user to change its energy and home settings online to update the thermostat.

Further developments and concepts, which will not be part of the final prototype due to limited resources, have already been considered and constitute an important part of the long-term version of the project. The key functionality that could be implemented to further personalise the user experience would be making the system open source. This would enable third parties to develop new functionalities on GLOW to broaden the user's possibilities, grow the user community and enable constant innovation on its platform.

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8. Appendices

8.1 Appendix A: PDS

Product Design Specification

Project: A Smarter Thermostat to Save Energy

Author: Theo Franquet, Alexandre Abou Chahine, Yumeng Sun, Guillaume Rame, Matthew Abdul-Rahim, Ilaria Albanese, Xingzi Zhu

1. Performance

- The product will act as a thermostat-it will calculate when the heating needs to be turned on
- It will use the Internet to retrieve energy prices and other data
- It will have a low energy consumption
- The device will help reduce the energy usage of consumers

2. Environment

- The product will be installed in properties that use the energy grid
- The prototype will be designed for use in the United Kingdom but its functionalities may be used and adapted to in other countries too
    - Prototype will be tested in London

3. Life in Service

- The device should last slightly longer than the product lifespan (#15) to give users time to obtain new devices - exact duration is not quantifiable at this stage
- The product should not require mechanical maintenance during this duration (#4)
- The device could be improved via software updates instead of requiring new hardware to keep it functional for a longer period of time (#4)

4. Maintenance

- The cost of maintenance needs to be minimal - hence the hardware should ideally not need repair or replacement during the product's lifespan (#3)
- In case of damage or unexpected failure of the components the instructions will clearly indicate how to fix the issue when minimal or refer to more competent individuals (via a customer service help chat perhaps)
- The software of the product could be updated via the Internet (#3)

5. Target Product Cost

- The product should aim to pay back for itself over the course of its life
- Preferably more cost-effective (including installation) than other “smart thermostats” on the market
- Current prototype cost target: £80 to £120

6. Competition

- There are many competitors on the market:
    - Smart Thermostats such as NEST - Well known Google owned “smart thermostat”
    - Several normal thermostats which will be cheaper but with less functionality

7. Shipping

- The product should be small and light (#12/13) hence shipping will be inexpensive
- Will be shipped as a complete device, rather than to be assembled
- Normal shipping channels are a feasible options as the product is only for houses on the grid

8. Packing

- The packaging must be durable such that the product gets to the user intact
- Packing should not increase the size/weight substantially to keep shipping costs relatively low (#7)

9. Quantity

- One unit per property
- Blue sky vision includes extra sensors to better estimate heating usage

10. Manufacturing Facility

- The device should be easy to assemble to keep production costs down and achieve an affordable final product (#5)
- The manufacturing process should not need any specific equipment or machinery and should be able to assemble by non-technical labour force

11. Customer

- Any residents living in flats/houses that use the grid for energy
- Prototype aimed at people living in the United Kingdom
- Future versions could expand to include other countries/situations

12. Size

- The product should be small so that it can fit in any household comfortably
- It needs to be large enough to display information in a readable format

13. Weight

- The product should be light enough to be easily affixed to the wall (#30)
- It is preferable for the product to be light (#5,7)

14. Materials

- Electronic components to be determined through research and design
- Casing will probably be plastic to reduce weight (#7,13) and cost (#5)

15. Product Life Span

- The product life span should be within 10 years (#3)
- To keep up with advances in technology the product could be updatable by software

16. Aesthetics, Appearance and Finish

- The device should be compact with a professional look
- The interface should be neat and uncluttered, presenting information in an easy to read manner

17. Ergonomics

- The product must be easy to use - users could be from a wide range of age groups
- Touchscreen interface has to be simple and user friendly (#16)
- Related website needs to be easy to navigate
- Software must be easy to maintain/update

18. Standards and Specifications

- The product must meet health and safety standards for the United Kingdom

19. Quality and Reliability

- High quality product within limited budget of £200 - (keep cost as low as possible while optimizing quality and reliability
- Must meeting specifications above (#18).

