Code Camp 2016
Home Automation and Smart Buildings

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1. Introduction

Nowadays, most people spend more time in offices than in their own apartments. Working place has become a very important part for every employee, and therefore companies spend thousands of euros in order to make working environments better. But usually people are careless about the resources they are spending: for example, when it is too hot in the room, instead of reducing the temperature in the room, employees usually open the windows around them. The company pays not just for the heating of the building,also pays electricity bills, so for a particular worker there is no need to think about reducing its own energy consumption.

Following this logic, the company owners now need to think about the ways to reduce their expenses in energy and heating. Our team tried to imagine and implemented a particular scenario about reducing energy consumption and thus saving the costs for company owners. Moreover, besides cutting costs for working environments, companies can also advertise their intentions to reduce the environmental impact that their operating processes create. They can be motivated to incorporate this factor in the image of their brand in order to gain additional distinctive feature.

2. Literature review

Being inspired by the Home Automation topic of the Code Camp, we decided to go deeper and to look for already existing solutions for home automation. We found a paper, that was interesting for us, because the authors suggest several algorithms which are quite similar to the algorithm we developed during Code Camp 2016. This paper suggests new algorithms for home automation process based on observation of human behaviour.

Authors of the “Optimization of Home Automation Systems Based on Human Motion and Behaviour” [1] claim that houses equipped with home automation system are not only energy- and costs-saving buildings, but also they provide more comfort for their users as there’s a possibility to operate the whole house remotely from everywhere. According to Mehrabi et al.[1], usually the home automation system consists of process unit which serves as a central unit, and sensors, controllers and loads. All the equipment installed at home operates via this central process unit, and in most cases it is not reasonable, as different types of living areas require different types of algorithms of equipment behaviour. In this paper authors suggest three different scenarios for home automation.

The first scenario is based on role-based flow charts. The idea is to have different algorithms for different rooms. As an example, washroom and living room were taken. For the washroom, authors suggest a flowchart based on the motion detection in the room; if there’s any motion - the lights will be automatically turned on. Usually washroom is the area where user requires the lighting of the room every time he enters it. However, this algorithm is not applicable for the living room, as the user not necessarily turns on the lights in case he/she just want to go to sleep. In addition, authors suggest to equip the living rooms with motion detectors which will only turn off the lights.

The second scenario appeal to the adaptive home automation system. This system in a comparatively short period of time will adapt to the needs of its users, learn their habits and schedule, and adjust the work of the system and equipment to these factors. For instance, if during the night nobody is awake, the sensors could easily operate in a sleeping mode. Additionally, the power consumption will be reduced significantly once the system knows the lifestyle of house’s residents.
The third scenario is based on a thermal modelling of the area. The system consisted of two lumped thermal resistances and one thermal capacity was modelled in MATLAB. Basically, this system takes into account the external temperature, and adjust the internal temperature respectively. The scenario suggests to generate the pattern of the HVAC system’s control signal. The next step is to use this control signal as a function of human’s behaviour.

As a conclusion, authors propose to combine these three approaches in order to achieve significant energy and costs savings. Also they claim that these approaches make home automation system more user-friendly, so the users don't need to program and reprogram system every time.

3. Scenario

For our scenario we used a set of equipment, which includes motion sensor (1), dimmer (2), Twilight sensor (3) and thermostat (4).

Figure (1) - Motion sensor

Figure (2) - Dimmer

Figure (3) - Twilight sensor

Figure (4) - Thermostat

Firstly, our system will detect the movement in the room using the motion sensor as a trigger. If there are people inside the room - the motion sensor will detect the movement and all the other sensors will start to work. If there's nobody inside - there's no need for running the whole system.

The next step comes when the sensor detects the movements. Usually companies try to build spacious offices, full of light and with big windows from floor to the ceiling. During sunny days, the sunlight easily comes through these windows to the room, increasing the temperature inside. Our light sensor will detect if the day is sunny, and adjust the thermostat accordingly. If the temperature in the room starts to increase, the thermostat will detect it and at some threshold value the heating of the room will be stopped. This is done to both decrease heat waste and increase comfort of the people inside.

Usually in most of the companies working day is scheduled, and it is easy to predict the end of working hours. Therefore, the other part of our system will control whether the employee turned off the lights in the office or not. After 15 minutes after the end of working day the motion sensor will check if the room is empty or not. If it is empty and the lights are still turned on - then the system will send a notification to the e-mail address of the worker, informing that the lights are still on, and inviting to come back and turn off the lights. If after another 15 minutes the lights are still on, that means that we are dealing with an irresponsible employee and there’s a need to change people’s behaviour. That means the system will automatically turn off the lights via the usage of dimmer, and the employee will be penalised with a certain amount of money cut off from the salary.

