University of Economics, Prague
Faculty of Business Administration
CEMS MIM - International Management

Impact of New Technologies in Energy on Households

Author: Bc. Dominik Novák
Supervisor: prof. Ing. Jiří Strouhal, Ph.D

D e c l a r a t i o n

I hereby declare that this master thesis on the topic of "Impact of New Technologies in Energy on Households" was developed independently using literature and information, referred to.

In Prague, 6th of July 2016

Název magisterské práce:

Vliv nových technologií v energetice na domácnosti

Abstrakt:

Diplomová práce si klade za cíl vyhodnotit potenciál domácích systémů pro ukládání energie pro koncového uživatele. V teoretické části proto představuje historický vývoj na energetických trzích v Evropě, s účelem identifikovat, jaký byl dopad tohoto vývoje na produkty nabízené poskytovateli elektřiny koncovým uživatelům. Poznatky z této analýzy jsou následně využity k sestavení modelu, který slouží k vyhodnocení profitability domácích baterií pro tuzemské domácnosti, a který je představen v praktické části diplomové práce. S pomocí modelu je provedeno vyhodnocení profitability domácích baterií pro tři různé typy domácností a zároveň jsou identifikovány základní hnací síly a omezení pro rozvoj adopce systémů pro ukládání energie tuzemskými domácnostmi.

Klíčová slova:

Energetika, technologie, baterie, fotovoltaika, elektromobilita, smart metering

Title of the Master Thesis:

Impact of New Technologies in Energy on Households

Abstract:

This master's thesis aims to assess and evaluate the potential of home based energy storage systems for the final user. In theoretical part it therefore describes the historical development of the European power sector with the purpose of determining, what was the impact of this development on products offered by energy providers to the final consumers of electricity. Findings from this analysis are then used to design a model, which is introduced and described in the practical part of the master's thesis. This model is afterwards used to assess the profitability of home batteries implementation by three different types of households and also to determine, what are the key drivers and constraints for the adoption of energy storage systems by households.

Key words:

Energy, technologies, batteries, photovoltaics, electromobility, smart metering

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Contents

1. Introduction

While on the first glance, power sector might seem as a rigid and uninteresting industry, it is exciting to observe that the monotonous facade is only a disguise for the ever present innovation. This master thesis therefore aims to reveal some of the existing technological innovation from the power sector, such as photovoltaics or electromobility and in the later parts it will also aim to suggest, what could be the next big thing in the electricity markets.

1.1. Electricity on the rise

Electricity has been one of the major drivers, or perhaps even the largest one, of our society since the second half of the 19th century. Since its introduction and expansion to general public it has gone a long way and nowadays it impacts almost every aspect of our lives.

Throughout the 20th century electricity has undergone a rapid development both in terms of its production and its applications. Today, whenever we plug in an electric device into a socket, the electricity flowing in can be coming from coal, oil, natural gas, nuclear fission, wind, sun or countless other renewable sources. Through the ever-present sockets we then power our home appliances, lights, computers, smartphones or even toothbrushes. The omnipresence of electricity and our dependence on it has influenced us to the extent that running out of electricity in our smartphone leaves most of us anxious and almost immediately seeking for a way how to recharge our phone again. Moreover, artificially induced city-wide blackout represent one of the strongest weapons of modern warfare in the arsenal of any radical group looking for a way of bringing masses of people into chaos.

1.2. Evolution of electricity markets

Seeing how the electricity has been gaining importance, it only makes sense that the markets with electricity have been evolving as well and are attracting increasingly more attention than they did just several decades ago. Electricity markets had originally been monopolistic, highly regulated and perceived electricity only as a commodity. Customers therefore had not really paid too much attention to the electricity or its provider and had only been concerned about their own consumption. However, this is a story long gone.

Nowadays, most of the European markets have either already undergone the liberalization, or are currently in the process of deregulation. This means that the markets are no longer monopolistic and under full control of the state and the entry barriers have risen, thus the markets are now open for new entrants.

The increased competition has inevitably resulted in price war among the energy market players in order to gain or retain their customers. Nonetheless, competing on price of a commodity could not last forever and once it has stabilized in a new equilibrium, new ways of gaining and retaining customers had to be introduced. Given the current low prices of electricity, the only remaining option for the energy players was to focus on customer service and to expand the service and product portfolio.

While this phenomenon can already be partially observed within our domestic market, by looking at other European countries, which have started the liberalization process earlier, we can determine which products and services are the most likely to gain attention, develop demand and have actual impact on customers.

1.3. Goal of the thesis

Within my master thesis, I will therefore focus on the identification of advanced and innovative energy markets in Europe and I will analyze how successful have been the already introduced new technological products on those markets. In order to provide a sound in-depth assessment of the technologies, I will however abstract from new services or offerings related to vertical or horizontal integration of the energy players, which also play role in the market evolution.

The specific technologies I will analyze are:

1) Photovoltaics
2) Electromobility
3) Smart metering
4) Home batteries

The initial analysis will allow to assess what is the general adaptation process and what are the key criteria for a new technology in order to succeed. Afterwards I will focus solely on the home batteries, as on the level of final consumers, households, they represent a new, however yet unproven, technology with great potential, both when used separately to even out electricity consumption throughout the day, thus lowering the consumption in peak hours, and in combination with other technologies, such as photovoltaics or electromobiles.

The key questions I aim to answer are:

1) Will the home batteries be the next big thing on energy markets?
2) Will the home batteries be beneficial for average household or will they develop their own market niche only for highly specific customers?
3) Will the purchase of home batteries make sense already today?

In order to fully answer these questions, I will identify the key variables with the highest impact on the viability of home batteries and I will use them as a cornerstone for developing a complex model, which will allow to test different scenarios for the application of home batteries.

2. Theoretical part

2.1. Basic definitions

In order to assess the development and innovative technologies within the energy market, we first have to define the power sector itself and understand its past development and future outlook. Therefore we will start with having a look on the European installed capacity of power plants, actual production of electricity and on the development of prices in the power sector. However, to do so, we first have to start with understanding the cornerstones of the electricity generation.

Kilowatt or Kilowatt hours?

The two key measurements used in the power sector are kilowatt (kW) and kilowatt hour (kWh). Both units have multiple variations according to their size, starting with watt and watt hour as the general units, moving to kilowatt and kilowatt hour representing the multiple of thousand (10^3), megawatt and megawatt hour representing the multiple of million (10^6), gigawatt and gigawatt hour representing the multiple of billion (10^9) and finally terawatt and terawatt hour representing the multiple of trillion (10^{12}).

Kilowatt is the basic measure of electrical power indicating the rate of using electricity, whereas kilowatt hour indicates the actually consumed electricity. As an illustration we can take a geyser with a 1 kW rating running for one hour, which would during that time consume exactly 1 kWh of electricity. (Understanding Electric Demand, 2005)

Installed capacity

As we have already established the key units we will be using during the overview of the energy markets, we will now apply this knowledge to determine, what the installed capacity is.

Installed capacity represents the maximum electric output an electricity generator can produce under specific conditions. (Frequently Asked Questions, 2016). Therefore the installed capacity is measured in megawatts and indicates the maximum capacity of potential electricity that the power plant is capable to generate.

Applying what we know about kilowatt hours, it would seem that gaining the actual amount of electricity is a simple matter of multiplying the installed capacity by 8 760, the total amount of hours in the year, which would result in the total amount of electricity generated during one year measured in megawatt hours. In reality however, the power plant itself consumers portion of the generated electricity for its own operations and another portion of electricity, depending on the distance the electricity travels, is lost during transmission to the final consumers.

To measure these losses we use the plant load factor, expressed as a percentage of the total generated electricity that reaches final consumers. As an illustration we can assume a 1 000 MW nuclear power plant, which is in theory capable of generating 8 760 GWh of electricity. During its operations the power plant itself consumes 10 % of electricity and another 15 % would be lost due to the transmission to final consumer, thus the overall PLF in this example would be 75 %, which equals 6 570 GWh of generated electricity per year. The real production of electricity is nonetheless governed by the actual demand which is unbalanced, hence the total generated electricity of our assumed power plant would in fact probably be much lower. (Getting enlightened about electricity, 2004)

Sources of electricity

Later on in this chapter, we will have a look on the development of electricity generation in Europe with focus on the different types of power plant used for the electricity generation. The overall mixture of the different types of power plants is commonly referred to as the energy mix and is affected by the regional policies regarding the electricity generation, market development and by the natural resources available in the region.

Power plants can be divided into two categories – those utilizing the fossil fuels and those utilizing the renewable natural resources. Due to their longer history and easier operations, fossil fuel based power plants nowadays generate the majority of the electricity worldwide and can be found all over the world, regardless the natural conditions. The most common type of such power plant is a coal-fired power plant, where coal is combusted in order to generate steam, which is afterwards used to actuate turbine connected to an electricity generator. (Coal & electricity, n.d.)

Similar principle is used for the power plants combusting oil, which is either burned directly to create steam, or burned under pressure in a combustion turbine with the hot exhaust gases directly propelling an electricity generator. (Electricity from: Oil, n.d.)

The combustion turbine principle is applied also in natural gas power plants, where the exhaust gases from burning natural gas propel the electricity generator. Second alternative is the combined cycle system where the exhaust gases are further used to raise steam to power a secondary steam turbine also connected to a generator. (Gas Turbine Power Plant, n.d.)

Last of the conventional power plants are nuclear power plants, which have been on the rise since the second half of the 20th century. Similarly as before, nuclear power plants also use steam to generate electricity, but instead of burning fossil fuels, they are using the exothermic reactions occurring during nuclear fission. Despite their high efficiency and capability of generating large amounts of electricity, nuclear power plants remain a controversial topic worldwide primarily due to the radioactive waste created as a byproduct of their operations. (Nuclear Power Reactors, 2016)

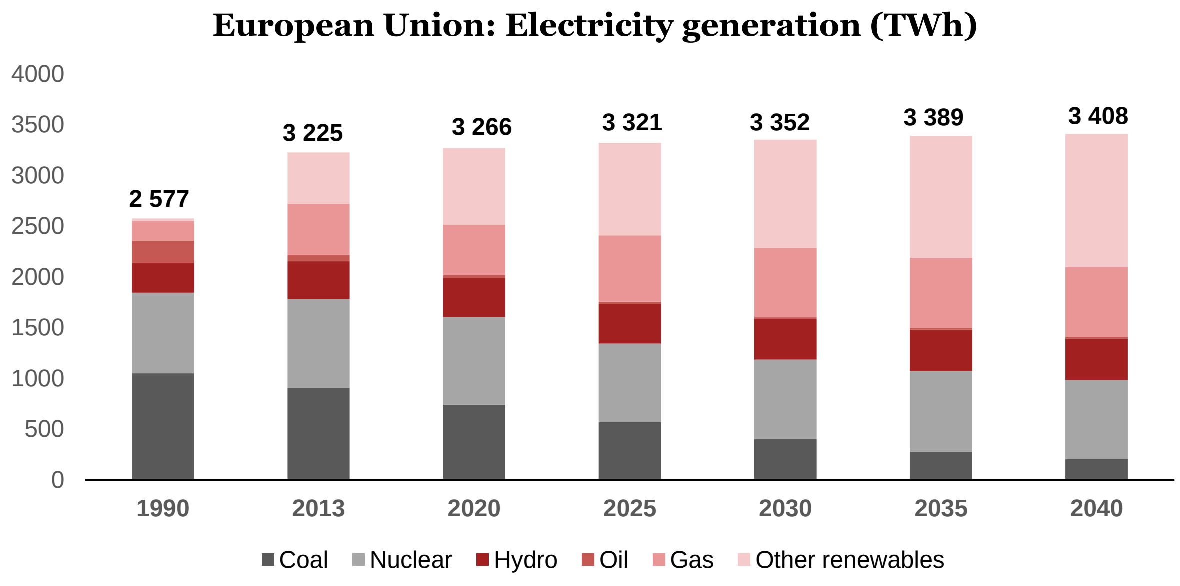
Alternative to the fossil fuels are renewables, which represent a wide group of various energy sources, which are environmentally friendly and derived from natural processes that are replenished constantly thus the renewable resources are sustainable in the long term. The renewable or also green energy technologies can be divided into three generations. The first-generation technologies include, for example, hydropower, geothermal and biomass combustion. Second-generation technologies are, e.g. solar heating and cooling, solar photo-voltaics, wind power and third-generation technologies are biomass gasification, bio-refinery, geothermal and marine energy, such as tidal, waves or ocean thermal differences. (Mohanty, 2011)

2.2. Energy market overview

As was already stated in the introduction to the master thesis, the power sector has gone through a rapid development throughout the 20th century. The largest boom occurred in the past couple of decades when the total generation of electricity in the European Union grew at a CAGR of 1.86 % in between years 1980 and 2010. In absolute numbers, the total generation in the countries of EU has during those three decades increased from 1 842 TWh to 3 202 TWh per year. (Nies, Magyar, Lorubio, & Renaud, 2013).

However, if we focus on the more recent development as seen in the Chart 1, along with a forecast of the electricity generation until the year 2040, we will observe that the growth of the electricity generation has stabilized and the forecasted CAGR until the year 2040 is expected to be only 0.2 %

Chart 1 European Union: Electricity generation (TWh)



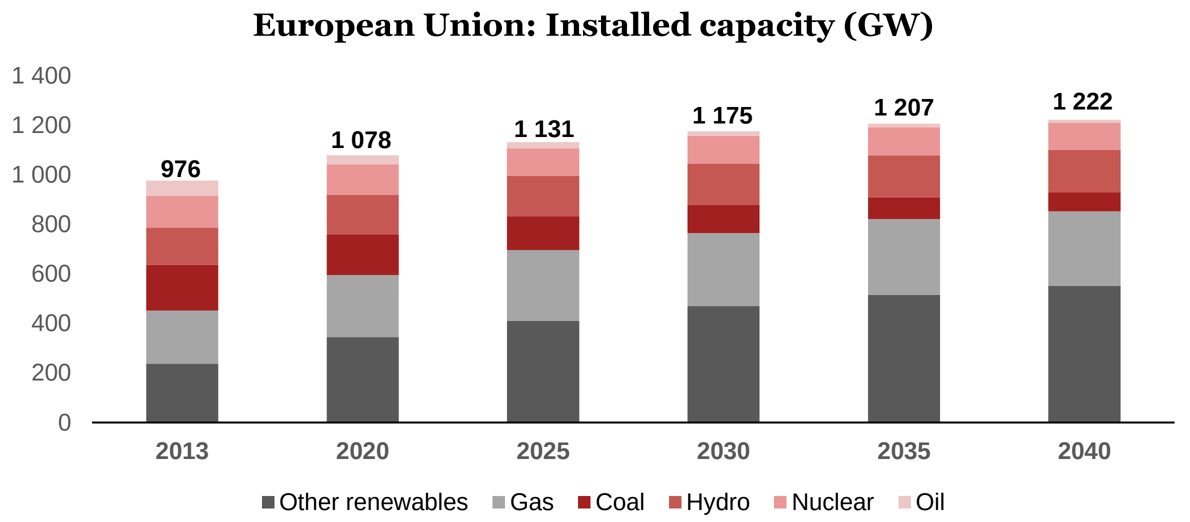
Source: (International Energy Agency, 2015)

The dramatic slowdown of the generation growth has multiple underlying reasons, with the primary cause being the stabilized population in the European Union, which is according to Eurostat projected to grow only at CAGR of 0.12 % in between years 2015 and 2040. (Eurostat, 2014) Secondary reason is the increasing saturation of the electricity consumption both within the industry and household sector. This is due to the fact that the European Union belongs among the most developed regions of the world, thus the electrification in industrial production and in households has already reached its maximum, with both the companies and the households shifting their focus towards efficient use of electricity. For illustration, if we take India as a representative of a developing country, the forecasted CAGR of electricity generation in between years 2013 and 2040 is a significantly higher 4.7 %. (International Energy Agency, 2015)

While the absolute size of the energy generation in the European Union is forecasted to be balanced, thus might indicate a market which is fully saturated and not undergoing any major development, detailed look on the composition of the European energy mix reveals a market-wide shift across the energy sources. Fossil fuels which represented the source of

72.9 % of generated electricity in 2013 are estimated to drop to 49.5% by 2040, hence effectively making renewables the major source of electricity in EU[1].

Chart 2 European Union: Installed capacity (GW)



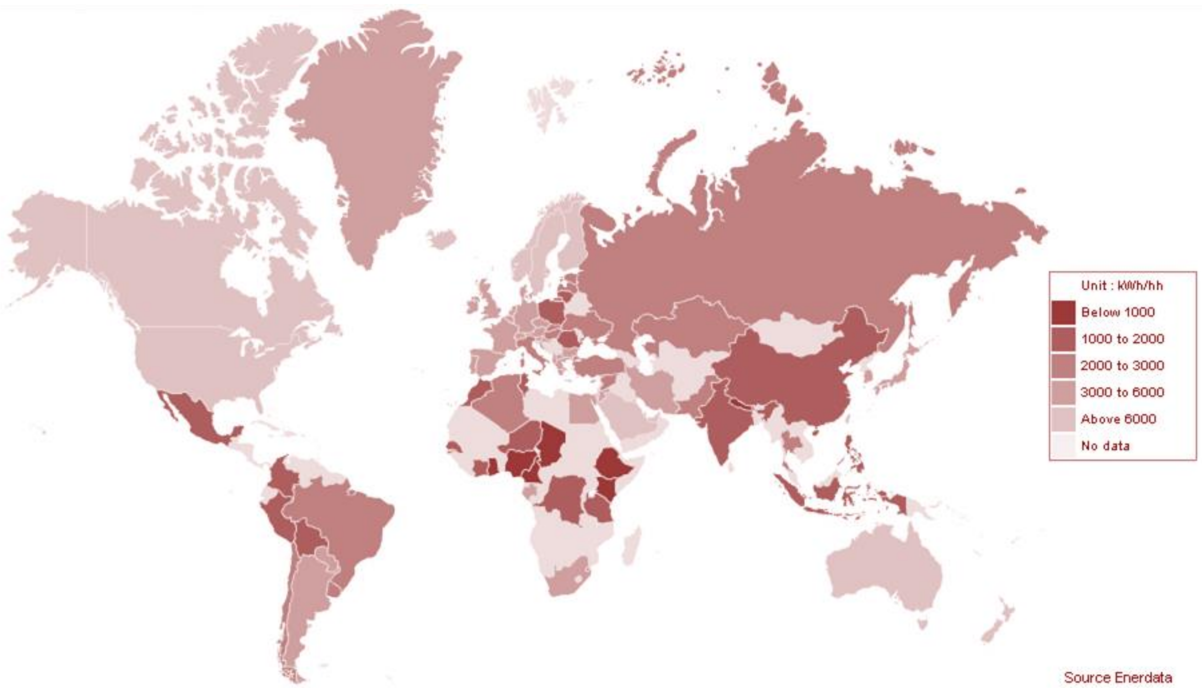
Source: (International Energy Agency, 2015)

Detailed look on the forecasted development of installed capacity in the European Union in the same period reveals a surprising growth at CAGR 0.8 % by 2040. The imbalance between the growth of generation and installed capacity is caused by the expected massive investments into renewables, which are expected to increase their share on the total installed capacity from 39.8 % in 2013 to 59.2 % by 2040, while keeping the installed capacity of fossil fuel-fired power plants relatively stable. Therefore, despite the increasing investments in renewables, the electricity generation is not forecasted to grow at the same pace, which is caused by the strong dependence of renewables on natural conditions such as amount of sun light or wind, resulting in their lower PLF compared to traditional fossil fuel-fired power plants[2].

Expected investments into the renewable energy, especially traditional wind farms and solar photovoltaic power plants, are a good indicator of the overall changing attitude towards electricity generation and sustainability.

[1] Appendix: Table 1 Electricity generation in EU (1990 - 2040)
[2] Appendix: Table 2 Electrical capacity in EU (2013 - 2040)

Picture 1 Average electricity consumption per electrified household - 2014



Source: (Global Energy Statistical Yearbook, 2016)

Last important aspect of the macro overview of the European power sector is the actual electricity consumption of households. As seen in the Chart 3 above, European Union ranks among the regions with the highest average electricity consumption per household, however its growth has been stagnating or even decreasing in the past years. In absolute numbers the European average consumption reached 3 781 kWh in year 2000 and has gradually decreased to 3 560 kWh in 2014. This is in line with the world development, as the electricity consumption per household in developed countries decreases, and the growth of the world average is driven primarily by the increasing electrification of developing countries. (Energy Efficiency Indicators, 2015)

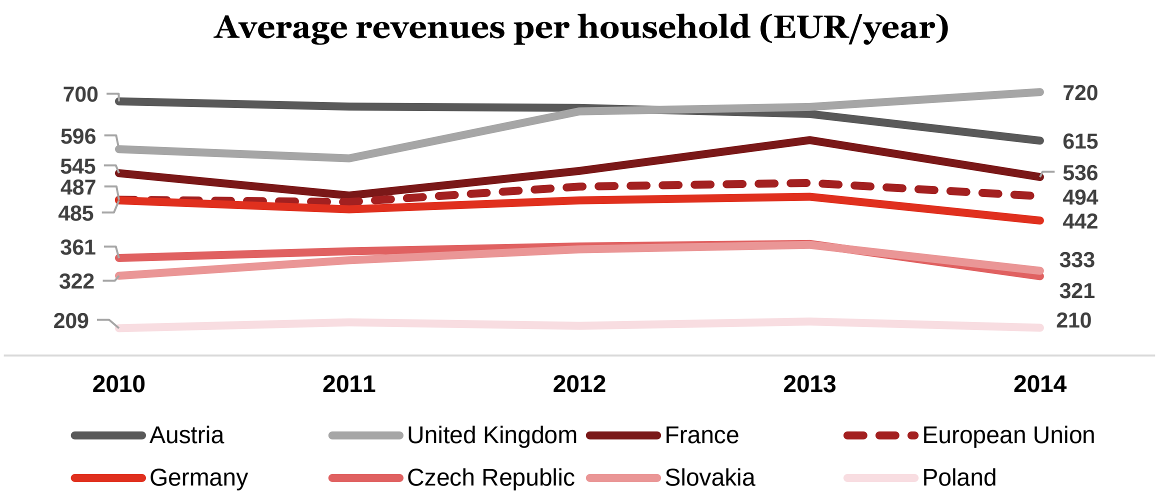
Even though households account only for a rather small share on the overall consumption of electricity, e.g. 24.2 % in the Czech Republic in 2011[3] (the rest being mostly industry and transportation), maintaining or increasing revenues from the household sector, has become increasingly difficult for the regional energy players.

