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Business Models in Smart Grids

A residential sector focused Energy Service Company

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BUSINESS MODELS IN SMART GRIDS

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Master Thesis

by

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Abstract

As pointed out by several experts of the Norwegian energy market, there are areas in the Norwegian grid where the load is close to exceed the grid capacity. This local situations are important because grid reinforcements are fairly expensive. Moreover, the electricity demand is expected to rise due to electric mobility.

The problem has been analyzed in regions like Florø in Norway, Gotland in Sweden and several other places. The literature analyzes how demand-side flexibility could be extracted by means of stochastic programming, solved from the customer's as well as the company's perspective. Mostly, papers focus on the technical implementation of realizing demand side management (DSM), contracting and supply chain integration. Very few literature about energy service companies (ESCO) in Norway exist. General papers on ESCOs focus on commercial, industrial and municipal customers and describe ESCOs on a more aggregated level. However, the literature fails to address the following: Are these new business models profitable? The objective of this thesis is to analyse whether the business model of an ESCO can work profitable in the exemplary case study region of Florø.

The energy supply chain is analyzed to understand the interaction with a new market player. The case specific business model of an ESCO is generated with the business model canvas. The ESCO is defined as a business model that combines the different services: installation of information and communication technologies (for DSM), micro-combined heat and power (CHP) systems and charging of electric vehicles (EV) as well as the management of these devices. Since the Florø case study provides good conditions to analyze the practicability of an ESCO it is used to model penetration levels of EVs and micro-CHP systems. Furthermore, the effects of DSM and energy saving measurements are calculated. For information on costs, different surveys, studies and papers are used. Combining costs and revenues leads to possible offers of the ESCO for the residential end-customers.

The calculation shows that the business model of an ESCO – under certain conditions – can operate profitable. This is especially because of the assumption that the local distribution system operator (DSO) is willing to pay for provided flexibility. Using this flexibility, grid reinforcements can be postponed. Offers of the ESCO that only contain DSM are basically unprofitable. The more technology a customer installs, the higher the savings for him or her and the higher are the profits for the ESCO due to synergies. The practicability of an ESCO in the German context is identified as critical due to missing DSO payments.

Contents

List of Abbreviations

AC: Alternating Current
ADCC: automation devices enabling communication and control
AMI: advanced Metering Infrastructure
AMM: automatic meter management
AMR: automated meter reading

BEV: battery electric vehicles
BMS: battery management system
BnetzA: Federal Network Agency for Electricity, Gas, Telecommunication, Posts and Railway/Bundesnetzagentur

CAPEX: Capital Expenditures
CCHP: combined cold, heat and power
CEER: Council of European Energy Regulators
CHP: combined heat and power
CPP: Critical peak pricing
CWE: central-western European

DC: Direct Current
DER: Distributed energy resources
DG: distributed generation
DLC: Direct load control
DMFC: methanol fuel cells
DSM: demand side management
DSO: distribution system operator

EEX: European energy exchange
EFET: European Federation of Energy Traders
EPC: Energy Performance Contracting
EPEX SPOT: European Power Exchange
ESCO: Energy Service Company
EV: Electric Vehicles

HAN: home area network

ICE: internal combustion engine
ICT: Information and Communication Technology

KfW: German reconstruction loan corporation/Kreditanstalt für Wiederaufbau

LAN: local area network
LPX: Leipzig power exchange

MoU: memorandum of understanding

NPV: net present value
NVE: Norwegian Water Resources and Energy Directorate/Norges vassdrags- og energiedirektorat

OPEX: operational expenses
OTC: over the-the-counter

PEM: Polymer Electrolyte Membrane
PEMFC: Proton Exchange Membrane Fuel Cells
PHEV: plug-in hybrid electric vehicle
PV: photovoltaic

REC: renewable energy certificates
ROE: return on equity
RTP: Real-time pricing

SFE: Sogn og Fjordane Energie
SOC: state of charge
SOFC: Solid Oxide Fuel Cells

Time of use: Time of use
ToD: Time of Day
TSO: transmission system operator

V2G: vehicle to grid
VMS: vehicle management system
VPP: virtual power plant

WLAN: wireless local areanetwork

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1 Introduction

> “Energy is liberated matter, matter is energy waiting to happen.”
> – Bill Bryson, a Short History of Nearly Everything

The universe is full of energy and matter and there is so much that in two billion years the earth’s oceans will be boil and no life can be expected to be there anymore. At the moment, however, humanity address less dramatic questions: How we can meet our energy demand of today and how can we keep our planet working in the short term.

Increasing energy demand due to an increasing number of EV and other electrical appliances and greater environmentalism caused rethinking. Whereas in Germany the so called “Energiewende” is supposed to promote new technologies to change the fossil fuel based supply towards a sustainable provision of energy, Norway is already a step further. Based on nearly 100 % hydro power, carbon-free, electricity production, policy is focussing on cutting emissions in the transport sector by promoting EV and investing in information and communication technology (ICT) to smarten the demand side.

When the energy demand increases in Norway more production and more transmission capacity is needed. Since additional production capacity is available, especially the latter can simply be solved by building up new transmission lines. Another option is demand side management (DSM) Giving the end-customer incentives to smooth demand, cut off peaks and, as a result, avoid expensive grid reinforcements for the distribution system operator (DSO) is a well investigated procedure.

When additional decentralized renewable production capacity enters the German market because of the “Energiewende”, the long-distance transmission lines as well as the distribution grids are increasingly stress. The options are again grid reinforcement or DSM. Although or different reasons, both countries face similar challenges and therefore can learn from each other.

How can we overcome the dilemma in which, on the one hand the customer considers energy as a “low interest” good and, on the other hand the customer has more and more weight for the whole supply chain? Demand and supply close ranks and shift closer towards the end-customer; decentralized generation and smart meters are no loanwords anymore. To master this difficulty the customers need to be seen in the whole context of the energy supply chain. Diverse changes have taken place on the energy market and influenced the different stages of the supply chain.

1.1 Research Question

As pointed out by several experts of the Norwegian energy market there are areas in the Norwegian grid where the load is close to exceed the grid capacity. To put more emphasis on this local situations is important because grid reinforcement are fairly expensive. Moreover, the electricity demand is expected to rise. DSM, EV as well as micro-combined heat and power (CHP) systems are powerful tools to help smooth the grid load, cut off peaks and as a result postpone grid extensions.

The problem has been analyzed in regions like Florø in Norway, Gotland in Sweden and several other places. The literature analyses how demand-side flexibility could be extracted by means of stochastic programming, solved from the customer's as well as the company's perspective. It has been investigated what contracts should be offered, how the whole supply chain can be improved and what new market participants like aggregators or Energy Service Companies (ESCO) could look like.

Mostly these papers focus on the technical implementation of realizing DSM, contracting, supply chain integration and so on; however, the literature fails to address the following: How can the research results be transferred and realized? How should new market players be shaped? What new business models are possible? Are these new business models profitable?

1.2 Drivers

The objective of this thesis is to analyses whether the business model of an ESCO can work profitable in the exemplary case study region of Florø. An ESCO combines different services: installation of ICT (for DSM), micro-CHP and load infrastructure for EV as well as the management of these devices. On the Norwegian island Florø the transmission capacity is insufficient and the local utility, Sogn og Fjordane Energi, is responsible for guaranteeing supply security. In order to cope with the bottleneck, the utility wants to investigate flexibility contracts with end-customers to bridge the time until the grid reinforcement. The Florø case study provides good conditions to analyses the practicability of an ESCO.

1.3 Outcomes

This paper will analyze the business model of an ESCO in detail. The structure will be analyzed with a business generation model and the profitability will be tested with real data from the city Florø in Norway. Revenue streams and costs will be modelled in a rather simplified model to cope with complexity. This thesis will show whether an ESCO will be able operate profitable and what drawbacks, risks and chances exist.

1.4 Outline

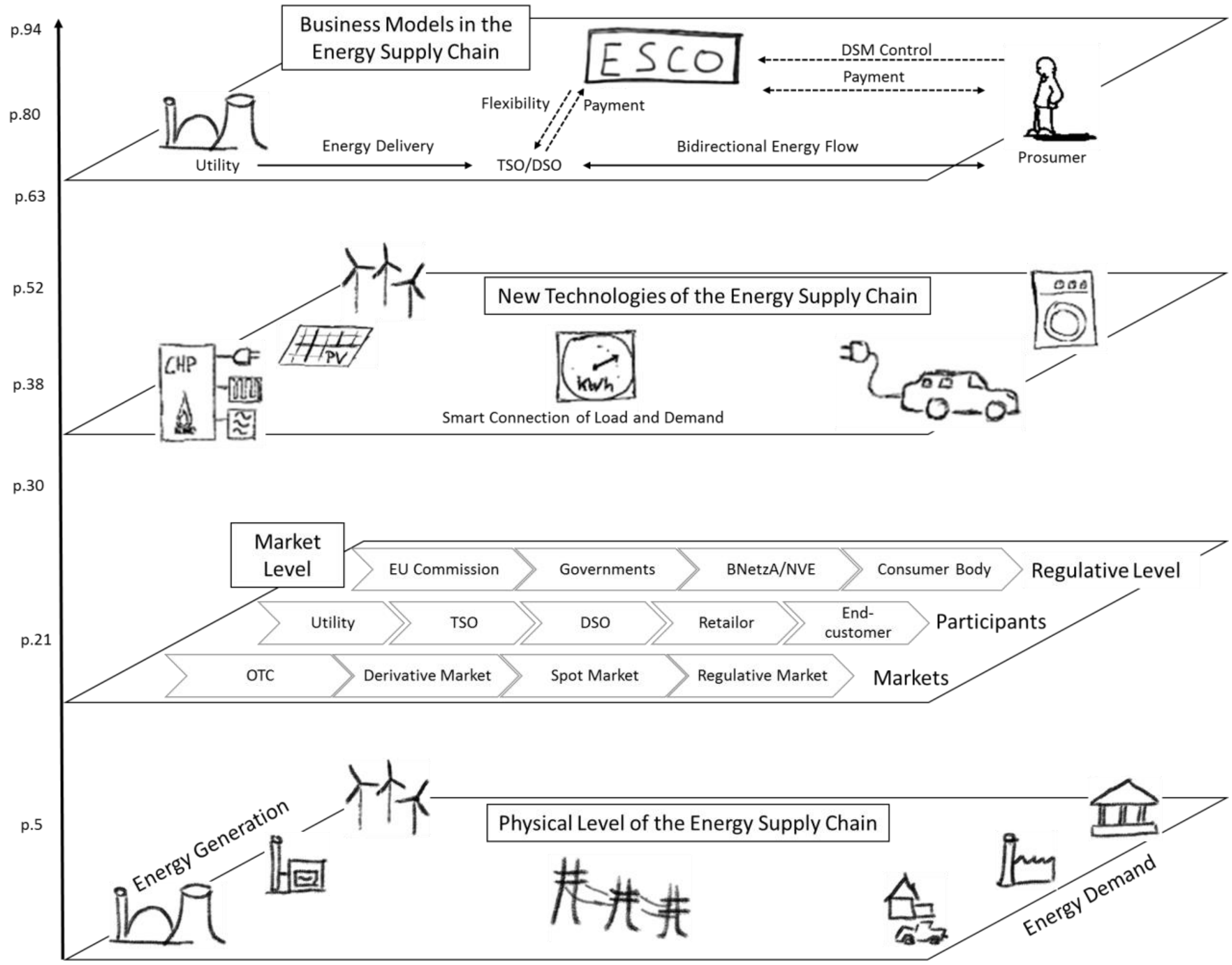

Figure 1 Overview of the Thesis

The structure of this thesis can be seen in Figure 1, beginning with the first level and chapter 2, the physical part of the energy supply chain. On the left side the upstream part is depicted with the different generation types: large scale generation, medium sized generation and small scale decentralized generation. Following the horizontal axis along the supply chain: transmission, distribution and the consumption side with households, industry and services are depicted. Also described in chapter two is the market level of the energy market shown on the second level of figure 1 especially dealing with trading, procurement, markets, electricity pricing and the participants on the markets.

Chapter 3, 4 and 5 describe new technologies of the energy market. They are aligned along the supply chain on the third level of figure 1. In the middle and discussed in chapter 3 are smart grids, including DSM, smart homes, smart meters and the internet of things. On the downstream side EV have potential to influence the whole supply chain. Today's EV penetration, the battery, influences of EV on the grid and EV business models are discussed in chapter 4. To the left and described in chapter 5, micro-CHP systems are analyzed in terms of control strategies, costs, incentives, network integration, DSM and contracting.

The topmost level of Figure 1 shows the business model of an ESCO giving an overview over chapter 6, 7 and 8. Chapter 6 gives information about business models like definition, design, frameworks and an overview of the business model canvas. The case study in chapter 7 is of further important because it leads the reader through the case description and the results regarding micro-CHP, energy savings, load shift potential and EV as storage potential in the case study region Florø. Chapter 8, business plan ESCO, includes the results of the case study and the information from the previous chapters to create a business model focused on the area of Florø but applicable to other regions. The subtopics of the chapter are an introduction into similar business models, the market situation, competitors, unique selling proposition, customer segments as well as a finance plan including ICT, EV, CHP, further incomes and customer price offers.

Chapter 9, conclusion, will conclude the thesis and gives information about lessons learned for Norway and Germany.

2 Electricity Value Chain

The supply chain of the energy production always includes the following steps:

1. The use of energy carriers, either free or purchasable,
2. the transmission into a superior form of energy (e. g. electric power)
3. the transfer of this energy to the end customers and
4. the local usage of the energy service itself.

These steps will be discussed in detail in the following chapter. This is important because of changes on the energy market and changes anywhere in the supply chain most probably influence other parts of the supply chain and all need to be revised and adjusted.

Exemplary in **Germany**, the demand for more environmentally friendly electricity drives a change towards renewable energy carriers. Great amounts of wind and solar power haves been added to the system. Since electric power cannot be stored sufficiently, production and demand, although fluctuating wind and solar power, need to be equal all the time. Since production is not freely adjustable anymore, there are three ways to deal with the problem of matching supply and demand: 1. Over-capacity which can always meet the peak demand, adaptability provided by adjustable production, 2. expensive energy storage capacities and 3. adjustment of the demand towards the fluctuating production. All three possibilities sound either unrealistic or expensive.

In **Norway** the energy system seems to be perfect - a 99 % satisfaction of electricity demand by cheap and flexible hydropower. But nonetheless a spatially extended grid with comparably small loads, a growth in energy consumption and an additional cross-border integration weaken the grid. The government stresses a grid expansion and customer participation. The former composed of upgrading the existing and the construction of new domestic as well as cross-border connections. Furthermore, a smoothing of demand in order to diminish maximum load times and therefore reduce the needed additional grid capacity. This is seen as a practicable way to reduce grid investments.

Norway and Germany face different problems but the solution process leads to similar actions to be taken. This is why both countries can learn from each other that explains precisely why this thesis tries to focus on a solution for variable problems.

A study conducted by Droste-Franke et al. (2012) shows that an amount of 7 to 18 GW of secured production capacity is lacking in Germany which has to be covered with additional generation, storage, load control or imports. DSM, Electric Vehicles (EV) and CHP are key factors to handle the fluctuating energy production of renewable energies like wind and PV.

The subchapters are structured in way that the reader can firstly get an overview of the technology, is then form about challenges and finally gets to know which participants can be found on the respective part of the energy value chain.

2.1 Generation

The generation part of the electricity value chain can be split up in centralized and decentralized generation. The biggest share of production capacity is run by big integrated utilities. The market is supposed to be under full competition. In reality the huge energy utilities in Germany as well as in Norway still have great market power (Bundeskartellamt 2014).

2.1.1 LARGE SCALE

In central European countries energy has traditionally been produced in big centralized power plants. These power plants use either lignite, hard coal or uranium as input factors to produce a heat source. In a generator, the generated hot steam is transferred into electricity which is fed into the transmission grid. Large scale power plants have the advantage of economies of scale and provide energy to low production costs. They are mostly used for medium and base load. Disadvantages are the slow reaction time that makes them unfeasible for peak load production, the raw material dependence, the huge environmental burden, the risk of a nuclear disaster and an extensive power grid that conducts the centrally produced energy to the distributed energy consumers. Other large scale generation plants are off-shore wind parks and hydro power plants. Whereas hydro power plants are flexible, off-shore wind parks follow the wind forecast.

2.1.2 DISTRIBUTED

The distributed generation (DG) is at most times connected on a low voltage level to the distribution grid. The distribution grid, normally designed to deliver energy to the customers, is now stressed by additional distributional generation, especially in Germany. This can have positive and negative effects on the grid. On the one hand, negative effects are for example: instability, problems with the power quality, negative flows, and higher transmission cost when DG is not fed-in at places of great load. On the other hand, positive effects are a reduction of transmission and distribution losses when load and generation move together and the energy flows through transformers and conductors are reduced. Any distributed production that can distribute expansive peak loads can additionally reduce distribution and operating losses as well as reduce the stress factor on the grid and postpone necessary transmission capacity investments. Decentralized generation can offer ancillary services to the network operator like reactive power support, voltage control and improving power quality (Donkelaar, Scheepers 2004, pp. 19–21).

