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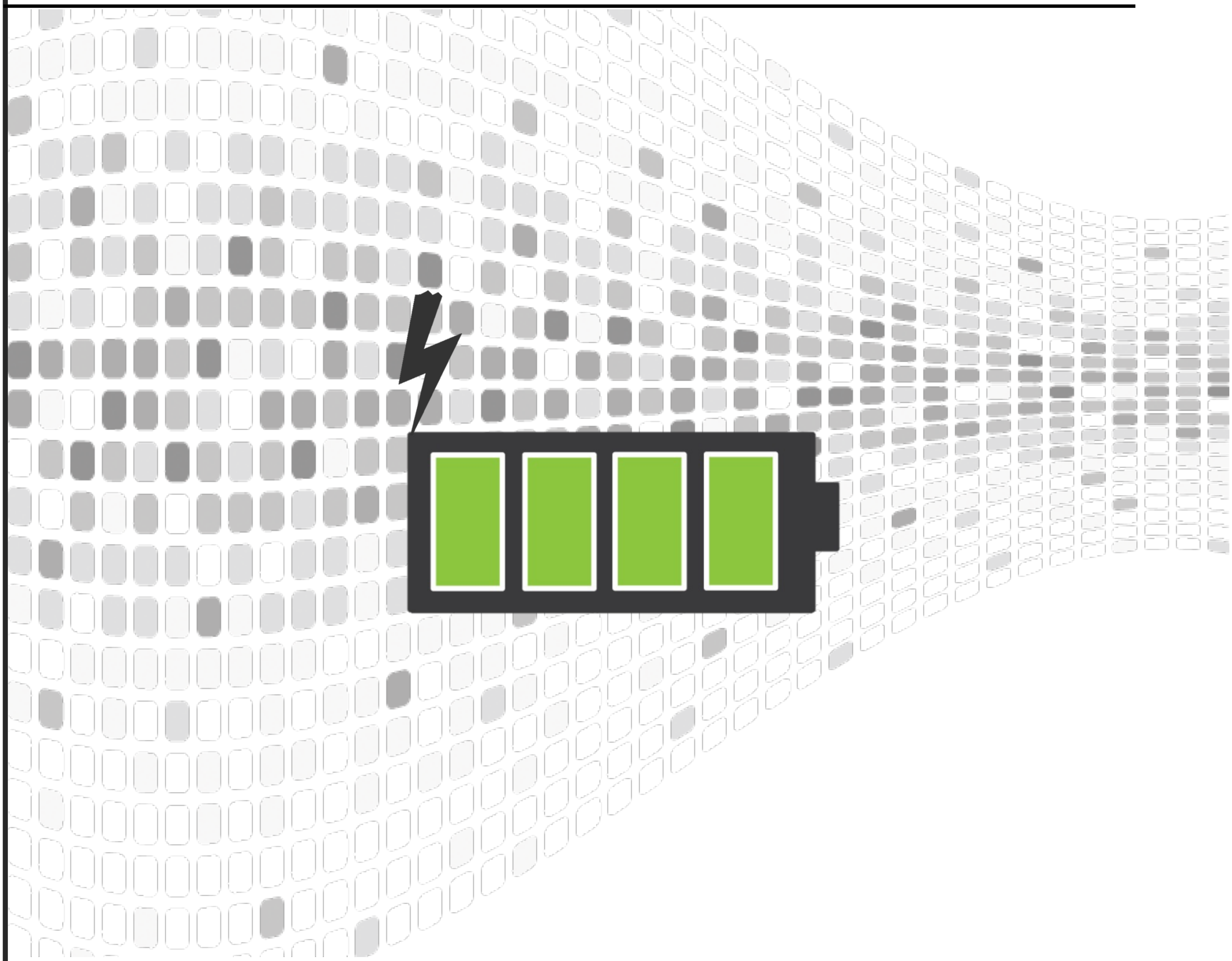
What do "digital energy" and "digital consumer" mean to you?



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1. Current Era

1.1. Environmental Aspect - Prologue

Global climate change is causing a century scale rise in the average temperature of the earth's climate system, with long lasting consequences for societies and economies (National Research Council of the National Academies, 2006). The current climate changes are particularly significant, due to the high probability that most of these changes are human induced (Santer et al., 1996). An increased electricity demand imposes a direct thread on the environment; more specifically emission of the green house gases (GHG) produced in the electricity generation from fossil fuels. Emission of the GHG contributes directly to the climate change and rising average global temperature levels (Cop21.gouv.fr, 2016).