Due to the completed electrification of households within member countries of the European Union, the potential for organic growth of revenues is diminishing. In order to maintain the revenue growth, energy players are therefore left with two options – either to keep gradually increasing prices, or to extend their product portfolios.

3 (Nies, Magyar, Lorubio, & Renaud, 2013)

This statement is further supported by the development of average revenues per households, computed as an average electricity consumption per household multiplied by price per kWh without tax and levies as seen on the following Chart 4.

Chart 3 Average revenues per household (EUR/year) without tax and levies



Source: (Eurostat, 2016), (Energy Efficiency Indicators, 2015)

In between years 2010 and 2014 the CAGR of average revenues per household in the European Union reached 0.8 %, which was, considering the decreasing consumption in the European Union[4], driven solely by the 2.3 % growth of electricity prices in the same period. (Eurostat, 2016)

However, detailed look on the development in individual member countries[5] reveals that despite the overall growth on the European level, only 9 member countries actually experienced a positive development of average revenues per household and their growth was mostly caused by their economic situation or country specific factors. Therefore, despite the positive CAGR of 0.8 %, the overall development of final prices for electricity within member states of the European Union was mostly negative with median value of -1.5 % CAGR.

The falling prices further increase the competitive pressures within local markets and effectively push the energy players to look for new revenue streams through the expansion of their product portfolio.

2.3. Liberalization

At this point we already have a basic understanding of the high level development of the European power sector in the past few decades. To have a complete picture, we have to now introduce another variable, which will help us to elucidate the observed market shifts. The name of the game? Liberalization.

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[4] As seen on page 14, paragraph 1

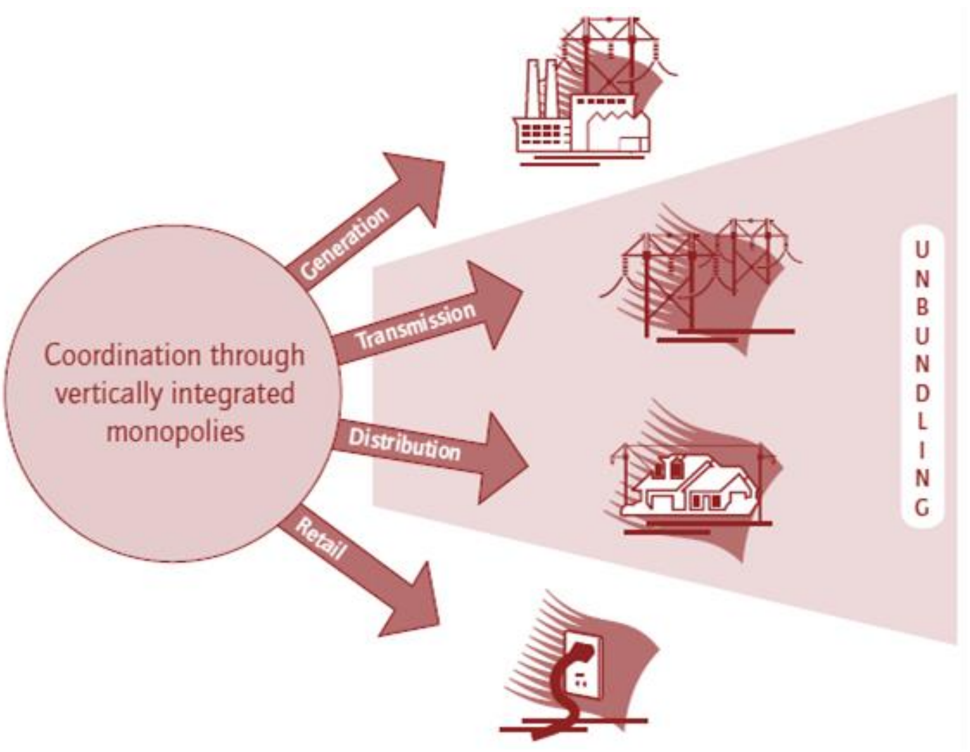
[5] Appendix: Table 4 Average revenues per household (EUR) excluding tax and levies

Financial Times define energy liberalization as a political and regulatory process that brings competition into former electricity and gas monopolies, with competition occurring mainly in power generation and sales activities, as network activities such as transmission and distribution traditionally remain regulated. The aim of energy liberalization is to create competitive markets, leading to more efficiency and innovation in the industry. However, the argument of price reduction is less valuable in the energy sector than in the telecommunications industry, mainly because of the rise of primary energy prices – fossil fuels and renewables. (Financial Times, n.d.)

Looking back at the European Union, during the 1990s were most of the national electricity and natural gas markets of EU member states still monopolized and did not allow for any market competition. Most of those monopolies were vertically integrated, which means, that the state-owned enterprises covered the whole value chain from electricity generation, transmission and distribution to retail, where the electricity is actually sold to the final consumers.

In the beginning of the 1990s the European Union has decided, that in order to increase efficiency and innovation within the power sector, liberalization packages have to be implemented. The main objectives of these packages were to distinguish which parts of the industry shall remain non-competitive and unbundle those from the vertically integrated enterprises, oblige the operators of the non-competitive parts of the industry (e.g. the networks and other infrastructure) to allow third parties to have access to the infrastructure, remove gradually any restrictions on customers from changing their supplier and introduce independent regulators to monitor the sector. (European Commission, n.d.)

Picture 2 A new model for the electricity sector



Source: (International Energy Agency, 2005)

European reform was pursued at two parallel levels. First, under EU Electricity Market Directives, member countries were required to take at least a minimum set of steps by certain key dates toward the liberalization of their national markets. Second, the European Commission promoted efforts to improve the interfaces between national markets by improving cross-border trading rules, and to expand cross-border transmission links. The underlying aim of both of these policies was to extend the principles of the European Single Market to the energy market, thus allowing companies from across the EU to compete with national incumbents, while improved interconnection would reduce cross-border transport costs and increase competition. (Jamasb & Pollitt, 2005)

The first and second EU Electricity Market Directives of 1996 and 2003 focused on unbundling the industry and on a gradual opening of national markets. The second directive further promoted competition by toughening regulation of access to networks and requiring independent regulators. (Jamasb & Pollitt, 2005) Nonetheless, despite those directives, the European energy sector still reflected the old market structure, characterized by national or regional monopolies, usually dominated by vertically integrated companies, which controlled electricity prices in the wholesale market and blocked new entrants to the market. In reaction to this, the European Union has introduced a third liberalization package in 2007, which provided the companies in the member states with three options for separating gas and electricity companies. (EurActiv, 2009)

First option preferred by the European Commission was the „Ownership unbundling", which obliged the companies that controlled both energy and transmission to sell part of their assets. Investors would still be able to keep participation in the dismantled groups, but only as long as they represented a non-controlling minority interest. (EurActiv, 2009)

Second option was to establish an „Independent System Operator (ISO)", which was a Commission's compromise allowing companies involved in energy production and supply to be allowed to retain their network assets. The control over the assets in terms of commercial and investment decisions would be left to an independent company (ISO), to be designated by national governments. (EurActiv, 2009)

Last option was to introduce an "Independent Transmission Operator (ITO)", which was designed as a response to the anti-liberalization efforts in France and Germany. This allowed the former state monopolies to retain ownership of their gas and electricity grids, provided that they are subjected to outside supervision. (EurActiv, 2009)

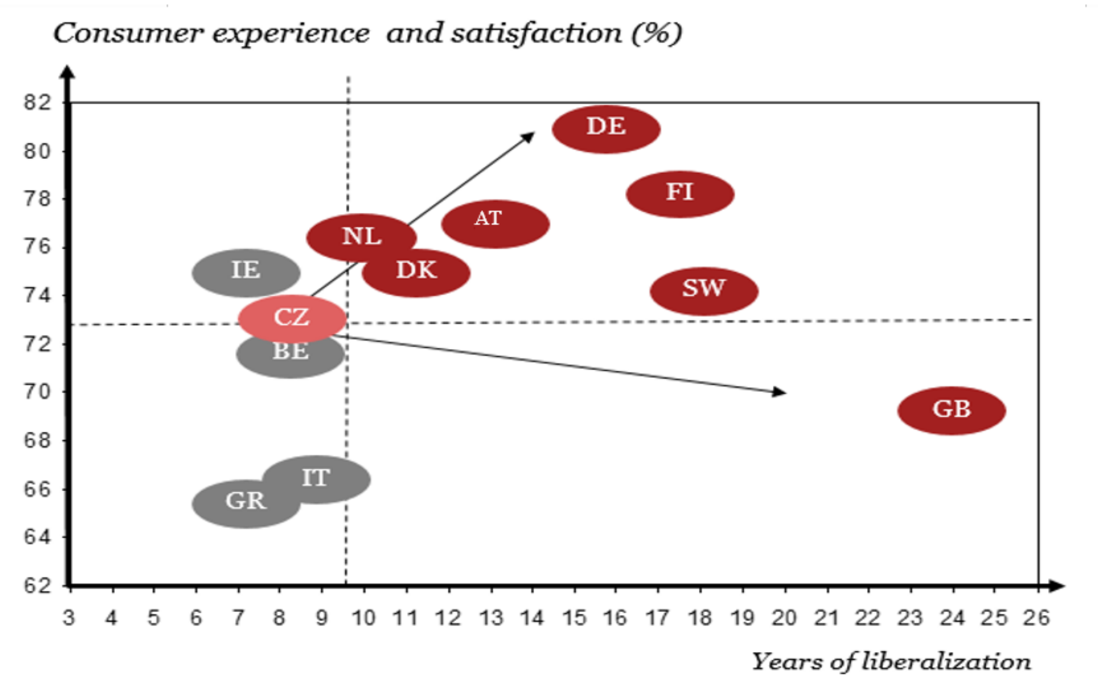
Nowadays, all of the European electricity markets have already been liberalized to some extent, but the progress and impacts of liberalization vary from country to country, with respect to the initial situation of its power sector, duration of liberalization and attitude of respective country's government.

2.4. Innovative countries

Up to this point, we have been observing the macro development in the European power sector in terms of generation, consumption, prices and shifts in the power mix. We have also briefly looked into the liberalization of the power sector in member countries of the European Union. Therefore, we already know that the electricity consumption in Europe has been growing very modestly in the past couple of years and its forecast promises a growth rate of only 0.2 % annually until the year 2040. Combining this piece of knowledge with the liberalization of European power sector which has started in the late 1990s we know, that the electricity consumption is not increasing whereas competition definitely is.

Before we start with the analysis of new products the European energy players has introduced in order to secure stable growth of revenues from the household sector, we need to determine, which countries are the most innovative and the most appropriate to draw a lesson for the future development of technologies within the energy sector, namely the home batteries. Diversity of those countries should also be taken into account, as it allows to assess the impact of new technologies on diverse markets and not only on the most developed ones.

Chart 4 Consumer experience and satisfaction vs years of liberalization of the energy market



Source: (PricewaterhouseCoopers, 2016)

First stage for identifying the progressive energy markets is a chart developed by PricewaterhouseCoopers, which compares the survey in consumer experience and satisfaction to years of energy market liberalization. This framework allows us to cherry pick the countries where the liberalization already took place and the consumers show generally high satisfaction with the electricity provider, thus implying existing pro-consumer approach and good offer of products and services.

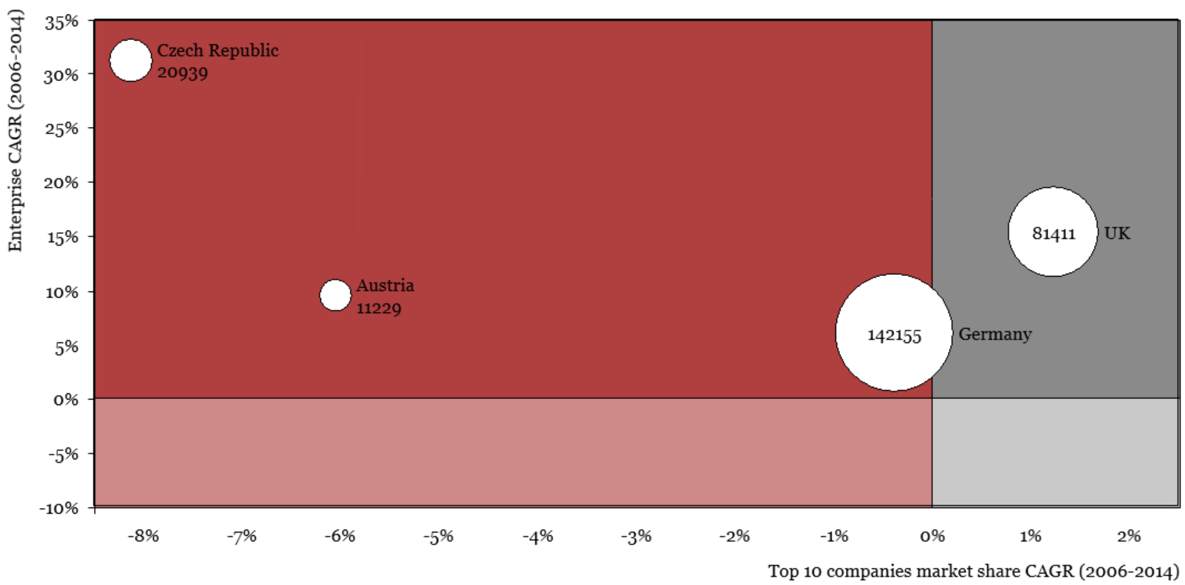
The most progressive countries based on this approach are namely United Kingdom, Sweden, Finland, Germany, Austria, Denmark and Netherlands.

Second stage of the selection process is based on the attitude towards liberalization process and attitude towards different energy sources in respective countries. At this point we need to cherry pick such countries where the liberalization has already ingrained and the market had an opportunity to adapt as well as countries with different preferences over the possible energy sources which affect the local incentives and preference of technologies related to renewables.

The countries selected at this point are United Kingdom, Germany, Austria and Czech Republic.

United Kingdom is a model country for the energy market liberalization as it had started the liberalization process in the 1980s, hence even before the EU directives were put in place. (Pond, 2006) Similarly, also Germany and Austria qualify as already fully liberalized markets but have significantly different preference of energy sources. Germany represents a traditional European market with balanced shares of coal and nuclear fired power plants along with a 30 % of electricity generated from renewables. (Clean Energy Wire, 2016) Austria on the other hand strictly refuses to generate electricity from the nuclear power plants and is therefore one of the best model countries in terms of utilization of renewables. (World Energy, 2015) Last country added to the selection is the Czech Republic, as it represents a relatively young market in terms of liberalization, has a diverse approach to energy sources and offers a good benchmarking position for the analysis of the rest of the countries.

Chart 5 Energy market disruption in selected countries



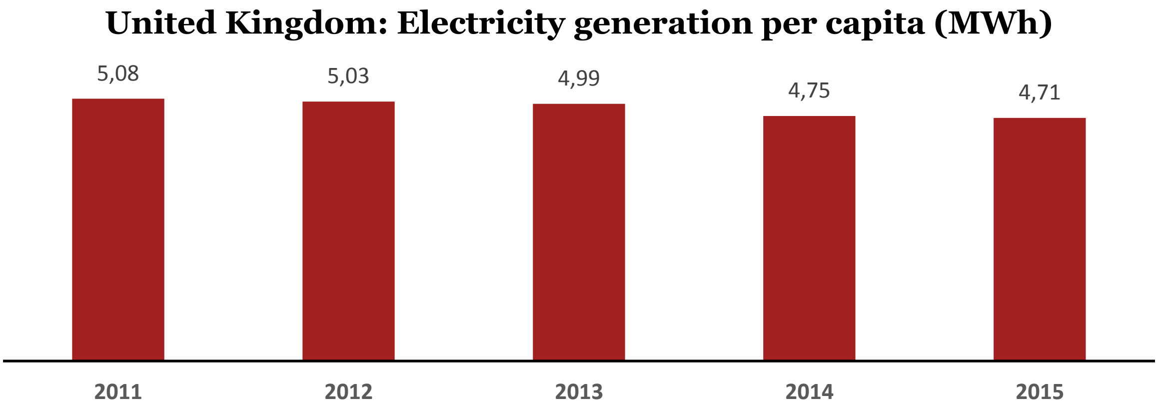
Source: Amadeus (export of financial data)

This selection of markets is further supported by the development of energy market disruption in those specific countries. To assess the market disruption we compare three variables – growth of top 10 energy players' market share, growth in quantity of energy players present in the market and the absolute change in size of the market computed as the change in sum of total revenues of all energy players present in the respective market.

The comparison confirms that United Kingdom and Germany represent stable energy markets, where the post-liberalization market changes have already settled. Czech Republic and Austria are on the other hand good examples of countries where the impacts liberalization are still omnipresent, thus the energy players are more likely to be introducing new products in order to win over customers.

2.4.1. United Kingdom

Chart 6 United Kingdom: Electricity generation per capita (MWh)



Source: (Trading Economics, 2016), (Market Line, 2016)

First of the countries selected for further analysis is the United Kingdom. The total generation in the UK reached 306.6 TWh in 2015 and the share of households on the overall consumption was 35.0 %, followed by commercial use and industrial use, each standing for 31.2 % of the total generation. As seen in the chart 6 above, the electricity consumption was declining since 2011 by 1.1 % annually. (Market Line, 2016) This is in accordance with the assumption, that electricity consumption in the developed markets has already reached its peak and is therefore currently stagnating or even decreasing.

The energy mix in the United Kingdom is rather diverse, utilizing all of the available sources of energy. Specifically, coal, gas and oil fired power plants generated 62.6 % of the electricity, followed by nuclear power plant delivering 19 % and renewables contributing with 19,1 %. (MacLeay, Harris, Annut, & others, 2016)

As was already stated in the previous chapter[6], United Kingdom was one of the first countries which started with the process of liberalization of the energy markets. This has allowed the energy market to stabilize and it results in the continuously growing market share of the top 10 market players, as seen on the chart 5. Similarly, also the number of new entrants in the UK's power sector has not been growing as significantly as in other markets.

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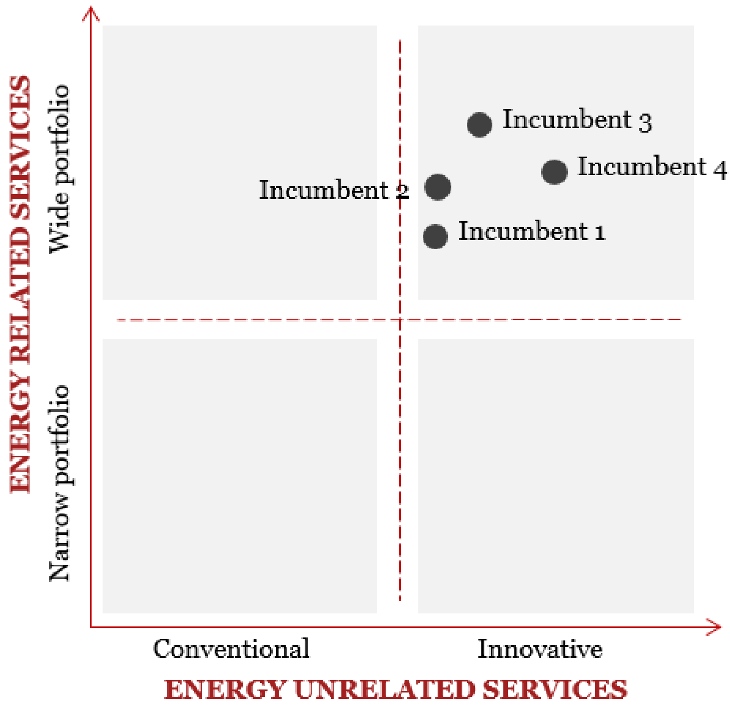
[6] Page 19, paragraph 4

Chart 7 United Kingdom: Energy players' portfolio comparison



Source: (PricewaterhouseCoopers, 2016)

Maturity of the electricity market in the United Kingdom is furthermore supported by the product portfolio analysis of the UK energy players performed by PricewaterhouseCoopers. The analysis clearly shows that all four analyzed incumbents have expanded their product portfolios both in terms of energy related services and energy unrelated services, such as telecommunications or banking.

Detailed look at portfolios of analyzed incumbents[7] reveals that all four players have included different sorts of new technological products into their offering. The most widely spread are photovoltaics, heat pumps and smart metering, which are usually offered in form of turn-key solutions. Some of the incumbents have also started offering financing services in cooperation with financial institutions for these products, thus are gaining additional revenues through commissions paid by the financing institutions for each client who decides to use the financing services.