2.2 Transmission and Distribution

The **German** alternating current (AC) grid is categorized by voltage:

1. Transmission grid: 220-380 kV
2. Distribution grid: 110 kV
3. Medium voltage grid: 1-30 kV
4. Low-voltage grid: 230 V or 400 V

Problems are mainly the additional decentralized generation of renewable energies. The DSM of the integration of renewable energies is limited by restrictions of the distribution grid.

The **Norwegian** network is also voltage categorized. It has an AC grid with a few direct current (DC) connections to Denmark and the Netherlands.

1. Main grid: 132-420 kV
2. Regional grid 22-132 kV
3. Local distribution grid: 11-22 kV
4. Low-voltage distribution grid 230 V or 400V

Problems in the Norwegian grid are the provision of reactive power and capacity limits in the network.

Especially in Germany the increased connection of decentralized capacity to the low voltage grids contains opportunities and threats. An energy production close to the customer can on the one hand reduce transportation costs, ease peak time loads and can avoid expensive network expansion. On the other hand feeding into the local grid can challenge the network operation. This means alternating power flows, equipment loading, voltage retention and available short-circuit power (Droste-Franke et al. 2012, p. 144). But a lot of problems just occur when the locally fed-in electricity exceeds local demand. This is basically the case in some regions in Germany with high photovoltaic (PV) capacity but normally not in Norway.

The participants on the transmission and distribution part of the supply chain are regulators and grid companies.

The role of the **regulator** is taken by the governments or government assigned institutions. On the European level this job is done by the Council of European Energy Regulators (CEER). CEER is a coalition of the local European regulators which have the overall target to create a single, competitive and sustainable market for electricity and gas in Europe. The German representative is the Federal Network Agency for Electricity, Gas, Telecommunication, Posts and Railway/Bundesnetzagentur (BnetzA). The BNetzA is especially responsible for all sectors with monopolistic structures in Germany. Norway is represented by the Norwegian Water Resources and Energy Directorate/Norges vassdrags- og energiedirektorat (NVE). The institutions regulate and implement frameworks to make the energy market as efficient as possible. Besides other things the BNetzA and the NVE regulate their local transmission system operators (TSO).

Grid companies manage the network and have two roles:

a) They are responsible as a monopolist for transmission, metering and supervision.
b) Further they are a service provider for installing measuring equipment, implementing changes due to power supply and connecting customers to the grid.

Grid companies can be separated by spatial extension into TSO and DSO. The transmission grid is affiliated to an integrated network, the natural monopoly. The TSO runs this monopoly and is therefore regulated by the local regulator (mentioned above). Mostly a kind of revenue cap regulation is implemented to limit profits, ensure a welfare optimized supply and guarantee that necessary investments are made. In Germany about 890 (BNetzA 2014) and in Norway about 160 (NVE 2010, p. 15) small DSO ensure the energy distribution to the end customer. DSOs are also the above mentioned service provider for the power supplier.

2.3 Trading and Procurement

2.3.1 UNBUNDLING AND LIBERALIZATION IN EUROPE

This part gives a short overview about the milestones of the European power market liberalization and why participants of energy markets often lament over strong regulations.

The German energy company EnBW Energy Baden-Württemberg AG states that about 60 % of its business is under governmental influence. This is because of the importance of the supply security, its partly monopolistic structure and the historical background. In 1997 the EU electricity directive demanded that 33 % of the energy market should be open till 2003. Subsequently in 1999 the European Federation of Energy Traders (EFET) was founded and the first online trading platform Enron Online commenced operation. After that in the year 2000 the Leipzig power exchange (LPX) and the European energy exchange (EEX) that merged in 2002 followed by the Nord Pool Spot in 2002, that offers both day-ahead and intraday markets, were founded. In 2003 the EU-"speed-up"-policy determined a 100 %

market opening till 7/2007 and a third-party access till 4/2004. The memorandum of understanding (MoU) in 2007 lead to market coupling on the central-western European (CWE) market which means that the pricing and the amount of transport capacity needed are allocated at the same time. In the year 2008 a joint allocation of interconnector capacity for CWE and an approach to find prices on the local spot markets took place. Furthermore in 2008 the European Power Exchange (EPEX SPOT) for spot trading was founded.

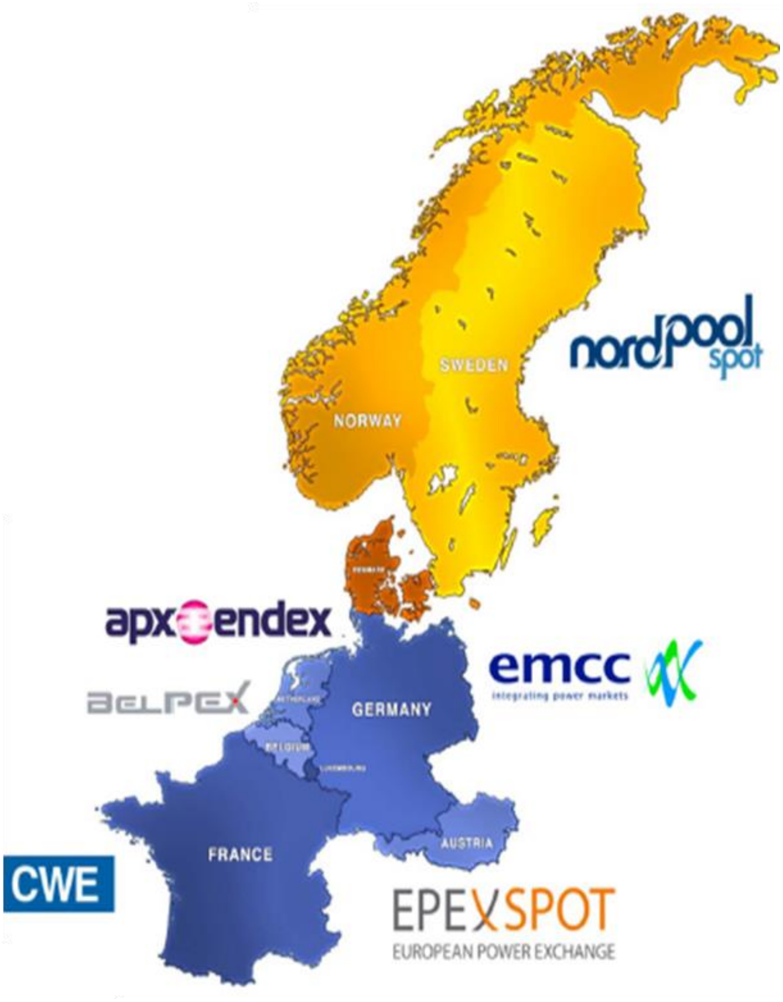

Figure 2 Energy Markets in Europe,
Source: (Jasper 2012)

Today, the huge European wholesale energy markets have a heterogenic structure and many liquid market participants like banks, utilities, oil and gas companies, as well as other small and big market players participate. The four most important trade centers for energy in Europe by turnover are: the ICE energy exchange including Brent North Sea oil, the continental European futures market EEX in Leipzig, the continental European spot market EPEX in Paris, as well as the main power exchange in Scandinavia Nord Pool.

2.3.2 MARKETS

2.3.2.1 Perfect Markets

A market is a place where supply and demand meet. Prices are determined and transactions conducted (BusinessDicttionary.com 2014). The ideal scenario is a market with perfect competition. The postulations for such markets are:

1. all goods are homogeneous, which means that
2. the goods have always the same attributes,
3. are divisible,
4. cause no transport costs and
5. through full transparency all information is always available for everybody on the market.

Macro-economic theory shows that perfect competition leads to a pareto-optimal equilibrium of supply and demand (Malinvaud 1972). This Pareto optimum is defined as a “state in which nobody’s utility can be improved without somebody else’s utility being degraded.” (Droste-Franke et al. 2012, p. 10) This optimum also reflects the optimum welfare of a society as a whole (Kailitz 2007).

The conditions for perfect markets are well known, but no real market fulfils all requirements and is therefore imperfect. Normally markets don’t need to be perfect as long as they fulfil the postulations to some extent.

2.3.2.2 What is special about energy markets?

1. Power as well as gas transports are grid-bounded. That means that the size of every market depends on the transmission capacity between and the storage capacity in the different regions.
2. The production capacity always has to exceed the demand. For power markets the production always has to follow exactly the volatile demand because of limited storage possibilities. This is realized by the TSO who is responsible for balancing and managing of the accounting grid.
3. While oil and CO_2 just have a spot and a futures market, the power market is sorted by maturity. It is split up into futures market, spot market, intraday market, after-day market and control energy market.

2.3.2.3 The economic role of energy markets

1. Allocation function: The wholesale spot market ensures an optimal use of resources in the short-term because only the most efficient plants with marginal costs under the market clearing price are used (merit order curve).

2. Long-term control and steering function: The derivative markets give price signals for future investments based on the long-term marginal costs.
3. Risk management function: By transferring price risks, the risks of the system can be balanced.

2.3.2.4 The environmental role of energy markets

For energy markets the environment is basically an external factor. In economics that is called an externality, whereby the externality itself is the cost or benefit that affects a party who did not choose to incur that cost or benefit (Buchanan, Stubblebine 1962). Down the road everything is about sustainability. “Sustainable development means to implement a growth that meets the need of the present without compromising the ability of future generations to meet their own needs.” (United Nations 1987) In other words it is worthwhile to ensure that future generations will have the same chances and resources as we have today. Environmental pollution as well as the exploitation of natural resources do play a role.

Steger et al. 2005) suggests a classification for a long-lasting energy system development. In his analysis he distinguishes three categories:

1. protection of the environment,
2. availability of resources (availability of inputs) and
3. design of the energy systems with respect to society.

Firstly, the protection of the environment includes four critical points (Droste-Franke et al. 2012, p. 10):

a) eutrophication and acidification due to environmental pollution,
b) land use,
c) depletion of the stratospheric ozone layer and
d) the greenhouse effect. Especially carbon dioxide needs to be considered when talking about environmental aspects, see Figure 3.

In this context the following graph shows the different CO_2 emissions per capita and GDP of Norway and Germany. Since Germany’s effort to reduce CO_2 emissions have increased in the past ten years its CO_2 emissions per person are slightly lower than those in Norway, although both countries still have a long way to go. Protection of the environment will be included in every business model analyzed in this paper.

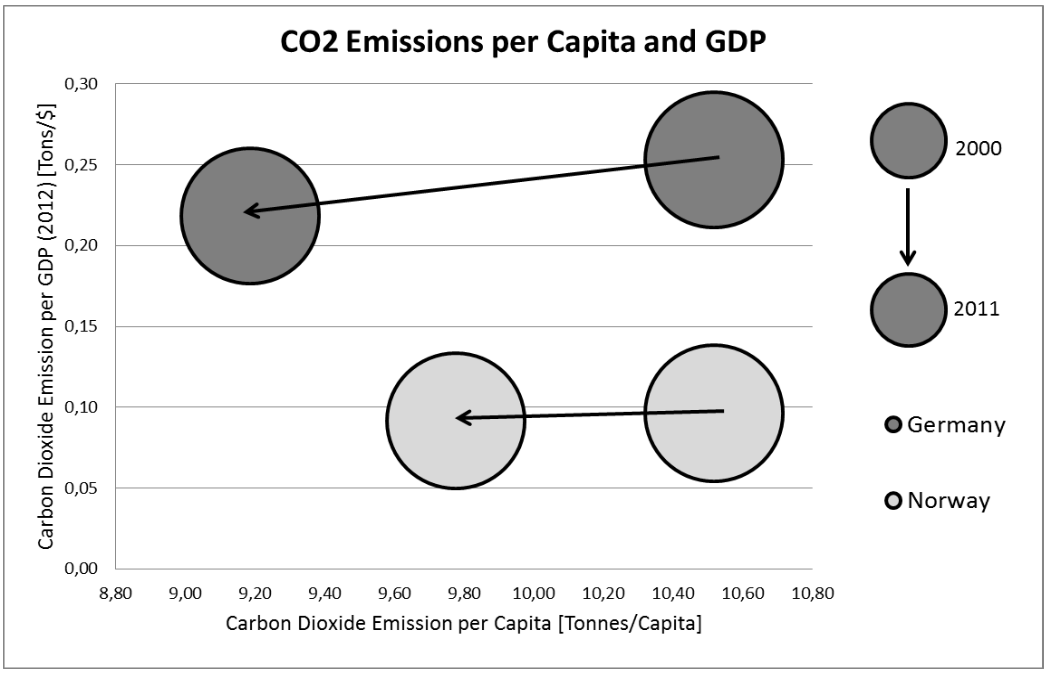

Figure 3 CO_2 Emissions per Capita and GDP in Germany and Norway,
Data from (International Energy Agency 2013)

Secondly, the availability of resources basically requires an evaluation of:

a) is the resource under competition with other utilizations,
b) is the resource limited or renewable and
c) how big is the resource.

Whereas Germany has quite limited resources of wind, sun, biomass and some lignite, Norway has access to great renewable as well as fossil resources. The potential for wind, water and biomass is huge (International Energy Agency 2013).

Thirdly, the design of the energy systems with respect to society plays an important role. As mentioned the society demands well-priced, environmentally friendly and secure energy supply. Besides that, Germany faces the challenge that not just because of the climate change but also because of steadily increasing prices for energy resources, it will have to rethink and ensure its future energy supply in a cost efficient way.

2.3.2.5 Participants on the energy markets

The **power suppliers** buy the energy over the counter or on the energy stock market and sell it to the end customers. Utility companies combine the job of producers and suppliers. The biggest utility companies on these two markets in Norway and Germany are Statkraft, E.ON, RWE, EnBW and Vattenfall.

Traders do physical and financial trade. They are buying and selling financial instruments such as stocks, bonds, commodities and derivatives. Trading strategies are purchase, disposal or hedging. The physical trade includes balance responsibility in order to settle deviation in the balancing market. To bring buyer and seller together a broker arranges transactions between them. He gets a commission when the deal has been successfully executed.

A **Market operator** runs the short-term physical electricity market. (Berntsen, Vatn 2013, p. 10)

2.3.2.6 The business role of energy markets

1. Hedging function: On the futures market companies can hedge price risks.
2. Optimization function: The use of the power plants can be optimized on the spot markets to increase profits.
3. Arbitrage function: In the presence of different prices on different markets risk-free arbitrage is possible which increases the market efficiency.
4. Speculation function: Dependent on their market price expectations of the market participants look for profit from either rising or falling prices through the energy future markets.

Figure 4 depicts that for the different energy supply chain steps, production, transportation and distribution, different markets exist. The energy generators want to sell their energy, the TSO/DSO wants to ensure the security of supply and the power supplier finally negotiates contracts with the end-customer. In contrast to the futures market, in which delivery is due at a later date, in the sport market the settlement happens in t+2 working days. That means that energy and cash must be delivered after two days. The payment for the energy is either done by delivery or provision. It is also shown in Figure 4 what products are traded on the different market places, and which form of payment handling is used. E. g. the Spot and futures markets can take place on an exchange like EEX or Nordpool, over the-the-counter (OTC) or by brokers on organized markets.