4. Implementation

For our project we used bottom-up approach for implementing our scenario. As a non-Standard solution we have chosen FS20 Wireless Control System. This protocol is not encrypted, and it is an unofficial standard for home automation in Germany. Out of available options we have chosen this one because in our application that targets businesses value per cost factor is very important. Regarding home automation management, FHEM was given as a requisite FHEM is a PERL server for home automation. FHEM could be used for wireless devices, such as switching lamps, heaters and radiators, gas sensors, and it allows to have access to the log file of different events (temperature, power consumption etc.)

Our scenario was implemented using notification mechanism in FHEM. It allows one to create a notification that executes predefined commands once certain event is detected. Motion sensor was chosen as the main trigger for the notification. Once it is triggered the required parameters are sent to switch controlling the lights and thermostat. Moreover, in order to differentiate the lack of motion another FHEM mechanism is used. After setting required parameters timers are set for all actuators. In the notification based on motion detection these timers are initially deleted and created after setting parameters. This allows system to understand and act in case person leaves the premises. If no further motion is detected the timer runs out, turning down the lights and setting low temperature. Also, additional function that sends an email notification to the predefined address is executed.

5. Calculation of Savings

For our scenario we took a standard office with the 18 square meters of space. This office is equipped with 1 PC and 2 LCD monitors, 1 laser printer, 1 phone, and 1 laptop. The next step is to calculate energy consumption of all the devices, CO2 emissions and heating spending.

We assume that for 4 weeks per year the employee has the vacations, that he has 8-hours working day with 1 hour lunch break. During the day he is out of his office for additional 1 hour (meeting with colleagues, coffee breaks etc.), plus for 2 weeks per year he has business trips.

Assuming that the company is not conscious about sustainability issues, and heating system runs continuously without any breaks during the whole year.

For calculating heating spendings, we used Commercial Energy Calculator by conEdison, which was developped in 2016 [2].

