ISRN LUTMDN/TMHP--12/5260--SE

ISSN 0282-1990

Apps for optimised energy usage
VISUALIZATION AND BEHAVIOUR

Eric Johansson

Thesis for the Degree of Master of Science

Department of Energy Sciences
Faculty of Engineering LTH
LUND UNIVERSITY
P O Box 118, S-221 00 Lund, Sweden

Apps for optimised energy usage
VISUALIZATION AND BEHAVIOUR

Eric Johansson

November 2011

This thesis work is the final part of a Master's degree project in Mechanical Engineering with orientation towards Energy Technology. The thesis has been carried out at the Department of Energy Sciences, Lund University - LTH and at Sigma IT & Management Sweden AB in Stockholm from the beginning of June and the following 20 weeks 2011 and covers 30 ECTS. Supervisor at Sigma IT & Management AB Stockholm: Johan Berneskog; supervisor at LU-LTH: prof. Jurek Pyrko; examiner at LU-LTH: assoc. prof. Janusz Wollerstrand.

Eric Johansson

Stockholm, November 2011

Thesis for the Degree of Master of Science
ISRN LUTMDN/TMHP--12/5260--SE

ISSN 0282-1990

© 2011 Eric Johansson and Energy Sciences

Efficient Energy Systems

Department of Energy Sciences

Lund University - LTH

Box 118, 221 00 Lund, Sweden

www.ees.energy.lth.se

ABSTRACT

This study investigates the possibilities to provide the end consumers of energy with information and statistics about their consumption in the form of a smartphone application. The report includes both electricity and district heating, but the focus is on electricity consumption.

Earlier studies show potential savings up to 15-20% when real time energy usage information is supplied to the end user. Savings up to 10% can be achieved when historical usage information is presented to the user afterwards.

The infrastructure needed to supply real time consumption data is in most cases in place, but the meter values are not made available by the local grid operating companies who own the meters. Changes in the legislation that will open the meter data market for competition are under way, and this will make possible for third party companies to offer energy visualization solutions.

The functionality for the conceptual application that was built as a part of this thesis was specified by a medium size municipal energy trading company from the south of Sweden.

The Android OS was chosen as the platform as this is one of the biggest and fastest growing smartphone platforms.

The application can fetch consumption data from a server and present these as well as energy saving advices for the user. The application can also fetch real time consumption data from a clip-on meter, making it a good base for further development when official real time meter values are made available in the near future.

TABLE OF CONTENTS

1 INTRODUCTION

1.1 Definition of problem

Until 2020 the European Union have a goal called 20-20-20 where one of the goals is 20% increase in energy efficiency (see chapter 2.3). To achieve this objective an optimized usage of energy will have to be applied. One way this optimization can be achieved is by changing the behaviour of the end user. To influence the end users to use their energy in a more effective way, information about the energy consumption must be supplied.

1.2 Purpose and scope

The purpose of the thesis is to analyse and develop a strategy for how applications for smartphones can be used to achieve an optimized energy usage in the household. Additionally a conceptual App is built to illustrate the strategy.

The following areas are analysed:

- **Which areas in the household have the greatest potential for optimized energy consumption?**
- **What motivations exist to change the behaviour of the end user?**
- **What changes are desired in the energy metering systems to support optimized use of energy?**
- **Define a reference architecture to provide relevant information and permit control for optimized energy use.**

1.3 Limitations

The study is limited to the grids in Sweden and focus on savings for households in Sweden. Results from earlier studies in the field of household energy consumption and energy savings will be used as guidelines for the design of the App, and no further investigations will be made.

1.4 Methodology

The first part is a literature study, in which existing systems for energy visualization are evaluated. The way energy companies measure and send readings for electricity and district heating are also examined.

Next step is to find out where the biggest savings are available. After that an evaluation of what features are desirable in an energy visualization application for a smartphone, and the technology needed to realize this. Finally a conceptual application is built.

From here on, the abbreviation *App* is used when referring to the conceptual application.

Terms and abbreviations can be found in chapter 14.

2 ENERGY SITUATION

2.1 Increasing energy demand in the world

Since the beginning of the 20th century humankind have gone from consuming less than 5 PWh per year of primary energy to around 140 PWh per year 2010. The demand will continue to increase over the next years as the population grows and the standard of living increases in the developing world. [1]

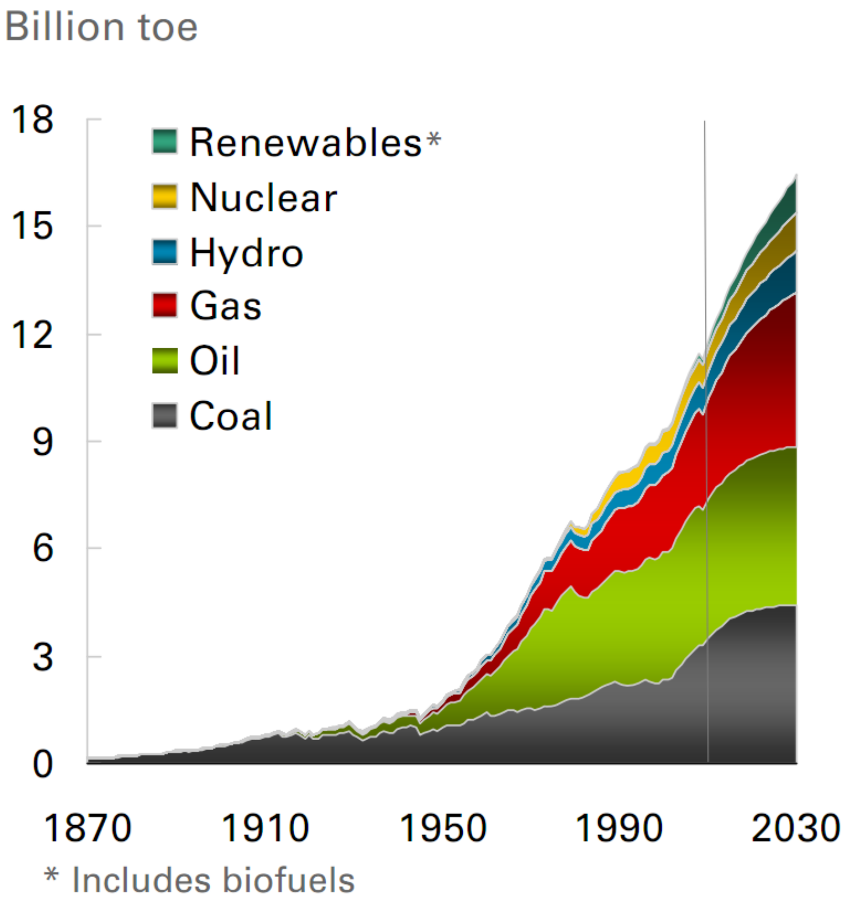

Figure 1. World Energy consumption and fuel mix [1]
1 Billion toe = 1 Gtoe = 11.63 PWh (IEA definition)

More than 80% of this energy comes from non-renewable fossil energy sources such as coal, oil and gas. Another 6% comes from nuclear power [2]. These sources are not endless and will in the coming decades have to be replaced by something else in combination with increasing energy efficiency.

2.2 Environmental effects of energy usage

By burning all the fossil fuels stored in the ground for millions of years in a very short period of time, the concentration of CO_2 in the atmosphere is increasing. According to the UN-organ IPCC (Intergovernmental Panel on Climate Change) there is a connection between the concentration of CO_2 in the atmosphere and the mean temperature of the atmosphere [4]. As the temperature slowly rises, the ice on the poles and glaciers is melting. When ice resting on land, e.g. Antarctica and Greenland melt, this raises the water level of the sea (see Figure 3 & 4).