20. Shelf Life (storage)

- The product should be able to last several years in storage - exact duration not quantifiable at this stage
    - Preferably the actual shelf life would be much less than this because the product would be produced in batches that can be sold off in a short period
- Provided packaging is durable (#8) the limiting factor to shelf life is the life of the electronics without power

21. Testing

- A working prototype will be built for testing (in London)
- This will need to meet the safety requirements (#24)
- Further testing focused on behavioural change could be done, including simulated power savings to assess the viability of our product

22. Processes

1. Identify the problem and generate ideas
2. Produce detailed product design (idea confirmation before building)
3. Build the prototype
4. Test the prototype and make appropriate modifications
5. Finalise idea and product
6. Present problem, ideas and final solution

23. Time Scale

- The project will be carried out in two university terms
- Deadlines:
    - 17th January 2016 - Interim Report
    - 13th March 2016 - Final Report and Website
    - 22nd March 2016 - Presentation of Ideas/Product

24. Safety

- As in #18, the product must meet UK health and safety standards
- The case should be sealed with no exposed electronics
    - If metal, the case must be grounded
- The case should have no sharp edges
- Any soldering must be precise with no short circuits to prevent hazards

25. Company Constraints

- Not Applicable

26. Market Constraints

- There are many thermostats on the market (#6), some similarly “smart”

27. Patents, Literature and Product Data

- Not particularly relevant to the project since it will not be are not produced for the market yet. However, future extensions will need to include:
    - Patents, literature and product data should be written in English. Product data should be highly explanatory yet easy to understand
    - For when target audience is expanded to include other countries, these need to be translated if necessary

28. Legal

- Abide to local (UK) laws - patents, copyrights, privacy, safety etc.
- Note that these laws differ in different countries, thus, for future work when target audience is expanded to include other countries, laws of other countries have to be considered

29. Political and Social Implications

- The hope is to prompt behaviour changes to save energy used for heating

30. Installation

- The installation should be as simple as possible in order to decrease cost (#5)
- The main product should be easy to affix to the wall
- If possible in the time constraint the product will be implemented with the wiring included in the design

31. Documentation

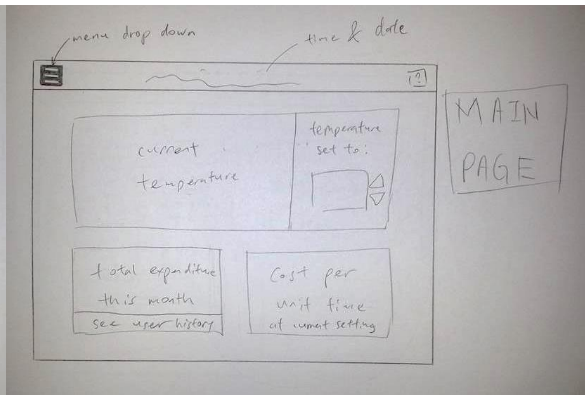
- The work done on the product should be documented for easy reference, to help improve the product further
- Reports on the progress and work done will be essential part of the project

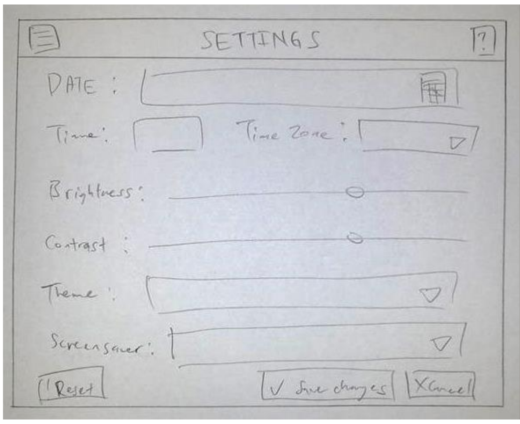
32. Disposal

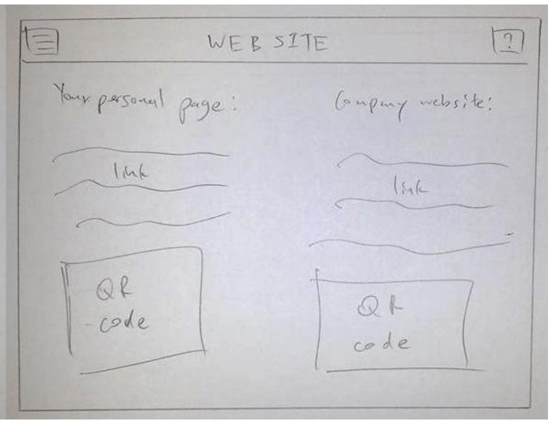
- Much of the hardware is electronic waste and hence will need to be disposable according to the WEEE directive
- The outer case should be disposable by traditional methods (optimally it should be recyclable)