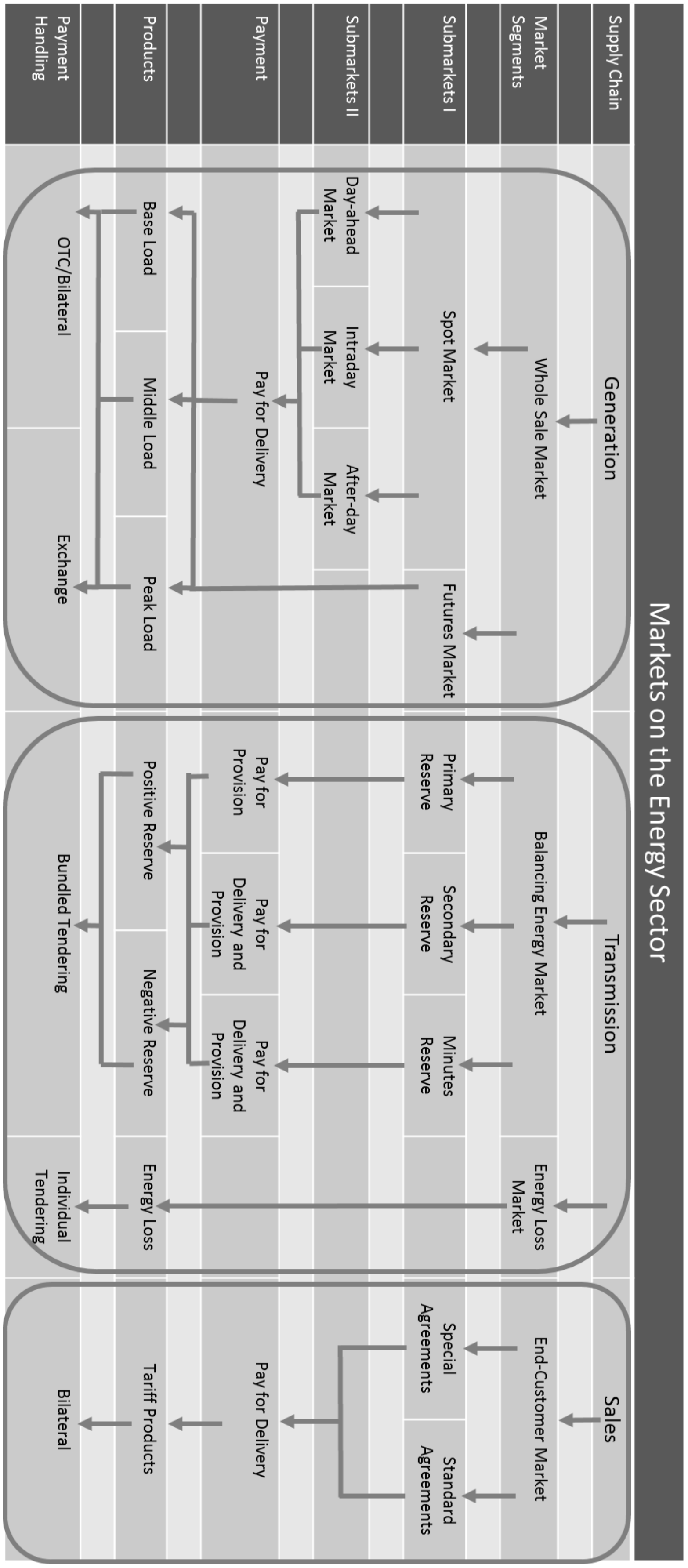

Figure 4 Markets on the Energy

Sector Source: (Leprich 2009) (Jasper 2012)

2.3.2.7 The control energy market

The control energy market has been installed to continuously balance generation and demand in real time. This is needed because of unexpected turn downs of power plants, changes in demand or forecast inaccuracy of renewable energies. For secure grid operation the TSO is obliged to hold reserve capacity. The service of the **primary control energy** is frequency-dependent and completely automatic. The energy is made available by the respective DSO in less than 30 seconds. The timeframe is $0 < t < 15$ minutes. The payment is transferred according to the provision, whether or not the energy is actually used. The **secondary control energy** is also frequency-dependent and automatically controlled by the power-frequency control. The activation time is maximum 5 minutes and the timeframe of delivery is 30 seconds < t < 15 minutes. The payment is made for the provision of energy and for the actual delivered energy. The **minute reserve** can be activated within 15 minutes for timeframes $t > 15$ minutes. The payment takes place for provisioning and the delivered work. In comparison to the other reserves, the two minute reserve is traded daily not monthly.

In order to be allowed to offer control energy on the market a pre-qualification for the seller has to take place in which the technical and administrative qualification has to be tested, see Figure 5. Furthermore, the minimum offering is always 5 MW. These 5 MW could be a challenge for a rather small energy service company.

Figure 5 The Way of Getting Into the Control Energy Market,
Data from (Jasper 2012)

2.4 Sales

The last step of the energy supply chain before the customer can consume the energy is the sales process. The lynchpin of sales and distribution are contracts between the end-customer and the supplier.

A contract is generally an agreement between two or more parties in order to exchange goods against money. Two parties close a deal if they both believe in an improvement of their financial situations. The crucial question for energy contracts is: what kind of pricing will households except and what kind of pricing are the suppliers willing to offer (Droste-Franke et al. 2012, p. 165).

Whereas in Germany the contracting partner for the end-customer is just the energy supplier, the Norwegian customer enters into contracts with the energy supplier and the grid operator. Both kinds of contracts will be described shortly here.

2.4.1.1 Grid Contract

The Grid contract arranges the payment for the transmission of the electricity. The tariffs for the grid contract in Norway are strictly regulated by the NVE and in Germany, before included into the energy price, by the BNetzA. In Norway, depending on the location of the customer, the prices for the transmission change. Prices in areas with dense agglomeration are lower than in rural areas with long transportation ways and lower energy demand. This is also called a zonal transmission pricing system. It has been implemented in Norway to cope with capacity limits (Bjorndal, Jornsten 2001, pp. 51–53). These capacity limits are reached during winter times when electrical heating increases demand. The consequence is that prices in winter are higher than in summer.

A standard customer tariff includes fixed and variable costs.

a) The fixed part is covering the fix costs of the grid, like installation and replacement etc.
b) The variable part covers the actual power losses of the transmission. (Sæle, Grande 2011, pp. 102–109)

Large energy consumers with Smart Meters can also draw on more flexible tariffs like Time of Day (ToD) tariffs. Beside the fixed and the variable part it includes an effect part that charges the customer just during expected maximal load times. (Berntsen, Vatn 2013, pp. 15–16)

Industry and commercial customers can also choose a Flexible Consumption tariff. The customers get compensated for providing flexible load that can be switched off by the network operator in case of a shortage of transmission capacity. A minimum of 90 kW of flexible load is required to use this tariff. (Berntsen, Vatn 2013, pp. 15–16)

An exemplary overview of tariffs of a local power company located close to Trondheim can be found in Table 1.[1]

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[1] Nord-Trøndelag Elektrisitetsverk is a power company serving Nord-Trøndelag in Norway. It is a country owned company producing nearly 4 GWh per year.

Table 1 NTE's Tariffs of Flexible Consumption,

Source: (NTE 2013)

Tariff	Notification time	Max duration of shut down	Fixed term [€/year]	Energy term [€/kWh]	
				Summer	Winter
FF1	Instantaneous shutdown	Unlimited	1125	0,0027	0,0049
FF2	1 hour notification	Unlimited	1375	0,0047	0,0069
FF3	Instantaneous shutdown	2 hours	1875	0,0061	0,0069
FF4	10 hour notification	Unlimited	1125	0,0011	0,0133

2.4.1.2 Electricity Price Contract

The **electricity price contract** is the most important part of the energy bill. There are three basically different contracts.

a) The fixed price contract is the easiest one. The customer gets a fixed price per kWh and the supplier gives a price guarantee for a determined time period.
b) The spot price contract is based on the spot price[2] plus a mark-up for trading and administration.
c) The variable price contract includes all other contracts. In Norway it is common to have a tariff that is composed of both: a fixed and a variable part. In Germany a day and night tariff is not uncommon.

Table 2 gives an overview of electricity prices in Norway and Germany. It sticks out that the household's energy prices in Germany are nearly three times higher than in Norway. The 50 % cheaper electricity production costs can be justified by the hydro power in Norway. Additionally the taxes are lower and the subsidies for renewables do not exist. The big difference of the grid rent can be explained with the higher share of more expensive cables in Germany.

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[2] Nord Pool in Norway and EEX in Germany

Table 2 Electricity Prices in Germany and Norway,
Source: (EUROSTAT 2013a, 2013b), (Statistik sentralbyrå/Statistics Norway 2011)

2013	Norway	Germany
Household Electricity Prices [€/kWh]		
Total Price (Electricity, Grid, Rent, Taxes)	0,112	0,287
Electricity Price	0,045	0,082
Grid Rent	0,033	0,065
Taxes	0,034	0,087
Renewable Subsidy		0,053
Households Electricity Prices by Type of Contract, Exclusive Taxes [€/kWh]		
New Fixed-Price Contracts -1 Year or Less	0,046	
New Fixed-Price Contracts -1 Year or More	0,047	
All Other Fixed Prize Contracts	0,046	
Contracts Tied to Spot Spice	0,043	
Variable Price (not Tied to Spot Price)	0,048	
Business activity, Electricity Prices, Exclusive Taxes [€/kWh]		
Industry (>500 MWh/Year)	0,089	0,129
Industry (>20,000 MWh/Year)	0,060	0,105

2.5 Consumption

The **end-users** represent the demand side. The end-user buys the energy via contracts from the energy supplier. The biggest customer groups are:

a) households
b) industry and
c) commercial business customers.

Whereby the **household** customer is generally called the price taker because his price elasticity of demand is inelastic (between -1 and 0) and the income elasticity of demand is low (between 0 and 1). The price elasticity of demand shows the percentage of increase of demand if the price of the product changes by 1 %. Income elasticity of demand is the percentage of increase of demand if the customers' income increases by 1 %. Electricity and gasoline are therefore also called essential goods. But this does not count for every customer. Since the liberalization of the energy market customers have the possibility to contribute to their energy consumption by investing in PV, solar thermal, geothermic or micro-CHP plants.

Industry customers can be identified by a high energy demand, a well predictable energy consumption and good demand shift potential. Because of high cost pressure DSM, local production and energy saving measures are at least partly realized. In Germany the industry gets large amounts of energy subsidies.

Commercial business consumers like offices, hospitals, schools etc. normally also have high energy demands. Through smart meter infrastructure load shift potential can be realized. Furthermore through high electricity and heat demand they are predestinated for micro-CHP plants.

The production of energy can be controlled and adjusted to demand. This is called the smart side of the supply chain. Also the transmission grid can be controlled relatively good. With the increasing share of weather dependent renewable energy feed-in the demand is supposed to become smarter too. Big energy customers in the industry sector are well-provided with smart meters and control infrastructure to adjust their energy consumption to fluctuating production. Blue-chip countries like Italy and Sweden (Stephan Renner et al.), go ahead and also install smart meters in local households to make a step towards smarter demand (Droste-Franke et al. 2012). Other countries still hesitate because of high costs and unclear profitability.

The perfect consumer of the future will be a so called prosumer[3], well-equipped with smart meter, local energy production, smart devices integrated in a smart home and an EV. These devices will facilitate him or her to control and shift load to low prize periods and to enjoy a higher service standard.

Even if customers already own an EV or decentralized generation; important interfaces, like smart meters, software tools or comprehensive service offers, to manage the new equipment rarely exist.

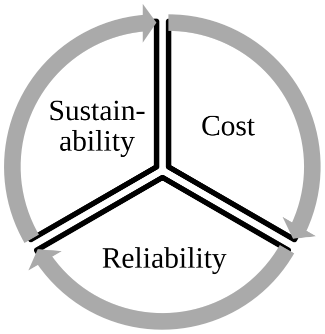

Figure 6 Energy Trilemma

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[3] Prosumer is a neologism describing the combination of a producer and a consumer.

This master thesis is going to analyze possible business models that could provide exactly what is missing to create a smart demand. A restricting factor is always the energy trilemma, which is composed of cost, reliability and sustainability, see Figure 6.

3 Smart Grids

3.1 Demand Side Management

On competitive electricity markets demand response can be seen as a bundle of strategies that can be used to increase the participation of the demand-side, or the end-users. Customers can be exposed to incentives like real-time pricing and may respond by reducing their demand during peak times through energy efficiency or by generating power by themselves. Furthermore, end-users have the possibility to shift their power demand to off-peak times or choose not to respond. Through customer responses the demand will be smoothed and average prices will be lower. The aim of demand response is to generate security, to ease system constraints and economic benefits for the market as a hole. (OECD, IEA 2003)

How DSM generally works can be seen in the Figure 7 adopted from (Aketi, Sen 2013). The customers have a time-of-use tariff and get information about low and high price periods. In order to reduce their costs they consume less during the high price periods and more during periods with low prices. The average demand is the same but the energy demand is smoothed.

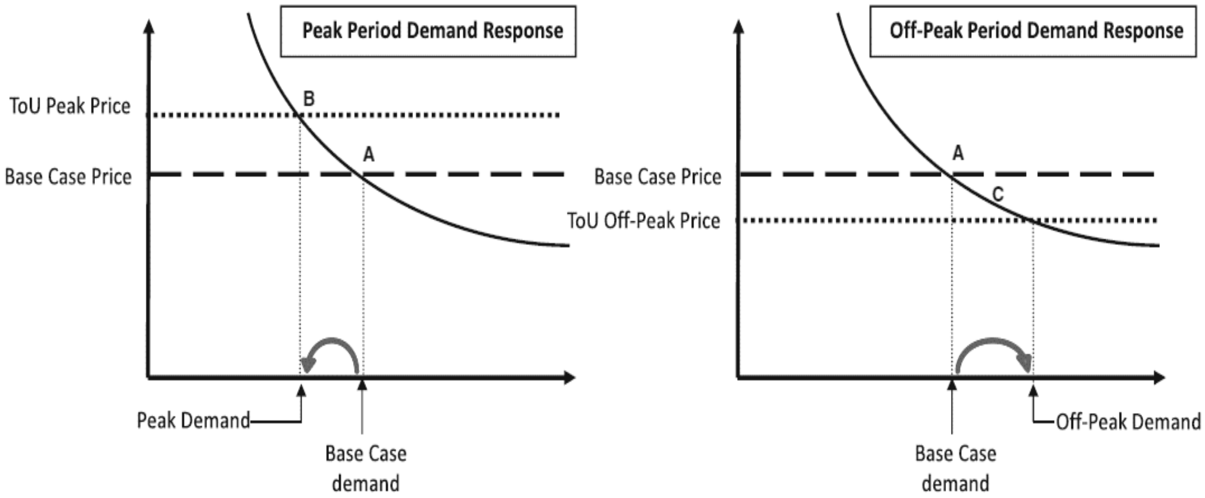

Figure 7 Demand Response,

Source: (Aketi, Sen 2013)

3.1.1 DISTRIBUTED ENERGY RESOURCES

Distributed energy resources (DER) are a bundle of technologies that provide the resource energy on the distribution level. These ancillary services for system operators are expected to play an important role in the future (Hatziargyriou et al. 2007). Distributed energy resources include three types of resources.

1. DG includes micro-CHP plants, PV as well as biomass and other locally generated energy.
2. Controllable energy load can be specified as all the load a customer has which can be shifted or reduced temporarily.
3. Small-scale energy storage systems like flywheels, lithium-ion batteries, plug-in and hybrid EV that can be seen as a load or a distributed generation and therefore can be used in both ways. Since the focus is on electricity storage, heat storages are not mentioned here. (Houwing 2010, p. 78)

Beside micro-CHP plants with one of the biggest shift potentials EV play an important role. EV represent a significant load and furthermore can be controlled intelligently with charging strategies like vehicle-to-grid (Kempton, Tomić 2005, pp. 280–294). Smart load control doesn't have to include any losses of comfort for the end-customer. Once the investments in control systems and ICT has been executed by a household the additional cost for including an EV in DSM are very low, which increases the profitability of the installed ICT. (Houwing 2010, p. 110)

Different solutions will complement each other. A great challenge mentioned by (Droste-Franke et al. 2012, p. xxxiii) will be the adequate implementation of balancing technologies on regulations.

1. Attributions and definitions with respect to balancing technologies should be clarified in the relevant regulations.
2. Decisions on attributing storage facilities to the grid or power generation levels should be made by the legislator.
3. Consequential, new fare structures and business models need to be developed.

3.1.2 TECHNOLOGIES

> "Storing energy requires specific technologies, which are in general neither cheap nor efficient."
> - (Droste-Franke et al. 2012, p. 83)

Energy for demand response is needed to balance supply and demand and therefore can be called balancing power. To define which kind of balancing power is needed the following questions need to be addressed:

1) difference between load and supply, even in situations with no wind and solar radiation, (Droste-Franke et al. 2012, p. 61)
2) location of balancing power demand,
3) duration and frequency of the demand.

On the other side the storage technologies can be classified by (Droste-Franke et al. 2012, p. 84):

1) type and location of storage systems (modular small devices, centralized use of economies of scale, double use like e-mobility batteries)
2) duration and frequency of power supply (short (minutes)-, medium (daily)-, and long term(weeks))
3) input and output type of energy to and from the storage system (electricity to electricity (positive and negative control), anything to electricity (positive control), electricity to anything (negative control)). Figures for comparing different technologies are shown in (Droste-Franke et al. 2012, p. 86)

In the case of Norway and Germany Table 3 provides an overview of energy storage technologies in the size of 1 kW to 1 MW using the above classification.

Table 3 Classification of Energy Storage Technologies,
Source: (Droste-Franke et al. 2012, S. 87–89)

	Input Output Type of Energy	Type and Location of Storage Systems	Energy-to-Power Ratio	Potential Norway	Potential Germany	Accep-tance
PHEV[4] with Bidirectional Charger	Storage	Modular Storage with Double Use	0-10h	High	Low	High
Grid-Connected PV-Battery Systems	Storage	Modular Storage with Double Use	0-10h	Low	High	Very high
PHEV One-Way Charger	Positive Control (Anything to Electricity)	Modular Storage with Double Use	0-10h	High	High	High

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[4] plug-in hybrid electric vehicle (PHEV)

CHP Units With Thermal Storage	Positive Control (Anything to Electricity)	Modular Storage with Double Use	1-10h	High	High	High
DSM of Electrical Loads (Shut Down)	Positive Control (Anything to Electricity)	Modular Storage with Double Use	1-10h	High	High	Low
Provision of Information[5]	Positive Control (Anything to Electricity)	Provision Though Apps, In-house Displays	24h	High	High	Very high
Electric House Heating or Cooling incl. Heat Pumps	Negative Control (Electricity to Anything)	Modular Storage System Without Double Use	0-10h	High	Very high	Very high
DSM (household)	Negative Control (Electricity to Anything)	Modular Storage System Without Double Use	0-10h	High	High	Low
DSM (industry)	Negative Control (Electricity to Anything)	Modular Storage System Without Double Use	0-10h	Very high	High	Very high
Cooling devices	Negative Control (Electricity to Anything)	Modular Storage System Without Double Use	0-10h	High	High	High

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[5] Information can be provided by: 1. real time information, e. g. consumption at a given moment (washing machine etc.), 2. historical usage data, e. g. consumption compared to previous periods or a model house, and 3. real-time billing information. (Davito et al. 2010)

3.1.3 ECONOMICS

A general analysis can be separated into monetary and non-monetary impacts. The monetized costs are important for business models on the market and new market entrants. A combination of both, a socioeconomic analysis, is of interest for the society (Norwegian Public Roads Administration).