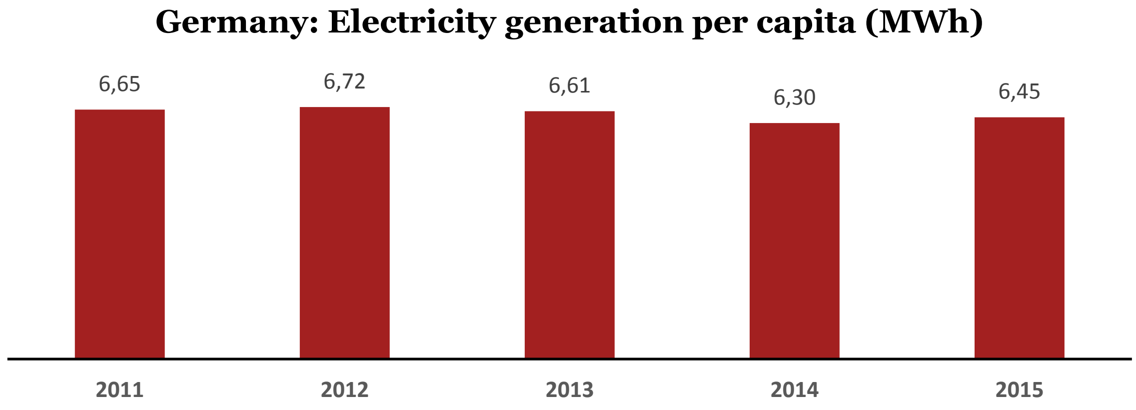
Other identified category of innovative products is electromobility, where some of the incumbents offer to set-up private or commercial charging stations for electric vehicles.

Interestingly, one of the energy players have also started to explore the potential of home batteries and will most likely introduce turn-key solutions in the near future.

[7] Appendix: Table 5 Energy players portfolio comparison

2.4.2. Germany

Chart 8 Germany: Electricity generation per capita (MWh)



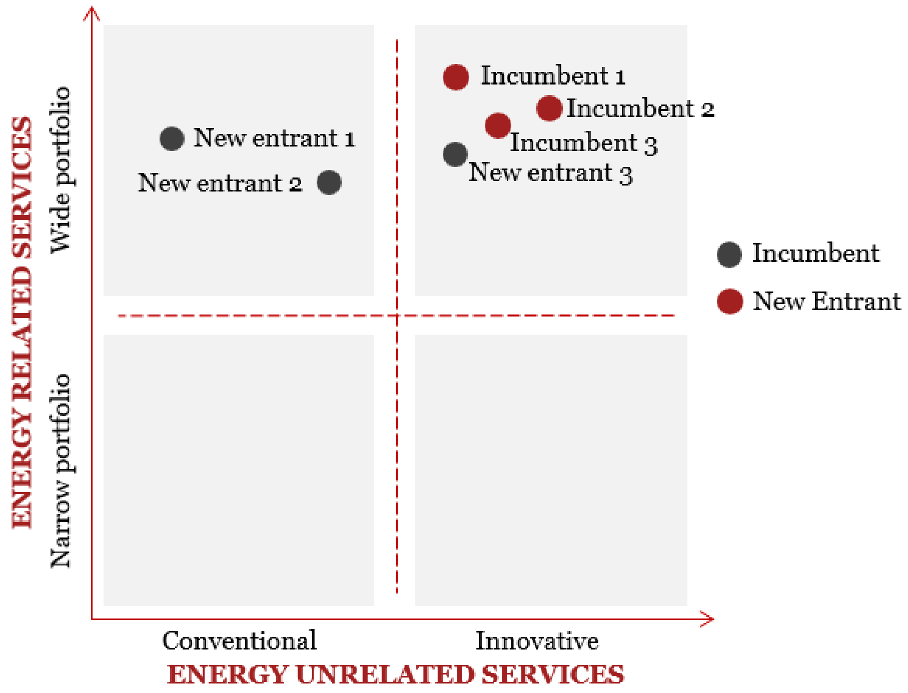
Source: (Trading Economics, 2016), (Market Line, 2016)

Second country selected for further assessment is Germany. The total electricity generation in the country reached 523.7 TWh in 2015, with households responsible for 24,3 % of the total consumption. The largest sector in terms of electricity consumption was industry, which was responsible for 43.7 %, followed by commercial and public services which consumed additional 29.9 %. Similarly as in the United Kingdom, also the electricity generation in Germany has been declining since 2011 at a rate of 0.9 % annually. (Market Line, 2016)

Country's energy mix is very similar to the United Kingdom, as Germany also fully utilizes all available types of power plants. The most significant contributors in terms of generation are coal, oil and natural gas fired power plants, which altogether produce 56 % of electricity. Renewables come as the second most important energy sources responsible for additional 30 % of generated electricity, with onshore wind power plants, biomass and photovoltaics being the most significant renewable sources. Last contributor to the energy mix are currently eight operational nuclear power plants which deliver 14 % of Germany's electricity, but the future outlook indicates their gradual phase-out in favor of increased investments into renewables. (Clean Energy Wire, 2016), (World Nuclear Association, 2016)

Liberalization was introduced to German market in the 1997, however, even before the market did not follow the typical structure of one state-owned monopoly, but was rather composed out of 8 companies responsible for electricity generation and transmission, with each company operating in certain region. Outcome of the liberalization was surprisingly a decreased number of companies involved in transmission and distribution, however followed by the entry of new local producers. Overall, liberalization did not really fragmented the market in terms of number of the companies, which can also be observed on the chart 5, where despite the large increase in the absolute size of the markets, top10 market players lost only a very small share of their relative market share. (Brandt, 2006)

Chart 9 Germany: Energy players' portfolio comparison



Source: (PricewaterhouseCoopers, 2016)

Analysis of German electricity market conducted by PricewaterhouseCoopers shows similar results to the United Kingdom. The established incumbents have been expanding their product portfolios in order to capitalize on their large customer base in other industries (mainly telecommunication) as well as developing their offer of products and services within the energy sector. New entrants on the other hand incline to one of two options; either to focus on extensive offering strictly within the energy sector, or to follow the footsteps of the market incumbents and expand their portfolio to non-energy sectors as well.

Detailed look on the product offer in terms of technological products[8] in energy sector shows high level of adoption of almost all of the introduced technologies. All three assessed incumbents offer photovoltaic solutions, charging stations along with a network publicly available charging stations and smart metering systems including smart homes solutions. Majority of the incumbents also offers heat pump solutions and even home batteries, however mostly as an extension to the photovoltaic systems.

New entrants have a rather diverse offer in terms of energy products, as each of them focuses on some of them, but does not aim to encompass all of them in the way the incumbents do.

Overall, the German electricity market clearly responds to the market need to introduce new innovative products into the product portfolios of energy players. The maturity of the market and good economic situation of the country also favors the adoption of innovative green technologies by regular household owners.

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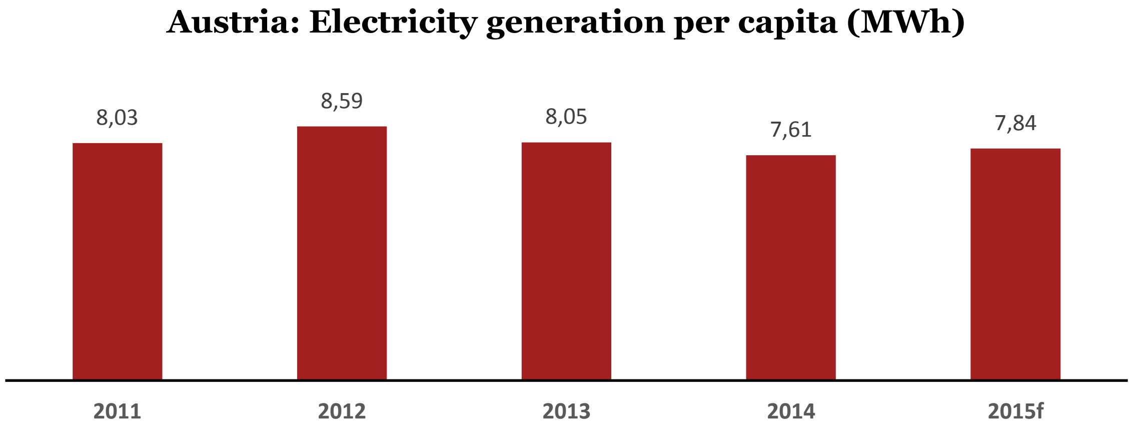
[8] Appendix: Table 5 Energy players‘ portfolio comparison

2.4.3. Austria

Chart 10 Austria: Electricity generatoin per capita (MWh)



Source: (Trading Economics, 2016), (Market Line, 2015)

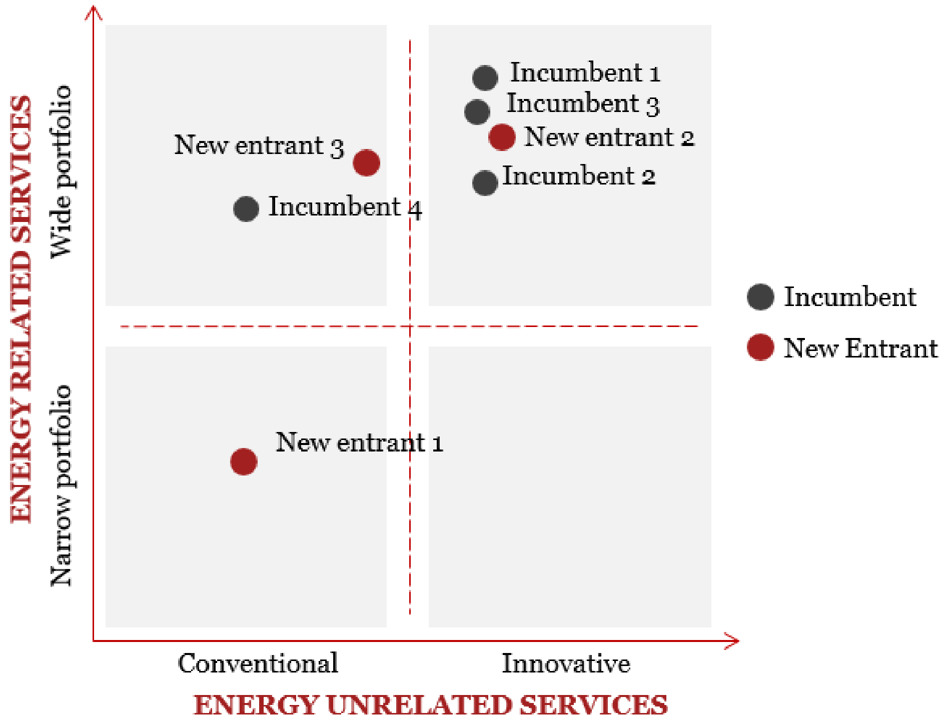
Third of the analyzed countries is Austria, which was selected as a representative of one of the younger countries in terms of market liberalization as well as a country with stricter policies towards its energy mix.

The overall electricity generation amounted to 68 TWh in 2014 and was forecasted to decline to 64.8 TWh in 2015. This is in accordance with the overall development in the Austrian power sector, where the electricity generation was declining by 2.4 % annually in between years 2010 and 2014. (Market Line, 2015)

Austria is the only country out of those selected for detailed overview, which has implemented stricter policies towards the sources of its electricity. This is driven mostly by the geographical conditions, which allow for a large investments into hydro power plants, usually in form of traditional water dams. The largest one, Kölnbrein Dam, has a capacity of 1 029 MW which is approximately half of the capacity of the famous Hoover Dam in the United States. Overall the renewables accounted for 76.6 % of total electricity generation in 2014 with the remaining 23.4 % supplied by conventional fossil fuel fired power plants. The geographical conditions allow Austria to completely avoid investments into nuclear power plants, making it one of the most significant opponents to atomic energy as well as one of the world's foremost lobbyist for the renewables. (Market Line, 2015)

Before liberalization the Austrian market constituted of one nationwide organization responsible for most of the generated electricity and transmission and several provincial companies, which were in charge of distribution and retail in their respective areas. The situation after the liberalization have not changed much, as the market structure still corresponds to original heavy feudal structure of providers and owners. This is further supported by the extensive use of investment heavy hydro power plants, which are owned by the market incumbents. Liberalization has therefore resulted mostly in increased number of renewables-based electricity producers and final electricity distributors. (Hofbauer, 2006)

Chart 11 Austria: Energy players' portfolio comparison



Source: (PricewaterhouseCoopers, 2016)

Product portfolios of the Austrian energy players follow a similar pattern as in the previous case of Germany. Most of the incumbents have taken advantage of their stable position on the market and have developed their portfolios both in terms of energy related and unrelated services. Analyzed new entrants on the other hand do not follow a single unifying strategy, but each of them focuses on a different approach to their portfolio.

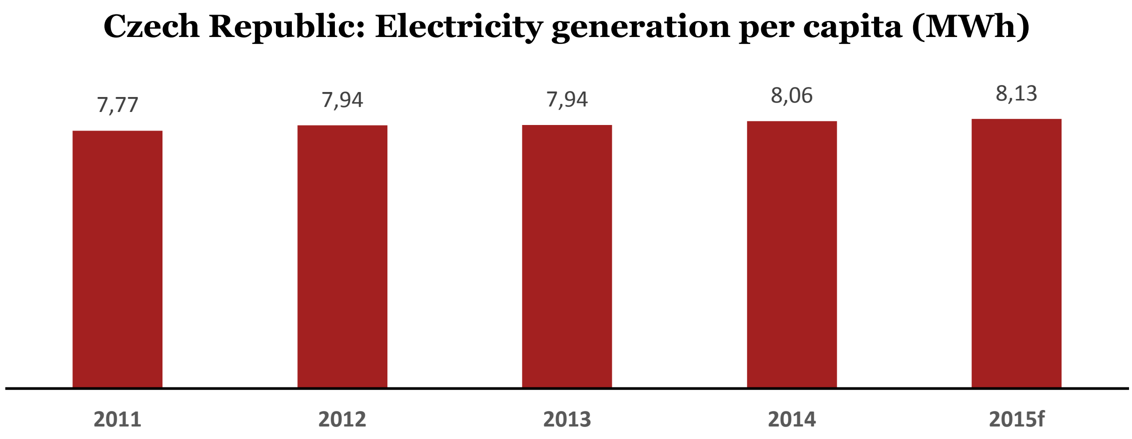
As in previous countries[9], photovoltaics and heat pumps represent a key element in portfolio of incumbents and some of the new entrants. Very well established is also the infrastructure for electric vehicles, as 5 out of 6 analyzed companies have already invested into their own charging infrastructure. Both incumbents and new entrants have been implementing various smart metering and smart home related solutions.

In general, incumbents in the Austrian market follow the trend identified in previous countries, thus they are trying to offer the whole range of new energy products. New entrants on the other hand show a different strategy than in case of Germany, as they are either trying to penetrate all of the products to at least some extent or they stick only to the traditional products – primarily distribution of electricity and natural gas.

[9] Appendix: Table 5 Energy players' portfolio comparison

2.4.4. Czech Republic

Chart 12 Czech Republic: Electricity generation per capita (MWh)



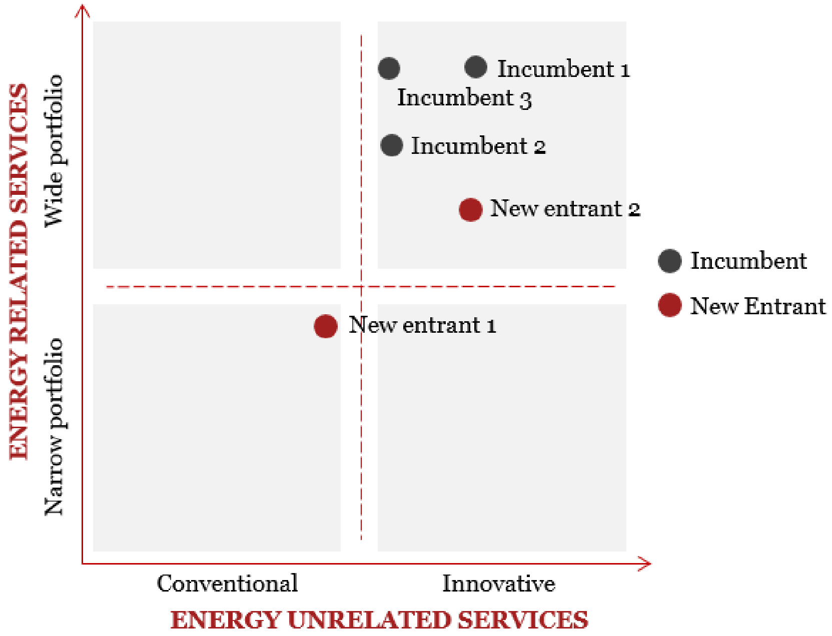
Source: (Trading Economics, 2016), (Market Line, 2015)

Last of the countries selected for detailed assessment is the Czech Republic, as giver our knowledge of local environment, it offers a good benchmarking platform for the previous countries. Total generation of electricity in 2014 reached 84.8 TWh and was forecasted to furthermore increase to 85.7 TWh in 2015. In between years 2011 and 2014 the Czech Republic was the only country out of those selected for analysis, where the electricity generation grew at CAGR 1.2 %. Detailed split reveals that in 2011 households accounted for approximately 24.2 % of electricity demand, whereas industrial use was responsible for more than half of the overall electricity consumption. (Market Line, 2015), (Nies, Magyar, Lorubio, & Renaud, 2013)

In terms of the energy mix, Czech Republic cannot leverage favoring geographical conditions as much as Austria, therefore relies on comparably diverse energy sources as the United Kingdom or Germany. Majority of electricity is therefore generated in conventional coal and gas fired power plants, which altogether contribute with 54 % of generated electricity. Second most important energy source are the two nuclear power plants, Temelín and Dukovany, which account for additional 33.8 % of generated electricity, thus effectively making the Czech Republic the number one consumer of nuclear energy out of the four analyzed countries. Remaining 12.2 % of electricity are produced from multiple renewable sources. (Market Line, 2015)

Czech power sector has been fully liberalized since 2006, when all customers have gained the opportunity to freely choose their electricity provider. Currently, the market is occupied by several incumbents who control most of the market, both in terms of generation and retail, but other market players have been entering the market since 2006 focusing mostly on the final retail part of the value chain. However, several new entrants have also invested into generation capacities, yet those account only for a very small share of the overall generated electricity. (Tichý, 2011)

Chart 13 Czech Republic: Energy players' portfolio comparison



Source: (PricewaterhouseCoopers, 2016)

Analysis of portfolios of selected market players shows similar trends as we have observed in countries where the liberalization has started earlier. Market incumbents are expanding their activities beyond the energy sector, mostly in form of cooperation with various banking and telecommunication companies in order to leverage their wide customer base. Within the energy sector, they are adopting new technologies into their portfolios following the example of more developed markets, which is driven both by global presence of the incumbents, thus implementing global trends, and by the demand from local customers.

Newly introduced energy products[10] focus mostly on the traditional technologies such as photovoltaics or heat pumps, but all of the incumbents have already started developing activities also in the electromobility, currently consisting mostly from the offer of private and commercial charging stations and developing a network of public chargers currently concentrated mostly in the region of the capital city. Smart metering and smart home solutions are not yet widely spread, but two out of three analyzed incumbents are beginning the implementation of their smart solutions. One of the incumbents has also recently acquired a well-established producer of home batteries, thus it is most likely, that energy storage solutions will soon be introduced to the market.

As stated before, new entrants to the market are situated primarily in the final electricity retail, thus do not try to concentrate on advanced technological products yet. Despite that, one of the analyzed incumbents is through cooperation already offering photovoltaic and heat pump solutions. Overall, based on the current development and similarities in culture and landscape of the powersector, in the future we can most likely expect a similar scenario as in Germany.

[10] Appendix: Table 5 Energy players' portfolio comparison

2.5. New technologies in households

So far we have already established that the power sector in Europe had been rapidly growing during the 20th century, but its growth has slowed down significantly in the past few decades and now the electricity generation is mostly stagnating. We have also had a brief look on the liberalization of the electricity markets in the member countries of the European Union and we have identified several countries for detailed assessment in terms of electricity market performance, impacts of liberalization and the reaction of energy players to new market conditions. During the assessment we have observed that in order to secure revenue growth from the household sector, companies were left with two options, either to continuously increase prices, or to introduce new products into their portfolios in order to gain new revenue streams. However, as the competition in the markets is getting stronger, increase in prices is increasingly difficult, hence the major driver of revenue growth from the household sector are the new products.

