TÉCNICO LISBOA

SMART Mila

Mechanical Engineering

Experimental methods in Energy and Environment

January, 2015

Tomás Valente, 65661

Miguel Moura, 65610

Catarina Laurência, 70930

Contents

Abstract

The goal of the present course was to find and tackle a problem with a component relating to energy and environment. In a first approach we visited Mouraria and spoke with the people to understand, in a social point of view, what is being difficult to them to approach or to find out what hurts them from a social or economic point of view. On the first visit to Mouraria we visited a small pastry shop and, in speaking with the owner, it was possible to understand that it is a struggle to pay the high electricity bill.

This issue is mainly related with the waste of energy/electricity in public or non-public spaces and it has an obvious economic impact for the owners of the space and obviously for the environment. Trying to join sensors technology with an important social line is the biggest challenge, and the most interesting one, of this work.

During those three months we were able to develop a prototype which we tested in a real case scenario, more precisely in Doce Mila, a pastry shop whose owners are Dona Mila and Sr. Guedes. The testing allowed us to obtain real and actual data about the energetic consumption of the place, and with this data and a lot of interview moments we were able to develop an interface to communicate with the owners in real time with the main purpose of creating awareness and giving some real numbers about their spending at each moment and the sum of the whole month till that moment.

The one week results allowed us to compute some possible savings by changing behavior and/or equipment, which could reach 1 467,72€ per year.

The last day of data collecting had the purpose of understanding if the tips and conversations with the owners were useful and if they tried to change their behavior in order to diminish their electrical bill. The result of that day showed a saving of 0.91€, however this value is subject to scrutiny due the uncertainty that can be better understood in the chapter “Analysis for energy audit purposes”.

Introduction

The last 50 years had an incredible boost of technology development in the world, with the evolution of transportation, information technology, energy exploitation and a lot of other contributions and so, the energy world had some problems keeping up with this fast evolution. One of the biggest setbacks faced is the variability of energy sources, as we all know fossil fuels are, without a doubt, the main way of creating final energy in the world, however there are many problems related with the use of those. Beside the fact that it is not infinite, fossil fuels and their use are one of the main reasons for the world largest rate of pollution and the creators of the global warming effect. Recently, the world is undergoing some changes, 2014 was earth's hottest year on record with an average temperature of 0.69 degrees Celsius above the 20th century average.

This looks like something normal but in fact it is something worrying since a lot of abnormal things are happening due to this. Some technology experts, researchers and others are trying to minimize this impact in a lot of ways, developing electric cars, diminishing the quantity of energy generated by fossil fuels with investigation on wind mills, solar energy or wave energy, however they are not close on finding a sustainable way to end fossil fuel dependency. One way to help the planet is to try and minimize the quantity of energy that is spent in the world and a way to do this is to teach people how they can use energy in an efficient way and make it not only a way of saving money but a way of helping the planet. Simple technologies as sensors and Arduino based platforms can be used to measure and interact with people, i.e., a sensor can be used to measure the electricity consumption which is processed by an Arduino and then some numbers and data can be shown to the user through a screen.

Product

The prototype to be developed consists on a device that monitors energy consumption and provides understandable information to its intended user, either by LED lights or actual screen displayed information. It became clear that in order to address this subject in this social environment, it is mandatory to "de-technicalize" most people's common idea of electricity consumption and to show that everyone can try to focus more on their own electrical efficiency without much knowledge and expertise. Thus, an interactive electrical consumption meter is addresses in this work.

Experimental Data Gathering Setup

In order to perform an energetic audit to the bakery, non-intrusive hall-effect sensor were installed in the electrical board, and data collected with ARDUINO. First preliminary setup consists also on a LCD screen and an SD-card module, as seen if Figure 1.

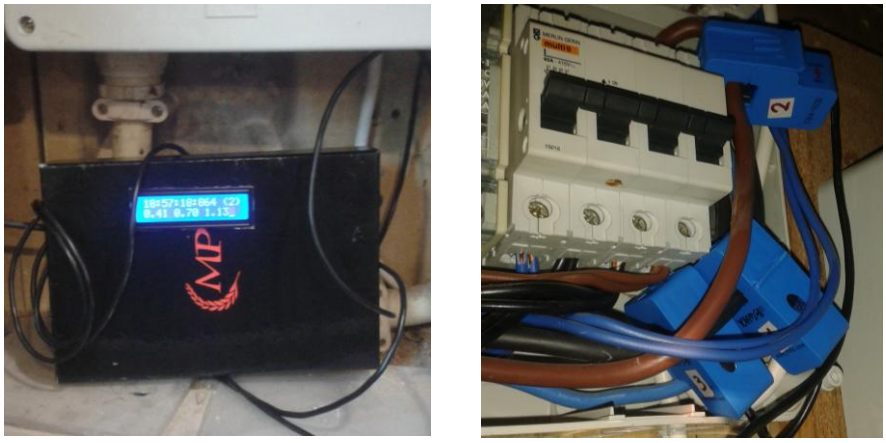


Figure 1 - First data gathering prototype

Analysis for energy audit purposes

Using the setup described above, one week worth of data was collected and post-processed using MATLAB. Figure 2 on the left portrays an example of the data acquired in one of the days, featuring all the three phases of the three-phase system installed in the bakery. Raw data is collected as current (Amps), which was converted in Apparent Power by the assumption that the voltage remains constant at 220 Volts.