For the monetary cost assessment the total cost of the energy production is important. It contains fixed and variable costs. The fixed costs can be broken down in infrastructure and investment costs.

For all of the above mentioned distributed energy resources a certain infrastructure - DSM-capable Information and Communication Technology (ICT) like smart meters and load control devices etc. – is needed. A study conducted by (Droste-Franke et al. 2012, p. 160) concludes that through DSM for the provision of balancing power, capacity limits will be reached soon. The analysis of the technical restrictions also showed that when load and generation are coordinated the utilization of DSM can be maximized, despite huge feed-in of renewables. Nevertheless to exploit the entire potential of DSM, (Droste-Franke et al. 2012) states that 1,000 € need to invested into the distribution grid per household, whereas the returns of DSM for the consumers are only 18 € per year and household in Germany.

Furthermore, the structure of the current electricity grid is also important for the installation of DSM. The amount of respective decentralized facilities that can be applied for balancing electricity flows in the system is limited by the power grid connections and restrictions of the distribution network (Droste-Franke et al. 2012, p. 42).

The fixed costs also include the specific investment costs for the different resources that will be addressed in the chapter 7. The variable costs accrue in the long term and include fuel demand of micro-CHP plants, maintenance, management, costs for trading, cost for billing and costs for taking risks etc. As mentioned, existing and future business models need to account for these total costs. The most important load shift potentials ascending with the costs are

- the management of domestic appliances,
- load-management of electric cars and
- controllable cogeneration with heat storages. (Droste-Franke et al. 2012, p. 83)

From a society perspective socioeconomic costs of energy production also include: opportunity costs, cost for the environment and land-use costs, which are not taken into account here.

3.1.4 CRITICS

As a consequence of flexible production and demand, smart grids help to balance both sides. To do this, beside the power grid, an information grid for fast and secure communication is needed. The coordination of decentralized energy resources like households, EV and rooftop solar power panels demands real time communication. When the bi-directional communication for DSM and central control is considered, the information flow turns into an information flood. Unanswered questions in this context are: Which risks are combined with sending huge amounts of personal data? How can the security of the system be ensured? Who owns the data?

Possible risks are eavesdropping, misuse and theft. By means of energy measurement abuse, burglars could see how many people are in a household; if someone is cooking, watching TV or walk the dog. Furthermore large-scale data gathering by unauthorized could be misused for market research, movement profiles etc. The security of the system as a whole is more vulnerable to disturbances, the more production and consumption is controlled centrally. When not only producers and grid operators are connected, but also consumers, companies and public buildings the provided target for hackers and criminals is even bigger.

The need for a secure transmission of the sensible data is of critical importance for the acceptance in public. A clear and detailed regulation concerning requirements of data transmittance, storage, usage, encryption and a limited circle of people and companies who has access authorization is required. Which risks a society is willing to take in comparison to the possible gains of an interconnected network need to be discussed in every society. It is very likely that countries will decide to take different levels in connectivity and data security. A comparison between Germany and Norway is difficult.

Germans see their privacy as an important and secured good even if they know that it isn’t anymore. Eavesdropping operations of the American and English security agencies CIA and Scotland Yard, are most likely wiretapping most of the German telephone calls and e-mails. That made people aware of privacy importance. Transferred to smart grids that could mean that Germany tends to a local optimization on the basis of price signal incentives. This system is based on a one-way data flow without central control. The external management of load cycles for the EV would probably obtain higher acceptance.

More openness towards new technology and a greater willingness to open up ones data for government, companies or others can be seen in **Norway**. It is likely that Norwegian households tend to choose the central control by a balancing group manager. By consenting to and giving up the direct control the whole system can be optimized more effectively and hence households will receive an additional premium. In this two-way data flow, loading of EV can be included much better and is also likely to be accepted. Though, the risk of losing the control over the data is bigger.

3.2 Smart Technologies

3.2.1 MICROGRIDS

A microgid is a system approach which views generation and associated loads as a local subsystem. Such a subsystem has a lot of advantages. It can be operated like an island, independently of the distribution grid and possible disturbances. This generates the potential to provide higher local reliability. Critical for a micogrid is the use of waste heat by placing the electricity generation near the heat demand. The consumed energy is normally produced on the basis of local resources and therefore more sustainable. (Lasseter, Paigi 2007)

3.2.2 SMART HOMES

Smart homes are capable to react intelligently by anticipating, predicting, and taking decisions with signs of autonomy. This includes network hardware oriented solutions as well as techniques from artificial intelligence (Augusto, Nugent 2006).

3.2.3 SMART METERS

An important range of smart homes is energy supply with a smart meter as the core part of the ICT in the smart home. Smart meters deliver additional data and control in comparison to conventional meters. The following list shows different smart meter classes sorted by intelligence in ascending order (Lukszo et al. 2010).

1. Automated meter reading (AMR) offers remote reading without physical access to the meter of gas, electricity or water.
2. Automatic meter management (AMM) or Advanced Metering Infrastructure (AMI) offers remote reading and management. This enables the use of different tariffs, dis- and reconnections of customers, curtailing of the energy use, etc.
3. AMM and AMI with automation devices enabling communication and control (ADCC) can steer shutting down customers for DSM, load shaping, automotive response to real-time pricing or time use pricing schemes, etc. (Houwing 2010) (European Comission 2007)

Smart meters are already in use for large customers and are currently being introduced to households. “Dynamic movers” like Estonia, Finland, France, Ireland, Italy, Malta, The Netherlands, Norway, Portugal, Spain, Sweden and the UK regulated by law to install a smart meter or have decided to do so. “Market drivers” like Denmark, Germany and Czech Republic are missing legal requirements however DSO and legal responsible companies install them. (Hierzinger et al. 2013)

With basic AMI the user can be provided with information about future events, based on forecast and day-ahead prices. Standard demand response means that signals arrive before the event and consumers respond uncoordinated by shifting their consumptions to other daytimes. This random shifting may create other critical peak times. As long as the coverage of households participating in DSM is low standard demand response works well. If whole villages correspond to the same incentives this lead to additional problems. (Aketi, Sen 2013)

3.2.4 INTERNET OF THINGS

The internet of things is one of the global trends of the 21st century. It refers to all kinds of smart devices which are connected via radio frequency or internet and help the user to cope with every day's life. These devices will for example help to control the electricity demand by providing a two-way communication between consumer and utility. (Aketi, Sen 2013) The potential of smart things businesses is promising, which can be seen in the latest acquisitions of Google or the Samsung smart home product line. Nest Labs the new subsidiary of Google is producing thermostats that learn user's habits over time and regulate the temperature accordingly. These thermostats communicate within each other, profile the user's behavior and anticipate the consumer's needs. (Trefis Team 2013) The (Gartner Inc. 2013), one of the biggest information technology research and advisory companies expects that the Internet of Things market will grow to 26 billion units by 2020. The Internet of Things is promising and can open up DSM to the mass-market. However, privacy violation and high prices are drawbacks and the future will show whether Nest Labs was a good investment for Google or not.

3.3 New Players

3.3.1 DYNAMIC BALANCING PRINCIPAL

A dynamic balancing principal has been introduced by (Hillemacher et al. 2013). This new intermediate could be a new player on future energy markets, bringing together the dynamic generation and the dynamic load. It communicates with customers and is the linkage to the DSO. This system is strongly based on the realization of load shift potential, see chapter 3.1. It could be important that the shape of the incentive system, to realize this load shift potential, copes with different spatial, social and cultural backgrounds of the people.

3.3.2 VIRTUAL POWER PLANT OPERATOR

A virtual power plant (VPP) is a cluster of distributed energy resources (chapter 3.1.1) controlled by a central unit. The objective is that grouped resources are more accessible and better manageable. (Werner, Remberg 2008) The control can be realized directly or indirectly. An indirectly control matches the distributed control strategy. Via price signals the households are induced to shift their distributed energy resources (Houwing et al.). The direct control matches the centralized control strategy whereas the virtual power plant operator decides when and which resources are used. This is expected to be simpler and cheaper in comparison to indirect control, where no local controllers that can react on prices are needed to be installed (Houwing 2010, p. 86).

Beside the intelligent control schemes, also control objectives are important. Here the following objectives can be distinguished:

a) Commercial control objectives include the following: Virtual power plants can be used to utilize the accumulated load shift potential of households (PEACOCK, NEWBOROUGH 2007). Another objective can be to place balancing power on the market or to balance wind power (Schaeffer, Akkermans 2006). It can also be used to smooth load in a substation of the distribution grid (Hommelberg, M. P. F. et al. 2007).
b) Technical control objective is the provision of power quality. Bundled micro-CHP plants can be used for voltage and frequency control as well as to produce reactive power for the TSO (Brabandere et al.). A recap of further technical literature on micro grids, virtual power plants and distributed energy resources can be found in (Houwing 2010, p. 88). A remark needs to be done here. A substantial constraint for the technical control objective is the resolution of the smart meter. To deal with power quality much smaller time resolution than the common 15 minutes are needed (Houwing 2010, p. 90). For example environmental control objectives target the CO_2 reduction of the energy system. (Pudjianto et al. 2007, 2008)

3.3.3 AGGREGATOR

An aggregator pools and trades power flows to and from end-consumers. In this role aggregators manage i. a. virtual power plants. The role of an aggregator can be taken by energy retail companies, generation companies, integrated utilities, distribution system operators or new market members like municipalities, telecom companies, IT companies or coalitions of demanders (Houwing 2010, p. 87).

Three important factors to establish a new market member are given. Firstly, demand, a strong tendency can be seen that traffic in Europe will be electrified, especially by EV. The additional load, the load shift potential and the possible storage capacity need to be managed. This is just one field among others with strong market growth potential. Secondly, the necessary information and communication technology is available. And thirdly, the acceptance to compensate such services is basically present. Possible business models are discussed in chapter 6.

4 E-Mobility

"If this is the future, I'm not that worried."
- Jay Leno (after driving the Tesla electric car)

4.1 Introduction

More than one billion vehicles drive on the world’s roads today. The influences on environment, economies and societies are significant (Subic et al. 2012). The transportation sector accounts for 53 % of the world’s oil consumption in 2009 and is responsible for 19 % of the world’s CO_2 emissions (OECD 2010) (World Resources Institute 2014). Thus, a global CO_2 reduction can be achieved by promoting EV. But this is just possible in combination with the generation of renewable energy. Although the energy consumption of EV will not turn the whole energy market upside down, with an increasing number of EV challenges will appear owing to the integration of EV into the distribution girds. The average German EV runs 30-40 km per day and consumes 15-20 kWh per 100 km (VDE 2014) resulting in a consumption of a circa 6 kWh per day.

In **Germany** around 16,000 of 42.5 million cars are EV (Bundesverband eMobilität e.V. 2014). This leads to a share of 0.03 %, which is negligible for the grid. The German government has announced to strive for one million EV on German streets till 2020 and five million EV till 2030. Yet both targets are somehow unrealistic at the moment (Doll 2013). One million EV in 2020 would lead to a yearly energy consumption of 1.4 TWh and, 0.25 % of the used energy in Germany respectively. This is neither a problem for production, transmission grid, distribution gird nor household installations. Only for higher penetration than 10 % problems could occur. But time and load controlled loading of EV can alleviate these concerns (VDE 2014).

Norway has a 50,000 EV target until 2018 (Valøen 2008). 9 % (Deutsche Welle) of the registrations for new cars are EV. Altogether, 21,000 EV are registered in Norway. The zero-emission vehicle-boom has been pushed by strong incentives of the Norwegian government. Owners profit from free commuting in the bus lane, no road and ferry tolls, no parking fees, lower insurance costs, 4,000 public load points with free charge up, subsidies for the installation of charging points at home, as well as the exemption from purchase tax and VAT (Vidal). Though pioneering, the yearly energy consumption of 50,000 EV, 365 MWh, is extremely low in comparison to a yearly production of 128 TWh (Statistik sentralbyrå (Statistics Norway) 2011). Nevertheless, future decentralized penetration could cause problems in the distribution grid.

The power load of an EV can easily approach the load of a typical domestic household at peak load (Garcia-Valle, Pecas Lopes, Joao A. 2013, p. 3). The higher the share of EV the higher the energy demand and the more severe the problems caused by EV can be. Literature suggests two options of how to enable a higher share of EV: firstly, the expansion of the infrastructure which means additional production and transmission capacity, and secondly, the implementation of enhanced charging management strategies using DSM to control the load of EV in a way that the grid is not surcharged and the customer’s needs are fulfilled (Garcia-Valle, Pecas Lopes, Joao A. 2013, pp. 3–4).

The most promising charging strategy is the so-called vehicle-to-grid (V2G) concept. EV are not only seen as loads but also as decentralized storage potential. During periods of high renewable energy production electricity can be stored in the battery of EV and either used for mobility services or as ancillary grid service. In this context one of the biggest problems is the premature aging of the battery (Kempton, Tomić 2005, pp. 286–297) (Letendre, Kempton 2002, pp. 16–26).

Literature basically distinguishes between battery electric vehicles (BEV) which use exclusive electric power and plug-in hybrid electric vehicles (PHEV) that use battery and standard fuel. All other solely fuel based cars are classified under the short-term internal combustion engine (ICE). Nonetheless, the core part of every EV is the battery that is therefore analyzed in the next chapter.

4.2 Battery

Electric mobility hinges on the question at what costs a sufficient battery can be provided. For the application of EV there are five key factors that are most important: power density, energy density, safety, lifetime and costs. A comparison of several available energy storage systems can be seen in Figure 8.

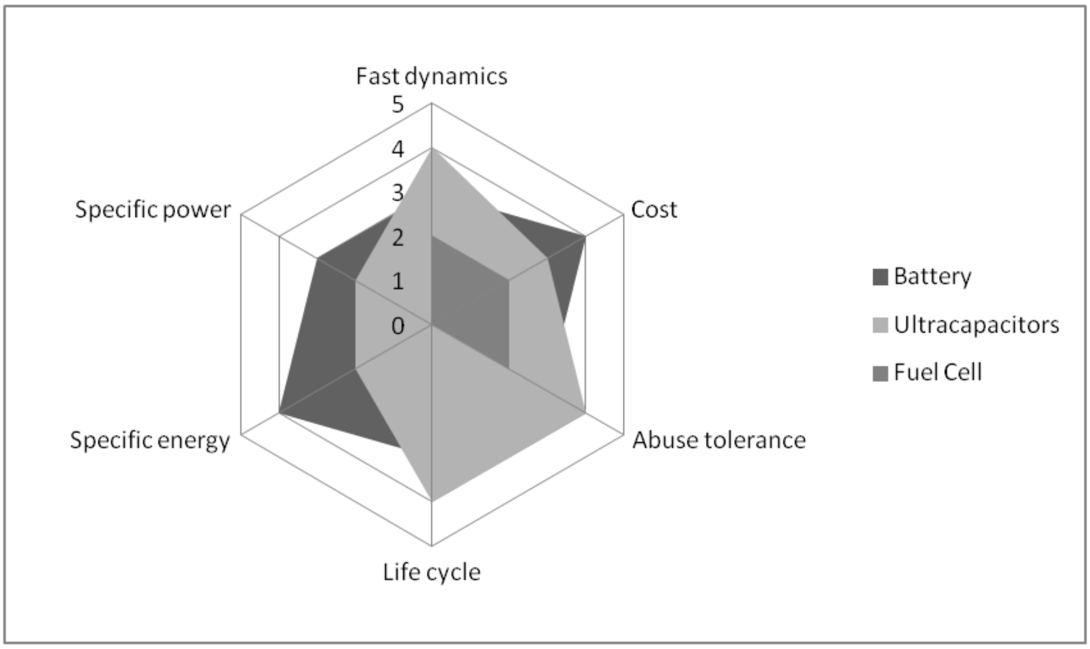

Figure 8 Comparison of Battery Storage Technologies,
Adapted from (Lukic et al. 2008)

At the moment, Li-Ion batteries are the most promising technology in terms of power density and efficiency (Garcia-Valle, Pecas Lopes, Joao A. 2013, p. 283). Still there are several factors that need to be taken into account:

1. The investments costs for a Li-ion battery suitable for EV were around 300 €/kWh in 2013; cost reductions can be expected (Wollersheim 2013).
2. A battery has a minimal and a maximum voltage that can be seen as a function of open-circuit voltage (OCV) and state of charge (SOC). The capacity of a battery depends on the load profile which is described by the C-rate (Wollersheim 2013).
3. The material of the cell determines weight, capacity and energy density of the battery.
4. A battery is more vulnerable during charge in comparison to discharge state. Temperatures under zero degrees during loading are extremely critical and the higher the temperatures are the higher is the stress for the battery (Wollersheim 2013) (Battery University 2014).