In this chapter, I will therefore provide a complex overview of the new technologies which were introduced as new products in the previously analyzed markets. Primary focus will be on the description and functionality of the technologies, their advantages and disadvantages, potential applications and their potential for generating revenues for the energy players. When applicable, I will also include simplified case studies to illustrate the benefits from their application. Technologies selected for detailed assessment are namely:

1) Photovoltaics
2) Electromobility
3) Smart metering
4) Home batteries

2.5.1. Photovoltaics

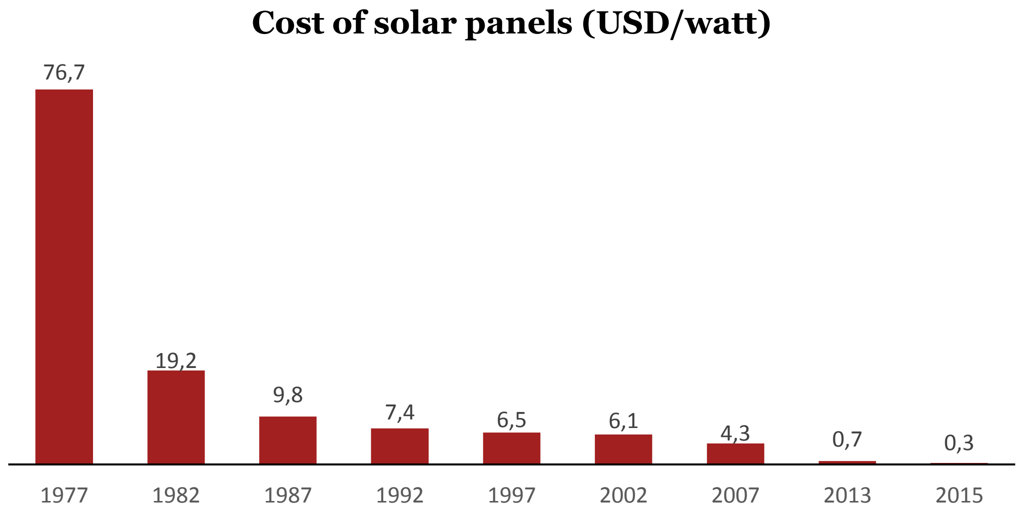
Photovoltaic systems have been probably the most popularized technology in the electricity sector in the past couple of decades. Its principles have been known already since the late 19th century, but its potential was not fully unleashed until the 1950s when the space race between the USA and USSR broke out. After initial rivalry with conventional chemical batteries, solar cells were quickly adopted as the primary source of electricity for satellites and later on for orbital space stations as well. (Perlin)

Implementation of solar cells in the space programme clearly showed that the concept is operational, yet the cost of solar cell per watt was out of reach for standard applications, as the exchange ratio reached more than 100 USD per one watt. Gradual innovation in the manufacturing process however allowed for the use of cheaper materials, thus pushing the price to 20 USD per watt. This started the adoption of photovoltaics mostly by oil rigs and the process gradually expanded to other solitary stand-alone applications, such as railroad warning lights or telecommunication repeater stations in distant rural areas. (Perlin)

Later on in the 1980s, the gradually increasing use of solar cells has provided the necessary boost for their expansion to other new areas of application. Initially, photovoltaics were considered mainly as centralized solutions for generating electricity in developing countries, which lacked the necessary infrastructure for electricity transmission. However, Swiss engineer Marcus Real soon proved the economic advantages of the micro approach through selling 333 rooftop solar systems to homeowners in Zurich and thus has lifted the barriers keeping photovoltaics from becoming the decentralized source of electricity as it is known today. (Perlin)

With the increasing demand and production capacities as well as the state policies towards renewables accompanied by incentives for investments into solar energy, prices of photovoltaics have been rapidly decreasing in the past few decades, thus effectively making photovoltaic solutions a feasible and affordable option for average households.

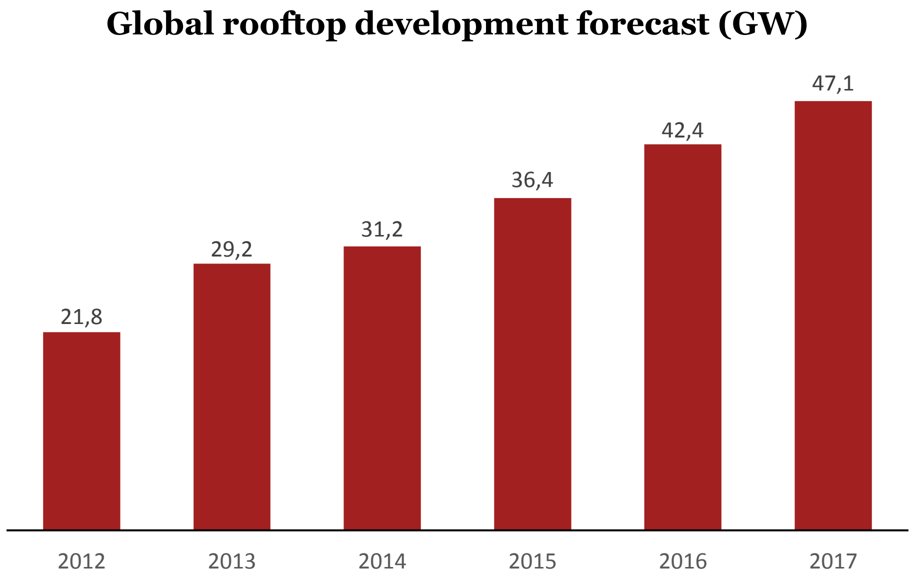
Chart 14 Cost of solar panels (USD/watt)



Source: (GTM, 2013)

As seen in the Chart 14 above, production price of the solar panels has decreased more than 100 times in between years 1977 and 2015. This was achieved mostly through technological innovation and increasing number of manufacturers and their production capacities, resulting in significant economies of scale. Aftermath of such price development is rather self-explanatory, as the total installed capacity of solar cells in the world increased almost 5 times in between years 2009 and 2013. (International Energy Agency, 2014) The rapid increase in installed capacity was driven mostly by the large-scale investments into solar power plants, however as seen on the following Chart 15, residential applications are following the very similar pattern.

Chart 15 Global rooftop development forecast (GW)



Source: (Masson, Latour, Rekinger, Thelogitis, & Papoutsi, 2012)

Household applications represented 21.7 % of the total installed capacity of photovoltaic systems in the world in 2012. In accordance with the decreasing production the adoption of solar panels among households has been increasing and, taking into consideration the newly introduced incentives for promotion of renewables, is forecasted to reach 47.1 GW globally, hence increasing its size by 116 % in the span of 5 years. (International Energy Agency, 2014)

Key advantages

Boom in the adoption of photovoltaics by households was not of course only driven by the decreasing price, but also by the increasing awareness of the advantages they can offer. The most important one is of course the electricity it produces, which, depending on the size of the photovoltaic system, can significantly decrease the need for conventional supply of energy from the grid.

Second aspect of their success lies also in the increasing demand for ecological products, which can be observed through the whole spectrum of consumer products. It is also in line with the general shift towards renewables, which are supported by governmental incentives, thus making the photovoltaics more affordable through different forms of subsidies.

Last driver of their growth is also connected to the regulatory system, as the overproduction from the solar cells is usually fed back into the grid at a favorable price. Households can therefore not only considerably decrease their consumption of electricity from the grid, but can also gain additional revenues or discounts from the electricity bill, based on the electricity they supply.

Key disadvantages

It is only natural that the advantages solar cells bring are balanced with a certain amount of disadvantages, which have to be considered before making the investments. Probably the first constraint that has to be taken into account is the geographical position and the usual weather conditions in the region where the household is situated. The average amount of sun light directly affects the amount of electricity produced, therefore in areas with minimum amount of direct sun light an investment into a solar cell system with installed capacity reaching several kilowatts can easily become a dead loss.

Another constraint is rather straight forward and it is the fact, that in order to be able to set up the photovoltaics on your roof, you have to actually be the owner of the property. This means that unless a whole residential building decides for a purchase of solar cells, photovoltaics are only available to families living in their own houses and not apartments. On top of that, even the shape of the roof has an impact on the feasibility of the photovoltaics solution, as it can greatly impact the exposure to sun and the available area for solar cells itself.

More technical limitation then comes from the fact that photovoltaics are the most efficient when the sun is strongest, which is usually around midday. On the other hand, consumption of electricity peaks in the morning (before we leave for work) and then again in the evening (when we arrive from work). Therefore, unless you opt for a photovoltaic system which includes some form of energy storage, most of the electricity the system generates will not be in fact consumed by the household, but more likely fed into the grid.

This is also related to the last constraint, which are the feed-in tariffs. Given the fact that considerable amount of generated electricity is fed back into the grid, the conditions under which is the electricity bought out play a major role when deciding about the feasibility and the return on the investment. As households cannot affect the feed-in tariff conditions, it therefore crucial to determine for how long the conditions valid at the moment of the investment will be fixed.

Case study

In order to better understand the physics of the photovoltaic solutions, we will use a simplified case study of a household investing into solar cells.

Annual electricity consumption:	10 250 KWh
Photovoltaics installed capacity:	8 kW
Electricity generated per year:	7 600 – 8 800 KWh
Investment:	11 540 EUR
Payback period:	11 – 13 years

Source: (Česká solární, not dated)

In this case study we assume a family of 4 living in a completely electrified house, where the electricity is used also for heating, with prices corresponding to current offer of incumbents on the Czech energy market.

The payback period in this case would reach approximately 11-13 years, however could be greatly affected by all the constraints listed among the key disadvantages of photovoltaics.

Potential business models for energy players

Introduction of photovoltaics to product portfolios of energy players represents an opportunity for different strategies, resulting in different requirements for capital invested by the companies, but also in different levels of potential revenues that can be expected.

The easiest option in terms of investments is to offer a photovoltaics-oriented project management, where for a fee the energy provider designs an appropriate solution for your household and secures the technology from other companies. Due to the very little requirements this is usually the entry strategy for an energy player interested in entering the photovoltaics market.

Second strategy composes of establishing partnerships with either a solar cell manufacturer or a financing institution, or potentially both. Energy provider then serves as a promotional and acquisition channel, gaining customers for the solar cell manufacturer or for the financing institution, in case the customers seek financing to cover the investment into photovoltaics. Expected revenues can be higher than in case of a simple project management, because the revenues of the energy provider are usually commission based, therefore equal a certain percentage of each investment into the photovoltaic solutions.

The most profitable but also the most investment heavy strategy is an acquisition of a photovoltaics manufacturer. In this case the energy provider gains the whole margin on the solar cells, thus acquires the maximum possible amount of revenues. This strategy can be further accompanied by establishing own financing services to allow customers to seek financing for their investment directly by the energy provider.

Overall, it is safe to say that due to continuously decreasing prices of photovoltaics and governmental policies, their adoption by households is most likely to furthermore increase. However, despite that, photovoltaics still represent a specific product which only fits specific types of households.

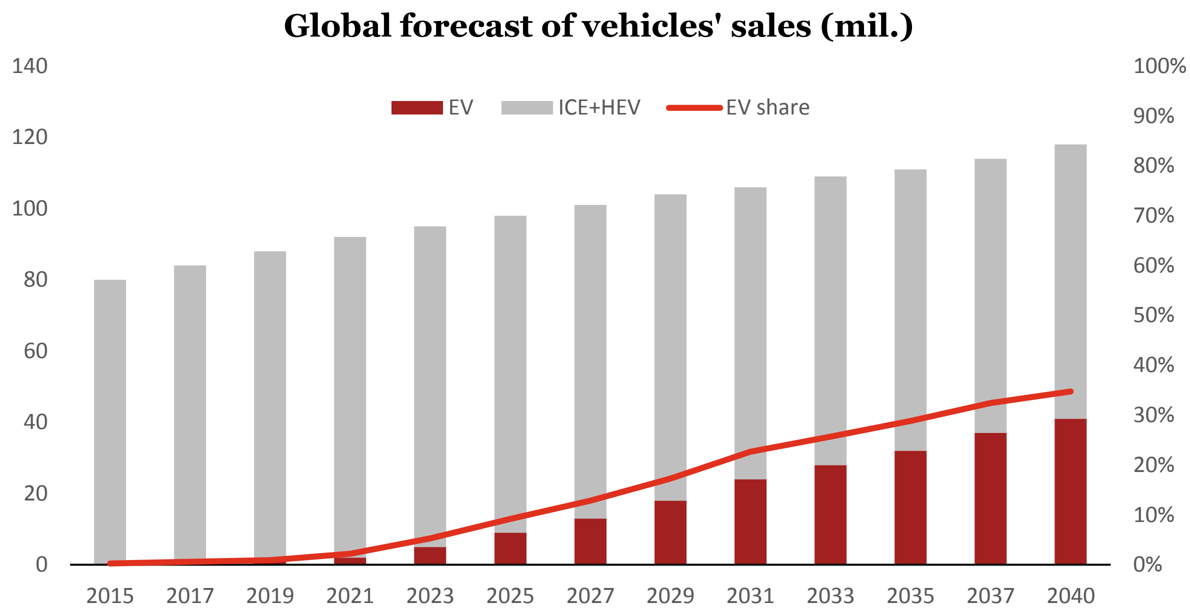
2.5.2. Electromobility

Second branch of new products identified in European energy players' product portfolios is electromobility. This is a much more recent product innovation than the previously mentioned photovoltaic solutions, however as the potential of electromobility is still increasing, it is quite likely, that due to the gradual shift from fossil fuels towards vehicles driven by alternative fuels, electromobility might in a horizon of just few decades achieve considerable market penetration.

As the term "electromobility" indicates, this category of products encompasses technologies related to the use of fully electric vehicles or alternatively plug-in hybrids. Therefore the most common products are usually private or commercial chargers, or development of public charging infrastructure. Another alternative which is not yet widely spread is the actual offer of electric vehicles by the energy players, either in form of rental vehicles or in form of actual dealership in cooperation with an electric car manufacturers.

Electric and plug-in hybrid vehicles have started gaining momentum since the year 2000, but the most significant boom came in 2005, when the sales of hybrid and electric vehicles in the United States reached 209 711 units, thus over 20 times more than in year 2000. (Todd, Chen, & Clogston, 2013) With the increasing sales the electric vehicles have started gaining more and more attention and attracted new manufacturers to enter the market. This has helped to change their perception from an interesting but rather imperfect gadget to fully competitive vehicles, which, depending on specific requirements, can be considered a compelling alternative to conventional cars.

Chart 16 Global forecast of vehicles' sales (mil.)

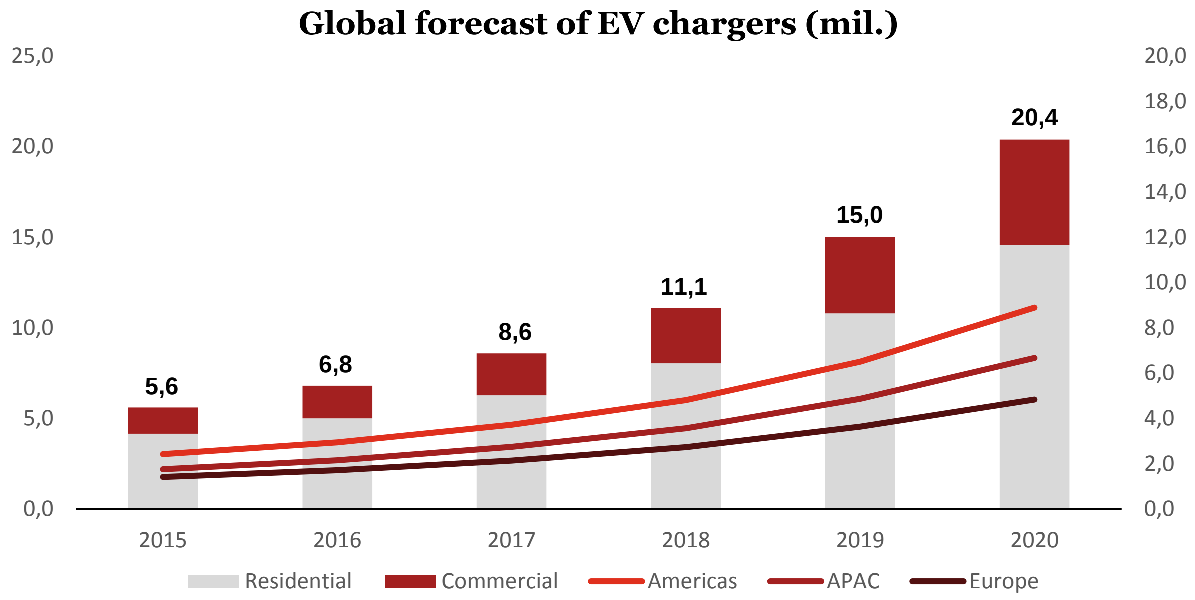


Source: (Randall, 2016)

Bloomberg analysis assumes that the spread of electric vehicles will follow an "s-curve", hence slowly gaining market share in the beginning through early adopters, but once the carmakers improve the range of their cars and manage to squeeze the price to approximately 27 000 EUR, the sales of the electric vehicles will quickly rocket reaching approximately 35 % of total vehicles sold by 2040. Although the remaining 65 % seems like a lot, it includes also the sales of hybrid vehicles, which could without much difficulties account for more than a half of the share. The determining point for this forecast will be the technological innovation which would allow to increase range, and decreasing the cost of the manufacturing process of batteries, which represent approximately one third of the overall price of the electric vehicle. (Randall, 2016)

According to the current outlook, both of these constraints will most likely be effectively overcome by 2020, as Tesla has already introduced an electric vehicle with a range over 200 miles and a price tag of 32 000 EUR. Moreover, Tesla is finalizing its large-scale production facility for car and home batteries, which will allow for significant economies of scale, thus driving the overall market price of batteries much lower. (Tesla, nedatováno)

Chart 17 Global forecast of EV chargers (mil.)



Source: (Technavio, 2015)

Second part of the electromobility equation are the EV chargers, which are both directly dependent on the demand for electric vehicles, as well as they directly impact the number of vehicles sold, because the existing infrastructure is one of the key purchasing criteria when considering an electric vehicle.

Forecasted development of the number of EV chargers sold indicates that the extremely close correlation with the sales of electric vehicles will result in a booming market for EV chargers. Current outlook presumes that the market will grow in between years 2015 and 2020 at a CAGR of 29.4 % with majority of the chargers purchased directly by households. The major driver of the growth are the governmental incentives promoting electromobility, which are widely adopted in the USA, where the growth is expected to be the fastest. Similar incentives have been lately adopted also in China, where the government plans to invest into 4.5 million charging points by 2020. Within Europe the governmental policies greatly vary from country to country, with the leading markets being Denmark, Norway, Netherlands, Germany, the United Kingdom and France. (Technavio, 2015)

Key advantages

Similarly as in case of photovoltaics, initial main selling proposition of the electric vehicles was the ecological side of their operations. This remains one of the major reasons for variety of governmental incentives, as these are usually adopted primarily in countries with highly pro-ecological attitude, such as Scandinavian countries.

The incentives themselves might represent an attractive motivation for a purchase of electric vehicle instead of a conventional car, because in some of the countries, the amount of state incentives decreases the market price of the electric vehicles to a level of traditional cars with combustion engine. In case of a sufficient EV chargers infrastructure, the benefits of electric vehicles can easily win over conventional cars.

The obvious ace in the EV cars' sleeve is their economy. Simple calculation quickly reveals that electric vehicles can operate at less than a half of the costs of a conventional car. Rather pleasing benefit of the electric vehicles are also different physics of their electric motors, which result in the availability of the full amount of car's torque from 0 rpm. In other words, not many cars can accelerate as fast as electric vehicles.

Key disadvantages

Currently, market-wide boom of the electric vehicles is facing primarily three main barriers. The very first one is their previously mentioned prices, which has so far kept EV cars from an adoption by general public. However, given the increasing subsidies and technological innovations, the prices of EV are being driven down and will most likely soon come close to the prices of conventional cars.

Second constraint is their limited range, which for most of the current EV cars in the market is just around 100 kilometers and which has predestined them into a role of city cars. Nonetheless, even this obstacle can be tackled through innovation, as Tesla already offers cars with a range of 320-480 km and it is likely, that other manufacturers will also be able to improve the range of their vehicles. Another solution lies in the developing charging infrastructure, which allows for a necessary power boost.

The charging time itself represents an obstacle, as it was usually a matter of hours, before the battery pack was fully charged, therefore the possibility for long distance travels using charging infrastructure was not really an option. According to the recent development, innovation might answer this issue as well, because recently developed Tesla Superchargers are capable of charging the EV car during 30 minutes enough to keep it going for 270 km.

Case study

Given the extremely diverse situation in terms of governmental subsidies in different countries around the world, it is difficult to compare the total costs of electric car to a conventional one. Instead, we will at least compare the economics of their operations, to provide a rough estimate of the annual savings that can be achieved through the purchase of an electric vehicle.

Annual kilometers:	20 000 km
Gasoline price per liter:	1.1 EUR
Price per kWh:	0.18 EUR
Gasoline consumption:	5.6 liters per 100 km
Electricity consumption:	16 kWh per 100 km

Annual gasoline costs:	1 239 EUR
Annual electricity costs:	572 EUR
Annual savings on fuel:	**667 EUR**

Source: (My Electric Car, not dated)

Considering owning the EV car for 5 years, the overall savings would amount to 3 335 EUR, which is a considerable amount, but in most cases is not sufficient enough to balance out the higher price of electric vehicles. The crucial variable therefore remains the amount of governmental subsidies, which are the one key determinant of a final market price of EV cars.

Potential business models for energy players

The clearly booming market of electromobility is an opportunity the energy players do not want to miss and therefore are developing more and more activities in this area. The easiest one is a simple introduction of discounted tariffs for owners of EV cars who can then charge their vehicles at a discounted price. While this strategy might not generate revenues directly, it could serve as a good acquisition channel, motivating customers the owners of EV cars to transfer the whole portfolio of their energy services to the energy player who introduces discounted tariffs for charging.

Second strategy leverages the EV charger infrastructure and it is the most commonly used one in today's market. Energy players offer construction of private or commercial charging stations, thus gaining a new and a direct revenue stream. Another option is to establish the public network of chargers, where the electricity costs (revenues for the energy player) are either covered by customers, or are subsidized by government.

Third option is the offer of electric vehicles as such. This can be either done in form of a fleet of rental cars, this is an option for which has decided one of the Czech energy incumbents, or it can be direct sales of electric vehicles of an existing manufacturer, where the revenues would arise from commission on each sold vehicle.

Given the complex nature of electromobility, a number of additional business models can emerge. To set an example, electricity retailers who are purchasing electricity during day, are buying at higher prices during peak hours. Therefore introduction of free parking and charging spots for owners of electric vehicles could allow them to charge the cars when the electricity prices are low and then use the cars as an electricity reservoir of cheaper energy during the peak hours.