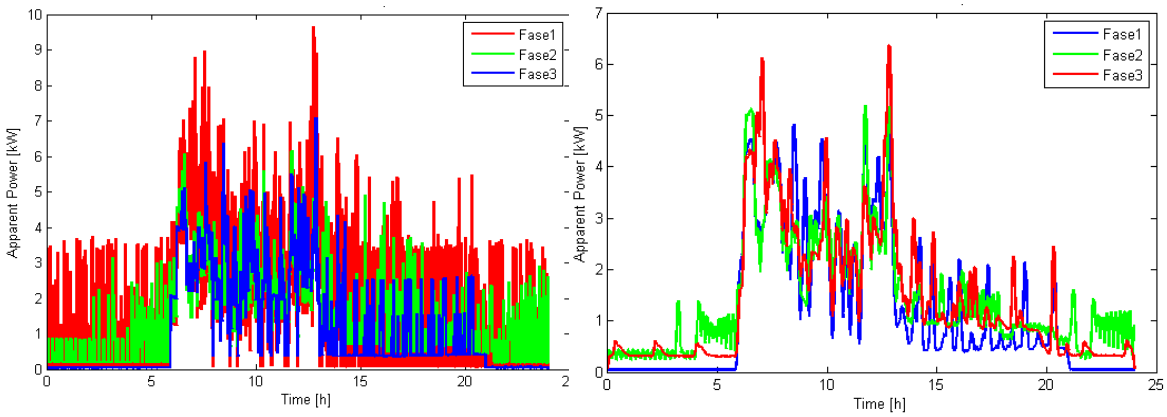


Figure 2- Three phase consumption with and without filter.
Apparent instantaneous Power [kW] versus time [h]

The acquisition frequency is high enough in order to correctly acquire all the surge peaks that at first glimpse may suggest a high level of noise. In fact, all these peaks are caused by electrical phenomena, which is of the utmost importance for the correct quantification of the actual electrical consumption. On the other hand, for an easy qualitative understanding of the specific behaviour of the bakery in a specific day, digital low-pass filters were applied, and its result can be seen on the right side of Figure 2. As a first analysis we could check the balancing of load distribution of each phase with the objective of lowering the hired power, however this is not possible due to the fact that most of the heavy-duty equipment are three-phase as well and its load is very near the actual hired power.

In order to trace the usual consumption profile of the bakery, the sum of the three phases of all the 5 days were processed by overlapping all the available data and compute all the relevant statistical results. Figure 3 shows the typical profile, computed with a moving average of every 6 minutes of data (1/10 of an hour) and by calculating the standard deviation at each of the abovementioned points.

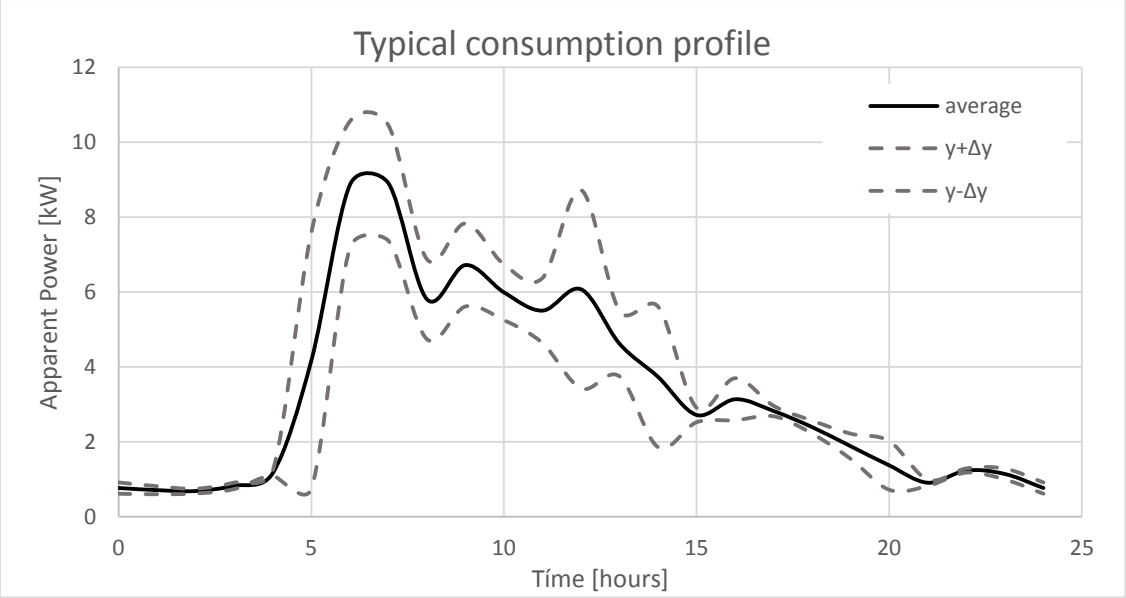


Figure 3- Typical consumption profile

The average deviation of the instantaneous power over the mean is 37%, and the maximum observed deviation occurs in the early morning (192%) – when the ovens are turned on – and the minimum deviation of 1% occurs at night. This suggests a relatively high uncertainty, due to the considerable low amount of data, and the high variability associated to the human factor. Nevertheless, the total consumption in kWh at the end of each one of the 5 days of data is 81.83±3.93 kWh. This means that the

instantaneous uncertainty is very large but the global daily consumption is accurate enough for our purpose analysis.

It is now possible to extract some results with high level of relevance for the owners. Figure 4 shows the average load distribution by equipment, providing an estimate of the distribution of the electricity cost between various sectors, and associated costs (Table 1).

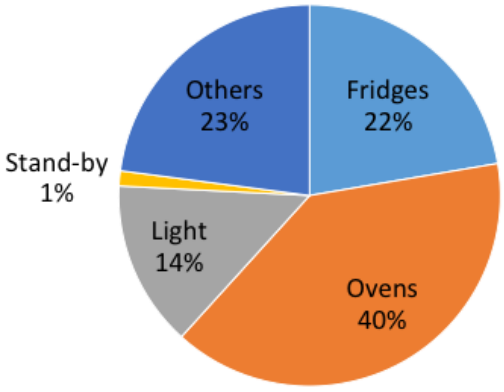


Figure 4- Consumption distribution

The savings in table 1 were possible to compute based on behaviour and technical changes as:

- Install a relay system to control the working cycles of the fridges, creating the possibility to force shutdown in peak hours;
- Use the ovens only in off-peak hours (if possible);
- Change the entire lighting system to high efficiency LED light bulbs;

The calculation description to obtain these savings is described in detail annex A, which was handed over to the owner.

Table 1 – Average actual cost and saving.