5. Full discharge of the battery should be avoided, i. e. low SOC should be avoided, low depth of discharge (DOD) is preferable. Charging between uses and partial discharge for Li-ion batteries is fine (Wollersheim 2013).
6. Avoiding full charges increases the cycles of a battery. Every 0.1 V drop below 4.2 V/cell doubles the cycles; the retained capacity drops accordingly. E. g. loading a battery just to 4.1 V/cell reduces capacity about 10 % but doubles the cycles (Battery University 2014).
7. Keeping the battery full charged means stress for the battery. Around half loaded and 3.92 V/cell is said to eliminate voltage-related stress (Battery University 2014).

Taking these points into account a customer improves the life-time of his battery by using smart loading, mainly because of slower loading.

4.3 Influence on Load

To identify the additional demand of EV some constant parameters and probabilistic parameters need to be taken into account. Probabilistic parameters try to identify common patterns like user behavior. Probabilistic parameters can be modelled and statistically interpreted. The average car for example in Hamburg and its suburbs is used in three out of four days, makes 2.6 trips a day that together take 49 minutes and is filled up with 1.3 persons (Follmer et al. 2010). Around 23 hours and 11 minutes the car is not used and could be plugged in and connected to the grid at home, at work or in designated areas. Constant parameters address figures about technology, strategy and other fixed values. An overview about important load factors can be seen in Table 4.

Table 4 Constant and Probabilistic Parameters of EV,
Adapted from: (Garcia-Valle, Pecas Lopes, Joao A. 2013, p. 58)

Constant Parameters	Probabilistic Parameters
EV penetration level	EV (PHEV, BEV, L7e[6], M1[7], N1[8], N2[9])
Charging station technologies	Daily travel distance
Availability of charging (home, home/workplace)	EV connectivity (return time)
Charging losses	
Charging strategy (dumb, dual-tariff, smart charging, V2G)	

A constant parameter - and of highest importance for the gird - is the charging strategy. Figure 9 and Figure 10 depict a standard load profile with EV penetration on a weekday and on a weekend. The load profile is divided into timeframes. Dependent on the charging strategy, the load can be shifted from one timeframe into another. The following strategies can be distinguished (Garcia-Valle, Pecas Lopes, Joao A. 2013, pp. 63–84):

1. **Dumb Charging** means that the EV is connected unplanned, normally after the last trip of the day. Analyses show that the dumb charging strategy can lead to "worst case" scenarios, especially when charging and peak load in the evening coincide. Therefore, dumb strategy might require premature grid investments.
2. **Multiple tariff charging** is the simplest way of DSM that offers the EV-user to shift his demand to off-pike times when energy is cheaper. In this case it needs to be avoided that all EV are plugged in at the same time causing a sharp increase in demand, depending on the number of EV.
3. **Smart charging** is a way of shifting the EV charging demand exactly to the off-peak valleys. The scenario is also called "valley-filling" as can be seen in **Fehler! Verweisquelle konnte nicht gefunden werden.**. This significantly improves the system's load factor and increases the base load. Smart charging requires advanced control management techniques.
4. **Smart charging with vehicle to grid (V2G)** is a smart charging strategy that additionally allows bidirectional power flows. That means that while an EV is not used the battery capacity

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[6] L7e: small city purpose vehicles

[7] M1: 4-seater passenger vehicles

[8] N1: carriage of goods with a maximum laden mass of less than 3,500 kg

[9] N2: maximum laden mass of 3,500–12,000 kg for commercial purposes." For further information about the different points from the table see Garcia-Valle, Pecas Lopes, Joao A. 2013, pp. 61–85

is used to meet peak demand or provide ancillary services to the grid and works as energy storage.

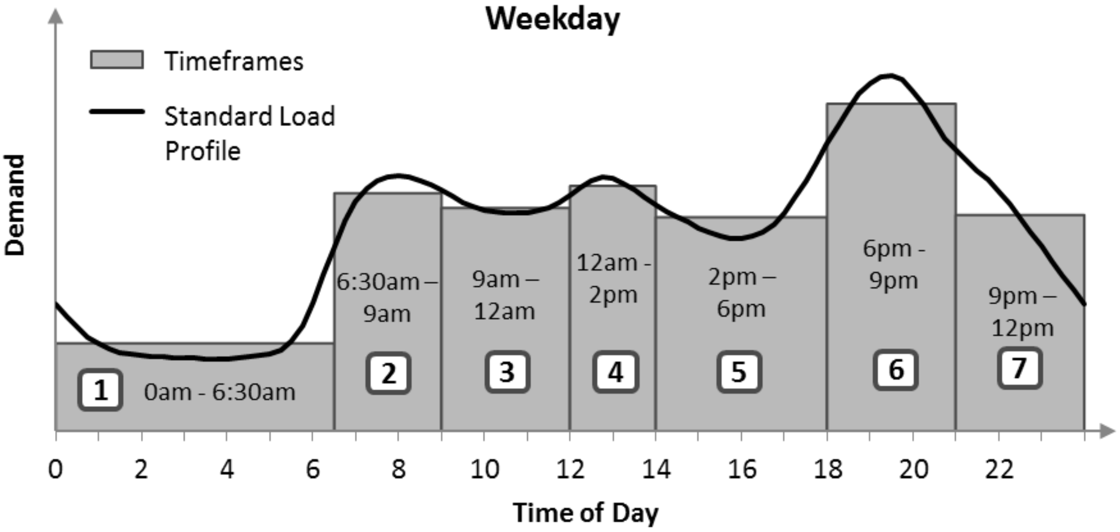

Figure 9 Weekday Load Profile with EV Timeframes

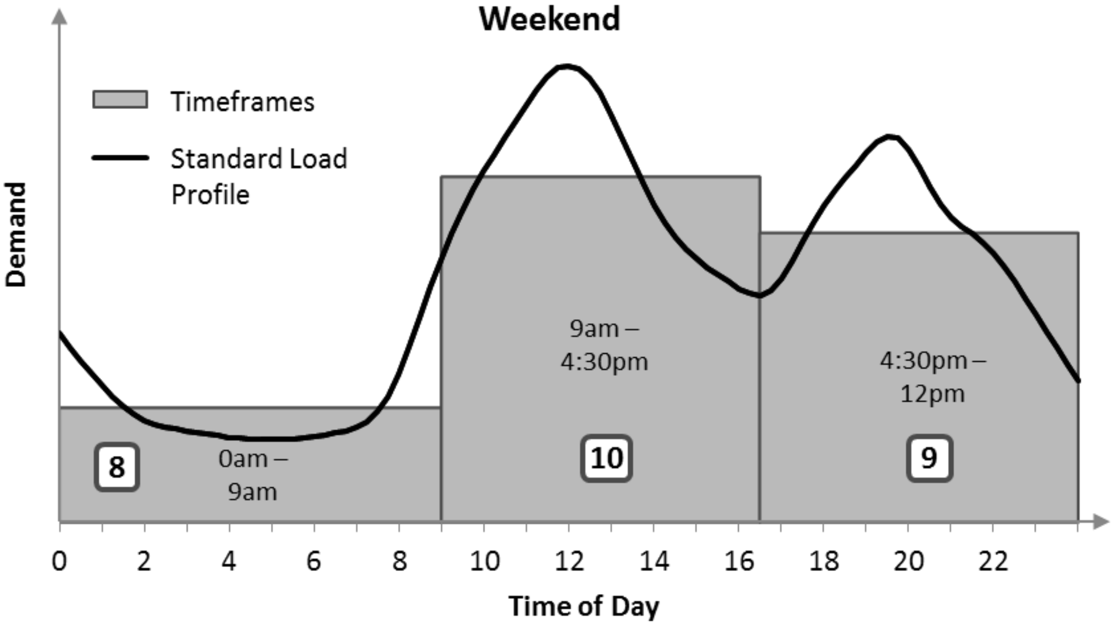

Figure 10 Weekend Load Profile with EV Timeframes

4.4 Network Integration and DSM

To enable different charging strategies every stage from the mobile EV, the stationary charging station, the aggregator and the grid operator needs to fulfil specific hardware, software and communication requirements.

Important for the EV is the monitoring of internal vehicle data. Every modern car already has a so-called vehicle management system (VMS) and a battery management system (BMS) that can be used internally in the EV or for charging optimization. The nominal battery energy[10], battery state of charge (SOC) and the instant power are real-time monitored (Dogger et al. 2011) (Garcia-Valle, Pecas Lopes, Joao A. 2013, p. 94).

The charging infrastructure builds the charging connection between grid and battery, using technologies such as over-current protection, ground-fault detection and normally digital communication to the EV including metering and billing.

The communication between EV, charging station and aggregator or virtual power plant (VPP) operator is dependent on: market integration, architecture and the determining system technology.

a) The market integration concept is based on a direct or indirect connection of the EV to the power market to generate savings for the EV owner (Garcia-Valle, Pecas Lopes, Joao A. 2013, p. 97).
b) The architecture concept includes the structure of the stakeholders and mechanisms. One aim is to build an interface between power market and the EV to influence the EV owner's behavior. The architecture can be controlled centrally by the aggregator, distributed by the EV owner or a combination of both (You et al. 2009).
c) To make the technology of different cars and brands work together, standards for components of soft- and hardware as well as for communication protocols are needed (Garcia-Valle, Pecas Lopes, Joao A. 2013, p. 97).

For further information see (Binding et al.) and (Østergaard et al. 2009) or especially for the vehicle-to-grid technology (Kempton, Tomić 2005) and (Kamboj et al. 2010).

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[10] Absolute energy of the vehicle: $E_n = V_{batt}*C_n$, V_{batt} is the nominal voltage of the battery pack; C_n is the nominal capacity of the battery pack

4.5 Business Opportunities

EV are a combined interdisciplinary interface between semiconductor technology, manufacturing, software management and energy economics. While taking a look at the charging and management of EV the following points offer opportunities for the implementation of possible business models:

1. **Load and revenue**: Consuming electricity results in an additional revenue stream for the power supplier and the grid operator.
2. **Scheduled charging**: Shift the charging to low price periods. For this a corresponding market structure and tariffs need to be available, e. g. a spot market tariff.
3. **Responsive charging and discharging (V2G)**: In response to real-time cost and control signals on the basis of signals from a grid or system operator the EV can be loaded and unloaded in a way that the system costs are minimized. Other optimization strategies are possible where the following play an important role for the revenue:
    a) Arbitrage when buying low and selling high on the energy exchange
    b) Distribution system support
    c) Reactive power compensation
    d) Generation support by “peak shaving” and “valley filling”
    e) Ancillary services
    f) Distribution upgrade deferral

    Of the here mentioned services responsive charging and discharging provides the major advantage.
4. **Backup power**: Upon grid failure the EV can be used to provide backup power. This is also referred to the term “vehicle to home”. For the implementation additional sensing and safety mechanisms need to be installed. (Garcia-Valle, Pecas Lopes, Joao A. 2013, pp. 90–91)

Hence, the following general business models can be identified ranging from business models that already exist to the ones that are still a long way off.

1. **Simple business models**: The car manufacturer earns money by selling EVs, the charging station producer sells electrical equipment, the electrician installs the devices and the utility company delivers the respective energy.
2. **Enhanced charging service**: All charging related devices and services are bundled in a single package and sold to the customer. This includes the charging station, the installation, the loading and normally an id-card for public loading. All this is either offered for a monthly fixed price or per unit in kWh.
3. **Enhanced charging service without ownership**: The service provider in this case owns the battery in the car. This has the advantage for the customer that he avoids the high initial

investment, shifts the responsibility for deterioration and it opens up the possibility for fast charging by changing the battery. The monthly payment would be quit high to repay the battery costs. An example for this model is “Think City”, a Norwegian start-up that rents out the battery units to their customers on a monthly basis. Another example is the business of Shai Agassi. The Israeli charges the battery with wind power and lends it to his customers (COWI 2008).

4. **Grid services**: The business model operator uses the aggregated ability of the batteries in EV to provide grid services. Requirements are the installation of ICT and a two way power flow between battery and grid. If the value of the grid service is higher than the cost for the electricity demand – accordingly a positive payment for the EV owner - as suggested by (Garcia-Valle, Pecas Lopes, Joao A. 2013, pp. 92–93) could be realized. If this is actually possible will be tested for a smart grid region in Norway in chapter 7.2.4.

5 Micro-CHP systems

> “Money is not everything, but without money, all is nothing.”
> – Unknown origin

5.1 Introduction

Combined heat and power (CHP) plants are normally small and medium sized power plants that generate electricity and useful heat. This combination is also called cogeneration and increases the thermodynamically efficiency of the energy source usage. If the power plant can additionally provide cold it is named “trigeneration” or combined cold, heat and power (CCHP). CHP/CCHP increases the efficiency of the fuel conversion in comparison to separate generation and therefore reduces CO_2 emissions, depending on the underlying energy mix.

Three different kinds of CHP plants exist: centralized-CHP plants with up to 500 MW_e, local heat-CHP plants with a maximum generation of about 10 MW_e and micro-CHP plants with small scale installations up to 10 kW_e. This thesis will focus on micro-CHP.

Three main technologies are used to power micro-CHP power plants: 1. internal combustion engines, 2. stirling engines and 3. fuel cells. (Pehnt et al. 2006)

1. ICE are the best commercially available and well-engineered technology on the market at the moment (e. g. Honda ecoPower 1.0 kW Otto-cycle, Kirsch BHKW L 4.12 2-4 kW Otto-cycle) (Preißner 2011). They are comparable to automobile engines (Pehnt et al. 2006). Such engines reach an efficiency of around 20 to 30 %, but have relatively high NO_X emissions (Houwing 2010).
2. Stirling engines (e. g. Viessmann Vitotwin 300 1.0 kW, Brötje Stirling, Bosch Stirling) (Preißner 2011) are external-combustion engines. They work by the repeat heating and cooling of a sealed working gas moved by a piston between hot and cold heat exchangers (Organ 2010). Stirling engines reach low electric energy efficiencies of about 10-20 % but offer high fuel flexibility and low NO_X emissions (Houwing 2010) (Ben Maalla, El Mehdi, Kunsch 2008). Though there are some companies on the market with stirling engines in the pilot and

demonstration phase, phone calls to these companies revealed that no company is producing sterling engines in bigger scale at the moment because cost got out of hand.

3. Fuel cells are based on a solid-state electro-chemical reaction that converts fuel and air directly into power and heat. This process can be significantly more efficient than ICE. Fuel cells can operate with natural gas as well as hydrogen fuels, but just with hydrogen the output is just energy and water and therefore locally emission free. The following fuel cell technologies are the most common but although still in research and testing phases: methanol fuel cells (DMFCs) usable in laptops, polymer electrolyte membrane (PEM) for the automotive industry using pure hydrogen as well as proton exchange membrane fuel cells (PEMFC) and solid oxide fuel cells (SOFCs) that has been downsized for micro-CHP. Fuel cells micro-CHP plants in the test phase are for example Callux Baxi Innotech Gamma 1.0, Callux Hexis Galilea 100 N and Callux Vaillant SOFC (Preißner 2011); (Hexis); (CeresPower; Houwing 2010).

CHP systems are designated to produce power, hot water and supply heating for houses and small businesses. The produced electricity can be fed into the grid or used internally. CHP plants are normally optimized to produce as much as possible electricity, though are basically switched on and off when heat is demanded (heat-led). The depicted layouts in Figure 11 and Figure 12 show an ideal case of how cogeneration can improve the use of primary energy (Houwing 2010, p. 6). The units of primary energy needed to produce 100 units of end energy diverge. The assumed efficiencies are idealistic and adopted from (Houwing 2010).

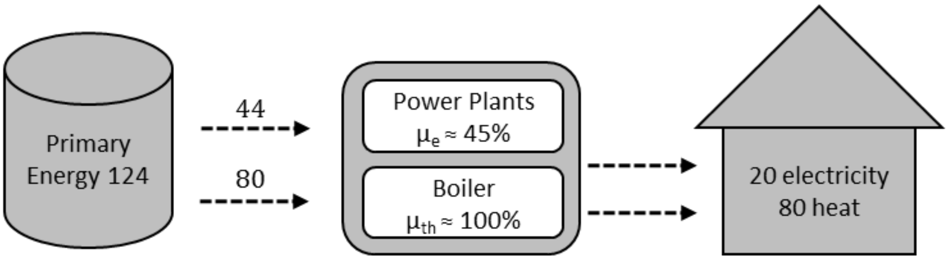

Figure 11 Energy Efficiency with Separate Generation, Adapted from (Houwing 2010, p. 6)

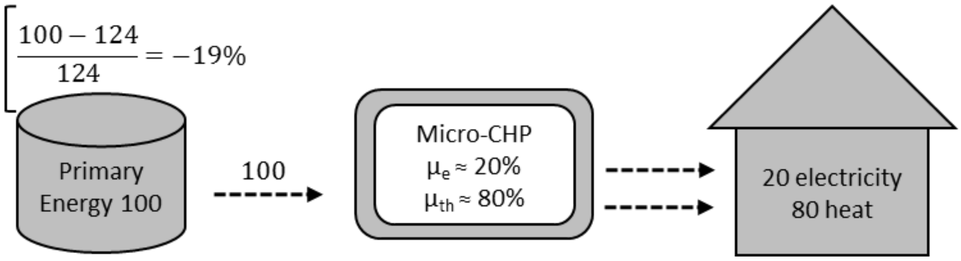

Figure 12 Energy Efficiency with Micro-CHP Generation,
Adapted from (Houwing 2010, p. 6)

The respective CO_2 savings depend on the fuel mix of the current electricity production, the type of household, the micro-CHP technology, the control strategy and the fuel used in the CHP plant. A broad study of (Dorer, Weber 2009) conclude that the average CO_2 reduction is around 9 to 24 % in Germany. Taking into account the exceptional energy mix, 95 % hydro power (OECD, IEA 2003), in Norway the CO_2 emissions will increase if not biomass is used as fuel for the micro-CHP plants. For a more detailed CO_2 emission calculation, (Pehnt et al. 2006) offer a life cycle assessment where they conclude a greenhouse gas emission reduction of 20-40 % for the normal German energy mix and gas fired micro-CHP plants. A set-off in chapter 5.7 reveals that these numbers are not realistic anymore. The decarbonisation of the German energy production, due to huge amounts of renewable energy, is processing so that the emission reductions with CHP shrink. Fired with biogas the additional emission would be unessential.

