"Internet of Things" contribution to Electrical Energy Efficiency and society eco-education.

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ABSTRACT

This paper aims at analyzing the place and possible contribution of "Internet of Things" (IoT) in the context of the EU's ambitious climate and energy targets for 2020.
Using qualitative methodology we are mainly focusing on Demand Side Management (DSM) as an effective method in balancing the load of Electrical Distribution Networks.
The role of IoT in DSM is to enable and enhance electrical energy peak demand reduction and its maximum uniform time-distribution achieved through society's eco- education.
Using computational tools such as Data Mining and Recommender System we can achieve results at the level of electrical energy distribution network reflected in peak reduction and its uniform time distribution.

***Keywords: Energy efficiency, Peak demand, Eco-education, Internet of Things*.**

20-20-20 EU goals, overview

"The climate and energy package is a set of binding legislation which aims to ensure the European Union meets its ambitious climate and energy targets for 2020.
The targets, known as "20-20-20" targets, set 3 key objectives for 2020:
- a 20% reduction in EU greenhouse gas emissions from 1990 levels;
- raising the share of EU energy consumption produced from renewable resources to 20%;
- 20% improvement in the EU's energy efficiency." *European Commission, (n.d.)*

At this point we can state that overall EU has already made big steps in achieving its goals and especially:

- So far EU is on track achieving 18% emission reduction in 2013. Also the first Kyoto commitment was over-achieved in the 2008-2012. European Commission (2015)
- 15% share of energy from renewable sources in gross final consumption of energy in 2013. European Environment Agency (2014)
- Energy efficiency is a delicate topic and requires a more detailed approach.

First of all, an overview of actual energy consumption trend in EU:

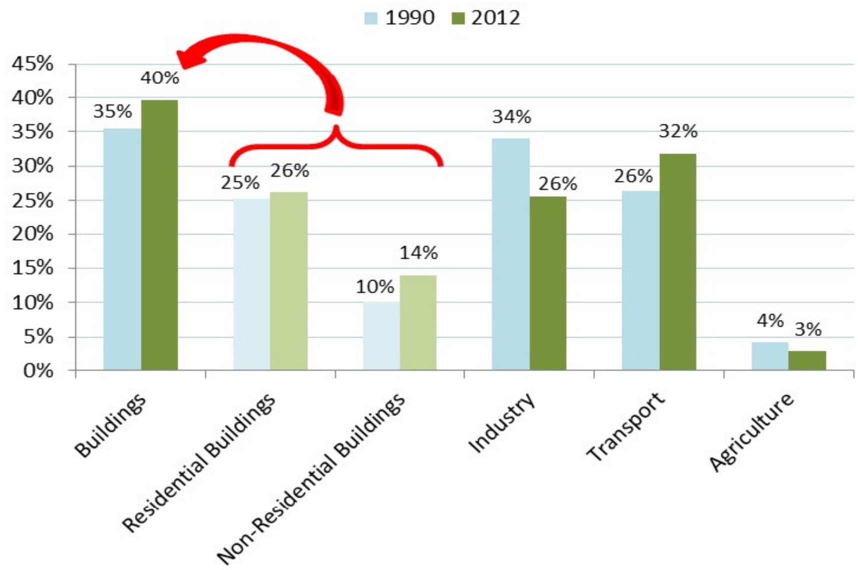

Figure 1: Share of buildings in final energy consumption in EU-28 https://ec.europa.eu/ (*2015*).

A brief analysis leads us to the conclusion that buildings energy consumption share tends to grow and has the biggest impact on the overall consumption trend. Following this idea, would suggest that electrical energy efficiency is mainly influenced by the optimization of energy consumption in this particular sector. The measures that were actually taken to reduce the power consumption and increase energy efficiency of household appliances and office equipment gave good results at the level of electrical energy end-user/consumer, but analysing it at a higher level, when the number of electrical devices is in continuous growth, we have to face the network's problem of demand peaks.

Generally Electrical Distribution systems adjust to the changing demand by dispatching additional generation, which are usually supplied by less efficient sources during peak periods.

Energy demand handled by Smart Grid, Metering and financial incentives.

The idea behind Smart Grid is to monitor energy flows and adjust it to changes in energy supply and demand accordingly.
Smart Metering aims to achieve monitoring of real-time consumption on the side of end-user (consumer) and it's estimated that will give an energy saving at 3% according to EU Joint Research Center, (July 2014).
Having Smart Grid for energy monitoring and flow control on one side and Smart Metering with real-time consumption data on the other side, such a system will theoretically react to energy demand growth or fall, but demand itself will remain the same or even increase, if it maintains its actual growth rate.
To deal with demand peaks and specifically to reduce and spread it, Europe uses financial incentives and behavioral change through education. Further we'll call this specific type of education eco-education.
Education is meant to encourage the consumer to use less energy during peak hours. Financial incentives reinforce eco-education by offering different tariffs for energy, usually two tariffs "High" and "Low", so the consumer pays more for kWh during peaks and respectively less during "off-peaks".
In this paper will adopt the Polish electrical energy market model as a reference in further discussion on the topic of financial incentives and eco-education.
Having said all the above polish operator "Energa" offers following tariffs for kWh:

Table 1: Electrical energy price in PLN/kWh, Energa, Poland. www.energa.pl (n.d.)