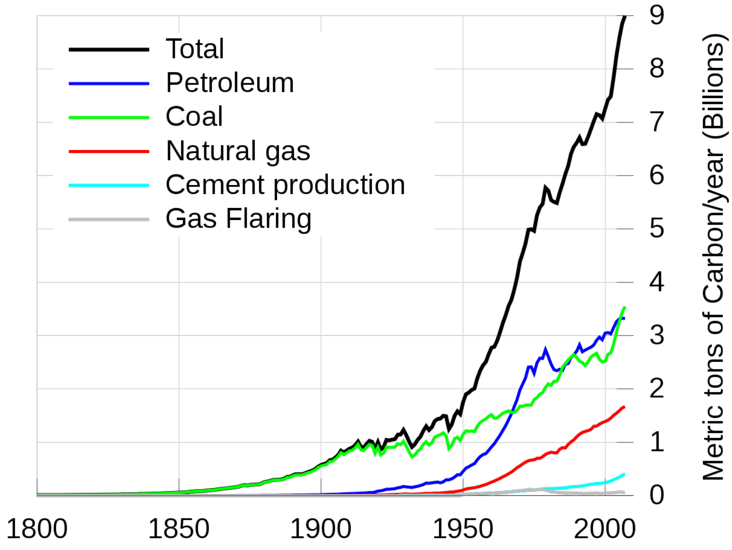

Figure 2. Mass of CO_2 released annually from energy consumption [5]

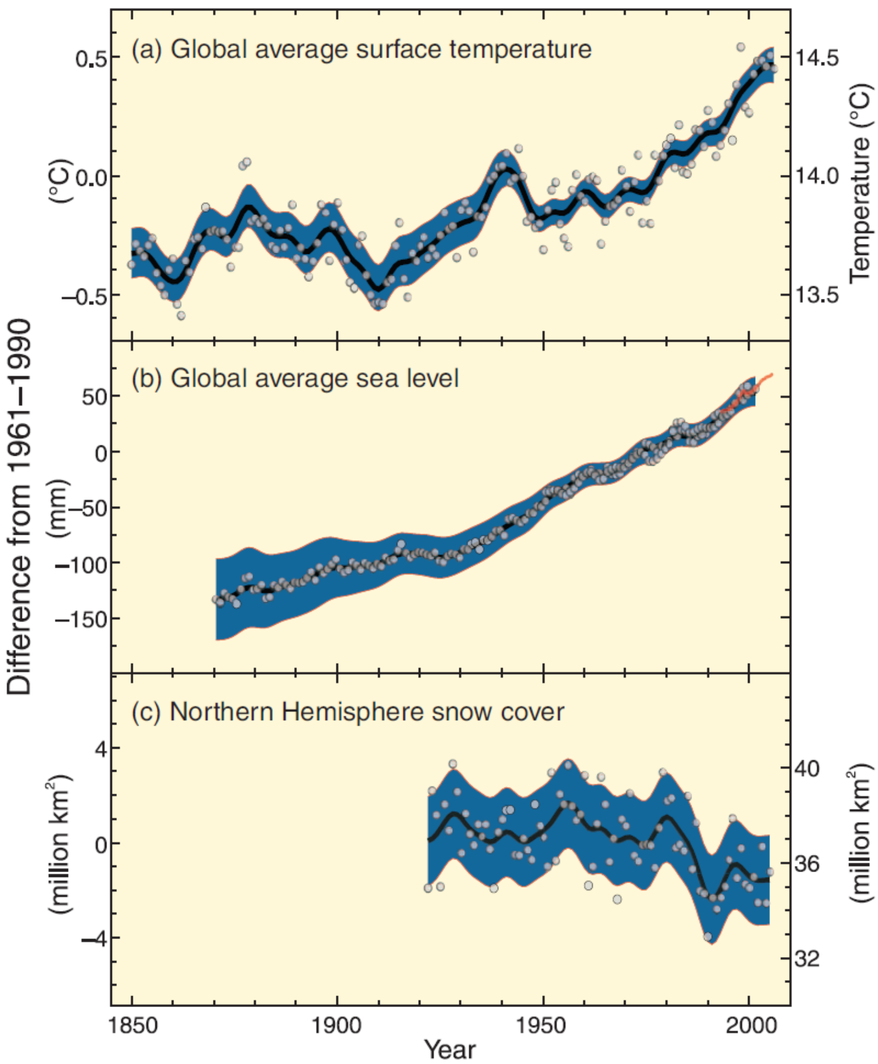

Figure 3. Changes in average surface temperature, average sea level and northern hemisphere snow cover for March-April.[4]

On some places on earth this will soon be a problem. The island nation of Kiribati in the Pacific Ocean is already feeling the effects of rising sea levels. Drinking water is getting polluted with salt water and beachfront villages have had to be moved [6].

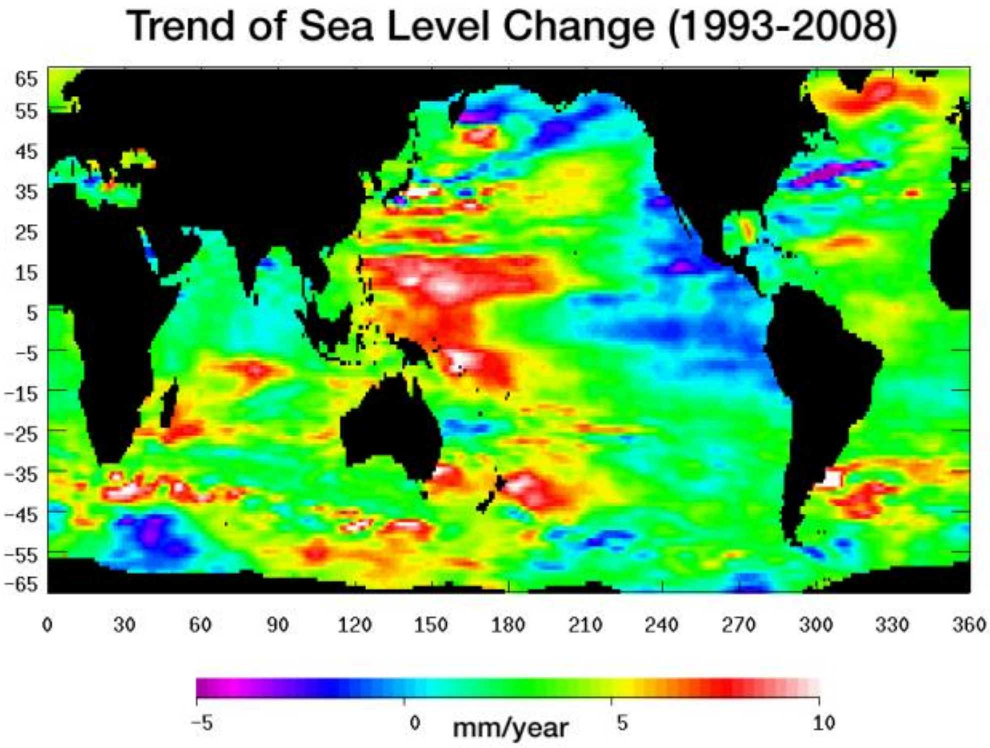

Figure 4. Sea level rise per year [7]

2.3 Energy strategy

To reduce the dependency on fossil fuels and to save the island nations drowning in the sea the EU has made a plan to ensure energy supply and try to save the environment called the 20 20 20 plan.

The goal for is for year 2020 and includes reducing greenhouse gas emissions by at least 20% compared to 1990 levels, increase the share of renewable energy in final energy consumption to 20% and to increase the energy efficiency by 20% compared to 1990 levels.

As more than 40% of the energy consumed in Sweden is being consumed in households, offices and public facilities (see figure 5), savings and identifying of losses must be made here in order to comply with the goal of 20% more energy efficiency.