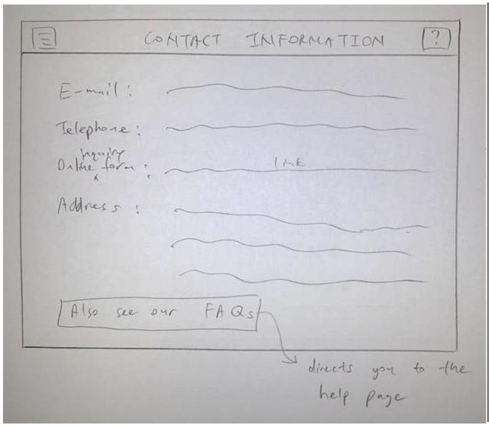
8.2 Appendix B: Interface Sketches and Screenshots

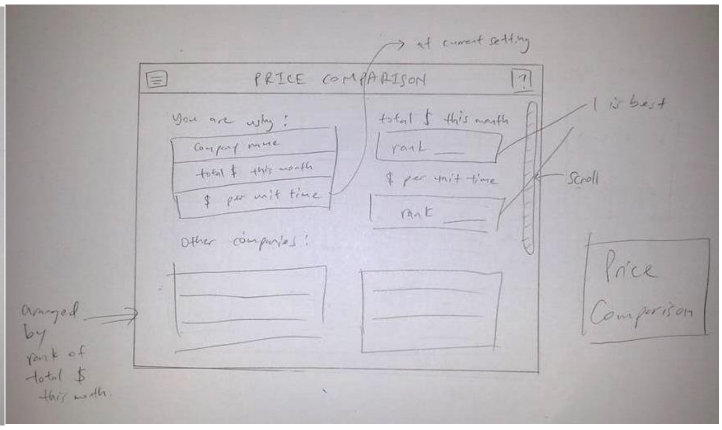
8.2.1 Yumeng's Sketches



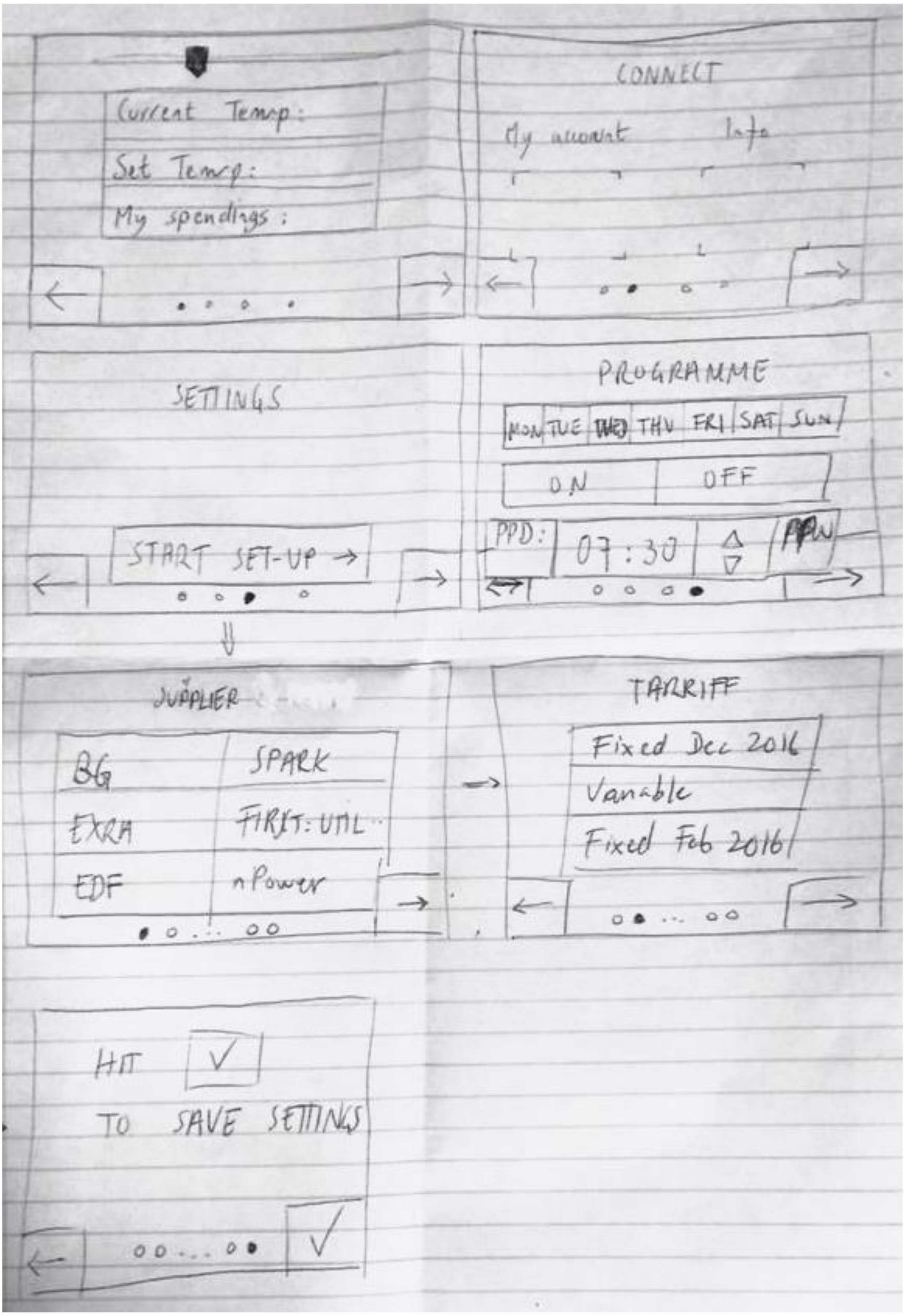




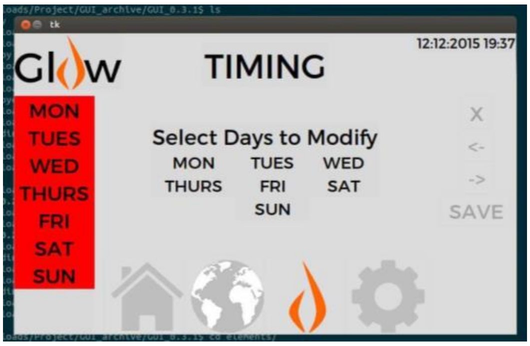


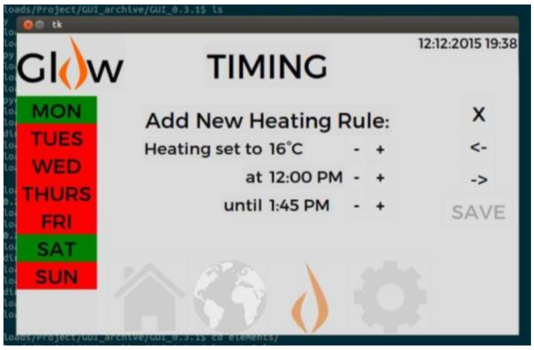


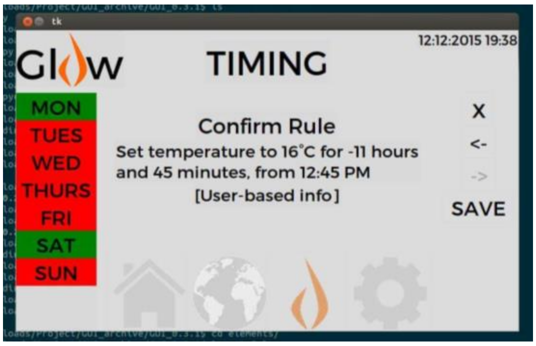
8.2.2 Theo's Sketches

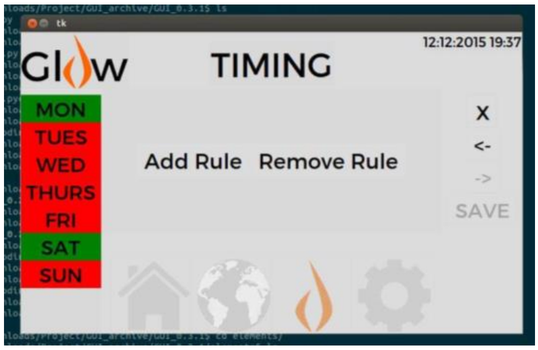


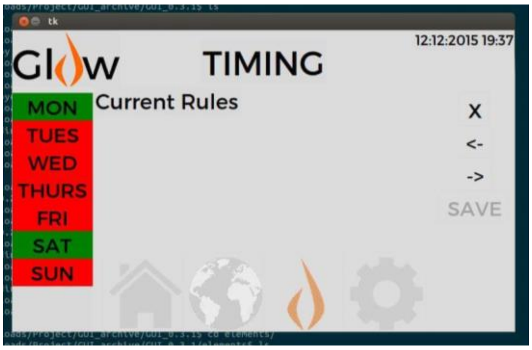
8.2.3 Interface Design



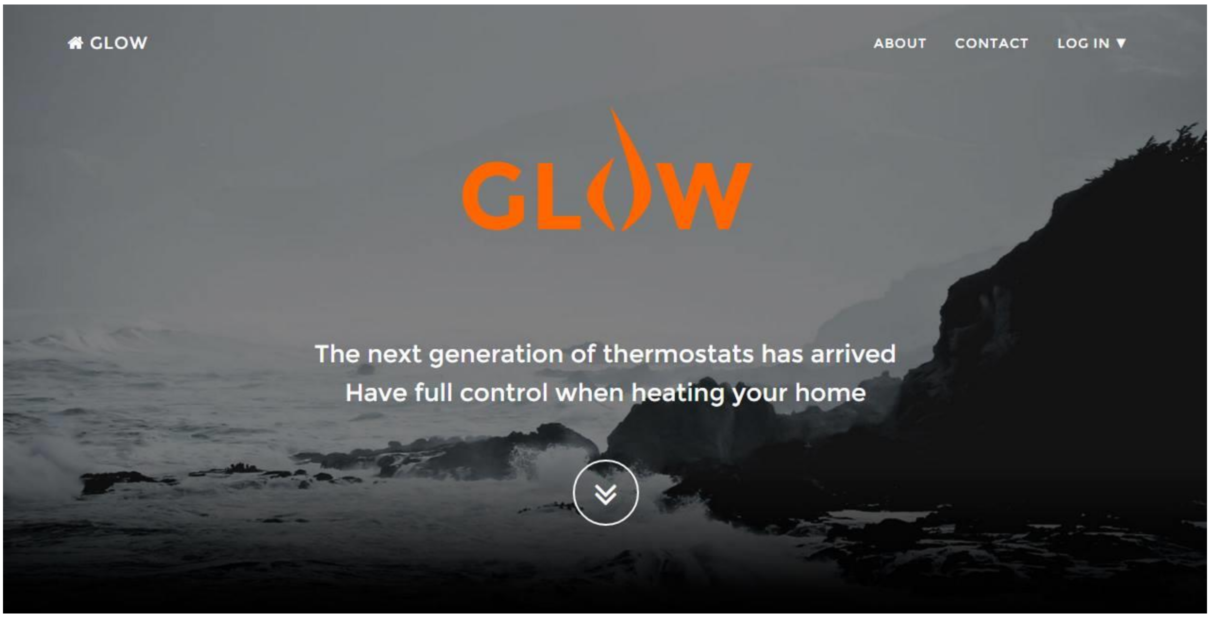


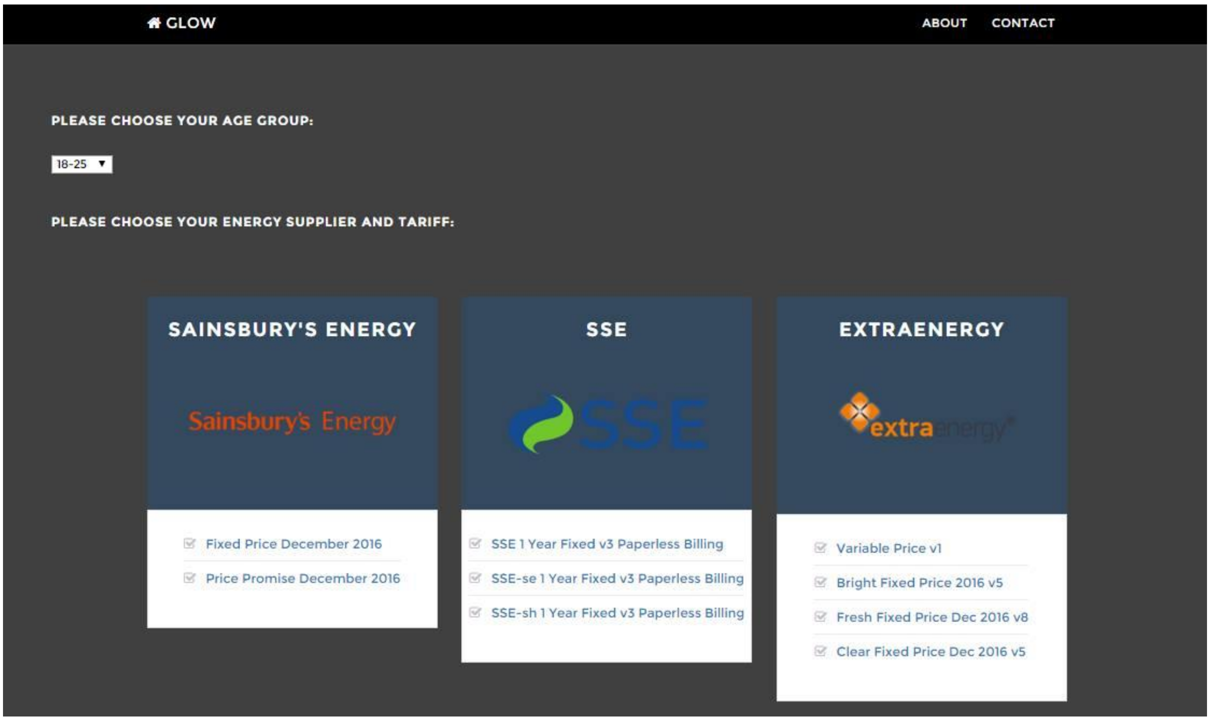






8.3 Appendix C: Website Screenshots





8.4 Appendix D: Data Sheet

maxim integrated™

DS18B20
Programmable Resolution 1-Wire Digital Thermometer

DESCRIPTION