Name of tariff Group	Uniform price	Peak price	Off-peak price
G12	-	0.3625	0.2401

Table 1: Time schedule for G12 tariff group www.energa.pl (n.d.)

Month	Peak time zone	Off-Peak time zone
From: January 1st To: December 31st	06:00-13:00 15:00-22:00	13:00-15:00 22:00-06:00

We can easily conclude that peak to off-peak ratio is 14/10 hours a day and price difference between High and Low tariff is 50% for this specific tariff group.

After more than two years since implementation of Smart metering in Kalisz region of Poland Energa operator made available report on effects of Smart Metering on network load and energy savings (see **Figure 2** and **Figure 3**).

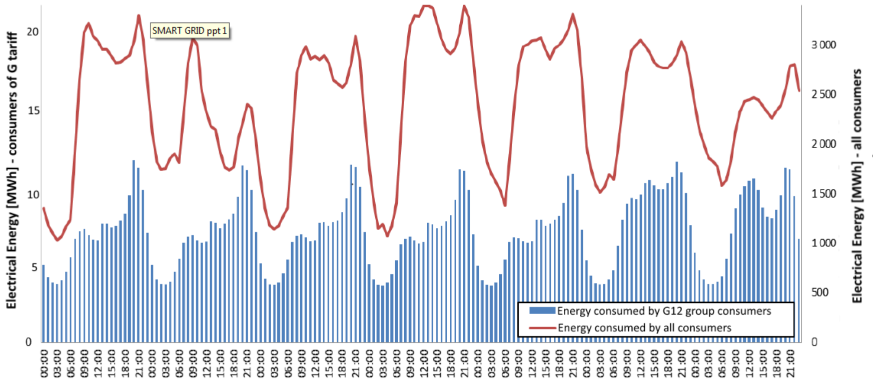

Figure 2: Network load profile of Kalisz region, According to Masiąg, R. (2014)

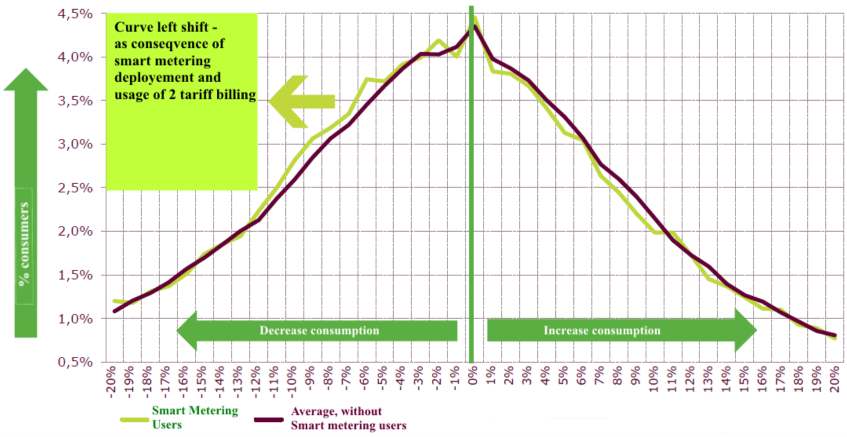

Figure 3: Energy savings of customers with Smart Metering compared to customers without. According to Masiąg, R. (2014)

Energa operator (2014) concluded that overall network load profile curve follows consumer's demand from G tariff and the tendency of energy saving for consumers with Smart Metering compared to regular meter consumer is higher by 0,22%.
Analyzing network load graph we can conclude that there is room for more efficient load distribution and a simple financial incentive does not completely stimulate the consumer for both, savings and time usage.
We tried to identify a few possible reasons why a consumer follows the energy tariff time zones with such a low rate of interest:

- The number of appliances that would allow their scheduling is still low.
- Consumer has to manually adjust and follow G tariff schedule, which causes that in many cases schedule is ignored or followed poorly.
- The number of appliances is too high and physically difficult to track and manage.
- Consumer is poorly informed on effective bill savings that can be achieved by following G tariff schedule.

We want to propose Internet of Things (IoT) technologies as a possible solution in stimulating consumers toward eco-education.

IoT and extended recommender platform contribution to consumer's eco-education.