CHP has been widely discussed in literature. Most of it, is in combination with other technologies and written from a technical point of view. Furthermore, CHP systems are seen as a stand-alone, non-intelligent power stations. Less work has been done on the field of active participation of micro-CHP plants in the electrical infrastructure. This comes along with very few literature about active control, DSM and improvements of technological economic feasibility through intelligent control (Houwing 2010, p. 14). Generally, intelligent control of micro-CHP systems has the potential to increase economic feasibility.

5.2 Control Strategies

Intelligent control schemes of micro-CHP systems can be classified in terms of control actions and information exchange. Figure 13 shows the different possibilites how to structure the heat and electricity demand of a household.

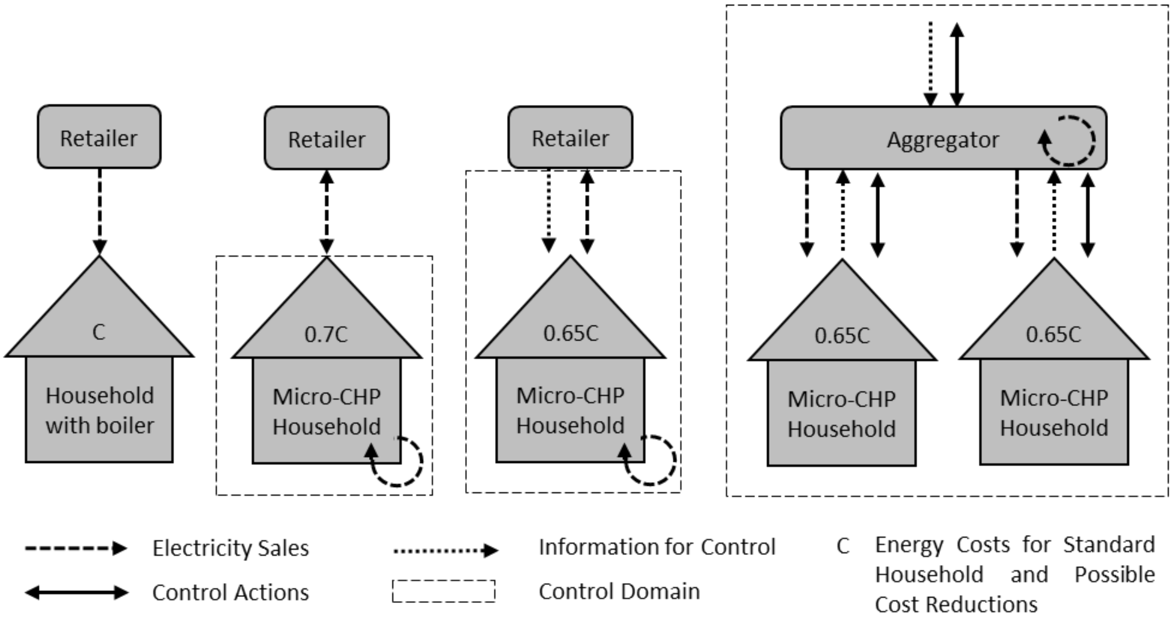

Figure 13 Control Strategies of Micro-CHP Systems,
Adopted from (Houwing 2010)

1. The **standard household** is depicted on the left hand side. The elctricity demand is met by a retailer and the heat demand with a local boiler. In Norway the the boiler is heated with electricity and in Germany with gas. The 100 % stands for the energy demand of the standard case.
2. The **decentralized control strategy** is based on local control. No additional information flow between the household and the retailer is needed. There are different possibilities like using additional hot water storages to improve overall performance. Basically micro-CHP generates substantial variable cost savings. Less electricity is used but more gas is needed, that results in an overall primary energy reduction of 30 % respectively the German energy mix (Houwing 2010, p. 55). Though the savings do generally not justify the high investments.
3. The **distributed control strategy**, shown in the third house, uses unilateral communication from the retailer to the household additionally. This can be for example price signals or other incentives to enable smoothing. Economic value is created by using the installed capacity more intelligently. Partly this value is realized as cost savings for the households. Additional savings are approximately 5 %; depending strongly on technology, pricing regime and the available storage volume. Once ICT is installed more distributed energy resources like EV and DSM can be joined without additional cost for ICT. (Houwing 2010, p. 85).
4. The **centralized control strategy** is based on a centralized aggregator which is monitoring and controlling the customers load and production via bidirectional information exchange. The

individual control schemes, as in the distributed control strategy, are lifted to an aggregated level. A moderate increase of the economic feasibility can be explained by the realization of economies of scale because reduced equipment is needed locally. Furthermore the predictability of the energy demand can be improved. The latter is due to clustering and averaging effects which make the demand profiles more predictable and outcomes controllable. The additional saving potential for households by participating in virtual power plants is moderate in comparison to local optimization and most likely not enough to join virtual power plants actively. Virtual power plants (chapter 3.3.2) are a cluster of e. g. distributed micro-CHP systems that are controlled and accessed by an aggregator (chapter 3.3.3). (Houwing 2010, pp. 78, 108) (Negenborn et al.) (Dam, Koen H. van et al.).

5.3 Costs of CHP Systems

This chapter gives a short overview about firstly the competitive market of micro-CHP, secondly lists the costs for different micro-CHP systems in comparison to a standard boiler and thirdly gets into detail into the cost structure of a micro-CHP system.

Micro-CHP plants compete on a market that has been completely penetrated by established products and technologies like gas, oil, solar and electric water heaters, district heating, as well as electricity straight from the socket. These goods are substitute goods.

A substitute good is a good with a positive cross elasticity of demand. This means that substitute goods, as a result of changed conditions, may replace each other. I. e. if the price of one good is going up, the demand for the other good is going up (Varian 2010). Examples could be oil and gas but also micro-CHP plants and heat pumps. Both are low carbon technologies and will play a bigger role in the future. That means that the most important factor for the decision on which technology will be used are the costs, and respectively the price for the end-customer.

Table 5 lists the expected investment costs and capacities of gas-fired boilers and different micro-CHP systems. Investment costs include costs of the prime mover, the auxiliary burner and balance of plant equipment. They exclude the costs of heat storage systems. For PEMFC systems, costs additionally include costs of the inverter and fuel reformer.

Table 5 Investment Costs of CHP Systems,

Sources: (Houwing 2010, p. 10), (Nefit 2014) (Veillant 2014) (Onovwiona, Ugursal 2006) (Pehnt et al. 2006) (Staffell 2007) (Staffell et al. 2008)

System	Investment Costs [€]	Prime Mover Capacity		Auxiliary Burner Capacity
		[kW_e]	[kW_{th}]	[kW_{th}]
Boiler	1,500-3,000	-	-	20
ICE Micro-CHP	5,500-7,000	1	4	20
Stirling Micro-CHP	5,500-6,000	1	5	20
PEMFC Micro-CHP	3,000-9,000	3	5	20

Since PEMFC is still in the research stadium it contains high R&D costs; though, it has a huge potential when cost decrease in future.

A study conducted by (Ruijg, Laag, P. C. van der 2003) estimated the justifiable financial scope for a higher investment through reduced energy costs of micro-CHP of about 300 to 1,100 € for stirling and ICE systems and around 700 to 1,600 € for solid oxide fuel cell systems in comparison to currently used gas boilers.

In Table 5, a spread of about 4,000 € in investment costs between a standard boiler and ICE or stirling micro-CHP systems can be seen. Using the annuity calculation leads to a need for variable costs savings per year of about 349 €.

$$a_f = \frac{r \cdot (1+r)^N}{(1+r)^N - 1}$$

$$a_f = \frac{0.06 \cdot (1+0.06)^{20}}{(1+0.06)^{20} - 1} = 0.0872$$

$$Variable\ cost\ savings = a_f \cdot Investment$$

$$Variable\ cost\ savings = 0.0872 \cdot 4000€ = 348.8€$$

Formular 1 Annuity Calculation

Underlying these numbers, too high investment costs and insufficient variable cost reduction make micro-CHP plants basically uneconomic. However, ancillary incomes from grid services can contribute to make CHP profitable.

Not just the investment, many important factors will influence the costs of a micro-CHP plant. A detailed look in the cost structure will be taken in the following. Time in operation, and fuel prices are the most important costs, followed by investment, discount rate, planning, plant manufacturing, financing, connection to the grid, billing, energy purchase, maintenance and insurance. Figure 14 shows a common heat demand over a year. The highest heat demand normally determines the size of the hot-water boiler and the plant itself.

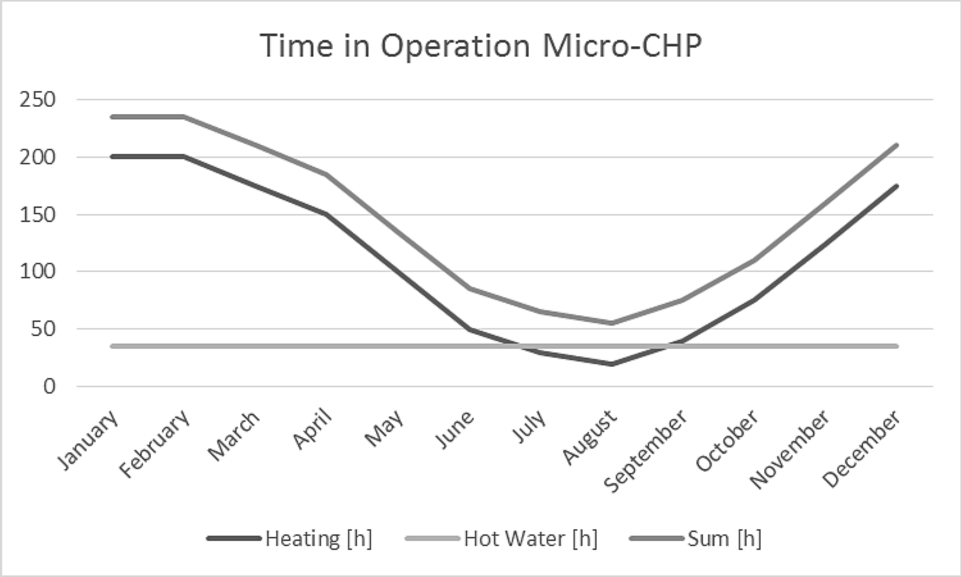

Figure 14 Time in Operation of a Micro-CHP Plant,
Adapted from: (Simader et al. 2004, p. 48)

As seen in Table 6, the bigger the plant the better the cost structure and, depending on the running time, the plants get more profitable.

Table 6 Costs of Low Emission CHP Systems of the Company Senertec, Source: (Simader et al. 2004, p. 56)

	Unit	Motor 5.0 kW	MGT 60 kW	Motor 70 kW	Motor 90 kW
Power Output	kW_{el}	5	60	70	90
Heat Output	kW_{th}	11,7	145	118,3	147
Power Efficiency	%	26	26	32	33
Thermal Efficiency	%	61	63	54	54
Module Price	€	13,500	101,000	78,000	91,000
Maintenance Cost (Full Service)	€/kWh	0.02	0.01	0.018	0.017
Lifetime	years	15	10	15	15
Discount Rate	%	6	6	6	6
Fuel Costs	€/kWh	0.035	0.031	0.031	0.031
Amortization with 4000 h/a	years	20,5	7,1	5,6	4,8
Amortization with 5000 h/a	years	14	5,4	4,3	3,7
Amortization with 6000 h/a	years	10,7	4,4	3,5	3

The ideal size of a Micro-CHP system needs to be calculated elaborately. For literature about this see (Simader et al. 2004). Important steps are the calculation of full load hours, heat demand, electricity production and the evaluation of inducements or incentives from the government or the TSO as well as possible contracting solutions.

5.4 Incentives and Profitability

Micro-CHP plants contain too high investment costs and insufficient variable cost reduction in comparison to conventional boilers. This leads to two questions: Who is still interested in having micro-CHP? And how can one solve this cost dilemma?

Three possible solutions for the latter are:

1. Governments could provide subsidies or tax benefits. CHP is rated by the European Commission as an important way to improve energy efficiency and security of supply (Simader et al. 2004, p. 44). With the policy 2004/8/EC (COGEN Europe 2004), Europe promotes so called “highly efficient” CHP technology which saves about 10 % of primary energy demand in comparison to separated heat and electricity production. Local governments often provide cheap loans and feed-in tariffs to promote CHP. For example in Germany three different kinds of subsidies are used.

    a) CHP-law (KWK-Gesetz) for all CHP-plants that use fossil energy sources. (Verbraucherzentrale NRW 2014)

Table 7 Incentives of the German CHP-law,
Source: (Verbraucherzentrale NRW 2014)

CHP-Law	Cent/kWh
Energy Price on EEX	3.26
CHP-Subsidy	5.41
Avoided Grid Costs	0.5
Feed-in Tariff	9.17

    b) Renewable energy law (EEG) for all CHP-plants that use renewable resources like biogas, rape methyl ester (RME) or wood pellets.

Table 8 Incentives German Renewable Energy law,
Source: (Verbraucherzentrale NRW 2014)

Renewable Energy Law	Cent/kWh
Remuneration	14.3
Basic Feed-in Tariff	14.3
Additional Payment for Energy Carrier	6-8
Gas Processing Bonus	1-3
Maximum Feed-in Tariff	20.3-25.3

    c) Cheap loans are offered by the German reconstruction loan corporation/Kreditanstalt für Wiederaufbau (KfW).

2. Market oriented policy instruments for the domestic sector like emission trading schemes could help to improve profitability of CHP-plants (Houwing 2010).
3. CHP plants can deliver certain system benefits for the distribution network (Houwing 2010, p. 12), (Cossent et al. 2009; Joode et al. 2009; Frías et al. 2009), (Scheepers et al. 2007)
   This includes: (Costa et al. 2008) (Marnay et al. 2008)
    a) Avoided network losses, e. g. when the energy is produced where demanded
    b) Improved reliability, e. g. through DSM or flexible controllable generation
    c) Postponing of network investments, e. g. when increased local demand would make a network extension necessary and this local demand could also be met by a decentralized micro-CHP plant.

5.5 Network integration and DSM

Micro-CHP plants are connected to the low voltage grid (Houwing 2010, p. 6) (chapter 2.2). This can lead to positive and negative influences on the grid. Beside other important factors the level of penetration of CHP plants plays an important role (Marnay et al. 2008). On the one side too large amounts of decentralized CHP can cause network instability trough capacity limits of cables and transformers (Landsbergen 2009). In such a case network equipment may need to be adjusted. Generally, large amounts of micro-CHP could be integrated into the grid without causing any major network problems (Landsbergen 2009; Pehnt et al. 2006). On the other side very few literature put emphasize on how micro-CHP generation can relax and stabilize the grid. Not even that grid investments can be avoided or postponed, micro-CHP can deliver a service to the grid. A major question is: do micro-CHP plants get profitable when they deliver additional services to the grid, for example when the benefits of the advantages are just and equitable allocated to the agent.

To take a look at the shifting potential a few general points need to be considered: (Droste-Franke et al. 2012, pp. 109–110)

- Micro-CHP plants, in comparison to bigger CHP plants, normally cannot work in monovalent operation and cannot be modulated. A monovalent operation means that during peak load times just heat is provided.
- Micro-CHP can be operated through connection and disconnection and that can be coordinated centrally.
- CHP plants are heat-controlled. The end customers require a heat provision at any time.
- Sufficiently dimensioned heat storage is part of any plant.
- It can be assumed that to fill up the heat storage with full power and to empty it under full load takes around 4 h (Droste-Franke et al. 2012, p. 110).
- Over the year the heat demand varies strongly (chapter 5.3).

There is a great number of manufacturers and models, so the exception proves the role.

To run a CHP plant profitable the operating hours must be maximized. To reach more operating hours a smooth heat demand is advantageous. Normally the heat demand in winter is much higher. CHP plants are constructed to run at full power during this high demand in winter. When the heat demand declines towards the summer also the operating hours per day decrease also (Nitsch 2008), (Droste-Franke et al. 2012, p. 111).

Table 9 and Table 10 show estimations of the positive and negative shifting potential of micro-CHP and local heat CHP plants for the year 2020 in Germany.