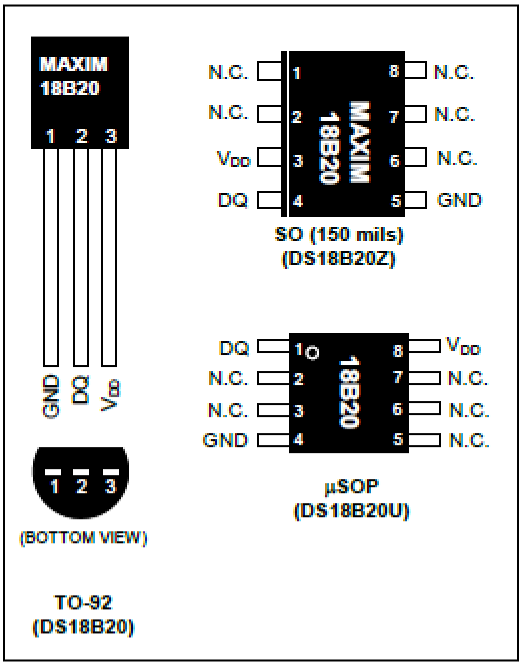
The DS18B20 digital thermometer provides 9-bit to 12-bit Celsius temperature measurements and has an alarm function with nonvolatile user-programmable upper and lower trigger points. The DS18B20 communicates over a 1-Wire bus that by definition requires only one data line (and ground) for communication with a central microprocessor. It has an operating temperature range of -55°C to +125°C and is accurate to ±0.5°C over the range of -10°C to +85°C. In addition, the DS18B20 can derive power directly from the data line ("parasite power"), eliminating the need for an external power supply.