In an attempt to lower the human caused influence on climate change, in December 2008 European Parliament approved a climate change package, with a main aim of 20% reduction in greenhouse gas emissions, 20% improvement in energy efficiency, and 20% share for renewables in the EU energy mix (European Parliament 2009). In addition, during the 2015 United Nations Climate Change Conference with 196 attending parties agreed on the common goal to limiting the global warming to less than 2 degrees Celsius compared to pre-industrial levels (Center For Climate And Energy Solutions 2015). The agreed initiative fosters both investment into clean energy and elimination of unsustainable elements such as coal and oil power plants. The quantity of renewable energy produced in the EU increased by 84,4% from 2003 to 2013 (Eurostat, 2015).

The shift towards the energy generated from renewable sources ,such as solar, wind and hydro, imposes a number of challenges on the energy market (IEA-RETD 2015). Compared to the traditional fossil based energy sources, renewables have three main inherent properties.

Firstly, an energy generation from renewable energy sources is volatile. Electricity supply from generators should meet the load by the consumers. However, based on the example of Danish wind power generation, the resulting variable net load, which is a electricity demand minus supply, is more volatile than the regular load (IEA-RETD 2015). As a result, combining volatile electricity supply from wind or solar energy sources with the regular electricity load makes the electricity demand curve more volatile.

The second property of renewable sources is their uncertainty. In other words, renewable energy sources are difficult to forecast because of their inherent dependency on natural cycles and weather. The weather is extremely difficult to predict, and balancing responsible party or system operator has to have a sufficient flexibility to take into account unpredictable generated output (IEA-RETD 2015).

Thirdly, unlike conventional power generation from fossil fuels, power generation from renewables is location specific, greenhouse emissions free, and feature very low operating expenses. Wind turbines or solar PV panels can achieve different level of efficiency depending on an outside environment. In addition, the operating expenses are not tied to the level of energy generated , but only to the regular maintenance costs (IEA-RETD 2015). No fossil fuel is burned in the process of energy generation which makes the renewable energy resource free from and does not result in any form of greenhouse emissions.

1.2. Solutions

The challenges of the renewable energy generation can be tackled by a number of solutions that extend grid flexibility. There are three main ways of increasing grid flexibility: by implementing dispatch able generation sources, a demand side management (DSM), and power storage solutions (Nerc 2010). The last two strategies are dependent on an efficient real time energy flow visibility.

When talking about the efficient real time energy flow visibility, an element of digital energy comes into play. The digital energy fulfils an important role in facilitating the environmental transformation and management in the grid. The digital energy represents an energy flow that is transparently measured in real time at a number strategic locations in the energy grid. A smart grid implementation is a prerequisite to realize a potential of digital energy. The digital energy map can be understood as a web, similar to the internet, where each node represents an individual household or business. The energy flow both ways such as data in the internet routes go downstream and upstream. As a result, the digital energy is flexible, highly influenceable, and measurable. The challenges of energy generation from renewable sources are directly linked with efficient energy management techniques, which can be possible thanks to a digital energy integration.

1.2.1.DSM & Energy Storage

As discussed in the previous section the digital energy enables a demand side management (DSM) that has an impact on the grid flexibility. DSM consists of two elements: a load shifting, and a load shedding. The load shifting represents moving or postponing electricity consumption from one point to another. The load shedding is method of reducing certain loads in order to match reduce supply and demand imbalances (IEA-RETD 2015). The electricity storage provides grid flexibility by utilizing power capacity and deploying the electricity in times of insufficient supply caused by peak demands. In addition, energy storage is extremely efficient when coupled with a volatile energy generation from a renewable energy sources. There are number of different types of power storage solutions. The largest scale of stored energy, 99% of Europe's capacity, is stored in a hydro pump storage. Subsequently, the energy can be stored using other alternative methods, such as in pumped heat, high powered flywheels and a liquid gas. The battery power storage, in general, has not been utilized for large scale power conservation of more than 100MW due to the high costs of production (IEA-RETD 2015).

Since the early 2015, the demand for the home power storage solutions has raised substantially: Tesla's storage solution, Powerwall, was sold out within a week for the until mid 2016 and hit 1 billion dollars of sales (Wesoff 2015). Taking into consideration that Tesla is not an only company on the market offering the home and business power storage solution, it can be concluded that average consumers are realizing the energy storage potential. The technology of lithium ion batteries has achieved a large leaps in its maturity, by increasing capacity and increasing number of cycles the battery is recharged (Carnegie et al. 2013). Despite the fact, that in early 2016 the cost of batteries is still considerably high, it is forecasted that thanks to economies of scale and an improved efficiencies in production the median cost of lithium ion storage will be 47% of today's cost (Vorrath 2015). The prediction can be already clearly seen via heavy investments into battery production such as Tesla's Gigafactory. Furthermore, extraordinary large amounts of venture capital seed has been offered to smaller start-up companies such as Powervault and Orison which offer similar home power storage solution as Tesla. As a result, batteries are expected to be deployed on large scale within the next five years. In addition, despite a considerably high price, there is already a high demand for home power storage solution

Customers currently utilize home power storage solutions for four main use cases: time-of-use bill management, increased PV self-consumption, demand charge reduction, and as a backup power. The first three use cases are interlinked because they are based on smoothing out the peaks on the energy demand curve by utilizing the energy from battery in times of high prices. It result in positive return on energy bill for customers if proper framework is established by the utility providers (Rocky Mountain institute 2015).