The Internet of Things computing concept. The IoT is not an easy to define concept and there are many groups that define this term in their own way, so we'll use an approach that is closer to our actual topic. We'll adopt a business oriented approach to define the IoT concept seen at the macro level.
According to Burkit, F. (2014) IoT is divided in three strategic categories based on type of enterprise they are reflecting:
"Enablers", technology-oriented companies that develop and implement the underlying technology.
"Engagers", that design, create, integrate and deliver IoT services to customers.
"Enhancers" that devise their own value-added services, on top of the services provided by Engagers.
In our further analysis we'll focus mainly on Engagers and Enhancers to see their possible contribution to Energy Efficiency and society's eco-education. For this purpose we need to define some terms that latter will be extensively used.
Smart house- an acquisition system as a part of IoT that is delimited by the range of normal house, flat or similar area of living. Smart house has sufficiently granulated acquisition system, which means that all power outlets are measuring consumed Active Energy and centralizes this data on the platform offered by IoT Engagers.
Data HUB- a service offered by IoT Engagers, cloud storage platform, where the data from Smart House is stored and further interfaced. They are offering all afferent APIs and services to securely access and process this data.
Extended Recommender System – a tool that uses as input data offered by Data HUB, processes this data and offers to end-user recommendations regarding his behavior and possible benefits. This system is categorized as IoT Enhancer.
Extended Recommender System's (ERS) main functionality will be to offer to end-users (electrical energy consumers) recommendations to match their habits related to usage of electrical energy and maximize possible bill savings. In other words ERS will search for a solution with minimum behavior change required from user to best-suite energy time- zone tariffs so it can also estimate direct financial benefits from adjusting his behavior.
Such a system will naturally use some dedicated computational tools. We'll focus mainly on Data Mining as a key tool in processing such a big amount of data related to energy consumption.

Data mining on its turn can use a couple of algorithms to accomplish its job. We'll simply enumerate them and won't go in details because it is out of scope of this paper.
Cluster analysis-discovering groups and structures in the data that are in some way "similar" and can be used to indicate cohesive groups of consumers.
Regression analysis-the prediction of power consumption for a new consumer is a classical regression problem.
Anomaly detection- is applicable in our case in fault or event detection
Classification is the problem of identifying in which set/category a new observation belongs to.
Now returning to the subject of Energy demand, Smart Metering and financial incentives we can assume the following situation:
- Electrical distribution network with Smart Metering implemented and running;
- Financial incentives applied to stimulate consumers to more effective energy use;
- Smart House in the context of IoT with Data HUB and Extended Recommender System;

Such a system will contribute at solving problems identified in the previous chapter - consumer follows the energy tariff time zones with a low rate of interest.
It will offer solutions that otherwise consumers would be forced to investigate, calculate and manage manually. In this way such a system will naturally increase the level of consumer's eco-education.
The success rate of such a system would normally depend mainly on type of electrical devices consumer is using and especially on their grade of autonomy.
By grade of autonomy we mean devices that can be controlled without the need of user's confirmation and are less dependent on use-time. A good example of high-autonomy electrical consumer would be for instance an automated irrigation system that can run mainly during night; also an electric car charger can be easily scheduled according to the owner's preferences. This kind of electrical devices will have the biggest weight and will mostly influence the overall optimization effect.
The opposite extreme case would be electric stove or refrigerator, here the ERS effect is reduced only at recommendation level and the decision is fully taken by the user and the overall effect is not precisely predictable. The ERS can only inform the user of possible benefits if the user will adopt an alternative decision.
For example a brief report on how much money would save user in case of adaptation of alternative behavior.
Estimation of the benefit of such a system is not a trivial problem and will be the subject of the separate research.

CONCLUSION

In the context of European Union struggle to achieve its 20-20-20 goals the IoT can contribute in the field of electrical energy efficiency by offering an effective tool for:

- Learning consumer's habits related to electrical energy consumption profile;
- Offer an optimal solution to minimize interferences with already adopted behavior and maximize the follow-up of energy usage according to active tariff zones;
- Categorize types of appliances based on their energy consumption profile;
- Detect anomalies related to energy consumption;
- Manage electrical devices with a high decision-autonomy grade;

It's obvious that such a tool will achieve its maximum efficiency only in synchronization with Smart Metering system. Also it will naturally contribute to society eco-education. By "naturally" in this context we mean that a regular user does not need to know all the theory behind Smart Metering, Demand Side Management, IoT and so on, the only thing he will require to do is to follow advice of ERS and depending on his degree of compliance will achieve respective bill savings. As a consequence, also Distribution Network Load profile will also normalize with respect to energy demand peaks.

This model in our opinion can be adopted also in other fields such as heat energy efficiency and industrial energy consumption optimization.

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