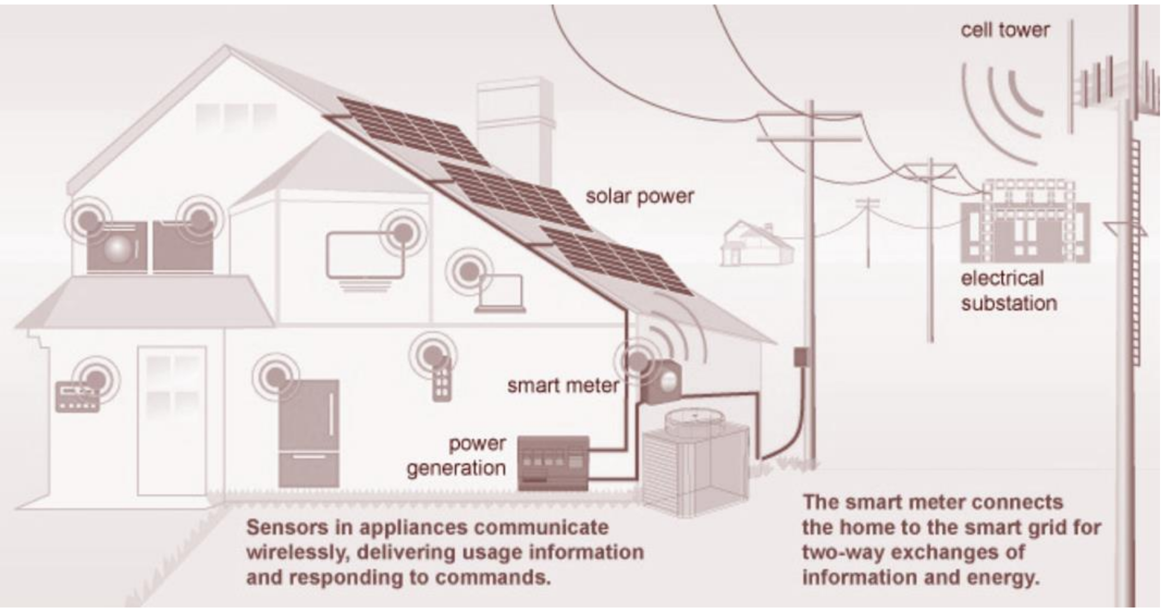
Rapidly increasing popularity of electric vehicles is forecasted to grow at even faster pace in the future. Introduction of new electromobility oriented product is therefore a necessary step for the energy players, both in terms of incumbents and new entrants. Furthermore, while affected by governmental subsidies, electric vehicles are not limited to a specific segment of customers as in the case of photovoltaics. Electromobility oriented products therefore represent a highly promising market segment.

2.5.3. Smart metering

Smart homes and more specifically smart metering systems are a relatively new topic in the energy industry. The technology consists of several different technical components, which may vary according to the needs of specific market, but majority of systems features accurate measurement and transmission of electricity and a provision of a two-way information gateway and communication infrastructure between the meters and relevant parties.

This gateway is then used to raise awareness and empower consumers through delivery of actual consumption data, improve CRM with automated invoicing based on detailed metering data, allow for better management of energy networks through shifting or reducing energy consumption and to encourage decentralized, micro-generation of energy, thus transforming the consumer into an energy producer. (ESMIG, nedatováno)

Picture 3 Smart metering



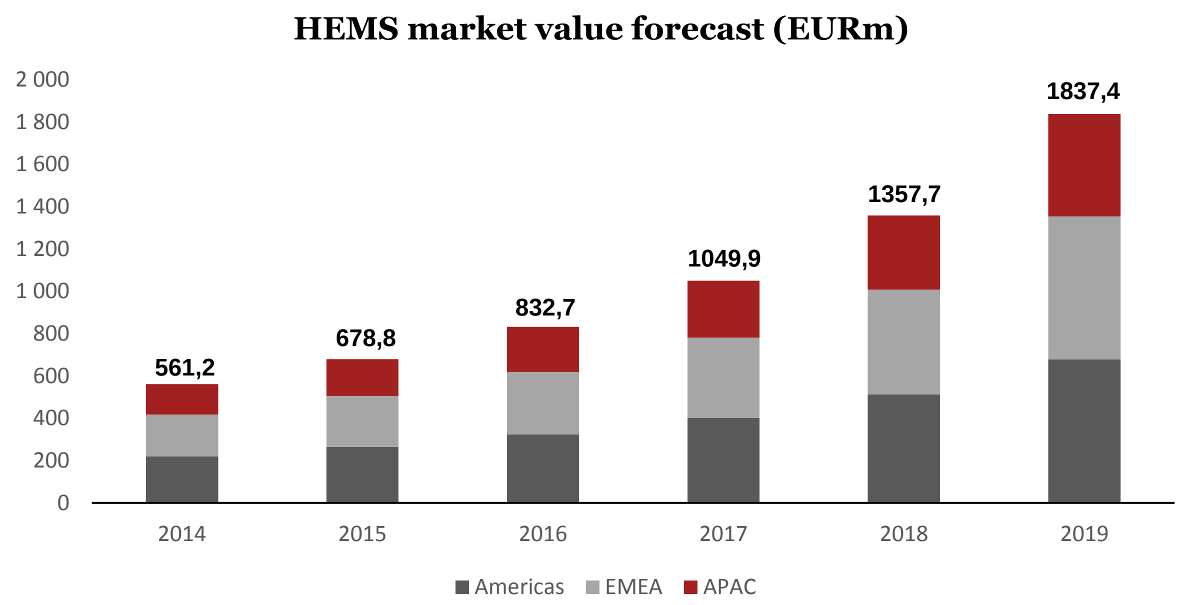
Source: (Bowen, 2010)

Key component of the system is the new smart meter able of monitoring real time electricity consumption and transferring the data to consumers and providers. Consumers can use this data to monitor their electricity consumption throughout the day, either via a home-mounted console or through their smartphones. This can be leveraged to adjust the electricity consumption according to the peaks in electricity prices, or when coupled to smart home appliances, the system itself can automatically regulate the use of the appliances. In reality, the system could turn on a dishwasher or a washing machine simply based on the time, when the electricity is the cheapest.

Energy providers on the other hand gain first-class data and can effectively manage the distribution of electricity based on the real time demand and patterns gained from the big data collection.

The initiative behind smart metering is also pushed forward by the European Union, which perceives them as the ideal tool for motivating consumers to manage their consumption better and to furthermore develop liberalization in energy markets. The EU therefore aims to replace at least 80 % of electricity meters in tis member countries with smart meters by 2020 wherever it will be cost-effective to do so. (European Commission, nedatováno)

Chart 18 Global home energy management systems market forecast (EURm)



Source: (Technavio, 2014)

Home energy management systems (HEMS) are devices which are installed in residential buildings to enable the provision of feedback on electricity consumption, as well as perform pre-programmed functions such as maintaining the temperature of the house or remotely controlling household appliances, therefore encompass the whole smart metering and smart home solution.

According to current forecasts, today's market is valued at 832.7 EURm and is expected to grow at CAGR 30.2 % until 2019. While the development is fairly balanced all around the world, EMEA (Europe-Middle East-Africa) is expected to be the fastest growing region, especially because of the previously mentioned EU initiative aiming for market wide implementation of smart metering in its member countries. In accordance with the previous analysis of selected countries, Germany and the United Kingdom are currently the largest players in the European HEMS market. (Technavio, 2014)

Key advantages

As smart metering and smart home solutions represent more of a platform than a single product pinpointing their key advantages is not as straight forward as in the case of previously analyzed technologies.

Currently their main selling proposition is primarily the overall increase both in in-household and in grid consumption efficiency due to extensive data communication. The continuous real-time flow of data between customers and their energy provider also promises potential for completely new customized tariffs which could be based on the very own consumption pattern of each household.

Smart solutions also offer levels of control and comfort unmatchable by traditional analog systems. When implemented and coupled to smart appliances or optimally a smart home center, it allows you to maximize the efficiency of your electricity consumption and if needed, also to control your entire house from the screen of your smartphone.

While the tendency to try and make our smartphones able of controlling every aspect of our lives might seem a bit unnecessary at the moment, it is quite likely that with the increasing adoption of solar cells, electric vehicles or home batteries, smart home solutions will offer the one single universal platform binding all of these technologies together.

Key disadvantages

Despite the fact that smart metering will be pushed to the market by both government and the energy providers, thus making the costs to final customers rather negligible, it will probably take some time before the technology actually spreads throughout the market. Therefore, also the potential benefits coming from new flexible tariffs will probably only appear once the market reaches some minimum amount of penetration.

Secondly, while smart metering itself offers certain advantages, the actual big thing happens only after connecting the smart meter to a smart home solution. This can provide a lot of comfort however investment into smart home solution can exceed 20 000 EUR, depending on the features customers are looking for.

Potential business models for energy players

Smart metering represents a possibly the most complex way of gathering big data by energy players. The potential business models are therefore based mostly on the data analysis and following adjustments. This is also the case for the previously mentioned flexible tariffs which would could be tailored to customers based on their individual electricity consumption patterns. Flexible tariffs would have a positive impact on customer satisfaction and possibly also acquisition, thus effectively working as both a retention and an acquisition measure. Similar possibility lies again in the thorough analysis of gathered big data, as energy players will gain detailed overview of actual consumption in households and also the electricity generation in case of households equipped with photovoltaics. This will allow to better forecast investments into generation capabilities of energy players, hence decreasing redundant installed capacity.

Second branch of possible opportunities can be derived from the offer of smart home solutions. This can take a form of simple project design and management where the energy player would get revenues for the design, or it can include a final delivery as well, where additional revenues could come either from commission paid by the smart home solutions manufacturer, or in case of an acquisition, energy player could secure the production as well.

While smart metering might not strike us as the most flashy new technology, due to the support from European Union, smart meters and eventually smart home solutions are expected do significantly increase their market in the upcoming years. They might also provide the very much needed unifying platform, which will interconnect other technologies, such as photovoltaics, electromobility or home energy storage systems.

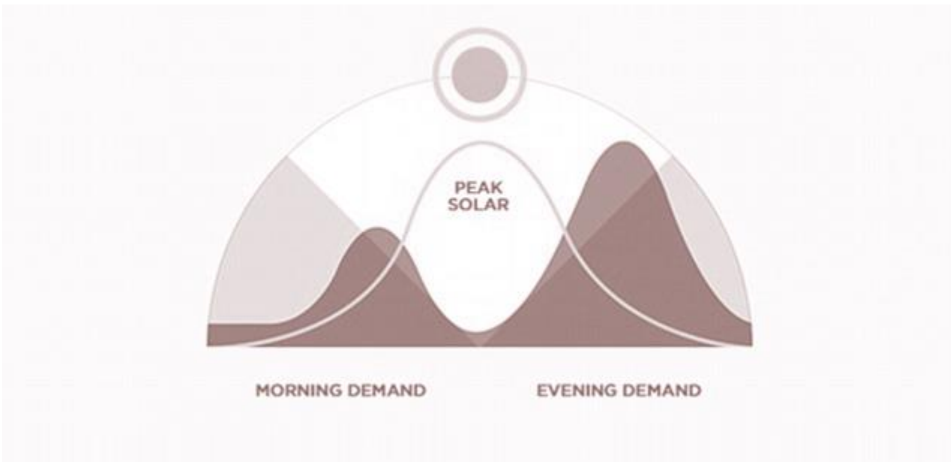
2.5.4. Home batteries

Last technology selected for assessment is the segment of home batteries, which will be also thoroughly analyzed in the second part of the master thesis. Home batteries as such have been around for quite some time already (first have appeared just after the break of the millennium), but have mostly been limited to being a component in household photovoltaic solutions, where they serve as an energy storage for storing the electricity generated during day for later consumption.

Public breakthrough happened in 2015 when Tesla has announced its home battery unit “Powerwall”. While the unit itself does not feature any major advantages over already existing alternatives, announcement of such device by a Tesla’s trending brand caused a strong media attention, followed by a rapid increase of general public in the home batteries.

The home batteries offer a variety of possible applications. The most obvious one is the already previously mention incorporation into a photovoltaic system, where batteries allows to store electricity generated during the day and save it for consumption which usually peaks in the evening. More innovative option is based on the different prices of electricity during the day, as battery allows to charge itself when the electricity is cheap, and then supply the electricity for household consumption during price peaks. The simple implementation of battery can also serve as a mean of balancing household consumption throughout the day, thus decreasing the necessary size of the circuit breaker which results in decreasing the fixed part of electricity costs. Last option is to use batteries simply as a back-up source of energy in case of blackouts.

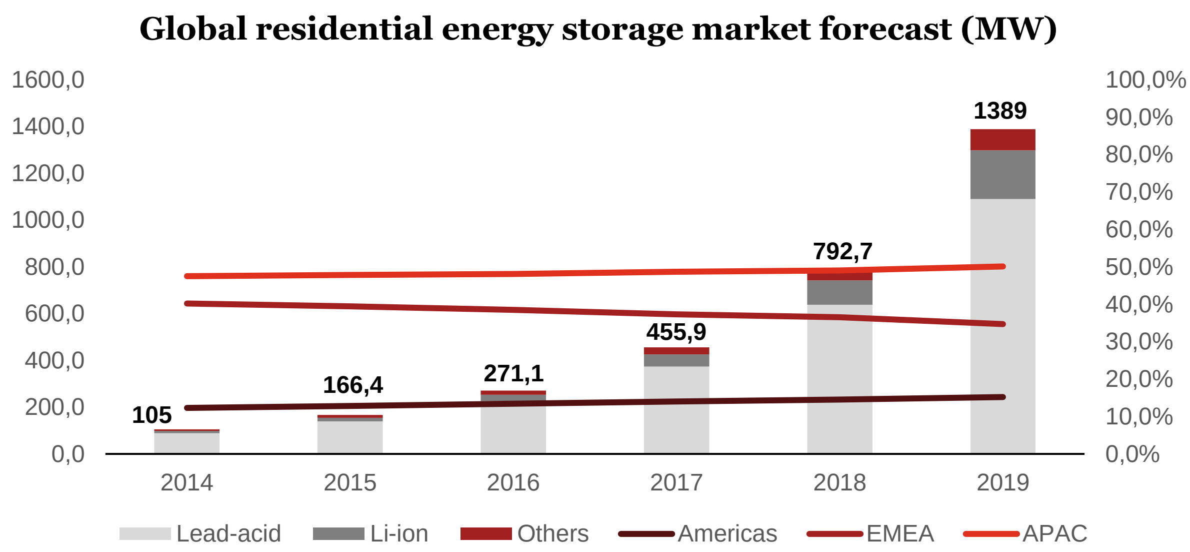
Picture 4 Electricity consumption peaks during day



Source: (Tesla, 2015)

Major constraint limiting home batteries from faster adoption is the still relatively high price per kWh of capacity, which along with the rather complicated quantification of benefits of the battery implementation restrains home batteries from wider adoption by households. Increasing production of electric vehicles and a construction of the new Tesla production plant focused solely on battery are however very likely to drive the prices of battery cells down in the near future, thus allowing for a fast paced expansion of the home batteries market. This trend could also be furthermore enhanced by car makers, such as Nissan, producing electric vehicles, who are now considering the expansion of batteries used in their cars to be offered as home batteries as well.

Chart 19 Global residential energy storage market forecast (MW)



Source: (Technavio, 2015)

Increasing attention towards home batteries and their decreasing price is forecasted to drive the market at a CAGR of 67.6 % per year until 2019, when the market size is expected to be more than 13 times the size in year 2014.

Lead-acid batteries are expected to still account for the vast majority of energy storage solutions, but their share is most likely to be gradually decreasing during the forecasted period from 85.0 % to 78.5 % in favor of increasing share of the more expansive Li-ion batteries. Regarding the geographical distribution, the market is forecasted to grow at a fast pace all around the world, increasing its size at least ten times during the forecasted period in each of the regions. The fastest booming region will most likely be APAC, where the development is driven by strong pro-renewables behavior of households in China, Japan and Australia, accompanied by a wide offer of governmental incentives.

Key advantages

The primary benefit for which have home batteries gained their fame is the implementation into the photovoltaic systems, where batteries allow to consume electricity generated during the day during the consumption peaks in the evening.

As mentioned before, batteries can also be used to balance out the consumption peaks during the day, therefore stabilizing household's electricity consumption from the grid on a level close to the average consumption per hour. This allows to decrease the size of the installed circuit breaker and thus decrease household electricity bill as well. Benefits of this application are rather difficult to quantify, therefore I will encompass them in the practical part of my master thesis, to clarify its profitability.

Batteries also allow to shift the consumption from the grid during the day, in a way that battery charges itself during consumption lows, when the electricity is cheaper, and afterwards supplies household with cheaper electricity during price peaks in the morning and evening. Quantification of this application will also be included in the practical part of this master thesis.

Apart from those, other applications of the home-based energy storage systems include the possibility to use them as a back-up source of electricity or to incorporate them to a smart home and electromobility solution, where the battery can be remotely controlled and also used to charge electric car when the electricity is the cheapest.

Key disadvantages

Perhaps the largest drawback keeping home batteries from wider public adoption is still their price. While the price per kWh has decreased significantly during the last couple of years, it still remains rather high for an average household. Nonetheless, current outlooks indicate further decrease in the price, therefore the energy storage systems could soon become affordable for almost every household. This issue will also be included in the practical part of master thesis.

Another disadvantage lies in the fact, that apart from the application in photovoltaic system, benefits of home batteries are difficult to quantify, therefore it might be challenging to compute the actual profitability. Designing a model allowing for a clear calculation of the investment profitability will be a primary objective of the practical part of this thesis.

Last drawback is the relatively narrow offer of simple-to-use home energy storage system. This issue will however probably disappear in the horizon of few years as more and more manufacturers are entering the home batteries market.

Potential business models for energy players

As we have learnt in the assessments of previous technologies, the easiest way of entering a market is to offer a project management for households interested energy storage solutions. This would also enable the energy player to first assess the actual demand for home batteries before deciding for other more investment heavy market strategy.

Second option is the direct offer of home batteries, which could either be manufactured by a different company, thus the energy player would get commissions from each battery sold, or the energy player could acquire a battery manufacturer, thus offer own batteries and keep the whole margin. This could also be accompanied by the same set of financing options as in the case of photovoltaics.[11]

Last set of strategies would a complex feasibility study in order to assess whether they are actually viable. First of the strategies would be to rent the batteries to households or to implement operational leasing scheme, where the used batteries would then be sold at discounted prices. Second strategy would consist of placing larger energy storage systems in residential buildings, which would effectively decrease the need for maximum size of circuit breaker, hence decreasing fixed costs of the energy player. In case of electricity retailers, they could also use the batteries for electricity arbitrage, similarly as in the case of electromobility.[12]

Home energy storage solutions offer a wide range of potential application, both for households and for energy players. Their profitability however has yet to be assessed, as they represent a very young and developing market. In the practical part of my master thesis, I will therefore aim to design a model, which will allow to quantify their benefits, thus serve as a cornerstone for calculating their profitability.

[11] Page 32, paragraph 4
[12] Page 36, paragraph 5

3. Practical part

Practical part of my master thesis will focus on a detailed assessment of business case feasibility for home batteries implementation. The main questions it aims to answer are:

1) Will home batteries be the next big thing on energy markets?
2) Will home batteries be beneficial for average household or will they develop their own market niche only for highly specific customers?
3) Will purchase of home batteries make sense already today?

In order to provide a complex and robust answer, I will design and develop an interactive model, which will allow to take into account the key determining variables and provide various scenarios based on the selected input data. To ensure that the outputs of the model are credible, I will base the calculations on features of existing home batteries, including their price and number of charging cycles.

As mentioned in the chapter "New technologies in households" in section dedicated to home batteries, energy storage systems allow for variety of savings, the most common ones being application together with photovoltaic system, electricity arbitrage or time shift of consumption. To measure the profitability of home battery solution, I will presume the most widely applicable case, the time shift of consumption in household.

3.1. General assumptions

The main assumed purpose of the home batteries in this model is to store electricity, with no regards to its origin, and offer it for later consumption to the household or business, thus allowing the time shift of consumption and not being primarily intended for electricity arbitrage (charging the battery when the electricity is low and feeding the electricity back to the grid during the peak hours, when the prices are higher). Based on this assumptions, it is safe to state, that the key determinant of a home battery application is therefore the electricity consumption of the one particular household.

Electricity consumption is affected by a large set of variables, ranging from the number of people living in the household and their electricity consumption behavior, number of household appliances and their efficiency, implemented lighting solutions, to building insulation or the heating system. Therefore, in order to simplify the model and to make it more versatile, we will consider the number of people in the household and the surface area of the building as the key determinants, which will be used to derive the actual overall electricity consumption.

Specifically, the number of people living in the household will be used as a multiplication constant for quantification of electricity consumption related to home appliances, water heating, and cooking, whereas surface area will help to identify consumption related to electric heating of the building. As the heating system can also be based on natural gas, heating plant or other alternative options, it will be possible to turn off the heating parameter in the model, thus allowing for one-click differentiation between households with electric and non-electric heating.

Another key assumption is the fact, that while actual batteries are available with specific capacity, for simplification and increased versatility of the model, I will assume that batteries can be purchased with any capacity needed, ranging anywhere from 0.01 kWh to several MWh. Therefore, I will focus on the price per kWh of battery capacity[13] and its forecasted development in time.

In order to determine the size of the actual monetary savings from the home battery implementation, we need to know the original amount the household pays for electricity. To provide a fully modifiable simulation, the model therefore includes price list of one of the Czech energy market incumbents, including a selection of available distribution tariffs and electricity circuit breakers. This results in a precise quantification of savings in the Czech market.

Second set of assumptions is related to the key technological features of the battery, namely the emergency capacity, number of charging cycles throughout the battery's life and its efficiency, which all directly affect the feasibility of the home batteries' case. In order to accommodate a specific request on battery's capabilities or to simulate a certain type of battery, the model allows to independently adjust those variables.

Starting with the emergency capacity, it represents the level of electricity measured as a percentage of total capacity, which is added on top of the minimal necessary capacity of the battery and serves as a buffer either for unexpected consumption or for emergency situations in case of electricity shortage.