1.3. Advanced digitalization

A digital era has begun in between years 1950 to 1970 with an adoption of a digital computer and has continued to present day (The Digital Revolution, 2016). Nowadays, the world is more connected to the internet as never before, which has an impact on both businesses and consumers. An increased connectedness of consumers and businesses favourably influences the communication exchange between the both parties (Westerman et al. n.d.). Consumers and businesses are becoming more digital due to a higher interaction with devices connected to the internet.

A digital consumer means to me an individual who is actively and naturally interacting with internet-connected devices without any extra effort. In addition, the digital consumer takes advantage of an large data available to him/her via a particular device such as smartphone, smartwatch or tablet. The digital consumer interacts differently than a regular consumer in a number of different situations and craves for higher visibility and transparency enabled by data.

In the context of energy, the digital consumers are looking for more flexible and responsive suppliers of energy. Furthermore, they expect more added value services from utility providers, such as real time analytics (Capgemini, 2015). In addition, digital customers are increasingly interacting with their energy ecosystem, thereby raising the need for a two-sided communication with utility providers, but also the opportunity for utility providers' to gain in-depth knowledge about such customers. Therefore, switching to digital, or online customer relationships allows utility providers to meet new goals of customer satisfaction (Capgemini, 2015).

1.3.1. Disruption

With an increased "hunger" for a transparent energy data analytics available online, conventional value chains of utility providers might be disrupted. Such needs of digital consumers present valuable incentives for new market entrants to enter the energy service sector (Capgemini, 2015). A digital consumer pursues higher visibility over his/her energy consumption. Products such as a smart meter connected to a smartphone application represent a starting point for a digital consumer in the energy segment. As an example, other players such as Google Nest with no previous experience in an energy business are successful in the market.

When a high demand home power storage is taken into an equation, a power of a digital consumer is expected to be increased. A digital consumer can directly decide when to utilize a power storage and not only reduce a consumption to zero, but also reverse consumption by generating energy back to a grid. Such an *active demand side management* has a high influence on energy flows in the grid. The options for a digital consumer to monitor and directly influence the consumption and production of energy are possible thanks to advanced Home Energy Management Systems (HEMS). Due to a decreasing costs of technology, and increased digitalization, an advanced HEMS system was perceived as a science fiction only a couple of years back. However, currently an advanced HEMS system can be even self built with the use of miniature computer, Raspberry Pi, and couple of extra modules attached that act as sensors and switches. The whole set up on average does not cost more that 200€ if a digital consumer enthusiast decides to integrate it himself. As a result, I would like to stress that the technology needed for an *active demand side management* such as energy storage and advanced HEMS is already available.

2. Research

Despite the cost of batteries is expected to decrease in the upcoming five years, the average price of an energy power storage system is considerably high for an average digital consumer. Since the technology for an energy management is implemented during a PV panels installation, the cost of batteries represents the highest cash outflow. As a result, the aim of my research is to provide a power storage simulation under a variable time of use pricing scenario. The outcome of a simulation provides an overall picture of a household production and consumption with and without utilizing power storage. In addition, net energy consumption cost benefits of utilizing power storage are provided in the simulations.

The methodology used is solely based on the quantitative simulation with a number of different input factors:

- Household energy consumption series
- Household energy production series
- Time of Use pricing series
- Storage capacity
- Max Output of a storage
- Fixed charge and discharge speed to the grid
- Runtime efficiency

Based on the input variables an energy model of an individual household is generated. The data sample used are 300 households located in northern Netherlands that are formed in a microgrid. The houses in the microgrid has implemented a variable Time of use pricing to balance the energy supply and demand. The energy generation capability of the microgrid featured a number of wind turbines and half of the households with solar panels. In addition, no power storage has been implemented in the microgrid to store power. As a result, a pricing strategy has been used to reflect over and underproduction. The figure bellow provides an overview of a one-day average household with an average monthly bill of 50€ and without an energy generation capability from PV panels.