	Average actual cost			Average savings		
Equipment	Daily	Monthly	Anual	Daily	Monthly	Anual
Fridges	2,71€	84,01€	991€	0,69€	21,39€	256,68€
Lightning	1,71€	53€	636€	1,51€	46,05€	552,6€
Ovens	4,79€	148,4€	1780€	1,77€	54,87€	658,44€
Stand-by	0.16€	4.80€	57€	-	-	-
Others	2.87€	86.53€	1038€	-	-	-

Analysis for user interactive prototype

With all this data it was now time to start thinking about the most important part of this project, i.e., how to communicate with the end-user and expose hidden useful information. Always having in mind the expertise and knowledge, or lack there of it, of our intended user we have to leave aside the usual technical approach and provide numbers that are inherently understandable and that provide a much bigger sensation and effect with its values, e.g., the effect of displaying the amount of kW of energy in use is nowhere near as big as displaying the actual euro cost of that same amount. Another information that can be extremely impactful and useful is the amount of money that has been spent in electricity since the installation of the product – monthly resettable. Now concerning the information that we feel is of utmost importance on projects of this type, we wanted to display the amount of money saved by their change in behaviour on electrical usage. Summarizing our product should display:

- Amount of kW of instantaneous use
- Cost of that kW of instantaneous use in €/hour
- Amount spent since installation/last reset in € (resettable)
- Amount saved by behavioural change in € (also resettable)

The first two numbers are relatively straightforward to calculate and derive only on electricity prices and sensor data. The third one is little bit trickier because we need to program the ARDUINO to accumulate past data and refresh it every program loop. However, the final one requires a much deeper study and bit of data manipulation in order to extract it. In order to know the amount saved we needed to have a comparison baseline and for that we conducted, again on MATLAB, a mean/average approach of relatively steady parts of our electricity consumption data and the result was the yellow line on the following graph.

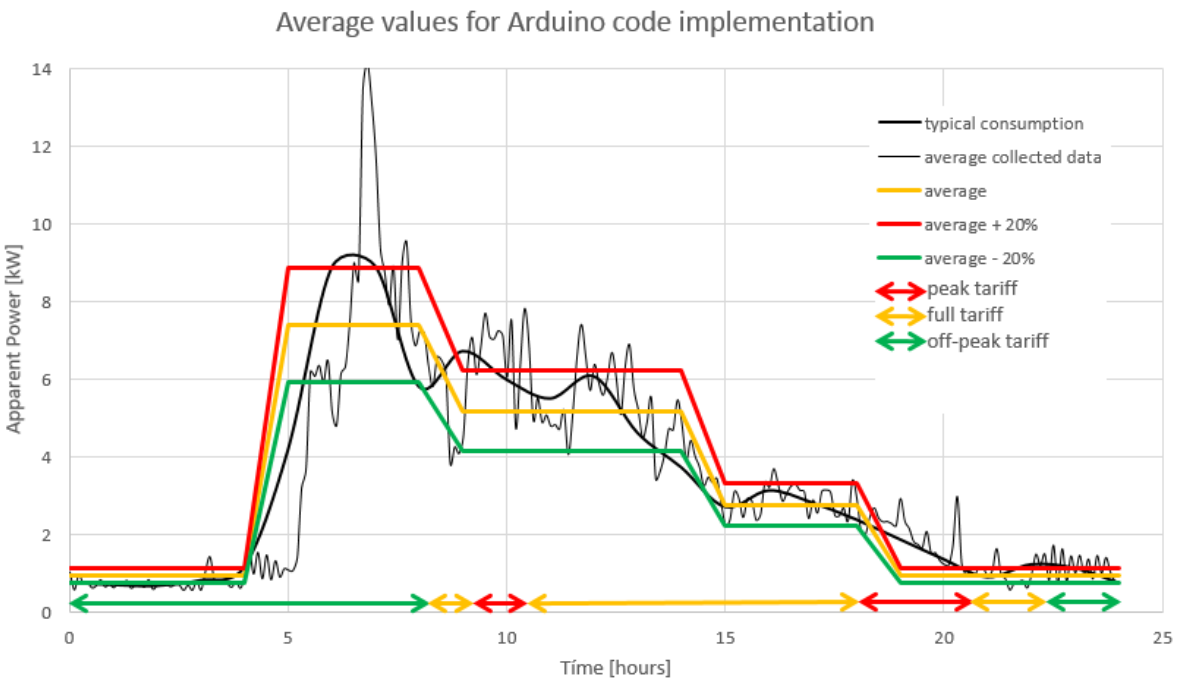


Figure 5- Mean electricity consumption

We then fed these values to the ARDUINO and programmed it to compare it, on time basis, with the current consumption, accumulate the savings over time and display it on our products screen. Also, in order to give the owner an idea on how critical his electrical consumption is at that time, an LED system reports green, yellow or red light according to the same values of the plot above. When the consumption is above 20% the average, a red light is displayed, and the same happens when the consumption is below 20%, with a green light. In the meanwhile, a yellow led represents a consumption of the same order of magnitude as the recorded values.

Another very important information that is mandatory to be known by our user is the way electricity prices vary depending on the hour of the day. Instead of using the same ARDUINO platform to display this information, we thought that a much more effective approach was to actually have a clock that could be read in order to interpret what pricing period we are on. With that in mind we created a back panel for an existing clock that displays the pricing periods using a colour scheme. Red symbolizes high cost electricity; yellow symbolizes medium cost and green the cheapest. The inner circle is to be read for the hours between 00:00h and 12:00h and the outer circle is for the hours between 12:00h and 24:00h. This back panel and the actual clock can be seen in the next images.

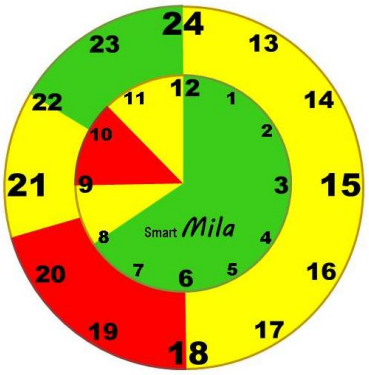


Figure 6- Watch backpanel

Figure 7- Watch picture

Finally there was the need to provide a set of data and tips to the owners of our current case study in order to instigate their behavioural change and so for that we wrote a simple document that we hand delivered to Sr.Guedes and Dona Mila for them to study. This document can be found in Annex A.

Final product

Figure 8- Final product

As already mentioned our LCD displays 4 values: the instantaneous kW consumption and it's hourly cost with that same consumption on the upper line, and the total savings and costs on the lower left and right side respectively. We also incorporated an LED light that varies from green to yellow or red according to instantaneous consumption. Green means we are using less kW than the baseline we have gathered for that day period, yellow means that we are using about the same as the baseline and, finally, red means we are over the baseline. On the right side of the containment box you have a screw type head that allows the user to adjust the LCD contrast for better visualization.