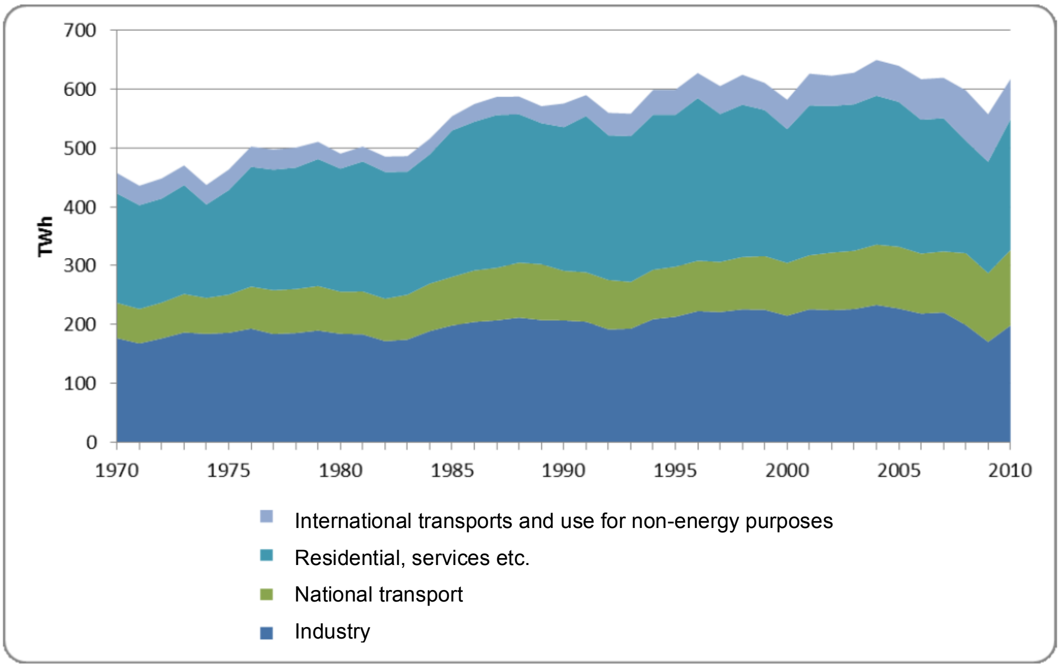

Figure 5. Total energy consumption in Sweden 1970–2010 [2]

About ¾ of the energy consumed in Swedish households is used for heating, and the remaining ¼ is used for lightning and appliances. There is potential for savings both in heating and in lightning and appliances. The potential energy savings for heating is among other things depending on the type of building, insulation and ventilation, but also on habits and the number of occupants. Potential energy savings for lightning and appliances is among other things depending on the type of lightning used and how modern the household appliances are, and also habits and usage patterns. More about this in chapter 12.1.7.

The first step towards achieving savings and identifying energy losses in the households is to make the consumers aware of their energy consumption and usage pattern [3].

3 ELECTRICITY MARKET

The electricity market in Sweden consists of consumers, producers, retail companies and grid owners. Some corporations have multiple roles, for example the company Vattenfall is a producer, grid operator and retail company.

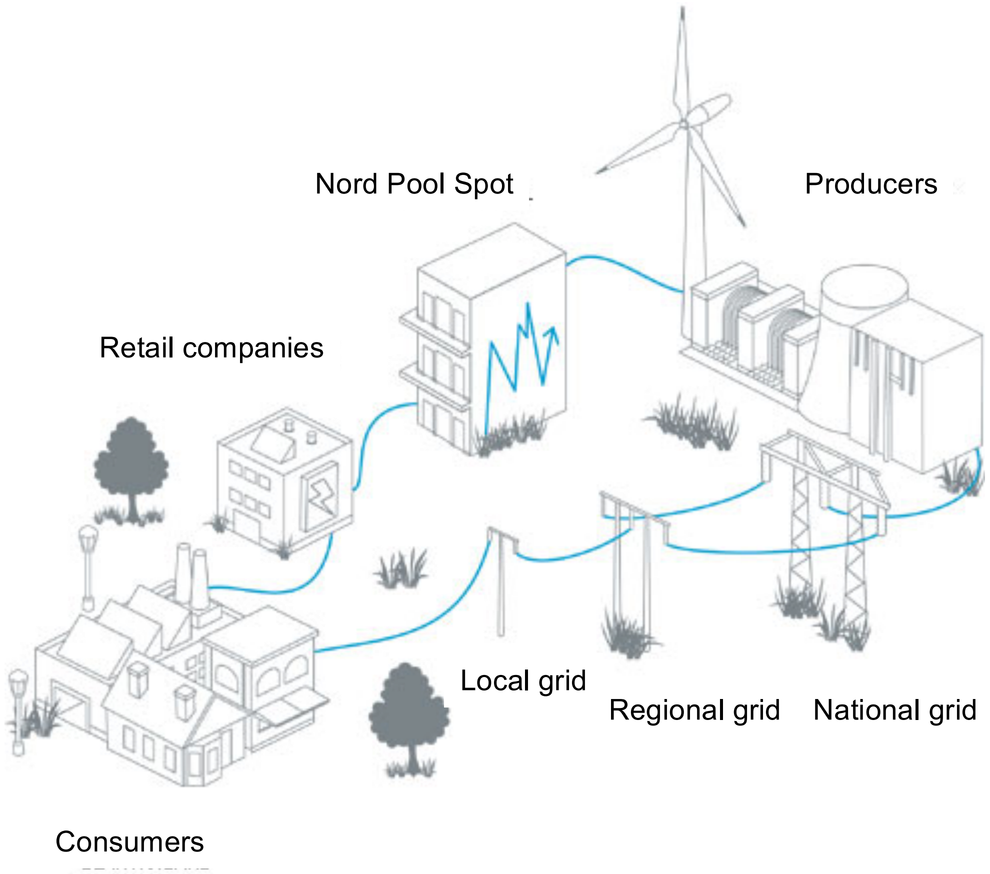

Figure 6. The electricity market [8]

3.1 Consumers

The consumers of energy include households and service, industries and the transport sector. Most consumers buy their electricity from the trading companies. Because this report focuses on energy savings in households, households will from now on be referred to as consumers.

3.2 Producers

The producers are owners of power plants. They need a contract with the grid owner who owns the grid where they are connected. The producers sell electricity to the trading companies via Nord Pool Spot.

3.3 Grid operators

The Swedish power grid is divided into transmission grid (220 - 400 kV), regional grid (30 - 130 kV) and local grid(0.4 - 20 kV). Svenska Kraftnät is the authority responsible for the balance between supply and demand and the owner of the backbone grid, including foreign connections. The regional grids are mainly owned and maintained by E.ON Elnät Sverige AB, Vattenfall Eldistribution AB and Fortum Distribution AB. The local grids are mainly owned by a large number of municipal companies.

The local grid owners own and maintain the meters, and control the meter data. They share this data with the trading companies for billing.

3.4 Trading companies

The trading company buy electricity from the Nord Pool Spot or directly from a producer. The trading company has a contract with and sell electricity to the consumers.

3.5 Nord Pool Spot

Nord Pool Spot runs the leading power market in Europe and offers both day-ahead and intraday markets to its customers. It operates in Norway, Denmark, Sweden, Finland, and Estonia. More than 70% of the total consumption of electrical energy in the Nordic market is traded through Nord Pool Spot. 350 companies from 18 countries trade on the market.[9]

4 ELECTRICITY METER TECHNOLOGY

After the 1st of July 2009 the energy companies in Sweden are required to charge the actual electricity usage on a monthly basis. This has led to a complete change of the meters to smart meters with remote reading capabilities, so called Automatic Meter Readers (AMR). These meters make it possible to provide meter readings for energy visualisation. [8]

Before the 1st of July 2009 the electricity customers were charged a flat fee, which was adjusted at the end of the year when the meter was read manually on site by a technician working for the net owner.

4.1 Meter/terminal

The meter is normally situated in or near the household. It collects the consumption data. The meter is connected to a communication unit/terminal which sends the data to the collector unit (see chapter4.2). This is done either by radio, GPRS, M-bus cable or via the electric grid. The technology used is dependent on the preferences of the net owner, type of household, and where the household is located geographically. A display on the meter normally show the number of used kWh since the meter was installed. A flashing LED (red or IR) blinks at pace related to the usage. Normally it blinks 1000 times per consumed kWh, but this can vary from manufacturer to manufacturer. This LED is used by some of the existing real time energy meters on the market (see chapter 6.1).

A meter suitable for being part of an energy visualisation system should be prepared for two way communication, and be able to respond to requests. The communication methods best suited for this are radio and GPRS listed below.

4.1.1 *Radio*

If the household is situated in a highly populated area, the meter can be equipped with a low effect radio transmitter (~0.05W), which transmits data to the collector unit (see chapter 4.2). The frequency 444 MHz is dedicated to meter reading in Sweden by Post och Telestyrelsen. The meter will not initiate communication, it will only respond to requests made by the collector unit [10].

4.1.2 *GPRS*

If the household is placed far from other consumers, the meter can be equipped with a module that can communicate with the central system with GPRS via the GSM net.

4.1.3 *M-bus*

In some cases the meter communicates with the collector unit with a new European standard called Meter-Bus. It is a low cost bus system for remote reading and powering of utility meters via separate wires.

4.1.4 *Electric grid (PLC)*

The meter is equipped with a module that sends a signal in the electric grid to the collector unit (see chapter 4.2). This is slower than the radio communication, but the signal can travel a longer distance. One supplier of this technology is HM Power AB, the system is called Turtle.