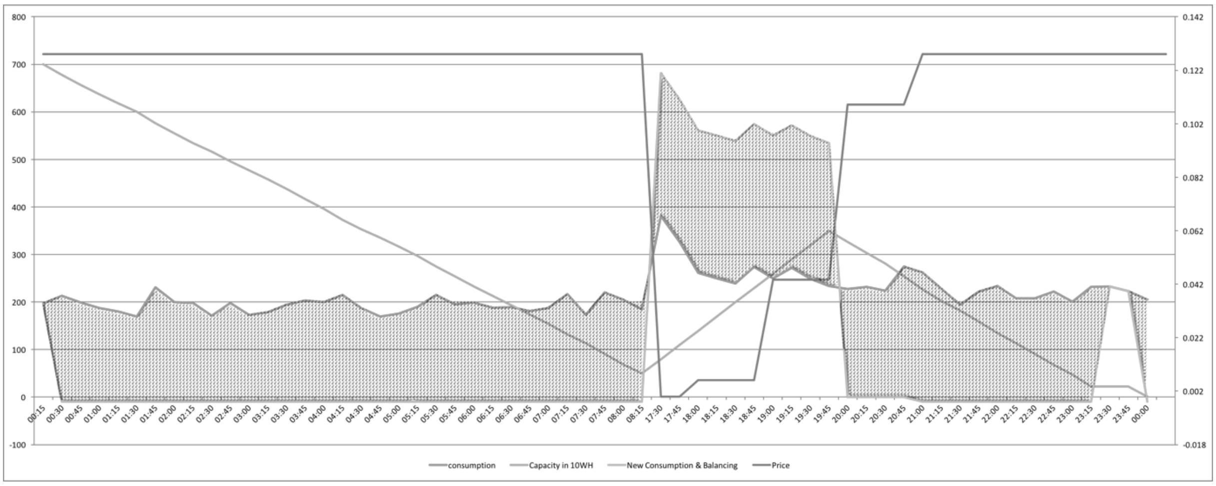

Figure 1: One Day Adjusted Consumption

The shaded areas visualize a delta in the energy demands when a 7KW energy storage solution is implemented. The axis to the right shows electricity prices, in addition a line on the top provides an information about the price throughout the day. It can be seen that an electricity price has started at the peak at around 0,128 per KW and ended at the same peak at 0,128 per KW. During the day, at 17:30 the price has dropped to 0 due to an energy oversupply in the microgrid. As it can be seen the energy consumption has increased due to the fact that a power storage initiated its charge.

The capacity level of a battery is indicated with a grey line starting at 700 level. The actual capacity was divided by 10 for better visualization in a single graph. The battery discharges to offset the consumption when the price of electricity is high. In addition, a consumption did not exceed the max output of an energy storage, which results in a consumption drop to zero. In the similar fashion the capacity line works for the rest of the days.

The particular household with an energy bill of 51€ was able to achieve cost benefit of 14€, approx. 25% decrease from the original monthly bill. The 7KW storage was simulated in this case, however, if a more expensive, 10KW solution is implemented the energy bill could be reduced by 18€, approx. 35% reduction. The calculation is based on the fundamental principle of a net metering, where the same price of energy is used when consumed from and supplied to the grid.

The variables such as charging speed, capacity of a storage, and discharge speed to a grid directly influence a behaviour of an energy storage solution. Optimal values shall be find per each use case. As a result, various optimization techniques such as Monte Carlo optimization strategy can be used to even improve the utilization of an energy storage and potentially decrease an energy bill.

When looking at the management of a digital energy by a digital consumer from a perspective of an utility company, the grid balancing can be induced via an efficient variable pricing strategy. Thus, each household would like to consume energy at the cheapest price which would induce higher overall consumption of the grid. On the other hand, in times of undersupply, utility company would be able to increase energy price to directly reduce the consumption. In case the battery storage is programed to trigger utilization automatically, utility company can directly benefit from customers’ home power storage solutions. Therefore, utility companies should promote home power storage installations at households, because households would be having a direct balancing capability of a grid.

3. Future Era

The increased influence of digital consumers on the energy flows in a grid the greater risk of instability is in the system. As a result, new measures will have to be implemented that would limit dangerous actions of a digital consumer and a utility provider. Not only the regulations have to be established towards net metering standards, but also the regulations that would ensure that the grid will be able to withstand increased flows of energy, for instance when a large number of batteries is charging or discharging.

There will be a possibility for a disruptive innovation in the digital energy segment. For instance, if consumers are able to link their households' storage systems they will be able to exchange energy among each other which would create a major stepping stone for a utility company. If utility companies do not adapt quickly to a digital consumer needs, other players will enter the market and take advantage of a digital energy. New business models will emerge, such as pooling of batteries that would link small home power storage solutions to earn on energy price arbitrage and at the same time contribute to a grid balancing. It is extremely difficult to predict what the future holds, however we certainly know that the digital energy and digital consumers will be major keystones in the upcoming sustainable energy revolution!

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