Number of charging cycles serves as a base for determining the overall lifespan of the battery. The input value will be deducted from batteries currently existing in the market, but as its value can be independently changed, it will ensure that the model remains employable even in case of a technological development which would increase the number of charging cycles.

Last assumption is related to the battery efficiency and allows to bridge the gap between the theoretical nature of the model and real-life results. In reality there is a transmission loss occurring during the charging of the battery which in simplification means, that in case of a 90% efficiency, we need to invest 10.1 kWh in order to fully charge a 10 kWh battery. While this could be a negligible parameter in case of a short-run simulation, the model presumes a long-run application of the battery until full depletion of its charging cycles, therefore the battery efficiency parameter significantly affects the final break-even point.

[13] As mentioned on page 41, paragraph 2

3.2. Model workings

The following chapter will be dedicated to the description of the inner workings of the considered model, in order to provide general understanding of the ratio behind its design. While the description of some parts of the model might be simplified in order not to explain excessive amount of details, the overall description will be complex enough to provide satisfactory understanding of the model.

The description itself will be structured into 4 blocks, those being: Electricity consumption, Battery, Tariff structure and Economies of decision making. This structure will allow to better understand how the model works and it will help to create necessary links among all parts of the model.

3.2.1. Electricity consumption

As mentioned already in the chapter dedicated to model assumptions, electricity consumption represents the key determining variable in case of the time-shifting[14] application of home batteries and it is used to identify the minimum capacity of battery needed, in order to even out the electricity consumption during the day.

The starting point for us will be the assumptions mentioned on page 44, to which we will assign specific levels of electricity consumption.

Picture 5 Model: Electricity consumption assumptions

	A	B	C	D	E
1					
2		Electricity consumption	Number of people in household	3	
3			Living area (m2)	130	
4			Lighting and household appliances (kWh per year per person)	1100	YES
5			Cooking	200	YES
6			Water heating (kWh per year per person)	1000	YES
7			Heating (kWh per year per m2)	70	NO

Source: author's model

In case the respective parameter is set to "YES" the calculation takes the parameter into account. This allows to flexibly adjust the model settings, especially in the case of different heating solutions.

The formula for calculation of household consumption per year is then formulated as:

=(IF(E4="YES";D2*D4;0))+(IF(E5="YES";D2*D5;0))+(IF(E6="YES";D2*D6;0))
+(IF(E7="YES";(D3*D7)-H29-H30;0))

Therefore multiplying the value set to lighting and household appliances, cooking and water heating by number of people in household and multiplying the heating consumption by the size of living area. In this specific case, the electricity consumption per year equals 6 900 kWh.

[14] As mentioned on page 44, paragraph 4

The next step will be to compute the average daily and hourly consumption. This is a simple matter of dividing the yearly consumption by 365 and then by 24.

Picture 6 Model: Electricity consumption outputs

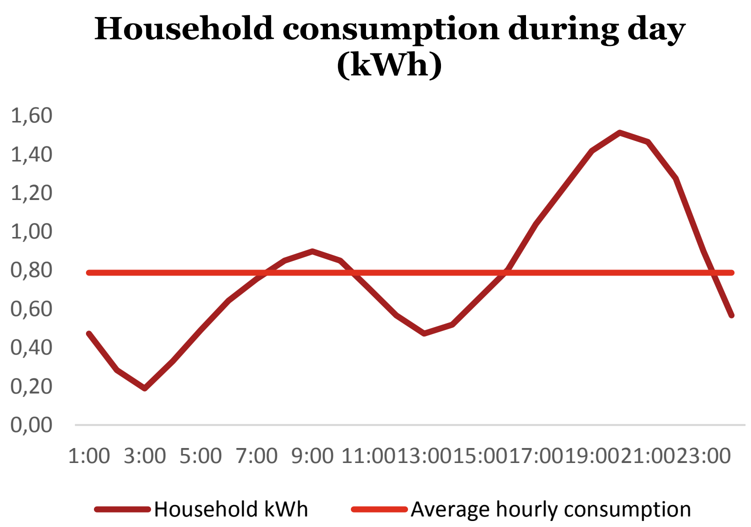
	A	B	C	D
1		Electricity consumption		
2		Yearly consumption	6 900	kWh
3		Daily consumption	18,90	kWh
4		Average hourly consumption	0,79	kWh

Source: author's model

In order to assess the home battery requirements, we need to identify the specific levels of electricity consumption throughout the day. To do so, we need to design an illustrative consumption curve of the household, which will show us the specific amount of electricity being consumed at each hour of the day.

As we already know the daily consumption of electricity, we will now assign a specific percentage of this consumption to each hour of the day[15]. This will allow us to model the morning peak and the evening peak of the consumption.

Chart 20 Model: Electricity consumption during the day



F	G
Time	%
1:00	2,50%
2:00	1,50%
3:00	1,00%
4:00	1,75%
5:00	2,60%
6:00	3,40%
7:00	4,00%
8:00	4,50%
9:00	4,75%
10:00	4,50%
11:00	3,75%
12:00	3,00%
13:00	2,50%
14:00	2,75%
15:00	3,50%
16:00	4,25%
17:00	5,50%
18:00	6,50%
19:00	7,50%
20:00	8,00%
21:00	7,75%
22:00	6,75%
23:00	4,75%
0:00	3,00%
CHECK	100%

Source: author's model

The calculation behind the curve is rather simple, as the value of consumption at each hour is computed simply the daily consumption multiplied by the percentage assigned to the respective hour.

Based on the initial assumptions, we devised the yearly electricity consumption of household, which was then split into average daily and hourly consumption. Then we used the values to model the specific consumption of household during the day.

[15] Assigned percentages are only illustrative and in order to analyze a specific household, its own specific consumption curve would be required.

3.2.2. Battery

As we have already analyzed the consumption, we can now move to the second module, which deals with the battery itself. Here we will determine the necessary capacity of the battery and we will analyze its charging and discharging cycles throughout the day. This will help us to determine the life span of the battery.

The cornerstone of the battery assessment is the selected purpose of the battery application, which is in this case the time shift of the consumption. This means that the main purpose of the battery is to even out the consumption from the grid, so that the household lowers its consumption from the grid during the peak hours, when the electricity is the most expansive, and respectively increases its consumption from the grid during the cheaper hours. In other words, the battery aims to flatten the consumption curve from the grid, coming as close to the average hourly consumption as possible.

In theory, we could therefore lower the consumption from to grid to the average hourly consumption as seen in the Chart 20. However, in reality we need to take into consideration the battery efficiency[16] by which we need to increase the average consumption from the grid.

Picture 7 Model: Battery assessment

F	G	H	J	K	L
Time	%	Household kWh	Inst. capacity	IC - household	Battery (cycle)
1:00	2,50%	0,47	0,87	0,39	1,15
2:00	1,50%	0,28	0,87	0,58	1,73
3:00	1,00%	0,19	0,87	0,68	2,41
4:00	1,75%	0,33	0,87	0,54	2,94
5:00	2,60%	0,49	0,87	0,37	3,22
6:00	3,40%	0,64	0,87	0,22	3,22
7:00	4,00%	0,76	0,87	0,11	3,22
8:00	4,50%	0,85	0,87	0,02	3,22
9:00	4,75%	0,90	0,87	-0,03	3,19
10:00	4,50%	0,85	0,87	0,02	3,21
11:00	3,75%	0,71	0,87	0,16	3,22
12:00	3,00%	0,57	0,87	0,30	3,22
13:00	2,50%	0,47	0,87	0,39	3,22
14:00	2,75%	0,52	0,87	0,35	3,22
15:00	3,50%	0,66	0,87	0,20	3,22
16:00	4,25%	0,80	0,87	0,06	3,22
17:00	5,50%	1,04	0,87	-0,17	3,05
18:00	6,50%	1,23	0,87	-0,36	2,69
19:00	7,50%	1,42	0,87	-0,55	2,14
20:00	8,00%	1,51	0,87	-0,65	1,49
21:00	7,75%	1,47	0,87	-0,60	0,89
22:00	6,75%	1,28	0,87	-0,41	0,48
23:00	4,75%	0,90	0,87	-0,03	0,45
0:00	3,00%	0,57	0,87	0,30	0,75
CHECK	100%	18,90			0,00

Source: author's model

[16] As mentioned on page 45, paragraph 7

To better describe the processes within the model, we will explain each of the columns separately. First three columns (F, G, H) need little introduction as they represent the electricity consumption during the day as explained on page 47. Following column (J, “Installed capacity”) represents the target level for flattening out the consumption from the grid. It is computed simply through multiplication of the average hourly consumption and the battery efficiency, which is one of the general assumptions.[17]

Installed capacity = average hourly consumption * (1+(1-battery efficiency))

In this case the battery efficiency is set to 90 % and the average hourly consumption is 0.79 kWh, thus the installed capacity equals 0.87 kW. Installed capacity will be further used when calculating the profitability of home batteries, as it will determine the minimum size of the circuit breaker. Therefore, 0.87 kW also represents the maximal amount of electricity we can draw from the grid at one time.

As we have determined the installed capacity, we can now move to identifying the actual size of the battery needed. This is the purpose of the next column (L, “IC – household”), where we deduct the actual household consumption at each hour (column H) from the installed capacity (column K). This computation returns the either the excess amount of electricity we can draw at each hour regarding the installed capacity, or the insufficient amount of electricity which needs to be drawn from the battery. As the battery needs to cover up for these insufficiencies, the required minimum capacity can simply be determined by summing up the negative values.

The required minimum capacity is therefore in this case 2.80 kWh. However, in order to forego potential risks such as power outage or increased consumption, we will increase the requested capacity by emergency capacity[18], which is in this case set to 15 %, resulting in the final requested battery capacity of 3.22 kWh.

Following column (L, “Battery (cycle)”) is a bit tricky as it quantifies the charging and discharging cycles of the battery. In theory, the battery charges when there is an excess electricity available and discharges when the household consumption is greater than the installed capacity (as indicated by green and red cells in column K). In reality, as we do not start each day with a fully depleted battery, we need to take into account the electricity left in the battery at midnight, therefore the precise quantification required introduction of a macro protocol, which recalculates the values. However, in order to simplify the description of the model, I will not deal with the macro itself in detail.

Based on the information about the battery charging cycles, we can now determine the number of charging cycles the battery undergoes each day, which is in this case 1.23. By dividing the number of charging cycles[19] by 1.23, we will then calculate the life span of the battery, which in this case equals 7.83 years.

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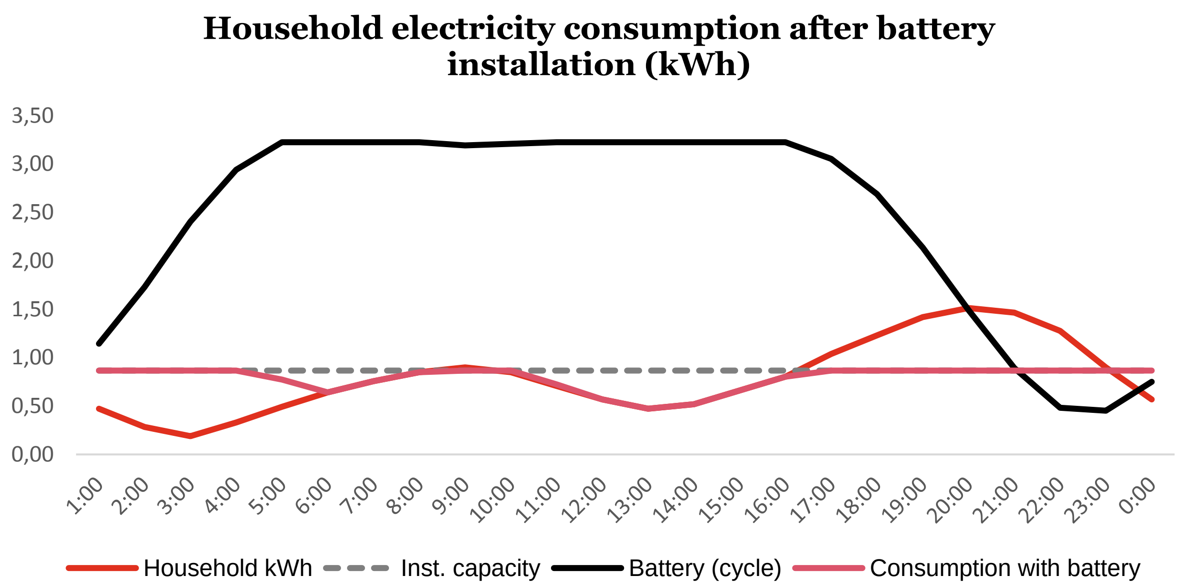
[17] As mentioned on page 45, paragraph 7
[18] As mentioned on page 45, paragraph 5
[19] As mentioned on page 45, paragraph 6

Chart 21 Model: Household electricity consumption after battery installation



Source: author's model

Chart 21 above shows how the household consumption has changed after the implementation of a home battery solution. The red curve ("Household kWh") represents the consumption of electricity within the household, as we have already observed in previous Chart 20, whereas the dashed line ("Installed capacity") shows the maximum amount of electricity the household can draw from the grid at one time.

The remaining two curves are new, and effectively explain the benefits of the battery implementation. The black curve ("Battery (cycle)") indicates how the battery is charging or discharging during the day, based on the differences between household consumption and installed capacity. The pink curve ("Consumption with battery") then shows the electricity the household actually draws from the grid during the day.

Comparison of the first and the last curve shows how the battery has flattened the consumption from the grid, thus lowered the requirements on the circuit breaker and the consumption during peak hours. However, it is clear, that the consumption is still not completely flat, as it falls down at 6:00 and 13:00. While this indicates, that the installed capacity could still be lower, it is caused intentionally by taking into account the battery efficiency[20]. In case the battery would be 100 % efficient, the household consumption from the grid would be completely flat and the installed capacity would equal average hourly consumption, 0.79 kWh.

In this block, we have established the necessary capacity of the battery, its life span and we have shown the positive impact of battery implementation on the household consumption of electricity from the grid.

[20] As mentioned on page 49, paragraphs 1 and 2

3.2.3. Tariff structure

In this block we will have a look on the structure of the electricity tariffs as it has the key determining influence on the profitability of the home batteries. The difference between the pre- and post- cost of electricity per year will serve as a basis for quantification of the return on investment and net present value of the home batteries implementation.

Apart from the actual consumption, electricity bill is determined by two things – the distribution rate and the size of the circuit breaker, both of which are being selected according to the needs of the specific household.

There are also specific additional parameters involved in the tariff structure, however these do not represent an opportunity for optimization through the implementation of battery. Therefore, while these parameters are included in the model itself in order to provide precise calculation, they will not be furthermore described within the master thesis.

Distribution rate

Simply said, distribution rate directly affects the price the household pays for electricity. It is assigned based on the electrification of the household and it governs the number of high-cost and low-cost hours during the day, as well as the price per kWh of electricity.

To provide an illustration, one of the basic distribution rates for which most of the standard flats are eligible, "D01d", contains no low-cost hours and the price per kWh is fixed at 1.44 CZK. On the other hand, families living in a house with electrical heating can opt for the rate "D35d" which includes 16 low-cost hours with price per kWh of 1.23 CZK and 8 high-cost hours with the price per kWh of 1.62 CZK.[21]

The impact of the battery from the point of view of distribution rate is such, that while the total consumption of electricity from the grid remains the same as before the battery implementation, the consumption is decreased during the high-cost hours and increased during the low-cost hours, which results in savings on the total cost of electricity.

Circuit breaker

Circuit breaker represents the fixed part of the payment for electricity, as it is a device, which governs the maximum amount of electricity which can be drawn by the household at one time. Depending on the distribution rate, the cost of circuit breaker can range anywhere from 87 to 7 187 CZK per year.[22]

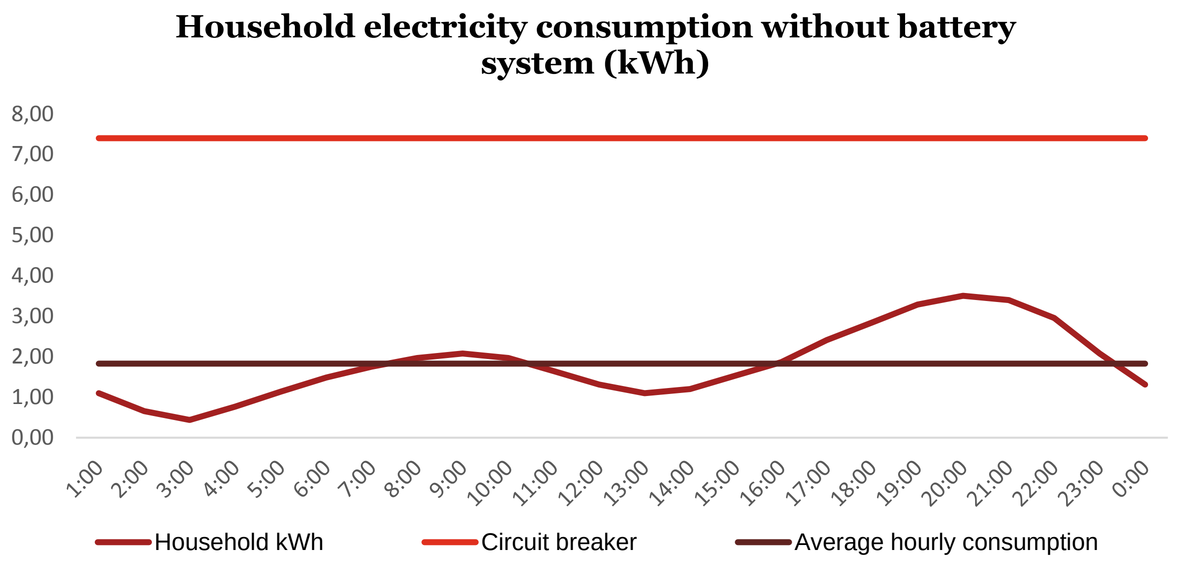
As the battery flattens the consumption curve, the peaks of consumption are eliminated, thus the size of the circuit breaker can be decreased as well, which results in additional savings on the cost of electricity.

[21] 2015 prices of a selected Czech energy provider
[22] 2015 prices of a selected Czech energy provider

Impact of battery implementation on the total electricity costs

To illustrate the impact of battery implementation on the total electricity costs of household, we will take a simple example of a family of three, living in a house with fully electric heating. Based on their electrification, they are eligible for the distribution rate "D35d" and they are using a circuit breaker which allows to draw maximum of 7.4 kWh of electricity at a time.

Chart 22 Model: Electricity costs of household without battery system



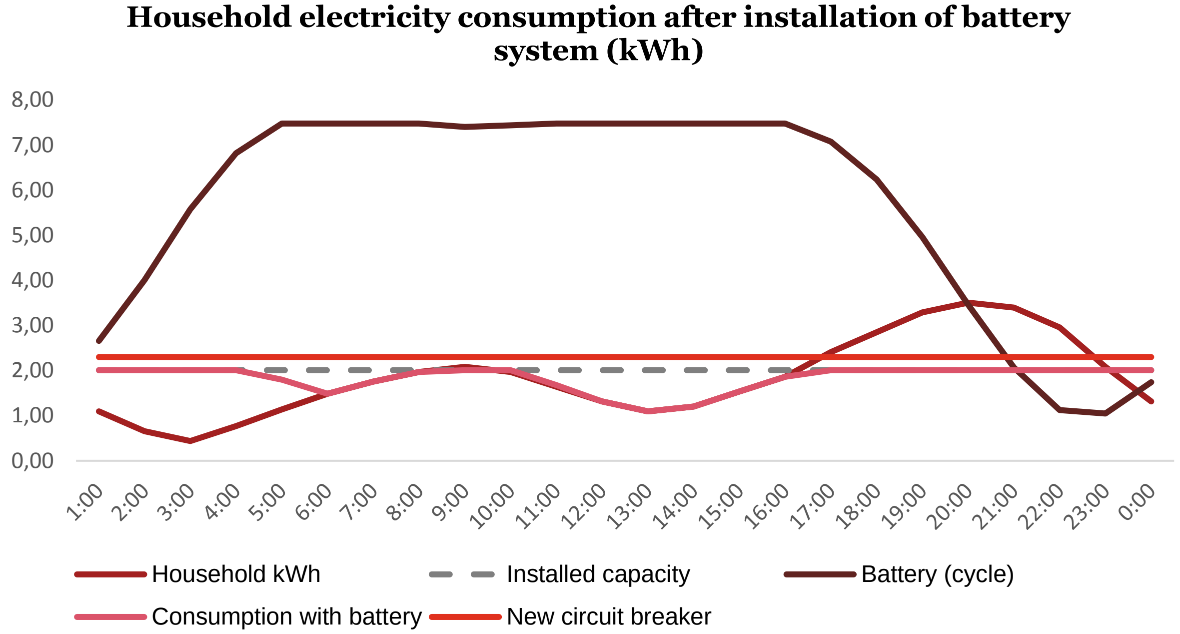
Total costs of kWh in high-cost	12 558 CZK
Total costs of kWh low-cost	11 743 CZK
Circuit breaker	4 182 CZK
Additionals	12 827 CZK
Total	**41 311 CZK**

Source: author's model

As seen in the calculation, majority of the costs come from the actual consumed electricity, whereas the circuit breaker counts only for approximately 10 % of the total costs. This is contrary to the actual costs of the electricity provider, where the costs of infrastructure (on the side of household represented by the circuit breaker) are responsible for the majority of costs.

Another important fact is the size of the circuit breaker itself, which is excessive compared to the actual consumption of household during the peak hours. This however reflects the actual situation in the market, as because of the relatively low costs for circuit breaker, households tend to overestimate its size in order to prevent power outage due to consumption in peak.