4.2 Collector unit

The collector unit is normally placed in an electrical substation somewhere in the neighbourhood. It collects and store data from up to thousands of meters. The collector unit is connected to the internet via GPRS or cable, and the net owner can collect the data from here [10].

4.3 Central system

The central system communicates with the collector unit and keeps track on which meter is situated where, and how often they should be read. It also verifies the readings before the invoice is printed [10].

4.4 Examples of meters installed in Sweden

E.ON uses meters from Metrima, Kamstrup-Senea and Landis+Gyr.

Fortum uses meters from Landis+Gyr which use a radio or GPRS terminal, or where no GPRS coverage is available, the electrical grid for communication. They also use meters from Actaris which communicates with GPRS.

Kalmar Energi uses a data collection and presentation system from Metrima with meters from AEM and Landis+Gyr. Communication is most frequently with PLC over the electrical grid, but other communication methods are also implemented.

Mälarenergi uses meters from Kamstrup-Senea which communicate via radio and meters from Actaris which uses the electrical grid for communication.

Vattenfall uses meters from Metrima, Kamstrup-Senea and Landis+Gyr.

5 HOW TO CHANGE HUMAN BEHAVIOUR

It is essential that the end consumers are aware of their energy consumption in order to change their behaviour. It´s important that the data is presented in a way that the consumer is familiar with and can understand [11].

5.1 Feedback

Except providing the grid owner with meter readings for billing, the energy meters have the possibility to provide meter readings for energy feedback [8]. Normally the customers will only get information about their usage when it's time to pay the bills.

5.1.1 *Direct feedback*

If the consumers can see changes in their consumption in real time, it's called direct feedback. When measurements are presented in a simple and user friendly manner, the consumers are able to change their habits, and surveys indicate savings up to 15-20% [11]. This is by far the most effective type of feedback [12].

5.1.2 *Indirect feedback*

When the users get information about their usage history after hand, for example via an invoice, it´s called indirect feedback. This kind of feedback is a good tool to visualize investments such as new household appliances which can give long term savings. Indirect feedback can give savings up to 10% if presented in a way that capture the interest of the consumer. [11].

5.2 Comparisons

Comparisons may help motivate energy conservation, with a sense of competition and ambition. It can also help to show if usage in a certain period is "out of the norm", alerting about a potential problem [13].

There are two basic types of comparisons: Historic comparison which relates actual to prior usage, and normative comparison which compares usage to that of other households. In Sweden most people are interested in historic comparison [14], while in Finland people are more interested in normative comparison [15].

It is important to make the comparison with a similar type of household in a similar climate. Some building and household characteristics that affect usage are: year of construction, floor area, number of occupants, type of isolation, type of windows etc. If the comparison shows above average consumption in a group perceived to be relevant for comparison, people are motivated to reduce their consumption [16].

5.3 Goal setting

To motivate energy consumers to reduce their usage, a goal to aim at can be a good idea. The goal should come with advice on how to reach it. It’s important the target level of consumption is not set to high, as a failure to achieve the goal can cause the consumer to give up. The goal can be to reduce usage by a fixed percentage, for example 20% compared to the previous month. If the consumer is above normal consumption for a similar household, the goal can be to reach the normal average consumption. There is a big difference in potential energy savings between households, and because of this, the goal must be adapted to the consumer [17]. Positive feedback or rewards when reaching a goal can be a strong motivator. An idea could be competitions in energy saving organized by the energy trading companies through social media like Facebook or Twitter to encourage savings and create positive publicity.

6 EXISTING ENERGY VISUALIZATION SYSTEMS

There are both direct and indirect feedback energy visualization systems on the market. The direct feedback type systems provide real time usage information and the indirect feedback systems provide historical consumption information.

There is a debate about whether direct feedback clip-on systems should be rolled out quickly to get fast results, or whether it´s better to upgrade the official meters to be able to provide accurate official real time metering data.

6.1 Direct feedback (real time) based systems

This type of systems provides the consumer with real time usage information. By looking at the monitor and switching appliances on and off, the consumer can see how much energy it uses. Stand by losses from individual appliances can also be identified by unplugging them and looking at the monitor. As mentioned in chapter 5.1.1 savings up to 15% can be expected. In a test performed by the author in an apartment occupied by three students the standby losses accounted for almost 20% of the total electricity consumption.

6.1.1 *Clip-on direct feedback*

This is an add-on system which work in parallel with the official metering system provided by the grid owner. Most of the direct feedback systems on the market in Sweden reads the flashing LED on the meter (See chapter 4.1) with an optical reader which must be physically put (glued) on the meter. The pulses are then transmitted via radio to a display unit that can be placed anywhere in the home.

The display unit normally can log usage statistics for later review. These values can however differ from the official readings done by the grid owner, because it uses a parallel less reliable system for the readings. Because of this the clip on systems can cause disputes about inaccurate data[18].

The radio transmitter use a battery and the display unit normally use a rechargeable battery. If the consumer does not have physical access to his meter it can be a problem.

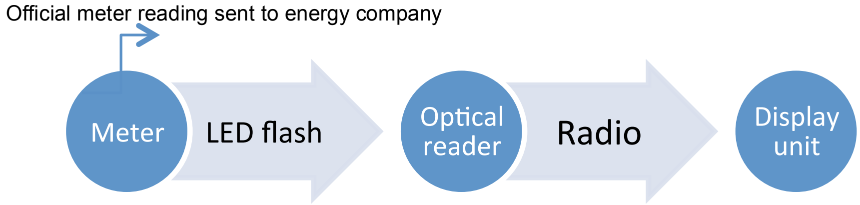

Figure 7. Data flow of clip-on systems

Examples of clip-on systems available on the market are Swedish built ELIQ and a British unit called minSolo, sold in Sweden by Fortum.

6.2 Indirect feedback (history) based systems

Most of the systems in this category are web based and provided by the energy trading companies. The information is based on the invoice of the previous month, and the resolution can vary down to hourly usage. The usage data is collected by the net owner, and given to the energy trading company on a monthly basis. If the net owner and the energy trading company are not part of the same cooperation, the data resolution presented to the consumer is monthly values in most cases, even if the net owner has access to hourly consumption data.

If hourly values are available, usage patterns and the total standby losses can be identified, and as mentioned earlier in chapter 5.1.2 savings up to 10% are possible. If only monthly values are available, historical and normative comparisons can be of interest and motivate savings. The existing meters and infrastructure are being used and no additional infrastructure is needed.

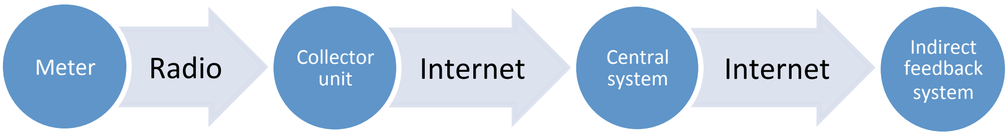

Figure 8. Data flow of indirect feedback systems

Some companies, for example Mälarenergi offer this service to their customers as an App for iOS and Android as well as on the web. If the user also is a customer for heat, water and internet broadband limited information about such usage can be found in the App as well. [19]

6.3 Direct and Indirect (combined) feedback based systems

It is possible to combine a history based indirect feedback system with a direct feedback system. The result is a fairly complicated system with parallel meter readings combined in the user interface.

E.ON is testing a system called 100koll, developed in collaboration with the Swedish company Wireless Maingate. For the real time direct feedback part the system uses a clip-on optical meter and a display unit which is connected to the internet via GPRS. Via this link the real time usage data is transferred to a smartphone application via a server. This requires a GSM subscription.

Historical indirect feedback values are transferred via the existing metering infrastructure and updated once a month. The consumer can view the historical data on the web, but the real time part is only available on the display unit and in the App. The indirect feedback is available on the web and in the smartphone App but not on the display unit.