Table 9 Negative shifting potential of CHP, Source: (Nitsch 2008), (Droste-Franke et al. 2012)

Negative Shifting Potential for Germany in 2020 [GW]		
	Summer	Winter
Micro-CHP	0,3	3
Local Heat CHP	0	5

Table 10 Positive shifting potential of CHP, Source: (Nitsch 2008), (Droste-Franke et al. 2012)

Positive Shifting Potential for Germany in 2020 [GW]		
	Summer	Winter
Micro-CHP	5,7	3
Local Heat CHP	5	0

The conduction of these results is rather simplified and is based upon a quite specialized future scenario, but it gives a direction of which kind of CHP contains the higher potential for DSM and in which order of magnitude the potentials during winter and summer lie. The transition periods hasn't been considered and could contain huge positive as well as negative shifting potential. These numbers for micro-CHP are based on an estimated installed power of 6 GW in 2020 and the assumption that 50 % of the installed capacity in winter and just 5 % in summer are always in operation (Nitsch 2008), (Droste-Franke et al. 2012, p. 110). Field experiments of a German gas grid company yielded in 1,025 to 5,233 hours of yearly operation of micro-CHP plants (Preißner 2011) which are much more than the assumed number in the calculations of (Nitsch 2008), (Droste-Franke et al. 2012, p. 110).

5.6 Business Opportunities

As (Simader et al. 2004, p. 61) put it in their paper, the realization of CHP plants does not fail most of the times because of poor profitability, it is rather informational and bureaucratic barriers, additionally high investment costs, complicated maintenance and tedious approval procedures. A great solution of these problems are the different forms of contracting. A contractor is a service company that takes over tasks from an individual. In the case of micro-CHP plants the company – the contractor – takes over completely or partly: planning, construction, financing and maintenance. What and to which extent decides the owner. The payment for the contractor is normally a contracting rate which is a part of the savings that are achieved by implementing the project. The contractor generally gives a guarantee for the success of his measures. (Simader et al. 2004, p. 61)

Different contracting forms can be: energy supply contracting, performance contracting, financing contracting and maintenance contracting. (Simader et al. 2004, pp. 61–64)

1. **Energy supply contracting**: The contractor does everything from planning, constructing, financing, running, procurement and maintenance. The payment is performance-related

targeting the most efficient energy conversion and the cheapest energy price. For the customer this is the easiest way, no investment, no risk and cheaper energy prices. A part of the spread between the old and new prices, the energy savings, is the payment for the contractor. Of course the payment is the higher the more service is provided and the more risk is transferred.

2. **Performance contracting** is basically used to finance big renovation and isolation work at houses. The contractor is financing and constructing everything and may even takes over the housing energy management. His rent is a share of the realized energy savings. The more energy is saved the higher the profits.
3. **Finance contracting** is leasing the financed and constructed plant to the customer. The plant management and therefore the risk is taken by the customer.
4. **Maintenance contracting** is a service to secure the running of the plant. The payment is balanced according to the effort.
5. **Control contracting** is the management of flexibility, load, including DSM and ancillary services.

Contracting could generally be done by every company that provides the know-how to do so.

5.7 Critics

The main governmental intention behind the support of CHP plants is the reduction of greenhouse gases. A short calculation will clarify how much CO_2 is actually saved and how noble the noble-minded intentions really are. Table 11 shows an overview about important data for the calculation. If not denoted separately in a footnote the data comes from the IEA. In the following three case scenarios are calculated: separated production – power plants and gas boiler - in Germany, hydro power production in Norway and micro-CHP production in Germany and Norway

Table 11 Comparison of German and Norwegian Energy Data,
Source: (OECD, IEA 2003)

	Norway	Germany	Unit
Efficiency of Electricity Mix Production	90	38	%
CO_2 Emissions of Energy Mix	307[1]	576[2]	g/kWh
Energy Consumption per Household	21,014	17,344	kWh/year
Electricity Consumption per Household	21,014[3]	3,359[4]	kWh/year
Natural Gas Consumption per Household	0	13985	kWh/year
Share Space Heating	64	66[5]	%
Share Warm Water	15	16[6]	%

Case 1: Separated production – power plants and gas boilers - in Germany

More than 40 % of Germany's electricity is produced in coal power plants. All German power plants have an average efficiency of 38 %. (Milles, Horenburg 2011). The spatial heat demand in Germany is normally produced in high efficient local gas boilers. A gas-fired local water boiler has an efficiency of nearly 100 %. To meet the German energy demand of 17,344 kWh/year 13,985 kWh/year of primary energy are needed to fire the gas boiler (µ = 100 %) and 8,840 kWh/year of primary energy are needed to meet the electricity (µ = 38 %) demand. The CO_2 emissions for the gas boiler are 7,733 kg CO_2/year (0,554 kg CO2 per kWh natural gas) and for the electricity production 1,935 kg CO_2/year (Icha 2013). All together the carbon emissions are 9,667 kg CO_2/year.

Case 2: Hydro power production in Norway

The Norwegian household end-energy demand of 21,014 kWh/year is produced by 90 % efficiency hydropower plants, 23.348 kWh/year of primary energy is needed. The CO_2 emissions are nevertheless not zero. Norwegian energy generator companies sell to a large extend the proof of origin, the so called renewable energy certificates (REC), of their electricity on the European market. After the electricity disclosure the share of renewable hydropower in the Norwegian energy mix went down to 23 %. Taking into account the guarantee of origin and the calculations in the RE-DISS project the carbon

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[1] NVE 2012
[2] Icha 2013
[3] Sæle, Grande 2011
[4] Musterhaushalt.de
[5] Umwelt Bundesamt 2014
[6] Bundeszentrale für politische Bildung 2009

emissions of Norway's electricity are 307 g/kWh. The overall CO_2 emissions are therefore 7,168 kg CO2/year. (NVE 2012)

Case 3: Micro-CHP production in Germany and Norway

Micro-CHP plants have efficiencies of more than 90 % (Voith 2013). The primary energy demand of a German household would be 19,271 kWh/year and of a Norwegian household 23,349 kWh/year. This leads to CO_2 emissions per household of 10,676 kg CO_2/year in Germany and 12,935 kg CO_2/year in Norway.

If a household would decide to replace the existing energy mix with a micro-CHP system, this would lead to a CO_2 increase of about 10 % in Germany and an increase of 80 % in Norway. Even if the efficiency of a micro-CHP plant is set to 100 %[1], the German CO_2 emissions would stay at the same level. That means as long as micro-CHP plants run with natural gas, no CO_2 emissions can be realized in Norway as well as in Germany. If a micro-CHP plant replaces just the most inefficient power plants on the respective markets instead of the average energy mix CO_2 reductions are possible. But the replacement of production capacity is determined by the merit order curve.

If the micro-CHP power plant can be operated with biogas, the CO_2 emission can be reduced significantly and the operation is beneficial for the climate. Therefore governmental incentives should be focused on facilities fueled by biogas.

Table 12 contains the CO_2 emissions for Germany and Norway with and without CHP. The numbers are the results of the above described scenario cases.

Table 12 CO_2 Emissions per Household

	Norway	Germany	Unit
CO_2 Emissions of Household	7,168	9,667	kg CO2/year
CO_2 Emissions of Household with Micro-CHP	12,935	10,676	kg CO_2/year

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[1] Micro-CHP efficiency of 100 % would lead to CO_2 emissions of 9,609 kg CO_2 per year and household in Germany and in 11,642 kg CO_2 per year and household in Norway.

6 Business Models

> "The past is a foreign country; they do things differently there."
> – L. P. Hartley in the Go-Between (1953)

6.1 History

Business models may exist since human kind produces and trades goods but they haven't been called like that till the early 20th century. Companies that successfully implemented pioneering business models with great success brought the term into every day's life. Especially American companies like McDonald's, Dell Computer, eBay or Facebook that changed the way of marketing should be mentioned here. In the last 20 years especially internet technology played a very important role for entrepreneurs.

6.2 Definition

A business model itself is used on the one side to describe and classify existing businesses as well as helping to generate strategies. On the other side they are used to generate new entrepreneurial settings. The process of constructing and creating business models is part of the business development and business strategy process.

Generally business models can be classified by field of product service systems: (Tukker, Tischner 2004, p. 247)

- Product-oriented services: traditional sales of products but with additional services like insurance, maintenance, supply of consumables and take-back agreements.
- User-oriented services: traditional products but rather sold than leased, rented, shared or pooled.
- Result-oriented services: delivery of results and services not products, like the mobility service instead of the car.

(Lee, Cole 2003) defined business models in an economic way as "a statement of how a firm will make money and sustain its profit stream over time."

(Slywotzly 1996) considers the different components regarding a business model as “the totality of how a company selects its customers, defines and differentiates its offerings, the tasks it will perform itself and those it will outsource, configures its resources, goes to market, creates utility for customers and captures profits.”

(Mayo, Brown 1999) considers the strategic outcome of business models as “the design of key interdependent systems that create and sustain a competitive business.”

(Osterwalder et al. 2010) state: „a business model describes the rationale of how an organization creates delivers, and captures value.”

By general word using the term business model is often related to innovativeness which rather doesn’t play a role in the literature.

6.3 Design

The business model design examines in greater detail the underlying idea of the business. It defines the logic of a business at the strategic level. In comparison to that, the business model development process or business modeling is the design on the operational level. An important part of business model designs are frameworks.

A framework gives a structure to describe and visualize complex subjects. In the area of business models plenty of frameworks have been introduced. A list of business model frameworks can be found in (Krumeich et al. 2012).

(Michael Lim 2010) proposed a business model design framework called Environment-Strategy-Structure-Operations (ESSO) Business Model Development that emphasizes the design theme. It aligns operations, strategy and structure with a company’s environment. The aim is to achieve a competitive advantage through effectively and innovatively managing costs, time and quality.

One of the most applied frameworks is the content oriented business model canvas. It is a trend-setting concept for business model generation covering the main areas: customers, offer, infrastructure and financial viability (Osterwalder 2004).

The book business model generation (Osterwalder et al. 2010) provides a 9 block approach that helps to identify, cluster and value business models.

1. Infrastructure
    a. Key activities
    b. Key resources

    c. Partner network
2. Offering
    a. Value proposition
3. Customers
    a. Customer segments
    b. Channels
    c. Customer relationships
4. Finances
    a. Cost Structure
    b. Revenue Stream

6.4 Business Model Canvas

As mentioned the business model canvas (Osterwalder et al. 2010) helps to structure and to identify possible business models. It has been chosen because it is widely used within entrepreneur circles and is one of the most common models for business model generation. The approach described here is the basis for the further development of the business model of an ESCO.

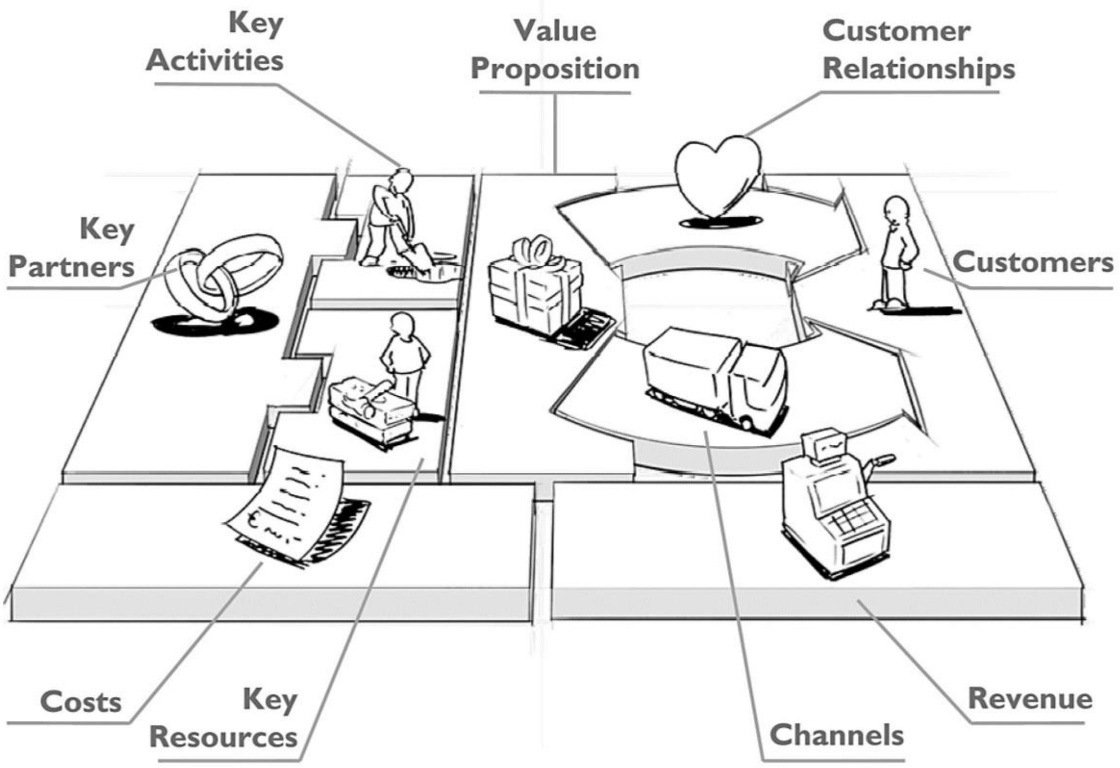

Figure 15 Business Model Canvas,
Source: (Osterwalder et al. 2010)

This chapter focuses on introducing the 9 blocks of the generation process and tries to give examples from the energy market to the different sub items. This chapter should therefore also give an overview about changes and chances of the whole energy value chain. When in the following chapters business models are introduced or generated they will always be grounded on the 9 block classification and the symbols are used as recognition factor.

6.4.1 CUSTOMER SEGMENTS

Customer segments are groups of people or organizations that the enterprise aims to reach and serve. An enterprise has to select customers segments carefully and then learn as much as possible about them in order to focus on the specific customer needs. The business model is designed around the customer’s needs. Different customer segments are needed when:

a) Customer needs of every segment require and justify a distinct offer
b) customers are reached through different distribution channels
c) customers require different types of relationships
d) customers have substantially different profitabilities
e) and when customers are willing to pay for different aspects of the offer. (Osterwalder et al. 2010, p. 1)

On the energy market there are plenty of segments and they can vary strongly. Table 13 shows the transactions and information exchange between energy market actors which are very often customer and vendor at the same time. This makes it also very difficult to separate possible customer groups on the energy market.

Table 13 Financial Transactions and Information Exchange between Energy Market Actors, Source: adapted from (Donkelaar, Scheepers 2004, pp. 43–45)

	Actor/Market	Offers	To	Expects in return
1	Fuel supplier	Fuel (gas, oil, biomass, coal)	DG operator/Large power producer	Payment for fuel on basis of contracted fuel prices
2	DG operator/Large electricity power producer	Electricity	Energy supplier	Payment for electricity on basis of wholesale contract
3	Energy supplier	E-program management	DG operator/Large power producer	E-program responsibility
4	Energy supplier	Electricity	Consumer	Payment for electricity on basis of a retail contract

5	Consumer	Outsources E-program responsibility	Energy supplier	E-program management
6	DSO	Grid access and use	DG operator	Payment of connection and use of system charges
7	Energy supplier	Switching data	DSO	
	DSO	Generation and consumption data	Energy supplier	
8	DSO	Grid access and use	Consumer	Payment of connection and use of system charges
9	Large power producer	Balancing power	TSO	Payment of basis of balancing contract
	TSO	Grid access and use	Large power producer	Payment of connection and use of system charges
10	TSO	Ancillary services	DSO	Payment of ancillary services costs
11	Energy supplier	E-Program	TSO	
	TSO	Balancing services	Energy supplier	Payment for deviations
12	Large power producer	Ancillary services	Ancillary services market	Payment on basis of ancillary services contract
	DG operator	Ancillary services	Ancillary services market	Payment on basis of ancillary services contract
13	Large power producer	Balancing power	Balancing market	Payment if dispatched
	DG operator	Balancing power	Balancing market	Payment if dispatched
14	Energy supplier	Balancing power (indirect)	Balancing market	Payment to producers (via energy supplier)

15	DG operator/DSO/energy supplier	Storage services	DG operator/DSO/energy supplier	Payment for storage service

16	Ancillary services market	Ancillary services	TSO	Payment
	Ancillary services market	Ancillary services	DSO	Payment
16	Balancing market	Balancing services	TSO	Payment
	Balancing market	Balancing services	DSO	Payment

Looking for some common patterns, possible customers on the energy market can be classified in:

a) Mass Market for end customers and energy suppliers.
b) Niche Market for services that are more specialized and addressing just a small group of end-customers.
c) Segmented: The energy producers can be segmented into decentralized generation operators (e. g. households) and large power producers (chapter 2.1).
d) Monopolistic: The distribution and TSO can be seen as the monopolistic customer segment (chapter 2.2).
e) None: The balancing market, the ancillary service market, as well as other energy trading markets are no customer groups rather distribution channels (chapter 2.3).