Preliminary implementation results

Figure 9- One day results

In order to fine-tune all the data processing algorithms and to fix any glitches in our product or even bugs in our extensive C code for the ARDUINO, we conducted several single day tests within Doce Mila itself. Unfortunately a number of problems had to be solved, which left us with only the possibility for a full implementation of one day. Nevertheless, figure 9 shows the results after that same day. It is also worth mentioning that the owners had a chance to read Annex A before that day and tried to apply some saving methods, e.g., turning off the oven before going into medium range tariff in the morning.

As demonstrated in figure 9, in the full day final implementation Doce Mila was able to save around 0.91€ and had a total day cost of 12.5€. However, due to the inherent instability of electricity consumption and its volatile behaviour when its variables change, further discussion about these results is mandatory in order to frame it as a real or approximate solution. Firstly we should consider our data analysis presented above and should take into account our maximum daily deviation from the mean for global consumption (± 4.8%) which should roughly translate into a value of 0.91±0.043 € for the daily saving and 12.5±0.6 € for the total cost of that measured day. Furthermore, and most importantly, we should take a few moments to comment on the validity of our results data.

We have to take into account that the results data is only provided by one single day of measuring and statistically speaking it should not be trusted, specially taking into account the fact that the average data that was used for the computation of these results comes from a week's period. Lastly, we should take into account the human factor involved in electricity consumption, i.e., no one is the same and no one acts the same day after day, meaning our saving estimate could be completely irrelevant in the day after just by having the user make little changes to its electricity consumption behaviour. This changes could be, for instance, a little modification in the working time of the ovens in order to have the benefit of the cheapest hours, the other possible reason is the attention on the stand-by devices since the owner said that in that night he turned it off completely.

Business plan

Executive Summary

Smart Mila is, basically, an interface between the energy consumption of an installation and its owner. It measures the energy consumption and presents the amount of money that the user is spending at a specific time and in the end of the month if he continues with the same behavior. With this device it's possible to control and monitor the money spent in electricity and of course to know how much energy is being spent. Having these to variables it is possible to improve the energy efficiency and see the results of their energy consumption behavioral change. Nowadays some companies are trying to develop something similar but the approach to the market is a little bit different from ours. Our approach is to provide a learning tool that provides a direct interaction with the user.

Customers/market

The future customers of Smart Mila can be any kind of people that has an interest in energy efficiency and, with it, costs reduction. These people can vary from owners of coffee or restaurant or simply someone who wants to have a more efficient house. In our business we offer a complete measuring device with an LCD ready to connect without difficulty. It can be connected to any singular equipment or it can be plugged in to the circuit breaker and measure overall energy consumption.

Market research

During the development of the product it was possible to test it in a real situation, with the help of a pastry owner, Sr. Guedes. We applied the device and measured the energy consumption during five days. The obtained data was shared with Sr. Guedes and with it, it was possible to redesign his behavior with the usage of electrical equipment. Our results were positive since with very simple changes we achieved a daily save of about 0.91€.

Marketing strategy

In the marketing field we are trying to be a bit different from the usual. We developed a step-by-step manual that explains how to build a device like ours and how to implement it. This kind of strategy is not a normal one but develops the curiosity

about the product and improves the willing to have one of those, with the possibility of having one finished and with all the work prepared to use.

A commercial will start the first connection of the company with the customer and a press release will do the after work.

A “How to build workshop” is another kind of approach that has the goal of connecting the customers with the company, as a “do it yourself” replica of our product can be the start of a relationship between the customer and the company that can be very important in a future product or service.

Table 2- Marketing prices

Marketing task	Price
Step by step	0 €
Commercial: duration 30-60 sec **Times: 1-60**	68,69-104.428,53 €
How to build workshop	0 €
Total	68,69-104.428,53 €

Competitor analysis

Table 3- Competitor analysis

Name	Product	Price	Strengths	Weaknesses
Galp	Smart Galp kit	±200€	Website and wireless connection	Indirect user interface, limited to one outlet
Genercy	Efergy e2 1.0	55-109€	Website, Co2 counter, wireless, application, cost	Price, limited to one outlet
Avidsen	Avidsen	19,90€	Price	Limited to one outlet, not user friendly user interface

Swot analysis

Table 4- Swot analysis

Strengths	**Weaknesses**
National product User-interface Easy to use Easy implementation More than one output Overall possible measurement	Simple without design improvements 1st prototype
Opportunities	**Threats**
Development of user relationship Easy reachable company Good communication tools	International market and old companies Skeptic people

Cost and pricing strategy

Prototype and real costs

Table 5- Prototype cost

Components	Price
Arduino uno kit	25€
Amperimetric clamp	13.53€
SD card reader	1.85€
Box	2.5€
Acrylic (up and down)	1.60€
Vinyl (Sticker)	1 €
Other costs	2 €
Watch	3.5€
Total	51.48€

Table 6- Real cost

Components	Price
Arduino uno	23.75€
3 amperimetric clamp (100 amp)	3x13,53€
SD card reader	1,85€
3 condensers	3x0,20€
10 resistences	10x0.05€
5 LEDs	5x0.45
1 LCD	12.48€
1 potentiometer	1.91€
2 PCB	2x4.31€
Cable (1m)	0.31€
Shrink sleeve (1 m)	0.37€
Box	5€
Total	98.23€

Tables 5 and 6 shows what was spent during the development of the first prototype and what would be spent in a complete copy of the prototype buying all the components, respectively.

Considering a prospect for mass production we believe that a 50% reduction in material costs can be easily achieved and with it, it is possible to have a product with a construction cost of more or less 49.20€.

Having all the prices it's possible to have an overview of a desirable price for the product and so, with a profit margin of 20%, the product will cost around 59.99€. For the workshop the price should be lower and we are thinking of having the price defined by the materials cost only, i.e. about 50 € per person. Taking into consideration the real results, with some uncertainty associated, the investment can be recovered really fast, with a approximated saving of 0.91€ per day, which corresponds to 18.2€ per month, the return is of 5/6 months if the price is the one without mass production, with mass production the return is less than 3 months.