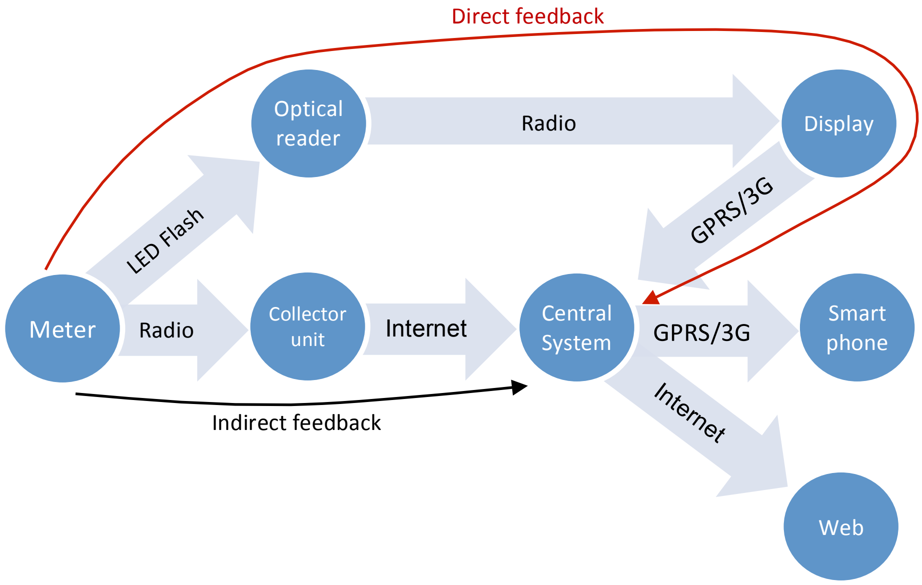

Figure 9. Eon 100koll data flow

The test has a public Facebook page, and from the comments made by the test participants there are a positive response, however some participants are questioning the technology used with parallel meter readings and worry about the cost of the final system.

7 SMARTPHONES

Almost all adults in the developed world own a mobile phone today. In 2010 almost 4 million units were sold in Sweden, and the prognosis for 2011 is similar. About 50%, 2 million of these units were smartphones [20]. Summer 2011 30% of the phones in use in Sweden were smartphones, compared to 25% in the end of 2010 [21]. With the current sales rate it will not be long before most people are smartphone users. 90% of the smartphone users surf the web and download applications [22]. Many people now days come in contact with the web for the first time on a smartphone. The application market in Sweden was worth about SEK 100 million in 2010. [23]

7.1 What is a smartphone?

A smartphone is an advanced mobile phone which combines the functions of a mobile phone and a hand held computer. Smartphones can run third-party Apps using advanced application programming interfaces (APIs).

There are no official definitions of what features a smartphone must include to be called a smartphone, but the different platforms or operation systems have their specific requirements. A typical smartphone today includes a camera, a high-resolution touchscreen, web browser that can display standard web pages, GPS navigation, Wi-Fi and mobile broadband access. As new technology is developed more features are included in the typical smartphone, the next one being NFC (near field communication).

7.2 Smartphone platforms

There are a number of different mobile platforms with different operating platforms for smartphones on the market today. The objective of an energy saving/visualization app is to achieve as big energy savings as possible, and because of this it´s important to reach out to as many people/customers as possible.

The two biggest smartphone operating systems in Sweden is Google´s Android and Apple´s iOS with about 13% of mobile phone users each after Q1 2011. Android has a growth rate of about 68% and iOS a 34% growth rate over the last 6 months [23].
In January 2011 the advertising network Widespace, who sell advertisement space in applications and on webpages, reported that Android units went from 5% to 50% of their total traffic during 2010. IOS units went from 50% to 36% during the same period [24]. Nokia´s Symbian used to be a big operating system, but Nokia announced early 2011 they will start producing phones with Windows Phone 7 from Microsoft instead. These phones will probably be on the market late 2011/early 2012, but at the moment they have a very small share of the smartphone market.

7.3 Conclusion

The smartphone is a new platform that soon will be every man's property and a tool with a big potential to visualize energy consumption. When developing an application for the Swedish market, Android and iOS are the operating systems with the most users.

8 POSSIBLE CUSTOMERS

There are a number of possible actors who can benefit from having an energy visualization App on the market. These are: Net/infrastructure owners, energy trading companies, and big real estate companies.

8.1 Local grid owners

Positive publicity can be obtained if the company can show it is helping the end consumers with tools for energy savings. Many local grid owners are part of corporations who also have an energy trading branch. The energy trading branch could benefit from the positive publicity created by the local grid owner to attract consumers using the energy visualisation service.

As the local grid owners own the energy consumption data and have direct access to the energy meters, they have the possibility to sell the consumption data, or to sell the service of an energy visualisation application to competing trading companies or directly to the end consumers.

These kind of companies have a natural monopoly over the local grid (the end consumers cannot change the infrastructure that connect the property to the grid), and they do not have to compete on the market and are not really interested in customer service. Mats Holmberg, spokesperson at Vattenfall, explains this clearly in an interview with the web magazine Realtid.se "*In this environment you are not rewarded for being best of breed"* [25].

8.2 Energy trading companies

Energy trading companies can benefit in many ways from supplying their customers, the end consumers, with information about their energy usage. Positive publicity can be obtained when the trading company shows willingness to help the end consumers with tools developed for energy savings.

New customers can be attracted when they discover they get the extra service of energy visualization. The energy trading industry is very competitive, and this type of service could be an argument when choosing whom to buy energy from.

Customers can be retained if they have bought or rented upgrades for their meters or just by being happy customers. If they like the service and start using it on a regular basis, the service can be a reason not to change to another provider and risk losing the service as a consequence.

An energy purchaser who knows exactly how much energy is consumed when and where can optimize its offers, and even increase reliability by reducing bottlenecks in the flow. [26]

A smartphone application can also be a new way of communicating with customers. News feed with events and offers, contact information, invoices and contracts could be included.

.

8.3 Big real estate companies

Big real estate owners, where every flat or household pays for their own energy and water consumption, could benefit from an energy visualization App.

Positive publicity can be obtained both in the media, and in the form of happy residents if the company shows it is helping the end consumers with tools for energy savings.

The real estate owner is able to plan the grid or infrastructure better if it can control the maximum load of the net. This can be achieved with indirect control via multiple tariffs [26]. Better contracts might also be negotiated with the energy trading companies if the real estate owner can control the maximum load on the fuse.

8.4 Conclusion

The energy trading companies would be most beneficial of providing an energy visualization App. The market these companies compete on is very competitive and it´s important to provide good service in order to attract new and retain existing customers.

9 GENERAL APPLICATION LAYOUT

The following guidelines for user interface software set by Smith and Mosier [27] should be considered:

- Provide only necessary and immediately usable data; do not overload displays with extraneous data.
- Display data in a directly usable form; do not make users convert displayed data.
- Display data consistently with standards and conventions familiar to users.
- For displayed data and labels, choose words carefully and then use them consistently.
- Provide a clear visual definition of data fields, so that the data are distinct from labels and other display features.
- When information handling requires a detailed comparison of ordered sets of data, adopt a tabular format for data display.
- Consider graphics rather than text description or tabulation, to display data showing relations in space or time (for example, trends).
- Consider a pie chart only in special cases to show the relative distribution of data among categories, i.e. for displaying data that represents proportional parts of a whole; but note that a bar graph will allow more accurate interpretation for such applications.

According to Karjalainen [17] the most important to present are:

- Presentations of costs (over a period of time).
- Appliance-specific breakdown, i.e. information on how much each appliance consumes proportionally.
- Historical comparison, i.e. comparison with own prior consumption. It should be noted that Haakana et al [15] say Finnish customers prefer normative comparison and Swedish customers prefer historical comparison [11].

Direct feedback is the most effective type of feedback if the objective is to achieve the biggest possible savings. It will also help catching interest. It can also be used to provide appliance specific breakdown of the consumption. Therefore it should be included in the App, preferably via official meter readings if the meter technology allows it.

10 POSSIBILITIES AND SUGGESTIONS

A possible feature for an energy visualization application would be if the variable price from the Nord Pool Spot is displayed in the app, with a price prognosis based on water levels in the water reservoirs and other factors. With this information an advice regarding if it´s time to switch price plan to fixed price or not could be made.

The possibility to view and extend contracts could also be included.

10.1 Indirect feedback App as a minimum

This is the easiest and most basic type of feedback, based on the same consumption data available on the monthly invoice. The existing metering infrastructure is used, and depending on the services offered by the provider of the App the contents can vary (electricity, heat, gas, pellets, water etc.). The data will be updated on a monthly basis, approximately at the same time as the invoice is ready to be sent.

Values for heating need to be outdoor temperature corrected if they are to be used in comparisons between objects or between years.