Each DS18B20 has a unique 64-bit serial code, which allows multiple DS18B20s to function on the same 1-Wire bus. Thus, it is simple to use one microprocessor to control many DS18B20s distributed over a large area. Applications that can benefit from this feature include HVAC environmental controls, temperature monitoring systems inside buildings, equipment, or machinery, and process monitoring and control systems.

FEATURES

- Unique 1-Wire® Interface Requires Only One Port Pin for Communication
- Each Device has a Unique 64-Bit Serial Code Stored in an On-Board ROM
- Multidrop Capability Simplifies Distributed Temperature-Sensing Applications
- Requires No External Components
- Can Be Powered from Data Line; Power Supply Range is 3.0V to 5.5V
- Measures Temperatures from -55°C to +125°C (-67°F to +257°F)
- ±0.5°C Accuracy from -10°C to +85°C
- Thermometer Resolution is User Selectable from 9 to 12 Bits
- Converts Temperature to 12-Bit Digital Word in 750ms (Max)
- User-Definable Nonvolatile (NV) Alarm Settings
- Alarm Search Command Identifies and Addresses Devices Whose Temperature is Outside Programmed Limits (Temperature Alarm Condition)
- Available in 8-Pin SO (150 mils), 8-Pin µSOP, and 3-Pin TO-92 Packages
- Software Compatible with the DS1822
- Applications Include Thermostatic Controls, Industrial Systems, Consumer Products, Thermometers, or Any Thermally Sensitive System

PIN CONFIGURATIONS



1-Wire is a registered trademark of Maxim Integrated Products, Inc.