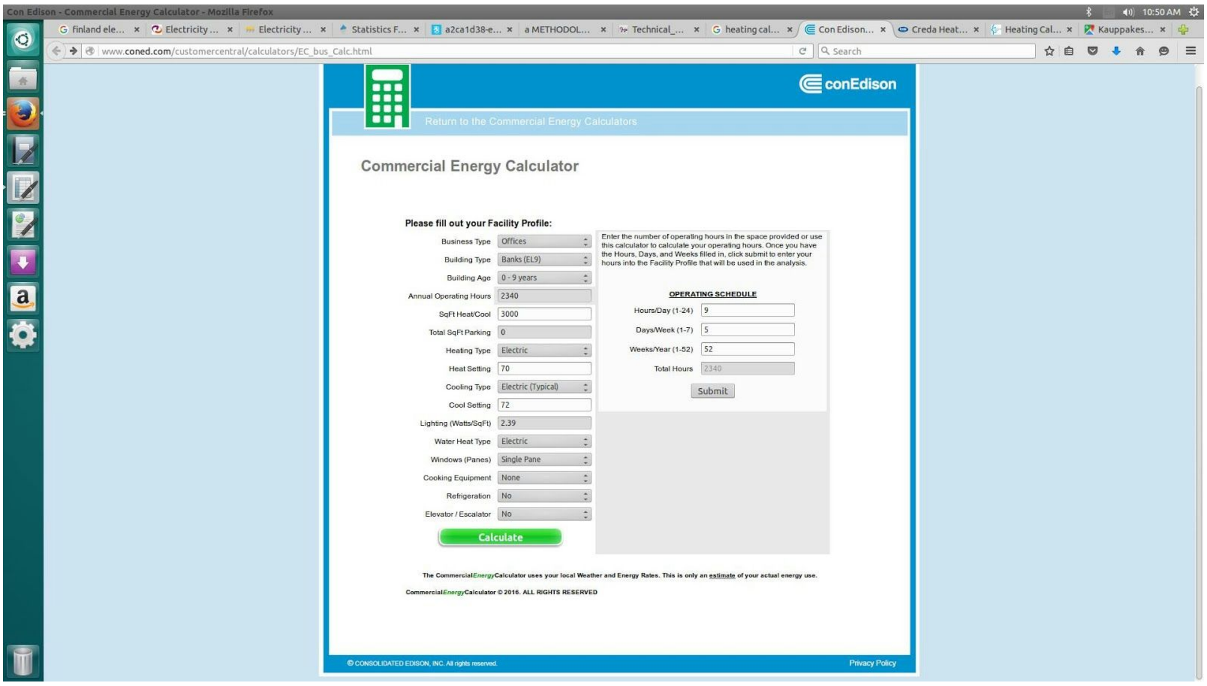

Fig. (5) - conEdison Calculator

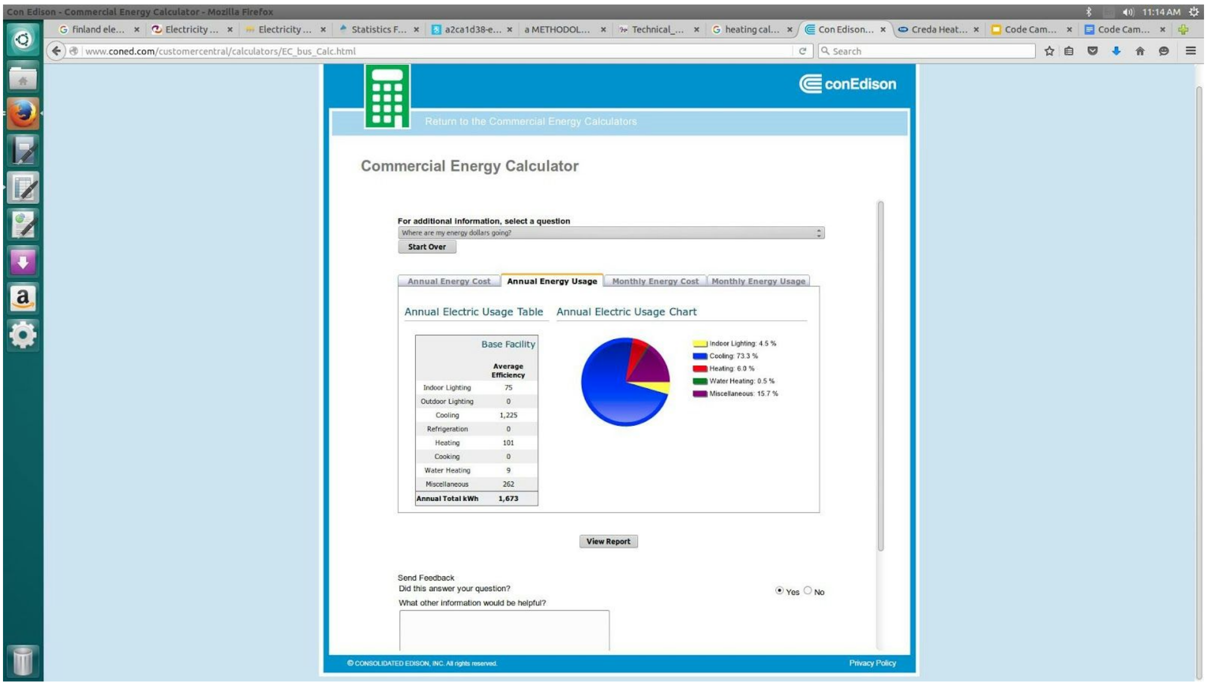

Fig. (6) - conEdison Calculator, graphs.

So far, we are consuming 1.598 kWh per year for heating.