10.2 Direct feedback from clip-on meter with Wi-Fi

This would be a variant of the existing clip-on meters, using the smartphone as display. A clip-on meter with built in Wi-Fi can be connected to the wireless network of the household. If the consumer owns a smartphone and has a wireless network in the household, the system is simpler and cheaper than existing clip-on direct feedback systems which also requires a dedicated display and in some cases a GSM subscription.

This solution:
- Requires a clip-on meter,
- Has direct communication with the App via internet or WLAN,
- Requires Wi-Fi network in the household.

10.3 Preferably direct feedback that uses existing infrastructure

In many cases the existing metering infrastructure allows real time meter reading, but is only available to the net owner company. The most logical and simple solution would be to use this existing metering infrastructure to provide the end consumers with direct feedback, on demand. This requires the cooperation of the net owner, and as they have nothing to win from sharing this information it would probably take mandatory instruments to make this happen. More about this is discussed in chapter **Fel! Hittar inte referenskälla.**.

This solution:
- Depends on the cooperation with the net owner.
- Depends on the type of meters/terminals used.

11 PROBLEMS/ISSUES

Energy usage patterns can give a hint about what the energy is used for, and this can intrude on personal integrity.

The energy usage information can also provide information about habits, for example what time of day no one is in the building. If the usage pattern is broken, it can for example signal that the residents are on vacation.

Therefore it is essential that the information is not publically available and is intrusion protected.

12 CONCEPTUAL APP

Cooperation has been made with a medium size municipal energy company from the South of Sweden to develop a working prototype of an energy visualization application, from here on referred to as the "App". The functionality for the App was specified by this energy company, and indirect feedback was chosen as the type of feedback.

Direct feedback is given via an optical Wi-Fi meter as discussed in chapter 10.2, or by using the camera on the smartphone to read the flashing LED on the meter.

The idea is that this conceptual App should be made prepared to be further developed into a commercial product. The direct feedback feature was not requested by the energy company and will probably not be included in a commercial product.

Agile software development was used with continuous debugging.

The conceptual App will consist of two parts:

- A smartphone App for the Android platform (possible to migrate to other OS),
- A service layer communicating with the App on one end and the energy company on the other end, as Figure 10 shows.

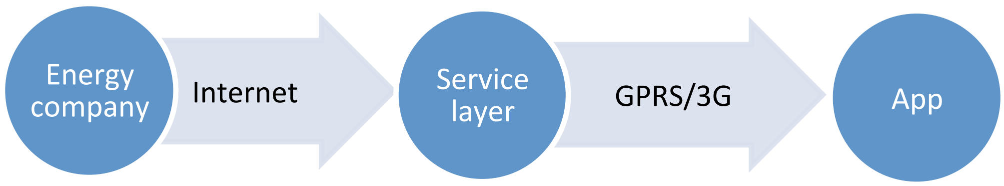

Figure 10. Communication of the App

12.1 App

The following services will be included, by request from the energy company:

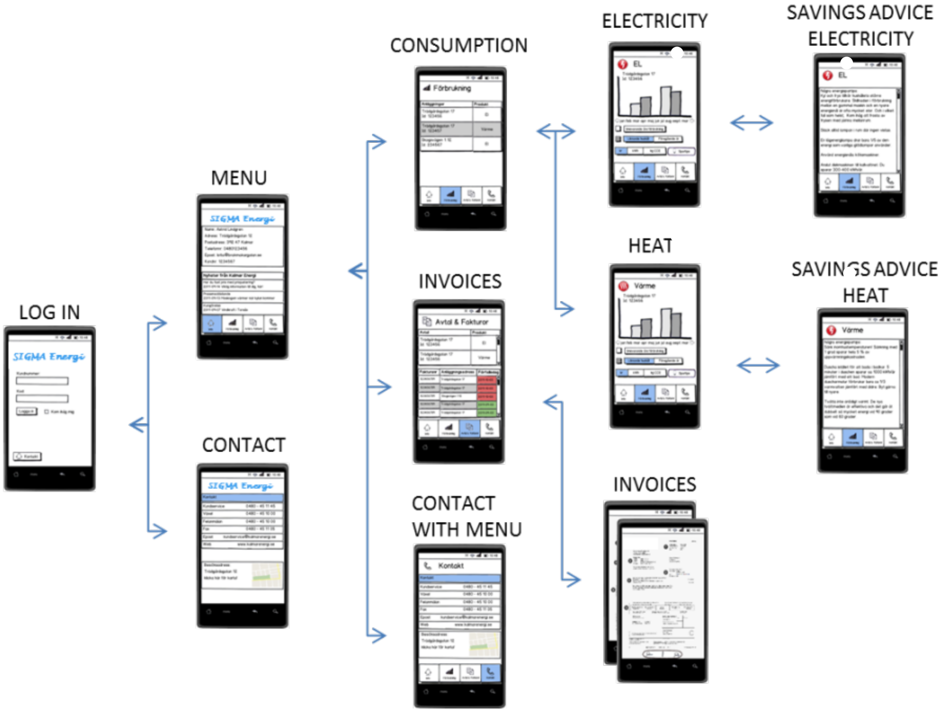

Figure 11. Functionality and architecture of the App

Some parts of the App have been developed in cooperation with consultants from Sigma Finland. Eclipse was used as the development environment and Team Foundation Server was used for source control and backup.

12.1.1 *Log in page*

The user will be required to log in using the same user id and code as on "my pages" provided by the energy company on the Web. When a successful log in is performed, all data except the invoices in PDF format will be fetched from the service layer.

Once logged in, the App will be navigated from a tabbed menu.

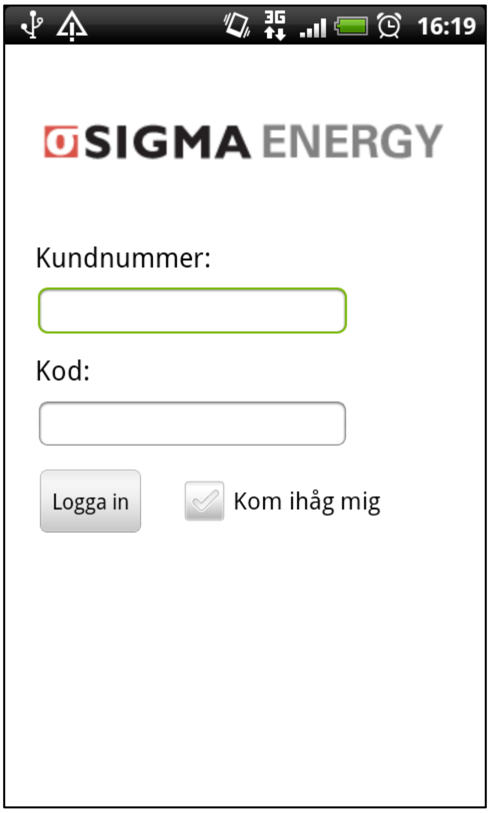

Figure 12. Log in page

12.1.2 *Information page*

The first page of the application shows what kind of information the energy company has about the customer. Name, customer number, address, postal address and phone number will be displayed.

A news feed will also be displayed, showing the latest three news entries from the webpage of the energy company. Here information about operation and downtime, campaigns, events, offers and general information can be displayed.

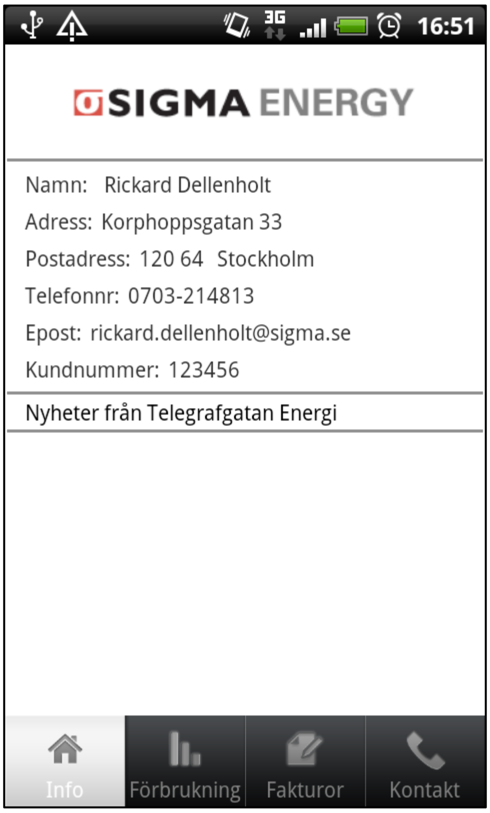

Figure 13. Information page

12.1.3 *Consumption*

If the customer has more than one contract, a list of contracts will be displayed, and the customer will be able to choose one. An example of a customer with multiple contracts can be a customer who own a house with contracts for both electricity and heat, and also owns a cabin with a contract for electricity.