8.5 Appendix E: Meeting Minutes

Meeting 1 22/10/2015

- assignment of roles and tasks
- discussion about stock keeping (rent EEE locker)
- decided on weekly meeting day and time
- created Facebook group and meeting minutes

Things to do:

- Individual research
- Rent a EEE locker
- Need someone in-charge of hardware, someone to do research on which sites have heating price databases, and someone to assist in web developing (distribute roles among Ilaria, Xingzi and Yumeng)
- Something about joining robotics club???

Meeting 2 26/10/2015

- Locker rented (Level 3, 374) by Xingzi. £5 per year.
  - Combination lock (6993)
- Researching databases and help with software programming
  - Xingzi and Ilaria
- Website developing
  - Yumeng
- Interface design (working with software)
  - Everyone can contribute, best design used
  - Layout, buttons, options
- Make an algorithm to suggest which company is the most price efficient for the user
- Main functions on device, additional functions on website

Things to do:

- Need to confirm hardware to order (raspberry pi*, screen (7" - size of iPad mini)*, thermometer etc.)
- Ilaria look up on how to claim from budget (which stores can we order from?)
- Arrange meeting with supervisor (think of choosing a supervisor?)
- Everyone try to design a suitable interface!!!
- Everyone come up with a few product names.
  - ETNA (logo on FB grp)
    - Europe Volcano
  - AESTAS
    - Roman Goddess of Summer, http://www.thaliatook.com/OGOD/aestas.html
    - meaning: our smart thermostat allows you to feel as though it is summer
  - GLOW
  - AURORA

Meeting 3   2/11/2015

- Ilaria Absent
- Email supervisor & arrange meeting
    - Next week Monday (12-1pm or 2-3pm)
- Confirm interface
    - Temperature setting: use up and down buttons
    - Settings page (brightness, screen off time)
    - QR code page (with short links)
    - Swipe or tabs to change page
    - Draw local time from Internet
    - Price Comparison
    - Programme

Things to do:
- Choose name & logo???

Meeting 4   9/11/2015

- Confirmed component ordering platform (online stores)
- Confirm hardware to buy
    - Latest raspberry pi module [Onecall 2461029]
    - 7" Raspberry Screen [Onecall 2473872]
    - MicroSD 4GB [Rapid 493633]
- Get a USB module thermometer/ thermal sensor for the raspberry pi or build one?
    - Found on Amazon but not on stores. Try to negotiate for budget?
    - OR: consider alternative digital thermal sensors available on stores?
    - OR: Build an analogue sensor and use with an analogue digital converter

Things to do:
- Further suggestions on product name
    - ITER (Intelligent Thermostat for Expense Reduction)
- Rearrange meeting with supervisor: 12 Nov 1pm EEE Level 10 Supervisor's Room
- Order confirmed components

Supervisor Meeting 1   11/11/2015

- Price transparency (is this the actual objective?)
    - Think of the actual problem you want to solve!
- Energy saving (so that ppl don't use more energy because they find it cheap, negative behaviour change) - don't focus only on prices (your target audience is not only students, be more abstract?)
    - Give statistics to give incentive to save energy
    - Consider social aspects too
    - Game/ competition to save energy??? (Refer to PHD students' work?)

    - Instead of one house, do a few (a system) - to encourage energy saving - cooperation - collective attention
    - User modeling (rich ppl, poor ppl, antisocial ppl etc…)
- Consider houses that have their own energy supply (PV panels etc.)
- Prototype need not include all considered functionality
- Feasibility VS Ambition

Things to do:

- Do reading and research!!!?
- Arrange next meeting with supervisor

<u>Meeting 5</u>   <u>16/11/2015</u>

- Monday 2pm as usual
- Raspberry pi has arrived
- write problem definition & PDS bullets points
    - Define the problem and link to functionality (Solution)
        - Lack of control and understanding of heating (electric and gas) expenses - Price transparency (& Contractor Price Comparison [optional])
        - Energy overconsumption - Energy saving via behavioral change; Give statistics to give incentive (energy saved can be used to power…) to save energy (user profiling - different statistics for different age groups/ occupation type)
    - Audience
        - United Kingdom
        - Both houses and flats
        - All age groups/ occupation type etc.
        - Need special functionalities for direct debit payment users?
        - Only those using grid power
            - How about those with their own energy supply? (Solar power etc.) - might not be adapting our project to these group of users.
- Website content
    - User Profile and Settings
    - Website page (product information and functionalities)
    - Additional functionalities
- Prototype - should be ready before holidays
- Interim report
    - PDS, management deadline, idea details, prototype functions, future extensions, references, Appendices etc.
    - Do during holidays?
- Decided to use Digital Thermistor