Chart 23 Model: Electricity costs of household after installation of battery system



Total costs of kWh in high-cost	9 049 CZK
Total costs of kWh low-cost	13 904 CZK
Circuit breaker	1 307 CZK
Additionals	12 827 CZK
Total	**37 087 CZK**
ANNUAL SAVINGS	**4 224 CZK**

Source: author's model

Implementation of the battery system allows to decrease the size of the circuit breaker to the level of installed capacity. However, as circuit breakers have predefined sizes, the closest one is rated at 2.3 kW, thus the additional space between the installed capacity and the circuit breaker serves as additional buffer for unexpected consumption.

As seen in the calculation, simple implementation of the battery has in this case resulted in savings of 4 224 CZK per year. This has mostly been achieved by decreasing the size of a circuit breaker and partially also by transferring part of the electricity consumption from high-cost hours to low-cost hours.

In this block we have explained the basics of tariff structure in the power sector, explained the two forms of savings coming from the implementation of a battery system and used an illustrative case, to provide a specific example of total household costs of electricity per year, both before and after the implementation of a home battery system.

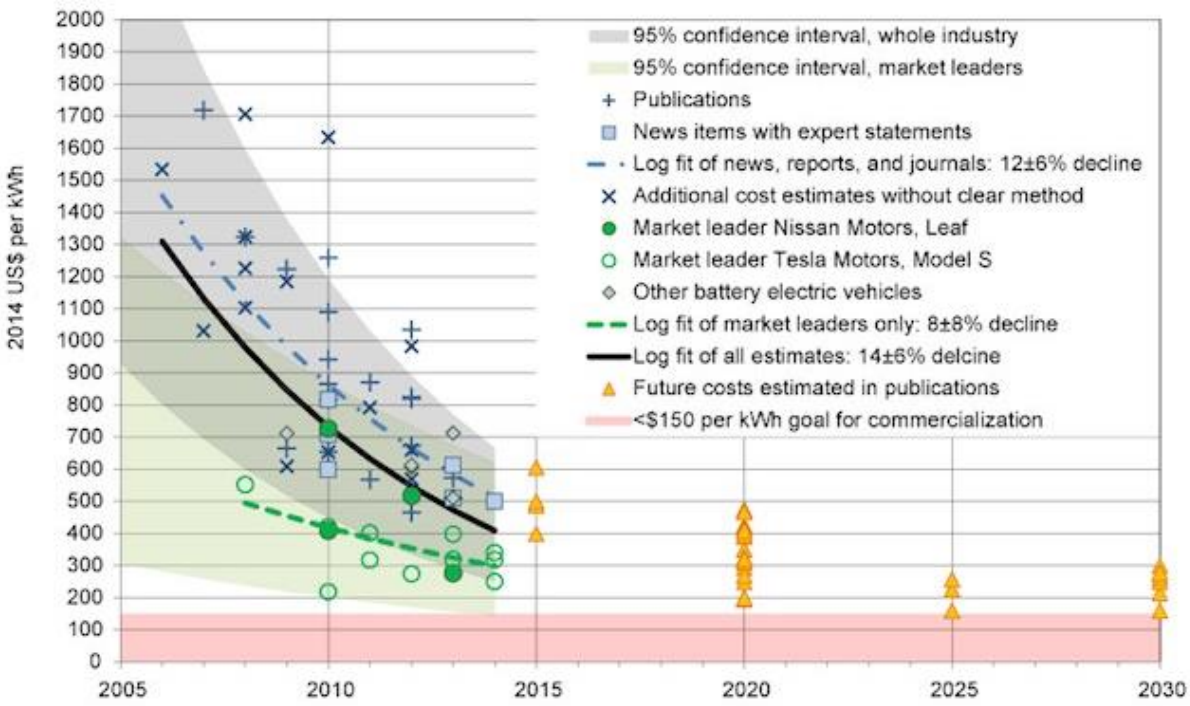
3.2.4.Economies of decision making

Forecasting the price per kWh of capacity

Up until now we have been setting up the ground for the decision making process, which will allow us to clearly decide whether or under which conditions does the battery system implementation makes financial sense.

The first thing we have to establish in this part, is that the price of batteries has been falling, and is forecasted to keep decreasing, which can be quantified in the price per kWh of battery capacity.

Picture 8 Estimates of costs of lithium-ion batteries



Source: (Nykvist & Nilsson, 2015)

Based on the data published by Nykvist and Nilsson, the model takes current development into account and further forecasts the future price development. This allows to have a specific price per kWh assigned to each year in between years 2006 to 2030.

On top of that, battery systems require not only the battery pack itself, but also a converter which transforms both the charged and discharged electricity. As the converter technology is closely related to the batteries, it is very likely that it will undergo similar development as the price per kWh. The model therefore further considers the decreasing price and recalculates it, based on the required capacity of the battery, as a price per kWh of a converter.

Summing up the price per kWh of battery and kWh of converter in each year then returns the price per kWh of the whole home battery system in respective years.

Real cost of the battery system

In order to decide out whether the implementation of the battery system makes financial sense, we need to look at it from two angles – the real cost of the battery system and the total sum of savings the system brings, which represents the maximum rational amount household should pay for the implementation.

Establishing the real cost of the battery system is rather simple, as it is only a matter of multiplying the requested capacity of the battery by the price per kWh of the battery system in current year.

Second calculation at this stage is to determine the break-even point at which would the implementation of energy storage system make sense. Calculation is again quite straightforward as we simple divide the real cost of the battery system by the life span of the battery. This returns the minimum amount of annual savings the battery needs to provide in order to make financial sense.

Savings-based cost of the battery system

Second viewpoint on the feasibility of the implementation lies in calculating the hypothetical price of the battery system, based on the total amount of savings. To do so, we need to multiply the annual savings coming from the implementation of the battery, by the lifespan of the battery system. This results in the total sum of savings over the course of life of the battery, thus also the maximum price household should pay for the battery system.

Further calculation allows us to determine the price per kWh of the battery system at which the implementation will prove profitable. This means dividing the maximum price household should pay for the battery system by the requested capacity of the battery. Model then uses the result to identify a specific year in which the implementation of the battery system breaks even.

Minimum capacity of the battery	6.50 kWh
Requested capacity of the battery	7.48 kWh
Number of charging cycles per day	1.23
Lifespan of the battery	11.18 years
Real current price of the battery system	107 559 CZK
Current price per kWh of the battery system	14 384 CZK per kWh
Break-even point (savings per year)	6 413 CZK per year
Savings based cost of the battery system	47 226 CZK
Savings based price per kWh of the battery system	6 316 CZK per kWh
Annual savings	4 224 CZK per year
Year of investment	**2024**

Source: author's model

Table above shows an illustrative calculation based on the same input values as in the chapter dedicated to tariff structure.[23] Apart from that, battery efficiency has been set to 90 % and the number of charging cycles to 5 000.

Model computed that the current price of the battery system is 107 559 CZK, while the total sum of savings the battery system provides over the course of its life is 47 226 CZK. Implementation in the year 2016 therefore does not make financial sense and due to the decreasing price of the battery system, the implementation will break even in the year 2024.

Forecast of future prices of battery system allows us to determine both the current price of the battery system and the year when the battery system broke or will break even. This means that we can effectively state, that while the implementation of the home battery system might not make financial sense today, it will turn profitable in a specific year – in the case above, 2024.

Return on investment

There are two additional criteria we should consider when deciding whether to implement the battery system, these are the return on investment and the net present value of the investment.

Return on investment is a simple indicator, which uses percentage to express the gain from the investment.

ROI = profit / investment * 100

Source: (Firemni slovnik)

From financial perspective, an investment breaks even when the ROI equals 0 %, and from then the higher the percentage, the higher the gains.

Net present value

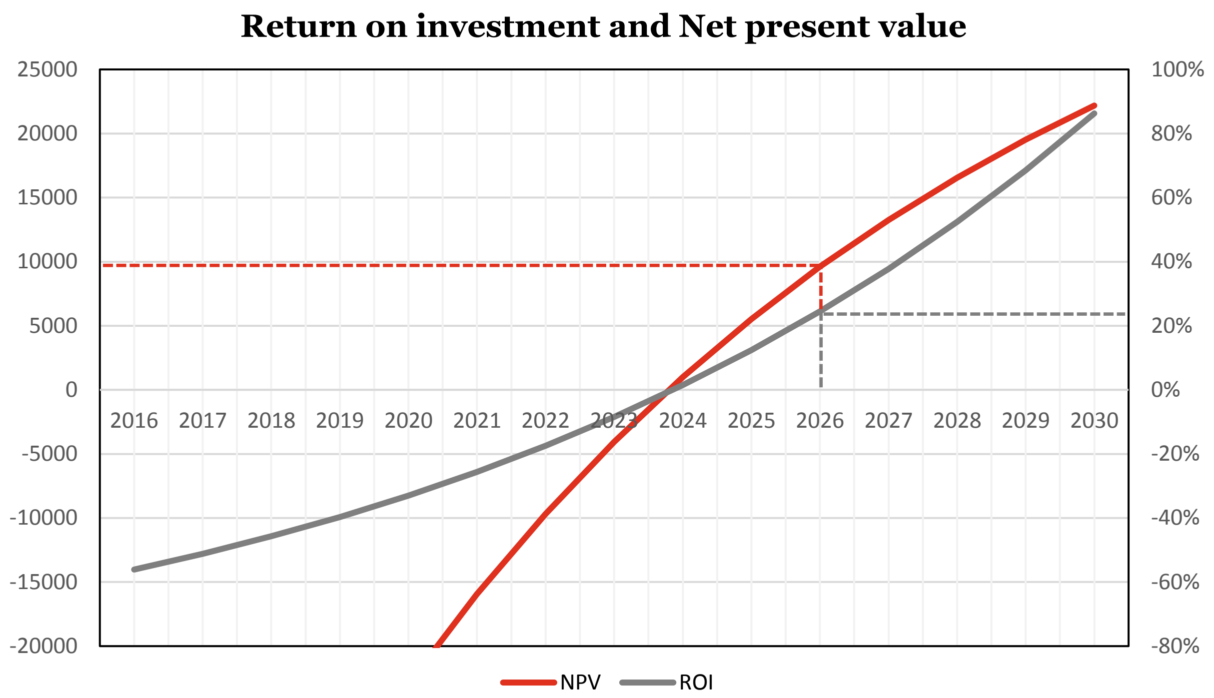
Net present value, or NPV, is used to determine the relative sum of the future cash gains coming from the investment. The sum is relative because it is converted to the current value as the cash flows are discounted by a set discount rate. In the case of the battery implementation, inflation rate has been selected as the discount rate.

$$\text{NPV} = \frac{CF_0}{(1+r)^0} + \frac{CF_1}{(1+r)^1} + \cdots + \frac{CF_t}{(1+r)^t}$$

Source: (BusinessVize, 2010)

[23] As mentioned on page 53, paragraph 1

Chart 24 Model:Return on investment and Net present value



Source: author's model

For illustration, we can continue with the case used earlier in this chapter[24] and calculate both the return on investment and net present value of the investment.

As stated already on the previous page, installation of the home battery system is not profitable in this case today, but will break even in 2024. Therefore, both the curves representing ROI and NPV intersect the axis in 2024. This means that in this year, the investment does not bring any additional value but also does not incur any loss.

If we move further in the future, we can see that postponement of the investment until the year 2026 would result in a positive ROI of 24.5 % and NPV of 9 603 CZK. This is the result of further decrease in the price per kWh of the battery system in between years 2024 and 2026.

Implementation of the concepts of return on investment and net present value within the model, allows us not only to determine in which year the investment breaks even, but also how large will be the benefits of the battery system according to the year of the implementation.

[24] As mentioned on page 57, paragraph 1

3.2.5. Case studies

The final chapter of the practical part of my master thesis will focus on the feasibility analysis of the home batteries implementation in different scenarios. In order to provide complex analysis, I will simulate 3 different scenarios of battery implementation, which will reflect three different types of households.

All of these scenarios will be based on the same setting for the specification of the energy storage system, in terms of efficiency, life-span and emergency capacity. Battery efficiency will be set to 92 %, which is a value indicated by Tesla for its Powerwall battery[25], whereas number of charging cycles will be set to 7 500 reflecting the average of Tesla's Powerwall and Sonnenbaterie systems[26], which are one of the well-established home battery systems in current market. Emergency capacity will be set to 20 % to cover short-term power outages or unexpected peaks in household consumption.

Selected scenarios represent:

1) Family of four living in an apartment
2) Family of four living in a small house
3) Family of six living in a large house

CASE STUDY 1: Family of four living in an apartment

First case study represents a typical family of four living in a standard-size apartment in a city. As the heating is often centralized or based on natural gas, in this case we do not consider electricity to be used for heating purposes.

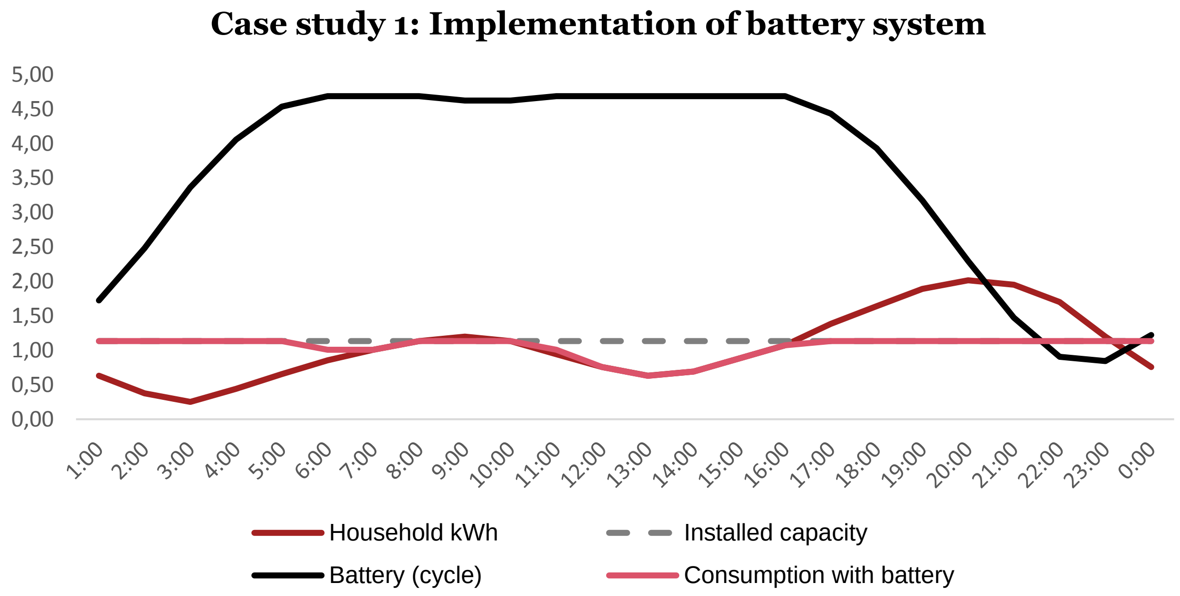
El.consumption per year	9 200 kWh
Distribution rate	D02d
Circuit breaker	above 3x16A and below 3x20A (max 4.6 kWh)
Total costs of kWh in high-cost	30 636 CZK
Total costs of kWh low-cost	0 CZK
Circuit breaker	852 CZK
Additionals	7 863 CZK
Total	**39 351 CZK**

Source: author's model

In this case the household is not eligible for a distribution rate with low-cost hours, therefore the whole electricity consumption comes at a cost of 1.44 CZK per kWh. The size of the circuit breaker is rather appropriate to the peaks in consumption and the cost of circuit breaker represents approximately 20 % of the total cost of electricity.

[25] https://www.tesla.com/powerwall
[26] https://www.sonnen-batterie.com/en-us/sonnenbatterie

Chart 25 Model: Case study 1, Implementation of battery system



Total costs of kWh in high-cost	30 636 CZK
Total costs of kWh low-cost	0 CZK
Circuit breaker	852 CZK
Additionals	7 863 CZK
Total	**38 931 CZK**
ANNUAL SAVINGS	**420 CZK**

Source: author's model

Due to the selected distribution rate, battery system implementation had no impact on the redistribution of consumption between high- and low-cost hours. Therefore the only form of savings comes from the decreased size of circuit breaker, which in total amounts to savings of 420 CZK per year.

Minimum capacity of the battery	3.91 kWh
Requested capacity of the battery	4.69 kWh
Number of charging cycles per day	1.22
Lifespan of the battery	16.90 years
Real current price of the battery system	81 259 CZK
Current price per kWh of the battery system	17 333 CZK per kWh
Break-even point (savings per year)	4 807 CZK per year
Savings based cost of the battery system	7 099 CZK
Savings based price per kWh of the battery system	1 514 CZK per kWh
Annual savings	420 CZK per year
Year of investment	**N/A**

Source: author's model

As the savings coming from the battery implementation are only 420 CZK per year, the overall savings amount to just 7 099 CZK. Given the capacity of the battery, price per kWh of the system would have to be 1 514 CZK as opposed to the 17 333 CZK of current market price. The implementation of battery system in this case therefore does not make financial sense, as the forecast of price per kWh until year 2030 does not estimate that the price would decrease enough for the investment to break even.

CASE STUDY 2: Family of four living in a small house

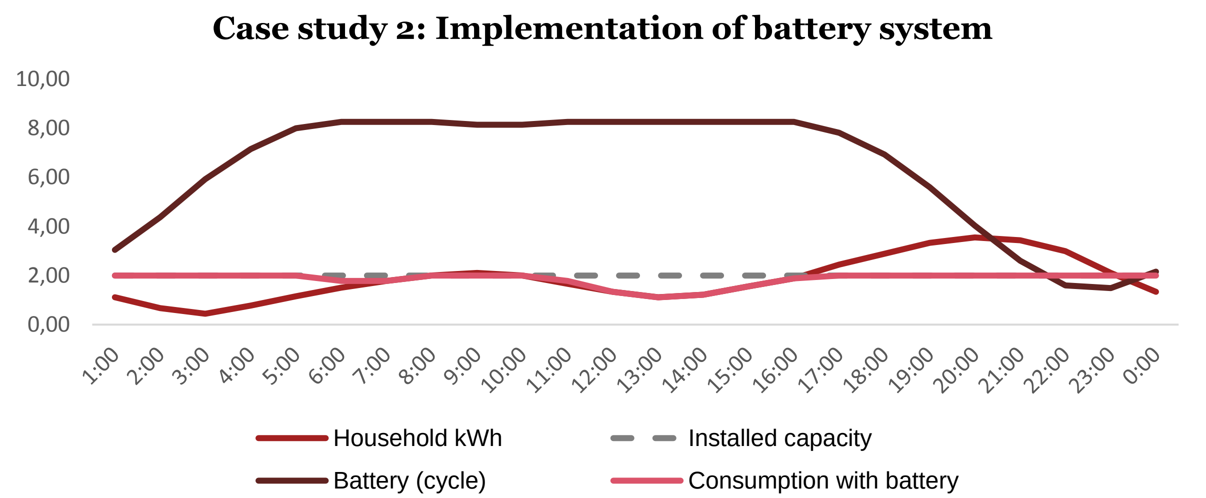
Second case study represents the same family, but this time living in a small house instead of an apartment. Therefore, this time we assume fully electric heating which will increase the electricity consumption and will enable the household to opt for a more favorable distribution rate.

El.consumption per year	16 200 kWh
Distribution rate	D26d
Circuit breaker	above 3x20A and below 3x25A (max 5.8 kWh)
Total costs of kWh in high-cost	32 015 CZK
Total costs of kWh low-cost	4 010 CZK
Circuit breaker	2 948 CZK
Additionals	12 973 CZK
Total	**51 946 CZK**

Source: author's model

This time, due to the presence of electric heating, household can opt for a distribution rate which grants it 8 hours of a low-cost electricity a day. The higher consumption also justifies a larger circuit breaker which however in this case represents only 5.66 % of total electricity costs due to the greater amount of electricity consumed.

Chart 26 Model: Case study 2, Implementation of battery system



Total costs of kWh in high-cost	26 748 CZK
Total costs of kWh low-cost	6 425 CZK
Circuit breaker	1 176 CZK
Additionals	12 973CZK
Total	**47 322 CZK**
ANNUAL SAVINGS	**4 624 CZK**

Source: author's model

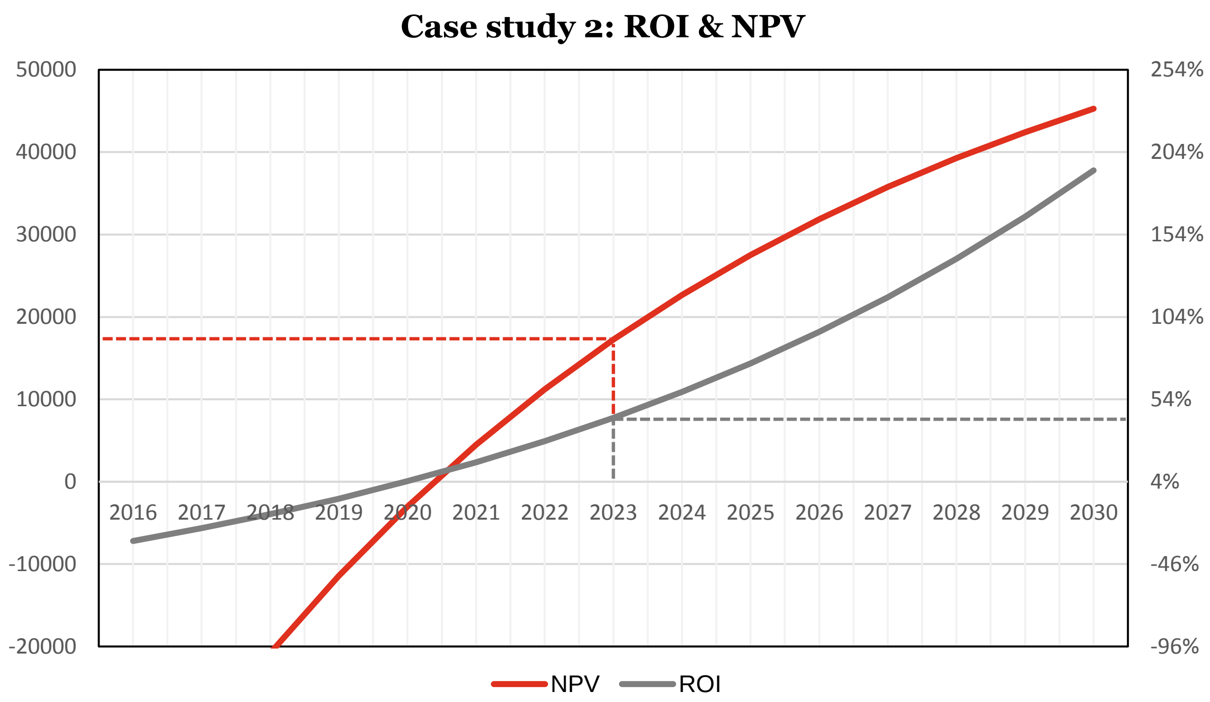
Redistribution of consumption between the high- and low-cost hours allowed for savings of 2 852 CZK and smaller size of circuit breaker granted additional savings of 1 772 CZK a year, therefore the overall savings from the implementation reach 4 624 CZK annually.