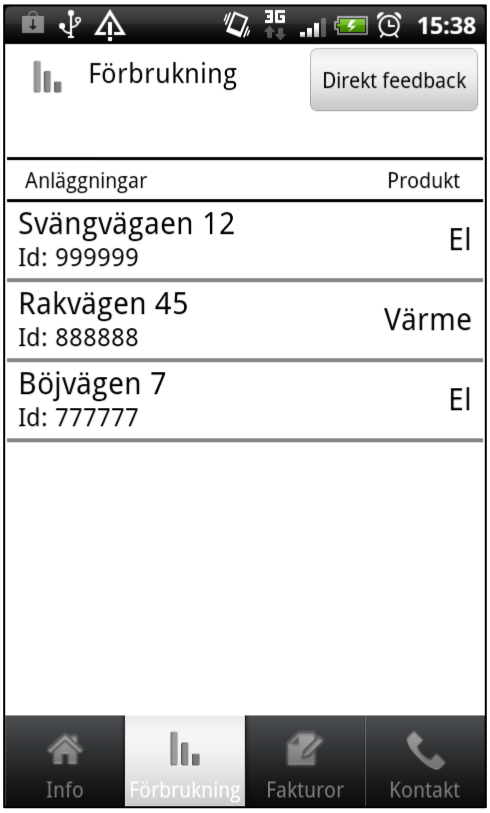

Figure 14. Consumption page

12.1.4 *Electricity consumption*

Indirect feedback will be shown in a bar graph. The default resolution will be monthly values, one bar per month as this is the kind of data available when the grid owner and the energy trading company are not the same company. The bars symbolizing the consumption of the month will be clickable, and a small pop up displaying the value in numbers will be displayed if a bar is clicked.

When the net owner and the energy trading company are within the same, higher resolution values are available, an option to display these will be displayed in the pop up. The graph will then change into the daily values of that month. Preferably hourly consumption data should be displayed if available. The daily and hourly values will only be available when the energy company is also the grid owner, as they do not have access to high resolution meter values where they do not own the grid/meters. Hopefully this will change in the future, see chapter **Fel! Hittar inte referenskälla.** about coming legislation.

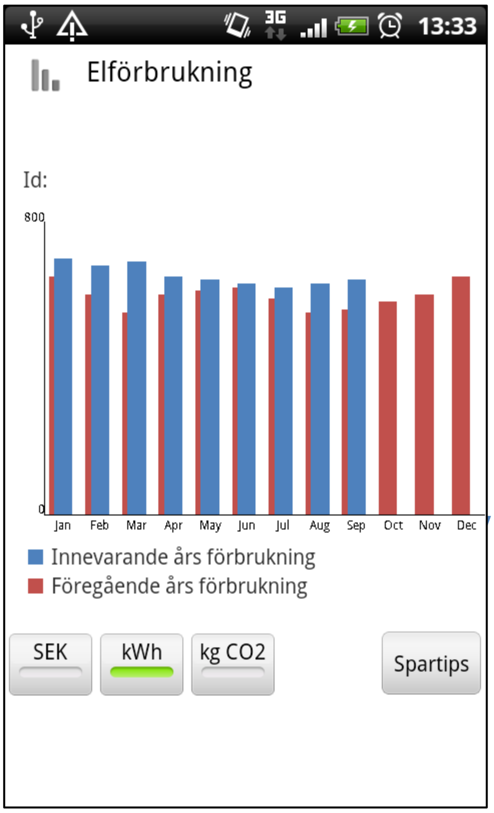

Figure 15. Electricity consumption

The unit most commonly used for household energy usage is kWh. Unfortunately, people have a very limited understanding of scientific units [23]. Therefore it should also be available as an option to present the usage in monetary units as this is something everyone can relate to. The information can also be presented in the form of environmental impact (for example, carbon dioxide emissions in kg). This unit also requires an explanation, or comparison with something people can relate to. For example "driving a car X km" A button or slider with the three options, kWh, monetary units and kg CO_2, is available in each graph. Consumed electrical energy, kWh, is the default setting.

Historic comparison is shown by default, monthly values from current and last year will be shown if available.

If the user has a variable tariff, it should be shown that both consumption and price go up during winter time. The address of the property and the facility id is also shown on this page.

12.1.5 *Heat consumption*

If the user also is a customer for heat, indirect feedback will be shown in a bar graph. The default resolution will be monthly values, but if higher resolution consumption data is available, the months will be clickable and daily values will be displayed. The same policies as for electricity consumption apply regarding units.

The address of the property and the facility id should also be shown on this page.

12.1.6 *Direct feedback*

This feature requires physical access to the electricity meter. Direct feedback is given either by using the camera of the phone to read the flashing LED on the electricity meter, or by connecting to an optical reader via Wi-Fi.

The Android application "Energy Meter" developed by Jon Lennersten is used for this functionality.

To use the camera of the phone to read the flashing LED on the electricity meter the phone must be held against the energy meter. The lens of the camera must be placed directly over the flashing LED. The flashes of the LED are registered by the application when the light intensity (blue line in the screenshot to the right) is higher than a pre-set threshold value (red line)

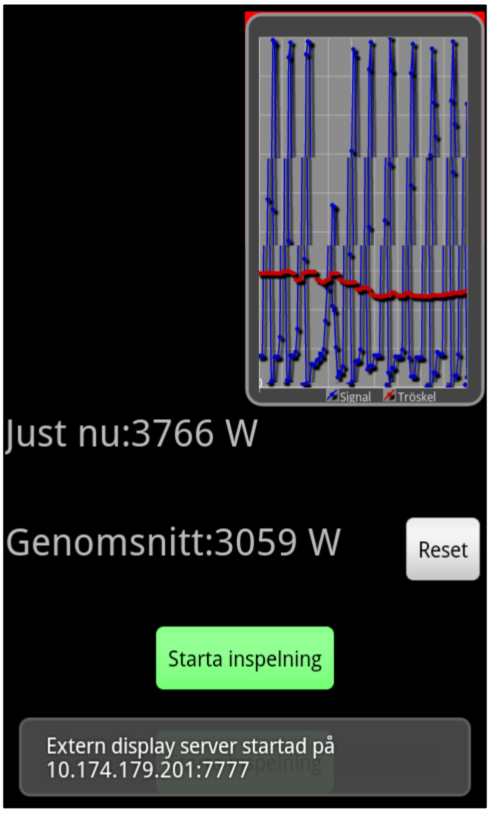

Figure 17. Direct feedback"

This application can be installed on a second Android device and act as a transmitter only. This turns the device into an optical clip on Wi-Fi reader which transmits meter values to the App via Wi-Fi or GPRS/3G. This feature was implemented to "Energy Meter" by request of the author.

12.1.7 *Savings advice*

This page should be accessible from the consumption pages with relevant, explanatory savings advices for the type of energy. In a commercial product these advices could be customer specific, but in the conceptual App they are fixed.

Examples for electricity:

- An energy saving bulb uses 1/5 of the electrical energy used by old school light bulbs, and LED lights uses about 1/10. There are better ways to heat the home than with light bulbs.
- Turn lights of when leaving a room.
- Use energy efficient home appliances.
- Modern freezers and refrigerators are considerably more efficient than older ones. Don't forget to defrost!

Examples for heat:

- Lower the indoor temperature with 1 degree Celsius and save 5% of the heating cost.
- Take showers instead of baths. A five-minute shower a day compared to a bath a day save you 1000 kWh per year. A modern shower head uses about 1/3 of water compared to old ones.
- Don't wash excessively hot. Modern detergents are effective in lower temperatures, and twice as much energy is used at 90 degrees Celsius compared to 60 degrees Celsius.
- Seal drafty windows and exterior doors.
- Connect the dishwasher to cold water. 300-400 kWh per year can be saved. Modern dishwashers heat incoming water with dirty water, and as a normal wash includes a number of water changes, this saving can be achieved.