Final presentation reactions

The final presentation took place at Mouraria on the 18th of December, in this presentation it was possible to share our work with professors, students and Mouraria residents as well as invited guests. In the end of the presentation the feedback was really good and it was possible to understand the impact of Smart Mila in Sr.Guedes and Dona Mila's daily life. Most of the audience questions were directed to and answered by Dona Mila as she gave her input on our product and it was possible to understand that she really enjoyed the product and that it is a really helpful device to help her control the waste of energy and mainly money.

Conclusion

As it became clearly more evident during the course of this report, electricity consumption and its measurement and analysis is an unstable and "noisy" science. There are too many variables, too much volatility, too much required information, etc. As engineers our main goal in this area is to provide estimates based on proven stable information and use common sense to comment and take conclusions from it. This is what our product does, we measure, we analyse and we estimate results, and its validity must be evaluated taking into to account the intended use for that information. Our product is a learning tool in the sense that it extracts and displays data that is simply not at the hands of the normal user, and so it allows for a learning experience as

to what influences more or less our electricity consumption and more importantly our electricity cost.

With the real experience in Mouraria it was possible to help the owner to apply some saving technics in order to decrease the electricity bill, those tips were tested during one day and compared with a reference day. With the results it was easy to understand the possibility of saving money changing only the behavior of the users, but we have to take into account all the variables of the electricity consumption, especially the human factor, which was not possible.

In another point we referred some more structural and deeper changes that can be made in the places were Smart-Mila is installed, such as renovation of some equipment, like light bulbs or control of others, like the fridges.

If the technical solutions proposed were achieved it would be possible to reach a value of about 1467,72€ per year. In addition, by behavioral changes we could reach savings of around 0,91€ per day, which means around 218,4€ per year. The validity of these results is discussed throughout the report.

All in all, Smart-Mila is proved to be a useful tool, not to be used alone but always with an active intervention of the user as a self-learning tool, with the main objective of informing and providing useful data that is able to help the decrease of electricity consumption.

For all those who want to try and tackle this problem by themselves, a simplified version of Smart Mila can be achieved by following the Step-by-Step found in Annex B.

Annexes

A. Recomendações para reduzir a conta de electricidade;

Recomendações gerais:

Fornos

- Sempre que possível opte por utilizar o forno nos períodos de vazio (a verde no relógio), e nunca no período de pontas (a vermelho no relógio).
- Só abrir o forno se necessário. Cada vez que o abre está a ter uma perda energética de pelo menos 20%.
- Aproveitar ao máximo a capacidade do forno, cozinhando de uma vez só o maior número de bolos (fazer um plano diário).
- Faça um plano de modo a que os bolos que necessitam de maiores temperaturas sejam os primeiros a serem cozinhados, e só depois os que precisam de menores temperaturas, e assim sucessivamente.
- Apagar o forno um pouco antes de finalizar a confecção: o calor residual será suficiente para acabar o processo, ainda durante bastante tempo.
- Manter o forno limpo para que o calor seja mais facilmente reflectido no seu interior, consumindo menos energia.
- Verificar se a porta do forno veda bem, substituindo as juntas e borrachas de vedação sempre que necessário.

Frigoríficos e Arcas.

- Fechar sempre a porta de acrílico do expositor refrigerado. Ter a certeza que estas portas ficam fechadas durante a noite.
- Ter a certeza que não há nenhum frigorifica/arca nunca na mesma sala em que estão os fornos (ou qualquer fonte de calor). Colocar os frigoríficos em local fresco e ventilado.
- Ao comprar um novo equipamento, opte sempre por um equipamento com etiqueta energética da classe A+ ou A++.
- Regular o termóstato de forma a manter uma temperatura de 5ºC no compartimento de refrigeração e de -18ºC no compartimento de congelação. Normalmente não são necessárias temperaturas mais baixas que estas.
- Descongelar as arcas antes que a camada de gelo tenha 3mm de espessura (conseguirá poupanças de energia de cerca de 30%)
- Limpar uma vez por ano a parte traseira do equipamento para libertar mais

facilmente o calor, e afastar a grelha traseira do equipamento o mínimo de 5 cm da parede.

- Verificar periodicamente o estado das borrachas de vedação que permitem o correcto fecho da porta do equipamento.
- Abrir a porta o menos possível e fechar assim que possível.
- Em caso do ausências prolongadas os equipamentos deverão ser esvaziado e desligados.
- Descongelar os alimentos transferindo-os do congelador para o frigorífico. Demoram mais tempo a descongelar mas poupa energia.
- Não encher demasiado o frigorífico, para que o ar possa circular livremente entre os alimentos.
- Manter os alimentos bem tapados, de modo a diminuir a libertação de humidade, evitando que o compressor gaste mais energia.
- Deixe arrefecer os alimentos que estão quentes até à temperatura ambiente antes de os colocar no frigorífico.

Iluminação

- Desligar todas as luzes que se encontram acesas desnecessariamente durante o dia.
- Tirar o máximo partido da luz solar natural.
- As lâmpadas florescentes (as de tubos compridos) gastam muita electricidade se estiverem sempre a ser ligadas e desligadas. Evite ligar este tipo de luzes se for apenas para as desligar em menos de 3 minutos depois.

Tv, rádio, e electrodomésticos gerais

- Desligar os aparelhos no interruptor em vez de os deixar em *stand-by*. Ligar alguns equipamentos (TV, vídeo, DVD, aparelhagem,...) a uma extensão de ligação múltipla com interruptor, para à noite facilmente se desligar tudo;

Como é cobrada a sua electricidade?

A sua instalação eléctrica é uma instalação trifásica com cobrança tri-horária, ou seja, consoante o período do dia existem três diferentes tarifas que aplicam ao seu consumo eléctrico. Essas tarifas são as seguintes:

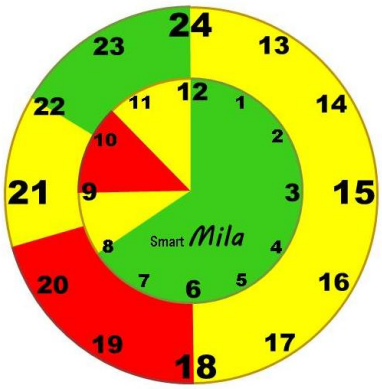
Pontas – 0,2938 €/Kwh, aplicado entre as 9h e as 10:30h e entre as 18:00h as 20:30h

Cheias – 0,1477 €/Kwh, aplicado desde as 8h até 22h excluindo as partes correspondentes ao período de Ponta

Vazio – 0,845 €/Kwh, aplicado das 22h às 8h

Para que possa perceber o impacto destas tarifas veja-se que entre o período de vazio e o período de cheias o preço da electricidade DUPLICA e entre o período de vazio e o período de pontas quase que QUADRIPLICA.