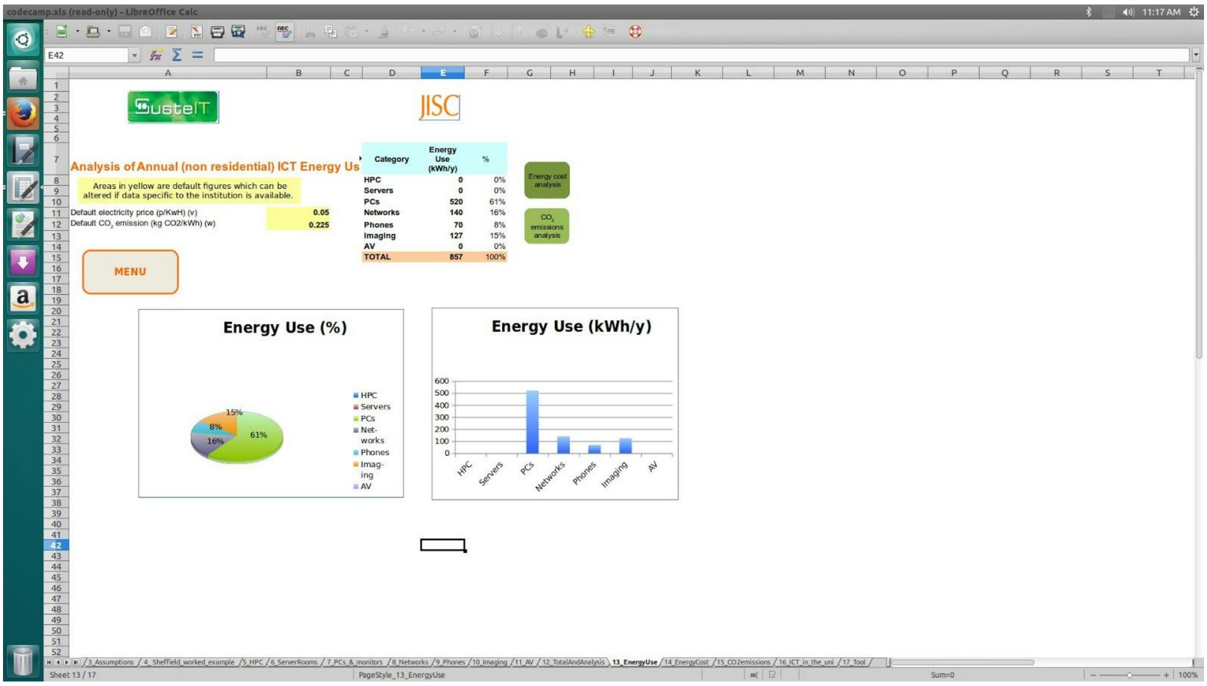

Fig. (7) - SusteIT tool for calculating office energy consumption & CO2 emission.

Plus additional 593 kWh per year for running all office equipment.

In addition, we should take into account the power consumption of our domestic Automation equipment. In this case, it will be dimmer and Tux-Radio.
For dimmer, energy consumption is 3.6 kWh/year, for TuxRadio it is 24.84 kWh/year.

The assumptions for running heating system and office equipment are as follows:

Electrical equipment:

Normal Scenario	Automation Scenario
9 working hours per day 5 days per week 46 weeks (4 weeks of vacations + 2 weeks for business trips) 1 PC, 2 Flat screens, 1 printer and lights Price of 1 kWh = 0.05 euros.	7 working hours per day 5 days per week 46 weeks (4 weeks of vacations + 2 weeks for business trips) 1 PC, 2 Flat screens, 1 printer and lights Price of 1 kWh = 0.05 euros.

Climate control:

Normal Scenario	Automation Scenario
12 working hours per day 5 days per week 52 weeks 18 m2, electric heating, comfort temperature 20-22C. Default CO2 emission for Finland = 0.225 kgCO2/kWh	9 working hours per day 5 days per week 46 weeks (4 weeks of vacations + 2 weeks for business trips) 18 m2, electric heating, comfort temperature 20-22C. Default CO2 emission for Finland = 0.225 kgCO2/kWh

So, the final table will look like:

	Energy consumtion, equipment, kWh/year	Energy consumtion, climate control, kWh/year	Energy consumption of automation equipment	CO2 emission, kgCO2/ year	Costs, euros	In cups of Coffee
Normal mode	557	1593	0	491.85	104.25	208
Automation mode	456	1063	28.44	350	70.65	140
Economy	101	530	28.44	141.85	33.59	68

5. Behaviour modification:

As concerns about energy consumption and environmental impact are rising, there is also emerging understanding that in order to fully address these issues a change of human condition is vital. As our system is designed to be used in working environment another reason for behavior modification is the company’s need to optimize its costs. In our system in case of the FHEM turning off the lights and thermostat by itself a notification is sent to the person, who should have done this otherwise. This serves as a reminder and admonishment. However, we do not believe that such measures will have a desired effect, therefore we propose that a second email is sent to the manager responsible for the particular employee. At the end of the month number of such notification is calculated and corresponding penalty is deducted from the salary of the worker. Another possible insensitive is bonus distribution using Green metric as one of the KPIs of the company for its different units.

6. Conclusions:

Of course, we will need to take into account that the average market price of motion sensor is around 40 euros, Twilight sensor costs around 50 euros, thermostat - 90 euros,and the price of funk dimmer is around 80 euros (all the prices are based on the data from Amazon website). That means 260 euros. The cost of the equipment will be covered in less than 8 years. However, that could be changed by using different cheaper and easier to integrate technologies such as Z-Wave or X10.

Furthermore, re-designing the workspace to make it more spacious and open, has become a trend now. Facebook, for instance, has implemented this design. Home automation system would be more efficient and cost saving in these scenarios, since a central control unit could handle multiple sensors and thus reduce the overall investment in the devices to be made, compared to partitioned workplace design. As stated earlier, the main focus of home automation system is cost saving and energy efficiency. If we calculate benefits just in terms of cost reduction, the results look off the target. But then, at the same time, there are some factors that are to be taken into consideration. Specially, aspects like the level of comfort that people will achieve by the use of these devices and the enrichment of the company image as a “green” company or a company more inclined to greenify it’s workplace, cannot be quantified but they are equally important aspects to be addressed by the home automation system.

References:

1. Optimization of home automation systems based on human motion and behaviour. T Mehrabi, AS Fung, K Raahemifar. *Electrical and Computer Engineering (CCECE)*, 2014 IEEE 27th Canadian
2. conEdison Commercial Calculator. Provided by http://www.coned.com/customercentral/calculators/EC_bus_Calc.html