12.1.8 ***Invoices and contracts***

Invoices and contracts from electricity, heat and pellets will be available depending on the type of customer. From the lists displayed on these pages the invoices and contracts are available.

Invoice number, facility address and due date will be displayed for the invoices. The background colour of the due date will indicate the status of the invoice, green meaning paid and red meaning not paid.

Figure 18. Invoices tab

12.1.9 ***Invoices***

If an invoice row is clicked a PDF will open up in a new window. It will be scrollable and zoomable, and the back button on the smartphone will bring the user back to the invoice list.

Figure 19. Invoices

12.1.10 *Contact*

Relevant phone and fax numbers, e-mail address, webpage and street address with a map are being displayed on this page.

All contact information is clickable and open up its appropriate tool for communication. The map with the visiting address will also be clickable, and Google maps will open up on click.

This page is accessible from both the login page and from the menu tab. If accessed from the login page (without being logged in) the menu bar will not be visible.

Figure 20. Contact

12.2 Service layer

The service layer is set up for communication with the app, and will contain a made up customer for testing and demonstration purposes. The other end, which will communicate with the energy company, is left open to be customized for individual energy companies and their specific needs.

All the data and text except the menus and headings displayed in the app will be fetched from the service layer. The different pages have their own data request, however all requests except the invoices are done at once after a successful login. This is done in this manner to make the App quicker once logged in, and for protection against poor carrier service when using the App on a train or in a car, where carrier coverage can be sporadic.

Today there is no support for authentication. The prototype and it´s functionality is available to users not logged in. Authentication is to be implemented specifically for each energy company, and will use its unique authentication mechanism.

The service layer has been developed in cooperation with Sigma consultants.

13 CONCLUSIONS

The energy demand will continue to increase over the next years as the population grows and the standard of living increases in the developing world. The first step towards achieving energy savings and identifying energy losses in the households is to make the consumers aware of their energy consumption and usage.

Earlier studies show potential savings up to 15-20% when direct feedback is supplied to the end user, and savings up to 10% when indirect feedback is available.

The metering infrastructure required to supply real time consumption data is available and in most cases in place in the households. The meter values are however owned by the local grid operating companies, who also own the energy meters.

The 22nd of June 2011 government bill 2010/11:153 was handed over from the Swedish government to the parliament. The name of the government bill is "Strengthened consumer role for a developed electricity market and sustainable energy system". It includes propositions to facilitate for the consumers, e.g. adapt their electricity consumption to current electricity prices, to streamline their electricity consumption, to produce their own renewable electricity and to charge their electrical vehicles. An important prerequisite for all this is hourly meter readings, which is proposed in the bill. It also suggests that the meter data market will be subjected to competition, opening for third party companies to offer energy visualization solutions for all customers.

If this bill is passed, direct feedback via existing meter technology will be made possible for the majority of energy consumers in Sweden.

A conceptual Android application was built as a part of this thesis. It can fetch indirect consumption data from a server, and present these as well as energy saving advices for the user. It´s also possible to get real time meter data via a second Android device acting as a clip-on meter. The conceptual application can be further developed and customized to be used by any energy company, and when official real time meter values are made available in the near future these can be presented in the application as well.

14 VOCABULARY

3G = **3**rd Generation mobile telecommunications, a fast mobile phone net.

AMR = Automatic Meter Reading

API = Application Programming Interface

App = Application, in this report an Application for Smartphones is referred to.

CFL = Compact Florescent Light

ECTS = European Credit Transfer and Accumulation System. One academic year corresponds to 60 ECTS credits.

EU = European Union

GPRS = General Packet Radio Service, a way to send data over GSM

GSM = Global System for Mobile Communications

IPCC = Intergovernmental Panel on Climate Change

LED = Light-Emitting Diode

M-bus = Meter-Bus, an European standard for remote reading of gas or electricity meters on two wire.

Mock up = Sketch of an application layout

NFC = Near Field Communication

OS = Operating System

PLC = Power Line Communication.

TOE = Tonne of Oil Equivalent

UN = United Nations

15 SOURCES

1. **British Petroleum,** The BP Energy Outlook 2030. 2011
2. **Energimyndigheten,** Energiläget 2011. 2011
3. **Boverket, Energimyndigheten och SWEDAC,** Energideklarationen. 2008 http://www.energiradgivningen.se/images/stories/energideklaration/energideklaration_bilagadn.pdf
4. **Intergovernmental Panel on Climate Change,** Synthesis Report Summary for Policymakers, 2007
5. **United States Department of Energy,** Global, Regional, and National CO_2 Emissions. In Trends: A Compendium of Data on Global Change. 2008
6. **Environment and conservation division Government of Kiribati,** National adaptation program of action. 2007
7. **NASA photo journal,** http://photojournal.jpl.nasa.gov/catalog/PIA11002
8. **Svenska Kraftnät** webpage, Elmarknadens aktörer, http://www.svk.se/Energimarknaden/El/Elmarknadens-aktorer/ 2011-09-14
9. **Nord Pool Spot webpage**, About us, http://www.nordpoolspot.com/About-us/ 2011-09-14
10. **Mälarenergis hemsida**, Din mätare, http://www.malarenergi.se/sv/foretag/elnat/din-matare/ 2011-08-10
11. **Darby, Sarah,** The effectiveness of feedback on energy consumption, a review for DEFRA of literature on metering, billing and direct displays. 2006
12. **Darby, Sarah**, Making it obvious: designing feedback into energy consumption, in: P. Bertoldi, A. Ricci, A.T. de Almeida (Eds.), Energy Efficiency in Household Appliances and Lighting, Energy Efficiency in Househould Appliances and Lighting, Springer-Verlag, Berlin, 2001, pp. 685–696.
13. **Fischer, Corinna,** Feedback on household electricity consumption: a tool for saving energy?. 2008
14. **Sernhed, K. & Pyrko, J. & Abaravicius, J**. Bill me this way! Stockholm 2003
15. **Haakana, M**. The effect of feedback and focused advice on household energy consumption." European Council for an Energy-Efficient Economy 1997
16. **Roberts, S. & Baker, W**. Towards Effective Energy Information, Improving Consumer Feedback on Energy Consumption, Centre for Sustainable Energy, Bristol, 2003.
17. **Karjalainen, Sami**. Consumer preferences for feedback on household electricity consumption. VTT Technical Research Centre of Finland. 2010
18. **Martiskainen, Mari and Coburn, Josie**, The role of information and communication technologies (ICTs) in household energy consumption, 2010
19. **MälarEnergis hemsida**, http://www.malarenergi.se/
20. **MobilTeleBranchens** hemsida, Mobiltelefonförsäljningen i Sverige, http://www.mtb.se, 2011-08-09

21. **Törnkvist, Sven**, ‘Industry Head’ på Google Sverige, pressrelease 2011-08-11
22. **MediaVision pressrelease** 2010-11-19, Smarta telefoner förändrar mediekonsumtionen
23. **MediaVision pressrelease** 2011-05-11, Mobiltelefoni Sverige: Android ikapp Iphone under Q1
24. **Widespace analys** 2011-01-27, Android redan förbi iPhone i Sverige
25. **Hässler, David**. Smarta elnät – osmart elmarknad. http://www.realtid.se/ArticlePages/200904/09/20090409121204_Realtid950/20090409121204_Realtid950.dbp.asp?sAction=lk#k1
26. **Hässler, David**. Elmätaren som vattenfall och regeringen stoppade. http://www.realtid.se/ArticlePages/200904/21/20090421115858_Realtid535/20090421115858_Realtid535.dbp.asp?sAction=SendLink&MailId=20090421115858_Realtid535.dbp
27. **Smith, S.L. & Mosier J.N**. Guidelines for Designing User Interface Software, Natl Technical Information, 1986

16 ACKNOWLEDGEMENTS

I would like to thank my mentor at LTH Prof. Jurek Pyrko, and my mentor at Sigma IT & Management AB Johan Berneskog. I would also like to thank Jens Alén, Johan Brohn, Rickard Dellenholt, Victor Ericsson, Andreas Holmlund, Richard Sjöberg and Robert Trouin from the Sigma office in Stockholm for the programming expertise and discussions about energy apps and thesis work in general. I am also grateful to Sami Hyytiäinen and Mikko Mäntysalmi from Sigma Finland for help with making the conceptual App more robust and professional, and to Carl Johan Löfgren for the input on what is possible with current technology and legislation.