Things to do:

- Write up a proper problem definition & PDS from above points (see separate Google docs)
    - Can do up a bullet point for supervisor

- Next week start separating report up and assign work
- Confirm details for feasibility study
- 3D printing for the case (next term) - can start thinking of design

Supervisor Meeting 2 20/11/2015

- Friday 1pm
- Understand our users - He gave us some reading about collective action. (The reading is with Xingzi)
- Think both from consumers and citizens' perspectives
- we currently focus on the present issues - might want to think about the future of a distributed energy system
- Consider what actions users take-switch down the heater/insulate windows
- Our project can solve energy poverty - we can help people without sufficient income to pay for the heating to visualize their spending

Things to do:

- building of the prototype
- Things to do before the next meeting
  -present the idea of interface
  -system architecture (hardware/software configuration)
- Consider
  -user behavior(Xingzi research on it)
  -what info we shall present to the users
- Arrange next meeting with supervisor

Meeting 6 23/11/2015

- Alex absent
- Brief all members about supervisor meeting content
- Discussed what to do next (see below)

Things to do:

- Write a proper PDS (in drive folder)
  - Can be slightly vague initially
  - Some points can be "not applicable at this point"
- Decide name and logo
- User behavior analysis - Xingzi & Yumeng (read article provided)
  - Brainstorm what information to provide to which group of users (affect interface design)
- Continue working on raspberry pi interface
- Start working on website soon
  - Wordpress
- Choose thermostat
- Alex to explain his research to group
- Report task assignment
  - Read up criteria on BB

    - Assign before Christmas
    - Mainly research?
- Arrange next supervisor meeting

<u>Meeting 7</u> <u>30/11/2015</u>

- Discussing what statistics to display - aim to encourage improvement in power saving
    - Power saved compared to average in region (on device)
    - Optional non-anonymous selection
    - A button that directs to money saved
- What to put in website - bootstrap (Grayscale theme)
    - Public - product explanation
    - User - login & settings
- report work distribution
    - Requirements see PDF in drive
    - See drive for details

Things to do:

- See same section in previous minutes in blue.
- Arrange next supervisor meeting (for last week of term)

<u>Meeting 8</u> <u>7/12/2015</u>

- Settle hardware delay problem
- Discuss project tutorial content
- Discuss stuff to show/ discuss with supervisor on Friday
- Product name decided: GLOW, logo done
- Discuss device design roughly
    - Position of thermistor probe
    - Case design

Things to do:

- Everyone continue working in their parts of the report (refer to tutorial slides)
- Interface design

<u>Meeting 9 & Supervisor Meeting 3</u> <u>14/12/2015</u>

- Thermometer sensor decision remade (better option discovered)
- Supervisor meeting today
    - Mainly show him interface design
    - Visualization of important data!!! Instead of Joules of energy used, show energy used can power (electrical appliance) for (time) etc.
        - Predictions?
        - Professor Spence? Human-computer interaction books
    - Different data shown to different types of user
    - Document what you are trying to get the user to do, how you would like them to react, what you would like them to understand, how you are going to achieve it
    - Encourage ppl to check statistics (incentives, point accumulation etc.)
        - Show data every time some heating settings are changed

        - Users can set notification frequency (how often data notifications will be sent)
        - Or notification after data has not been checked after a while
        - Attention capturing (red if too much energy used? Green if very good? Yellow if normal?) - link to phone app?
    - How to sustain users' interest in the product?
    - Find out how users use this device
    - Device is opt in (but if it is not configurable/ customizable, ppl might be discouraged from using it)
    - Future extensions - api

Things to do (for Winter Break):

- Individual report sections (by end of December)
- Compile & submit interim report (everyone must read through the report at least once before this)
    - Can consider emailing report to supervisor before submission
    - If report can be submitted multiple times can submit drafts
- Website & device interface design

<u>Meeting 10</u>   <u>11/1/2015</u>

- Hardware available
    - Screen 16:9 ratio
    - Raspberry Pi
    - SD card
- Report matters
    - Confirm suggestions & changes
    - Tone & Language
    - Delete overlapped content
    - Format report
    - References and Appendices
- Submit report for formative marking by 6pm

Things to do:

- Report
    - Further Editing
    - Submit by 17 Jan