Minimum capacity of the battery	6.88 kWh
Requested capacity of the battery	8.26 kWh
Number of charging cycles per day	1.22
Lifespan of the battery	16.90 years
Real current price of the battery system	114 826 CZK
Current price per kWh of the battery system	13 917 CZK per kWh
Break-even point (savings per year)	6 797 CZK per year
Savings based cost of the battery system	78 152 CZK
Savings based price per kWh of the battery system	9 467 CZK per kWh
Annual savings	4 624 CZK per year
Year of investment	**2020**

Source: author's model

While the implementation of the home battery system is not financially rational today, the model predicts that due to the decreasing price per kWh of battery system the investment will break even in year 2020.

Chart 27 Model: Case study 2, ROI & NPV



Source: author's model

Detailed look on the development of the ROI and NPV curves clearly shows, that in year 2020 the ROI turns positive thus investment starts to make financial sense. Interestingly though, while ROI is positive already in 2020, decision based on the NPV would only approve the investment one year later in 2021.

For illustration, if the household required at least 40 % of ROI, the investment would have to be further postponed up until year 2023, when the ROI reaches 43 % and the NPV amounts to 17 247 CZK.

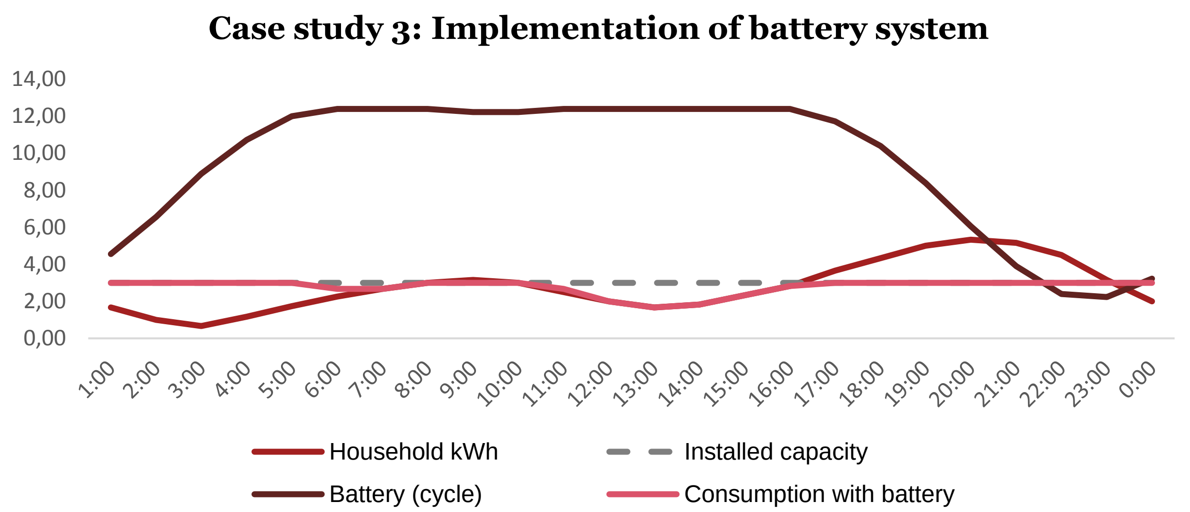
CASE STUDY 3: Family of six living in a large house

Last case study consider a larger family of six living in a large family house with fully electric heating and other electricity-heavy devices. This results in a more favorable distribution rate than in case studies 1 and 2 and also requires a larger circuit breaker.

El.consumption per year	24 300 kWh
Distribution rate	D35d
Circuit breaker	above 3x40A and below 3x50A (max 11.5 kWh)
Total costs of kWh in high-cost	19 073 CZK
Total costs of kWh low-cost	17 835 CZK
Circuit breaker	6 534 CZK
Additionals	18 886 CZK
Total	**62 328 CZK**

Source: author's model

Electric heavy appliances allow the household to use a distribution rate with 16 hours of low-cost electricity a day. High consumption also results in a much larger circuit breaker than before which costs 6 534 CZK a year in comparison to 852 CZK in the first case study.



Total costs of kWh in high-cost	13 591 CZK
Total costs of kWh low-cost	21 214 CZK
Circuit breaker	2 091 CZK
Additionals	18 886 CZK
Total	**55 782 CZK**
ANNUAL SAVINGS	**6 546 CZK**

Source: author's model

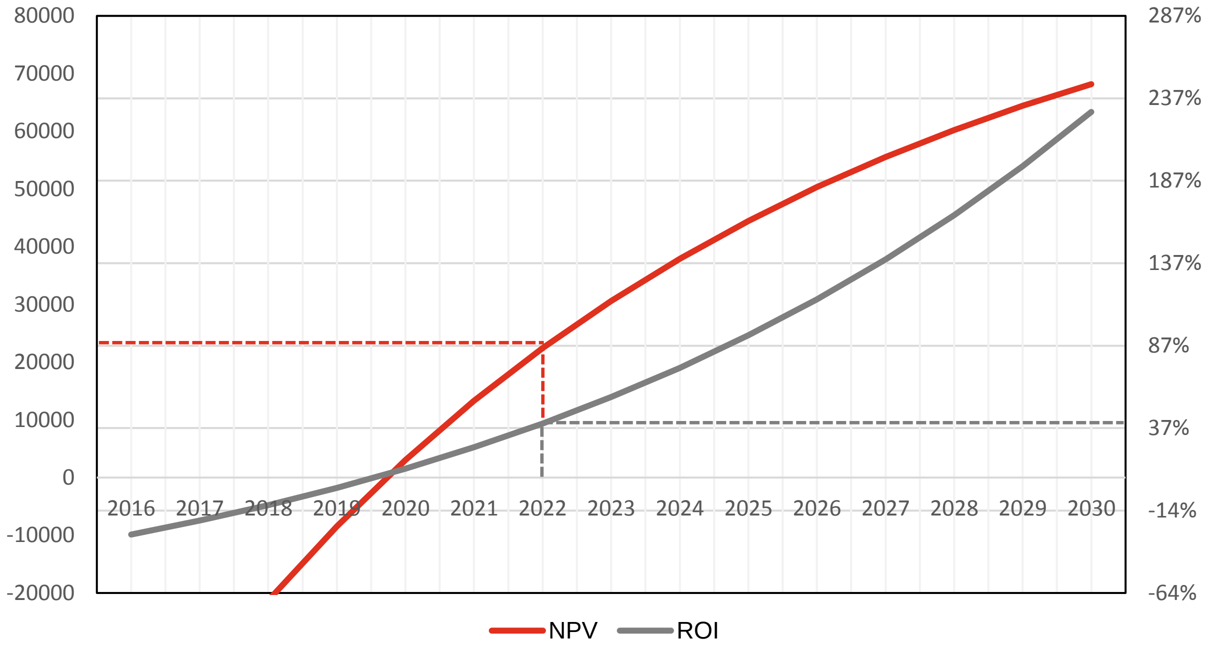
Large share of low-cost hours in D35d distribution rate resulted in savings of 2 103 CZK, while the smaller circuit breaker decreased the annual costs by additional 4 443 CZK, thus the total sum of savings on electricity due to the implementation of battery system reaches 6 546 CZK.

Minimum capacity of the battery	10.32 kWh
Requested capacity of the battery	12.38 kWh
Number of charging cycles per day	1.22
Lifespan of the battery	16.90 years
Real current price of the battery system	153 810 CZK
Current price per kWh of the battery system	12 421 CZK per kWh
Break-even point (savings per year)	9 100 CZK per year
Savings based cost of the battery system	110 649 CZK
Savings based price per kWh of the battery system	8 936 CZK per kWh
Annual savings	6 546 CZK per year
Year of investment	**2019**

Source: author's model

Similarly as in the previous case, battery implementation is not financially rational in 2016 but due do the decreasing prices per kWh of battery system the investment would break even in 2019.

Case study 2: ROI & NPV



Source: author's model

Analysis of the ROI and NPV curves confirms the break-even point in 2019 but again shows, that in order to make the investment profitable from the point of NPV, it would have to be postponed until the year 2020.

In case the household would again require at least 40 % of ROI, the investment would have to be postponed until 2022 when the ROI reaches 40.1 % and NPV amounts to 22 443 CZK.

4. Conclusion

Based on the designed model, we can now determine whether or not, do the home based batteries have the potential to significantly change the landscape of power sector.

The initial questions the master's thesis aimed to answer were:

1) Will the home batteries be the next big thing on energy markets?
2) Will the home batteries be beneficial for average household or will they develop their own market niche only for highly specific customers?
3) Will the purchase of home batteries make sense already today?

Will the home batteries be the next big thing on energy markets?

It is more than safe to state, that home batteries will definitely play an important role in the new decentralized environment of future power sector. In terms of the time shift of consumption, their biggest advantage is that they allow to significantly decrease the necessary size of the circuit breaker which brings savings both to the households and to the energy players.

Considering the fact that fixed costs, in this case simplified limited only to the circuit breaker, represent majority of overall costs on the side of the energy players, it is clear that the energy players will push the energy storage systems to the market as it will allow them to decrease their own costs.

Will the home batteries be beneficial for average household or will they develop their own market niche only for highly specific customers?

Feasibility of home batteries highly depends on the purpose of their installation. In my master thesis I have focused solely on the purpose of time-shifting the consumption, which is in its nature applicable to any household. However, I have not quantified the benefits of home batteries used in cooperation with photovoltaic systems or electric vehicles.

According to the conducted simulations in chapter "3.5.2. Case studies" it is highly unlikely that energy storage systems will be widely adopted by smaller households living in apartments where the households can only opt for the basic distribution rates without low-cost hours and where they tend to use smaller circuit breakers.

On the other hand, simulations have proven that in case of larger households with higher share of electrification (e.g. electric heating) which leads to distribution rates with high- and low-cost prices and larger circuit breakers, installation of home batteries is likely to make financial sense. The specific benefits need to be evaluated for each household separately, but based on the analyzed case studies, savings coming from redistribution of the consumption of electricity throughout the day and savings coming from decreasing the size of the circuit breaker, were sufficient on their own to justify the installation of home based energy storage system.

Will the purchase of home batteries make sense already today?

Similarly as before, answer to this question depends primarily on the purpose of the battery installation. In my master thesis I have dealt only with the time-shift of consumption, which based on the performed case studies did not prove profitable today.

However, in 2 out of 3 case studies, the investment reached its break-even point in the upcoming 3-4 years and in case the investment would be postponed up until years 2021 or 2022, it would already generate 40 % ROI.

On technological side, the major driver of the profitability of home energy storage systems will be mostly the progress in increasing their life span. Further simulations in the model, which were not included directly in the master thesis, have shown, that while 5 000 charging cycles of Tesla Powerwall were usually not sufficient to justify the investment, 10 000 charging cycles of Sonnenbaterie systems (i.e. twice the life span) were usually sufficient to reach the break-even point in most of the cases before year 2020.

Second driver of the adoption of home batteries might come from the market itself as energy players in Czech Republic are considering changing the tariff structure in order to better reflect their own cost structure[27]. The most likely outcome of the new structure would be a significant decrease in price per kWh of electricity, accompanied by a large increase in the prices of circuit breakers.

While the total costs of electricity from the point of household would remain approximately the same, circuit breaker would play a much larger role in the electricity bill. Taking into consideration that home batteries have the potential to radically decrease the necessary size of the circuit breaker, implementation of the new tariff structure would magnify the impact of home batteries implementation and radically increase the overall annual savings coming from their installation.

[27] http://www.novatarifnistruktura.cz/

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5.1. Appendixes

Table 1 Electricity generation in EU (1990 - 2040)

Electricity generation (TWh)								Shares (%)		CAGR (%)
	1990	2013	2020	2025	2030	2035	2040	2013	2040	2013-40
Total generation	**2 576**	**3 225**	**3 266**	**3 321**	**3 352**	**3 390**	**3 408**	**100**	**100**	**0,2**
Coal	1 050	905	742	571	400	276	205	28	6	-5,4
Oil	224	61	33	21	16	14	12	2	0	-6,0
Gas	193	507	497	654	683	694	693	16	20	1,2
Nuclear	795	877	863	772	785	799	777	27	23	-0,4
Hydro	290	371	380	392	400	406	411	11	12	0,4
Bioenergy	20	178	206	222	238	250	261	6	8	1,4
Wind	1	235	400	517	631	717	780	7	23	4,5
Geothermal	3	6	9	12	15	19	22	0	1	4,9
Solar PV	0	81	127	146	161	174	185	3	5	3,1
CSP	-	4	8	11	16	23	32	0	1	7,7
Marine	1	0	1	3	7	17	30	0	1	17,2

Source: (International Energy Agency, 2015)

Table 2 Electrical capacity in EU (2013 - 2040)

Electrical capacity (GW)							Shares (%)		CAGR (%)
	2013	2020	2025	2030	2035	2040	2013	2040	2013-40
Total capacity	**976**	**1 078**	**1 130**	**1 175**	**1 208**	**1 222**	**100**	**100**	**0,8**
Coal	185	164	136	113	87	77	19	6	-3,2
Oil	60	36	24	18	16	12	6	1	-5,7
Gas	214	250	285	295	307	300	22	25	1,3
Nuclear	129	124	111	112	113	110	13	9	-0,6
Hydro	150	159	164	167	169	171	15	14	0,5
Bioenergy	38	43	46	48	50	52	4	4	1,1
Wind	117	181	225	266	294	314	12	26	3,7
Geothermal	1	1	2	2	2	3	0	0	4,7
Solar PV	80	117	134	146	155	161	8	13	2,6
CSP	2	3	3	5	7	9	0	1	5,3
Marine	0	0	1	3	7	13	0	1	15,7

Source: (International Energy Agency, 2015)

Table 3 Average electricity consumption per electrified household (kWh / household)

Average electricity consumption per electrified household (kWh/household)								
	2000	2005	2010	2011	2012	2013	2014	2000 - 2014 (%/year)
World	3 166	3 335	3 327	3 298	3 325	3 350	3 353	0,4%
European Union	3 781	4 003	4 000	3 762	3 866	3 824	3 600	-0,3%
Austria	4 622	5 031	4 903	4 772	4 783	4 756	4 653	0,0%
Belgium	5 608	5 876	4 369	4 044	4 138	4 096	3 872	-2,6%
Bulgaria	3 391	3 051	3 531	3 631	3 516	3 388	3 321	-0,1%
Croatia	4 043	4 436	4 128	4 017	3 935	3 690	3 544	-0,9%
Cyprus	4 704	5 550	5 791	5 571	5 383	4 591	4 438	-0,4%
Czech Republic	3 254	3 379	3 254	3 046	3 124	3 133	3 064	-0,4%
Denmark	4 369	4 194	4 051	3 922	3 859	3 959	3 878	-0,8%
Estonia	2 498	2 840	3 487	3 321	3 348	3 182	2 957	1,2%

Finland	7 910	8 495	9 045	8 401	8 694	8 292	8 041	0,1%
France	5 178	5 202	5 793	4 990	5 569	5 859	5 036	-0,2%
Germany	3 425	3 605	3 515	3 317	3 369	3 304	3 079	-0,8%
Greece	3 713	3 938	4 023	3 899	4 271	3 922	3 758	0,1%
Hungary	2 536	2 777	2 800	2 831	2 668	2 660	2 717	0,5%
Ireland	5 184	5 269	5 295	5 020	4 896	4 730	4 723	-0,7%
Italy	2 750	2 842	2 767	2 761	2 691	2 542	2 432	-0,9%
Latvia	1 288	1 786	2 340	2 162	2 185	2 181	2 243	4,0%
Lithuania	1 310	1 654	1 948	1 990	2 002	1 951	1 999	3,1%
Luxembourg	4 650	4 578	3 968	4 038	4 243	3 952	3 795	-1,4%
Netherlands	3 191	3 404	3 325	3 171	3 331	3 323	3 291	0,2%
Poland	1 566	1 822	1 993	1 940	1 934	1 935	1 897	1,4%
Portugal	2 864	3 501	3 684	3 457	3 602	3 507	3 545	1,5%
Romania	1 057	1 269	1 578	1 631	1 695	1 673	1 674	3,3%
Slovakia	3 271	2 780	2 525	2 594	2 713	2 813	2 724	-1,3%
Slovenia	3 871	4 072	4 061	4 014	3 941	3 957	3 883	0,0%
Spain	3 365	4 126	4 334	4 312	4 203	4 040	3 944	1,1%
Sweden	9 643	9 626	8 708	7 853	8 261	8 025	7 752	-1,5%
United Kingdom	4 597	4 934	4 512	4 222	4 230	4 145	3 941	-1,1%

Source: (Energy Efficiency Indicators, 2015)

Table 4 Average revenues per household (EUR) excluding tax and levies

Average revenues from household (EUR) excluding tax and levies						
	2010	2011	2012	2013	2014	CAGR
European Union	487	482	515	523	494	0,8%
Belgium	633	636	658	648	648	0,6%
Bulgaria	238	250	248	261	229	-2,9%
Czech Republic	361	375	386	391	321	-5,0%
Denmark	422	460	436	421	403	-4,4%
Germany	485	466	485	493	442	-1,8%
Estonia	242	234	258	316	286	6,9%
Ireland	841	795	906	923	948	6,1%
Greece	392	400	455	459	452	4,2%
Spain	614	689	742	708	671	-0,8%
France	545	496	549	616	536	2,6%
Croatia	386	369	380	403	356	-1,2%
Italy	0	386	389	381	374	-1,0%
Cyprus	925	964	1259	1045	826	-5,0%
Latvia	223	207	250	210	193	-2,3%
Lithuania	186	200	209	168	179	-3,7%
Luxembourg	569	586	623	572	543	-2,5%
Hungary	378	378	315	282	257	-12,1%
Netherlands	409	397	439	439	430	2,7%
Austria	700	688	685	672	615	-3,7%
Poland	209	222	214	223	210	-1,9%
Portugal	403	351	398	424	449	8,6%
Romania	135	138	135	149	152	3,3%
Slovenia	429	433	470	466	447	1,1%
Slovakia	322	356	380	389	333	-2,1%
Finland	903	908	947	914	860	-1,8%
Sweden	1041	1081	1084	1091	980	-3,2%
United Kingdom	596	576	678	687	720	7,7%

Source: (Eurostat, 2016), (Energy Efficiency Indicators, 2015)

Table 5 Enegy players' portfolio comparison

	Company name	Photo-voltaics	El. storage	El. vehicles	Charging docks sales	Public charging stations	Heat pumps	Boilers	Heating centres	Smart metering	Smart homes
CZ	Incumbent 1	yes	no	no	yes	yes	yes	yes	no	yes	no
CZ	Incumbent 2	yes	no	no	yes	yes	yes	yes	yes	no	no
CZ	Incumbent 3	yes	no	no	yes	yes	yes	yes	no	yes	yes
CZ	New entrant 1	no	no	no	no	no	no	no	no	no	no
CZ	New entrant 2	yes	no	no	no	no	yes	no	no	no	no
GB	Incumbent 1	yes	no	no	no	no	yes	no	no	yes	yes
GB	Incumbent 2	yes	no	no	no	no	yes	yes	yes	yes	yes
GB	Incumbent 3	yes	no	no	yes	no	yes	no	yes	yes	yes
GB	Incumbent 4	yes	yes	no	yes	no	yes	yes	yes	yes	yes
AT	Incumbent 1	yes	no	no	yes	yes	no	no	yes	yes	yes
AT	Incumbent 2	yes	yes	no	yes	yes	yes	no	no	yes	yes
AT	Incumbent 3	yes	no	no	yes	yes	yes	no	no	no	yes
AT	Incumbent 4	no	no	no	no	yes	yes	no	no	no	no
AT	New entrant 1	no	no	no	no	no	no	no	no	yes	no
AT	New entrant 2	yes	no	no	yes	yes	yes	no	yes	yes	no
AT	New entrant 3	no	no	no	yes	yes	yes	no	no	yes	no
DE	Incumbent 1	yes	no	no	yes	yes	yes	no	no	yes	yes
DE	Incumbent 2	yes	yes	no	yes	yes	yes	no	no	yes	yes
DE	Incumbent 3	yes	yes	no	yes	yes	no	no	no	yes	yes
DE	New entrant 1	no	no	no	no	no	yes	no	no	yes	no
DE	New entrant 2	yes	no	no	no	yes	no	no	no	no	no
DE	New entrant 3	no	no	no	yes	yes	no	no	no	yes	yes

Source: (company websites)

5.2. Table of figures