Para que mais facilmente possa saber em que período se encontra ao longo do dia criámos o painel interior de relógio da figura abaixo.



Iremos implementar isto num relógio real e oferecer-lho.

O circulo interior representa as horas do período das 00h às 12h e o exterior representa das 12h ás 24h. Cada uma das cores representa o período em questão, sendo vermelho para Pontas, amarelo para Cheias e verde para Vazio.

Recomendações específicas

Nesta secção pode encontrar algumas recomendações mais específicas para a Doce Mila e a sua quantificação em estimativas de gasto e poupança caso as cumpra. Iremos analisar três tipos de equipamentos diferentes – frigoríficos, fornos e luzes.

Frigoríficos

Neste momento o seu frigorífico tem os seguintes custos aproximados:

- 2,71€/dia
- 84,01€/mês
- 991€/ano

Neste momento o seu frigorífico funciona com um ciclo aproximadamente constante de funcionamento, ou seja, liga e desliga o seu compressor em intervalos igualmente espaçados durante todo o dia.

A recomendação que podemos dar neste caso passa por contratar um técnico especializado que possa implementar um sistema de relés que activa o frigorífico em horas com tarifa mais baixa e que apenas o ligaria caso a sua temperatura fosse abaixo de um nível especificado. O cuidado a ter seria evitar que estes fossem abertos nas alturas de maior custo por forma a evitar perdas de temperatura no interior. A estimativa de poupança por nós calculada caso implemente este sistema seria de:

- 0,69€/dia
- 21,39€/mês
- 256,68€/ano

Fornos

Neste momento os seus fornos representam os seguintes valores em termos de custos monetários da sua factura de electricidade:

- 4,79€/dia
- 148,4€/mês
- 1780€/ano

No entanto, após a análise aos dados que retirámos através do nosso protótipo conseguimos ver que os fornos também trabalham fora dos períodos de menor custo. A nossa recomendação seria, caso possível, apenas trabalhar com eles no período de menor custo, as horas de vazio.

Conseguindo apenas utilizar os fornos neste período a sua poupança seria a seguinte:

- 1,77€/dia
- 54,87€/mês
- 658,44€/ano

Luzes

Esta dica diz respeito ao consumo efectuado para iluminação no seu estabelecimento. Os valores actuais estimados são:

- 1,71€/dia
- 53€/mês
- 636,12€/ano

A nossa recomendação passaria por fazer substituir as suas 15 lâmpadas actuais de tecto por lâmpadas de LED cujo consumo é significativamente mais baixo. Os valores de poupança associados a esta mudança são:

- 1,51€/dia
- 46,05€/mês
- 552,6€/ano

Obviamente esta mudança implica um investimento e deverá consultar um electricista para obter os valores de implementação. No entanto, para que tenha ideia do que pode poupar e para tomar uma decisão sobre se quer implementar ou não a mudança de lâmpadas, aqui fica os valores que nós estimamos em termos de custos de implementação e retorno desse investimento:

- Custo: 212€ (15 x 12€ para as lâmpadas e 8 x 4€ para trocar o apoio no tecto para as lâmpadas de aspecto de tubo comprido)
- Retorno do investimento: Ao fim de 4,6 meses, ou seja, a partir do 5ºmês começará a poupar os valores referidos acima.

B. Step-by-step

1 – Monitorização de consumos com Arduino

Tendo em conta possíveis poupanças que resultem da aplicação de algumas dicas das secções anteriores, é agora importante poder aceder a esses dados para que possam ser quantificados. Esta secção apresenta um guia passo-a-passo em como construir e programar uma plataforma que leia, trate e guarde dados de sensores que medem a corrente elétrica instantânea. Esta mediação poderá ser feita no quadro elétrico geral, onde se terá informação sobre o consumo total da habitação, ou poderá ser implementado por zonas, ou mesmo em apenas uma tomada elétrica ou extensão.

1.1 Arduino com apenas 1 sensor

Para começar, iremos agora dar instruções de utilização de um sensor só, que servirá apenas para o consumo total de uma instalação monofásica, ou apenas uma tomada ou uma zona.

O equipamento mais simples precisará sempre de, no mínimo o seguinte:

- Um computador com o *software* gratuito do *Arduino*;
- Uma placa Arduino (nós utilizámos o UNO por ser o mais comum) – 23.75€;
- Um sensor não invasivo de medição de corrente elétrica – 13.53€;
- 2 resistências iguais de valor igual ou superior a 10kohms – 2 x 0.15€;
- 1 resistência de 33ohms – 0.05€;
- 1 condensador eletrolítico de 10µF – 0.25€;
- BreadBoard – 6.89€;
- Fio elétrico, ferro de soldar, fio de estanho;

Para começar, e se esta é a primeira vez que usa um *Arduino*, recomendamos a leitura atenta de estes dois *links*: (link1, link2);

Para aprender um pouco sobre os sensores que vamos utilizar, recomenda-se a leitura de esta página;

O esquema de montagem do sensor na *Breadboard* é muito simples, e pode ser consultado na imagem seguinte:

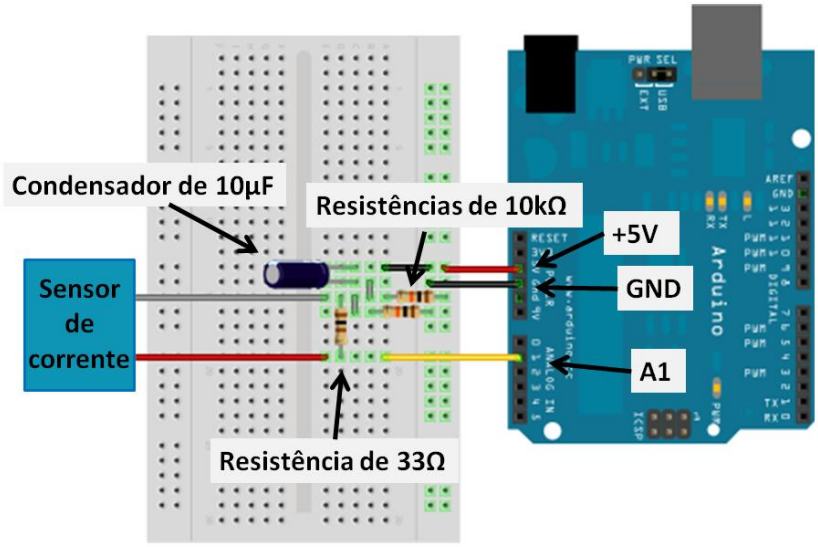


Figure 1- Esquema do sensor na Breadboard

O código a ser implementado pode ser descarregado aqui. Este código não é protegido por direitos de autor. É *open-source* e pode ser usado e editado livremente.

A calibração a ser utilizada depende do sensor (30Amp ou 100Amp) e da resistência que for utilizada a fechar o circuito dos terminais do sensor. Para se calcular a calibração, no sensor está impresso a relação de corrente medida no circuito primário, e qual a corrente máxima no circuito secundário. Por exemplo, num sensor de 100A, deverá estar escrito 100:0.05, o que resulta de uma corrente máxima de 100 aperes a excitar um enrolamento primário de 2000 espiras, no caso do sensor que foi recomendado na lista de material acima. Se o sensor for de 30ª, para as mesmas 2000 espiras, deverá ter escrito 30:0.015 pois 30/2000=0.015. Este valor deverá ser dividido pelo valor da resistência utilizada, que no nosso caso é de 33 ohms.

Assim o valor da calibração será: 100/0.05/33 = 60.6

Para recolher dados poderá carregar no Serial Monitor (canto superior direito) e copiar para o Excel os valores que aparecerem.

1.2. Adicionar um cartão de memória SD para guardar dados

Para evitar ter o computador constantemente ligado ao *Arduino*, poderá ser conveniente comprar um leitor de cartões de memória para guardar os dados. Para isso recomendamos este leitor de cartões –1.85€ .

O esquema de montagem do leitor de cartões, a ser adicionado ao circuito anterior, é o seguinte:

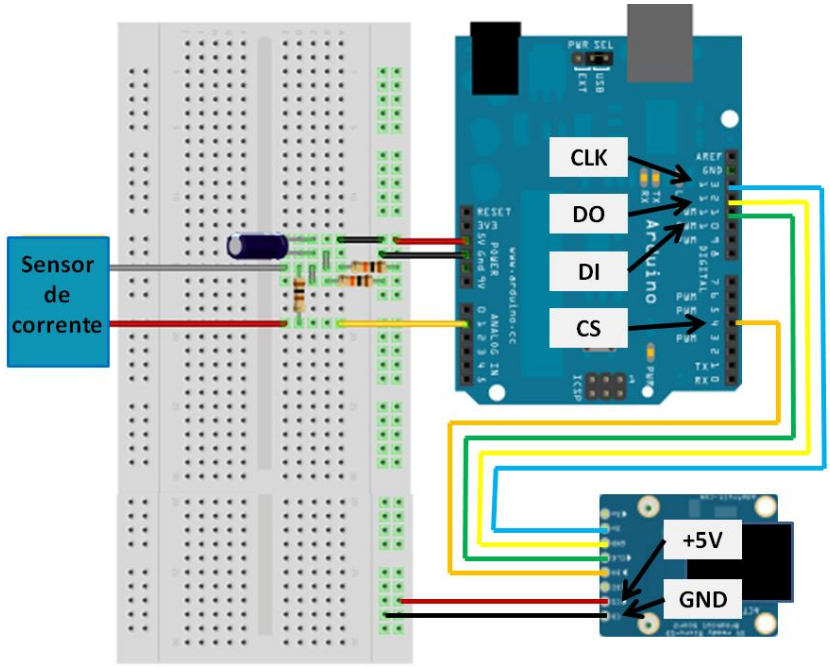


Figure 2- Esquema de montagem do leitor de cartões

As ligações deste módulo *breakout* de 6 pinos são as seguintes:

- CLK ligado à entrada 13 do *Arduino*;
- DO/MISO ligado à entrada 12 do *Arduino*;
- DI/MISI ligado à entrada 11 do *Arduino*;
- CS ligado à entrada 4 do *Arduino*;
- GND ligado ao *ground*;
- VCC ligado a +5V;

O código para o esquema em cima pode ser descarregado aqui. Este código não é protegido por direitos de autor, é *open-source* e pode ser usado e editado livremente.

1.3. Adicionar um ecrã LCD

O próximo passo será adicionar um ecrã LCD ao projecto. Para isso será necessário além do ecrã, um potenciómetro para regular o contraste, e mais alguns fios. O material extra a ser adquirido é o seguinte:

- Ecrã LCD retro-iluminado de 2x16 caracteres – 13.53€;
- Potenciómetro de 1kΩ - 1.25€;

As ligações do ecrã e potenciómetro de ajuste no esquema anterior são as seguintes:

- RS ligado à porta 8 do *Arduino*;
- Enable/E ligado à porta 7 do *Arduino*;
- D4 ligado à porta 5 do *Arduino*;
- D5 ligado à porta 6 do *Arduino*;
- D6 ligado à porta 3 do *Arduino*;
- D7 ligado à porta 2 do *Arduino*;
- R/W ligado ao *ground*;
- As pontas do potenciómetro são ligadas ao *ground* e +5V;
- A ligação do meio do potenciómetro ligada à porta V0 do ecrã (entrada 3 do *LCD);*

O esquema de ligação, tendo por base o circuito do passo anterior é o seguinte:

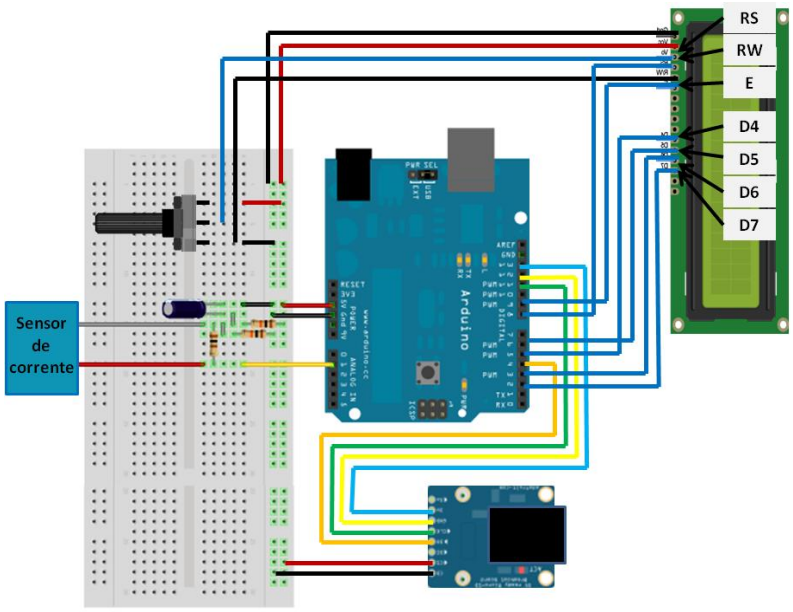


Figure 3- Esquema final com um sensor

O código para o esquema em cima (Arduino com 1 sensor + cartão SD e LCD) pode ser descarregado aqui. Este código não é protegido por direitos de autor, é *open-source* e pode ser usado e editado livremente.

Acrescentar mais sensores e LED's indicativos

Caso este projeto se destine a medir consumos numa instalação trifásica, ou seja interessante medir consumos em farias zonas da casa, será necessário implementar mais sensores. No seguinte exemplo foram introduzidos mais dois sensores de 100A.

Este próximo passo inclui também 3 *LED's* (verde, amarelo e vermelho) configurados para apresentarem uma indicação visual do estado da intensidade de consumo elétrico. No código disponibilizado em baixo, os *LED's* acendem em comparação com uma referência média que foi anteriormente medida para varias alturas do dia. Estes *LED's* poderão ser programados apenas para acender quando o consumo elétrico ultrapassar um certo valor.

Para implementação de mais dois sensores, deverá ser repetidos os passos acima para um só sensor. As saídas analógicas de cada sensor serão ligadas às portas A2 e A3 do *Arduino*.

Para as ligações dos *LED's* tendo em conta que se esgotaram as portas digitais do *Arduino* (As portas 0 e 1, Tx e Rx respectivamente, não podem ser utilizadas) os *LED's* terão de ser ligados também às portas analógicas: A0, A4 e A5, sendo para isso necessário fazer um pequeno truque na programação, como poderá ser visto no código disponibilizado mais abaixo. O esquema de ligações é o seguinte:

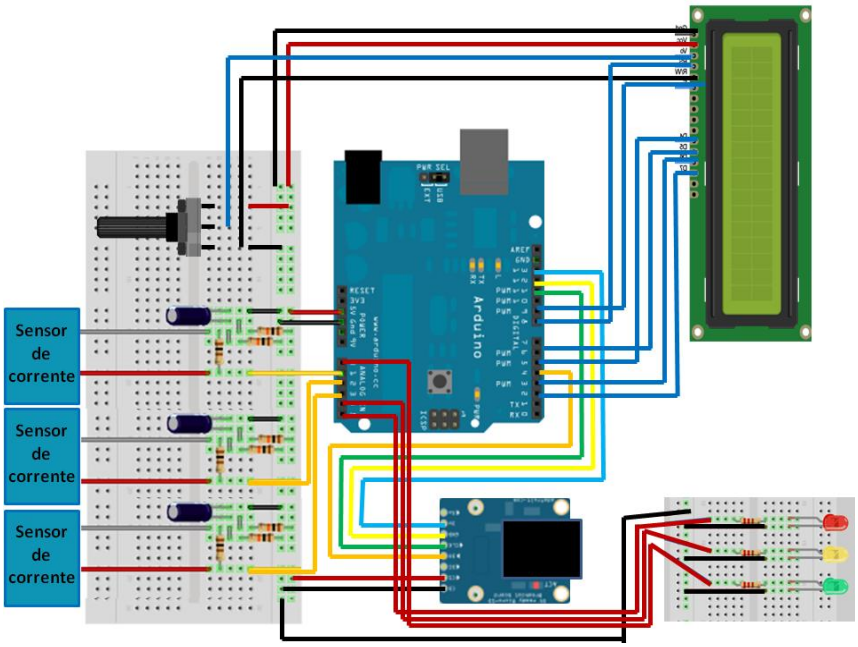


Figure 4- Esquema final com LEDs e três sensores

O código para o esquema acima pode ser descarregado aqui. O texto que aparece no ecrã poderá ser alterado e personalizado para cada caso.

Para qualquer dúvida, questões ou sugestões, utilize o separador “Contactos” para entrar em contacto connosco. Bons projetos!

C. Press-release

Be smart, be efficient, follow Mila’s path

Save money, save water, save energy, those are three main topics being discussed in the world and it looks like in Lisbon it is no different, since 3 engineering wannabes from Instituto Superior Tecnico are, in the last 2 months, transforming “Doce Mila”, a pastry shop, in the most exceptional and energy efficient shop of the whole universe of Mouraria.

With their 5 years of brain development they faced an incredible challenge, to build a device that measures the energy consumption of Doce Mila and with the output data to improve the usage of the equipments regarding energy consumption by the owner, Sr. Guedes.

Besides the measuring they have a user’s interface that shows the money that will be spent at the end of the month with the consumption at an exact moment. With this, even someone that doesn’t understand a thing about engineering can have an insight of their performance at the time. This device can help, not only in pastries or public spaces but in houses too. In order to make it possible to everyone they have done a step-by-step manual that teaches all the basic steps on how to build something similar with less than 50 euros and achieve savings up to 70 euros per month for the most inefficient cases.

Catarina, Miguel and Tomás, the engineer apprentices are on their way to help the development of a new era of energy effiency.

D. Short social media phrase

A new energy efficiency concept was born! With Smart Mila you will be able to save electricity and more importantly to save money so you can travel and enjoy life without being worried about that scary paper in your mailbox at the end of the month.