6.4.2 Value Proposition

The value proposition represents the products and services that create value for the specific customer segment. Depending on this offer the customer decides what he or she wants to consume. Very important to keep in mind is the following: which customer needs are we satisfying or which customer’s problems are we helping. (Osterwalder et al. 2010, pp. 22–23)

Some distinctions of value propositions with examples from the energy field could be:

a) Novelty: This, for example, could be something entirely new like the introduction of personal helicopters replacing private cars (Climate-KIC 2013).

b) Price: A common value proposition is to offer a similar value at a lower price. This has been done successfully for example by low cost energy suppliers which offer cheaper energy than the old-established utilities.
c) Performance: Increased performance is a traditionally way of creating value and a powerful driver for new enterprises. A performance plus has been reached by introducing quantum technology-based transistors and other electrical devices to the power networks.
d) Customization: A tendency towards individualism can be seen form vintage styled jeans to individualized car features or furniture combinations form Ikea. These concepts are called mass customization and co-creation (Pine 1999); realizing economies of scales and still giving the customer the feeling of individualism. Tailored solutions for decentralized production in households could be mentioned here or the procurement of renewable energy are examples for this concepts.
e) Design/brand/status: Distinguishing features are also superior design, an outstanding brand or status symbols like EV or an autarchic internal energy supply.
f) “Getting the job done”: This could be called the value proposition to simply help the customer to get a certain job done like delivering electricity, gas and water.
g) Cost reduction: Another possibility is to offer the customer the help to realize cost reductions for example installing smart meters and information and communication technology to help the customer to benefit from changing energy prices.
h) Risk reduction: Offering a participation in a virtual power plant for trading the distributed generation creates value by risk sharing.
i) Accessibility: Making accessible what customers haven’t had before is another way of creating value. For instance giving the end customers the possibility to actively participate on markets and sell their self-produced energy.
j) Convenience/usability: Ease the customers’ life by e. g. creating apps for the control of the energy production and consumption in a household with energy spot price data or profit situation and thereby creating a lot of value for the customer.

A value proposition can be quantitative based on price and efficiency as well as qualitative based to improve customer’s overall outcome and experience.

As Michael Porter stressed, every company should adopt and focus on just one strategy. If it fails to do so, it will result in a “stuck in the middle” scenario (Porter 1980).

6.4.3 CHANNELS

The channels are important to deliver the value proposition to the customers. That includes communication, distribution, sales, purchase of products and services, customer support and evaluation. (Osterwalder et al. 2010)

One distinguishes between different channel types. possible channels are own sales force, shops and web sales that are direct channels as well as partner stores and wholesalers that are indirect channels.

To approach the customer the following channel phases will be at least partly followed (Osterwalder et al. 2010):

a) Awareness, inform the customer of what the company offers
b) Evaluation, help the customer evaluate our value proposition
c) Purchase, which channel types does the company use?
d) Delivery, how is the value proposition delivered?
e) After sales, customer support

Market aggregation and virtual power plants are two fields on the energy market that contain possibilities for new business opportunities. Depending on who is entering the market different channels will open up. Old-established firms like utilities and DSO already have their regular clientele. Such a direct connection normally leads to higher margins. New market entrants usually cannot draw on an established clientele. To build up own direct channels is costly. In such a case indirect partner channels are a good possibility to expand and benefit from the partners strength. Though the margins are lower; more options are available, such as wholesale distribution, retail or partner-owned web sites. New market entrants from other customer related industries like telecommunication companies can also use their existing clientele. To find the right mix of channels is crucial.

6.4.4 CUSTOMER RELATIONSHIPS

Customer relationships encompass all relationships between a company and a specific customer. The relationship should be deliberately chosen by the company considering: What type of relationship does each customer segment expect? How expensive are established and expected relationships? And, are they compatible with the business model? (Osterwalder et al. 2010)

The manifold opportunities reach from dedicated personal support and assistance to self-service where the customers are provided with the necessary information to help themselves. Communities or co-creation are further types of relationships often used in internet companies. These could be essential parts of the new energy economy to create trust between the company and the customer considering that supply and demand move together and the customers reveal personal data to the optimizing company.

6.4.5 REVENUE STEAMS

The revenue stream is the summed up cash a company receives from its customer segments. Revenue and cost determine the profit. The main question a company has to ask itself is the following: What value is the customer willing to pay? Fulfilling that will, the company can generate value streams for each customer segment. A revenue stream can thereby be comprised of transaction revenues from one-time payments or recurring revenues for ongoing payments for persistent delivery or post-purchase support. (Osterwalder et al. 2010)

A bouquet of possibilities exist on the market to generate revenue streams.

a) Asset sale, like smart meters (chapter 3.2.3) or micro-CHP systems (chapter 5), is the change of ownership of a physical good in return for money.

b) Most of the offers on the energy market are recurring revenues. A usage fee is taken for the delivery, trade and transmission of energy. The more service is used the more the customer pays. This leads to the dilemma of utilities; requested by the government to encourage their customers to save energy meanwhile earning money by every kWh sold.

c) Selling a continuous service for example a monthly subscription fee could be a possible revenue stream for apps or programs.

d) Lending, renting, licensing or leasing could be used for batteries of EV or micro-CHP systems.

e) Brokerage fees can be used when an intermediation service between two parties is performed. Examples are the matching service on the energy stock exchange, the service of a called aggregator (chapter 3.3.3), operators of virtual power plants (chapter 3.3.2) or other trading and aggregating companies. The revenue stream normally emerges from a percentage of the sold value.

f) Especially used in media industry, event management and software services – but not so common in the energy sector - are advertising.

How successful the revenue streams are generated depends on the above mentioned way of asset sale, usage fee, brokerage fee, advertising and so on but also on the chosen pricing mechanism. On the one hand there is fixed pricing: list-, product- feature dependent-, customer segment dependent- or volume dependent pricing. On the other hand a dynamic pricing where the prices changes with the market conditions is possible. This could be based on negotiations, yield management, real-time pricing or auctions. The energy market covers nearly all of these pricing mechanisms.

6.4.6 KEY RESOURCES

No business can be created out of the blue. Every business model requires therefore key resources for: the value proposition, the distribution channels, the customer relationships and the revenue streams. The kind of resources differs depending on the business model and can be physical, financial, human or intellectual. (Osterwalder et al. 2010)

An energy producer needs his capital-intensive production plants whereas a trader relies on human knowledge that creates his computer models. Intellectual property will be more important the more high-end technology finds its way into the energy sector. Key resources do not necessarily have to be owned. They can be leased or acquired from key partners; this counts especially for financial resources.

6.4.7 KEY ACTIVITIES

Key activities paraphrases all important things a firm has to do to make its business work. They can mostly be described easily even though the realization is another story. Key activities transfer key resources into value for the customer. (Osterwalder et al. 2010)

Energy generators run plants for energy generation. Consulting companies or energy advisers solve problems. Companies like Visa or Facebook but also TSO and DSO can be placed in the category network or platform related key activities.

6.4.8 KEY PARTNERSHIPS

For many business models partnerships and alliances become cornerstones for success (Osterwalder et al. 2010). Partnerships can reduce risk or help to acquire resources. The following types of partnerships can be distinguished:

a) Strategic alliances between non-competitors (Dyer et al. 2001)
b) Coopetition: strategic partnerships between competitors (Neumann, Morgenstern 2007)
c) Joint ventures to develop new businesses
d) Buyer-supplier relationships to assure reliable supplies (Porter 1980)

The motivation for creating partnerships is either economies of scale, reduction of risk or acquisition of particular resources and activities. Key partners should be kept limited - as many as it takes, as few as possible. A key supplier for an energy generator for instance is the feedstock supplier.

6.4.9 COST STRUCTURE

The cost structure includes all major costs of running the business model. What are the biggest cost factors? Which key resources and activities are most expensive? As mentioned in the value proposition the most business models fall in either a value-driven or cost-driven cost structure. The value-driven structure emphasizes value creation over cost.

This is the case for example in the supply sector for the oil market. The cost-driven business models put more concern in a lean and cost minimizing cost structure and may subordinate everything else to that in an extreme case. It could be useful to separate the costs into fixed and variable costs to identify economies of scale or potential economies of scope. (Osterwalder et al. 2010)

7 Case Study

7.1 Description

The case study data comes from the small city Florø. Florø is the westmost Norwegian city and is located at the west shore of Norway between Ålesund and Bergen. The city Florø on the eponymous island Florø has about 11,700 inhabitants of which 10,000 are living on the island itself, see Figure 16.

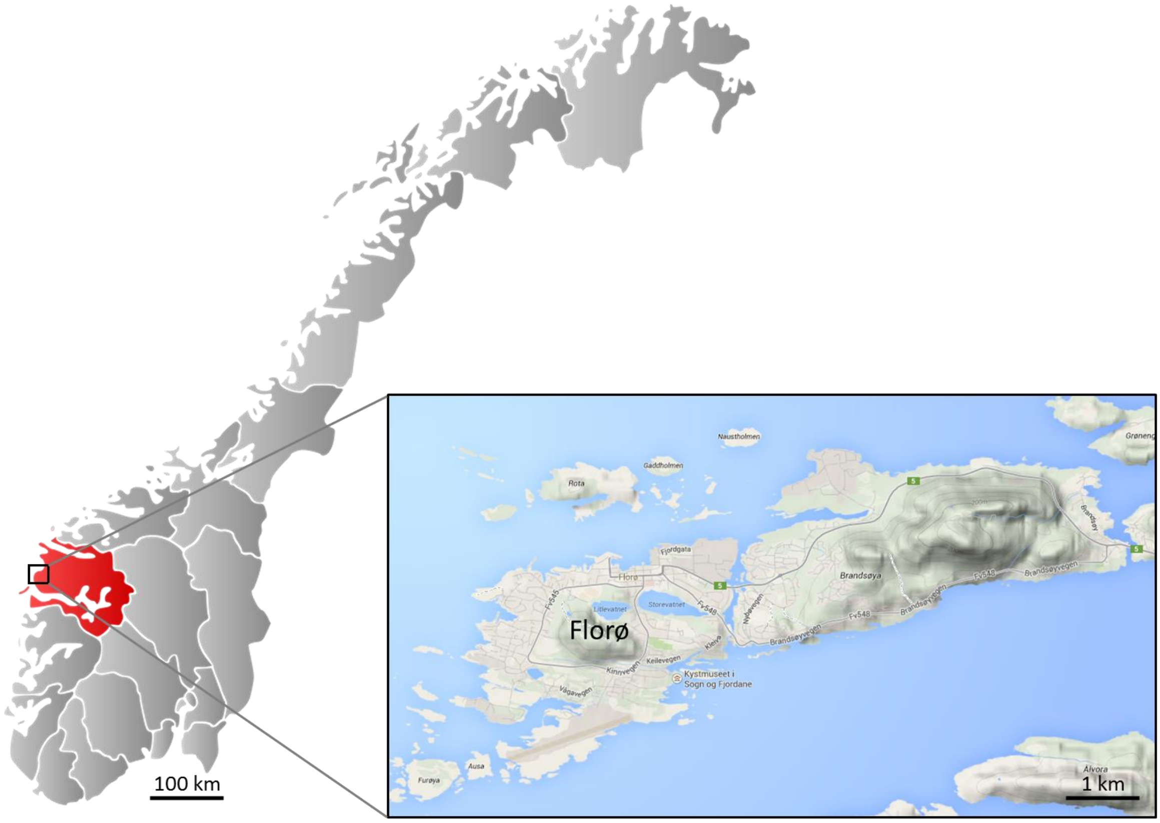

Figure 16 The Sogn og Fjordane County in Norway and the City Florø,
Source: (Google Maps 2014; Wikipedia 2014b)

All information on Florø is based on data form the local electricity distributor and retailer, Sogn og Fjordane Energie (SFE). The island is provided with electricity via two overhead power lines and a submarine power cable. The capacity of delivery ranges between 45 and 50 MW. This is because of seasonal thermal expansion of the power lines during summer times. During high temperatures the overhead lines are slightly longer and the losses higher. The average energy demand of Florø in the year 2013 was 22 MW. The highest metered consumption was 48 MW. In case of a problem with one of the overhead power lines the transmission capacity drops to 35 to 40 MW. Table 14 provides an overview of the data from the case study region Florø.

Table 14 Data Florø,
Source: Local Utility SFE

	Value	Unit
Transmission Capacity	45-50	MW
Total Consumption	193	GWh/year
Residential Customers	3963	
Commercial Customers	829	
Consumption Residential Customers	68	GWh/year
Consumption Commercial Customers	125	GWh/year
Grid Reinforcement Investment	16.5	Million €

SFE is responsible for the metering infrastructure and the grid expansion. SFE plans a reinforcement in 5 years, to stabilize the grid and extend the transmission capacity. The costs of the project are 16.5 million € (135 MNOK). The data were made available by SFE to performed studies to find out how grid stability can be guaranteed till the end of the reinforcement.

Figure 17 shows two exemplary days of 2013 to demonstrate the strongly varying energy demand. Whereas in summer the demand is quit constant between 15 and 20 MW (light dotted line), winter it is higher and lies between 20 and 35 MW (dark dotted line). The solid lines show the exemplary electricity price of a summer and winter day (right axis).

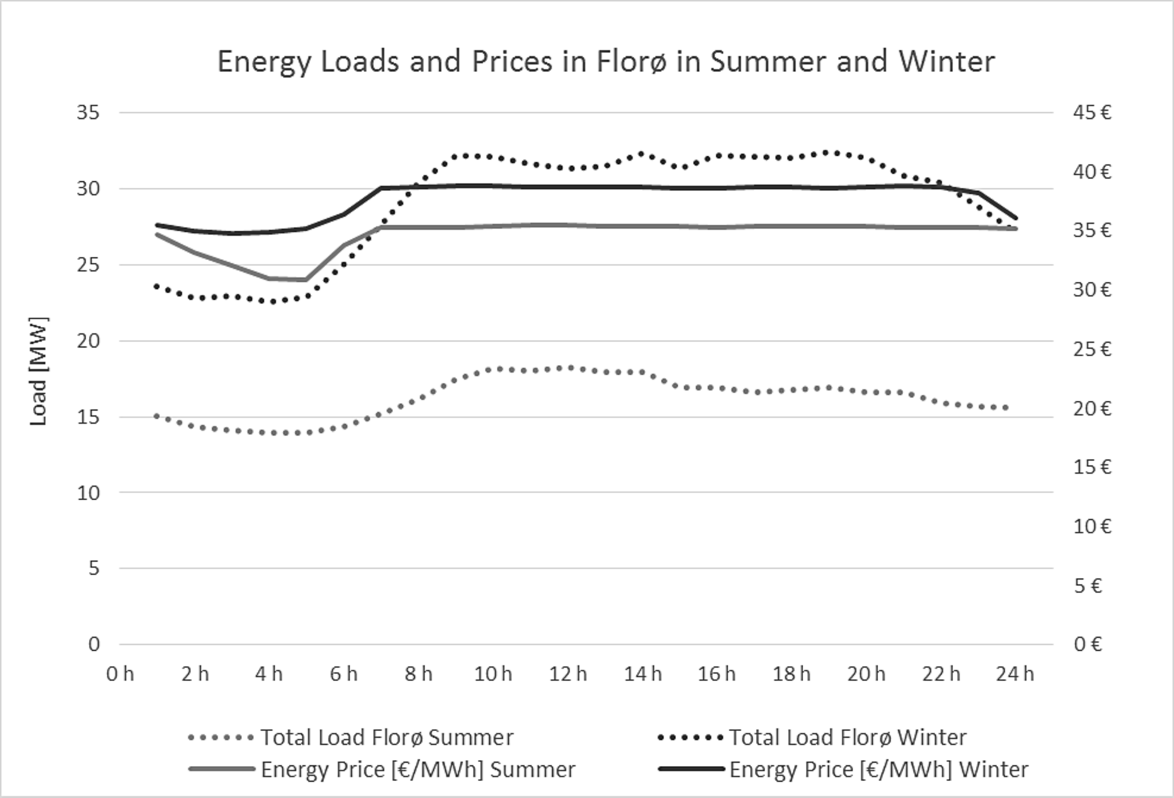

Figure 17 Energy Loads and Prices in Florø in Summer and Winter

7.2 Analysis

As mentioned in the introduction, new technologies on the energy market make room for new business opportunities. In chapter 3, 4 and 5 the technologies EV, CHP and DSM are introduced. For the business model the focus is on the most important distributed energy resources of every type:

1. Micro-CHP systems as distributed generation capacity (chapter 5),
2. energy savings (chapter 3),
3. load shift potential of customers as controllable energy demand (chapter 3) and
4. EV as energy storage (chapter 4).

Other storing technologies will not be introduced because they are neither cost nor energy efficient, or they can be included in one of the groups mentioned.

All technologies should be part of the business model whereas the question, which technology to use, can be evaluated by deciding: where, how much and how long are the needs for balancing power for the DSO and what facilitates saving potential for the end-customer.

7.2.1 MICRO-CHP SYSTEMS AS DISTRIBUTED GENERATION

The shifting potential of micro-CHP plants with thermal storage in percentage share of the installed power can be seen in Table 15 which has been introduced in chapter 5. As explained in chapter 3.1 negative shifting means that an oversupply is absorbed and positive shifting means that in times of supply shortage or excess demand the energy demand can be reduced. Ergo the positive shifting potential is high especially during summer times during winter times the negative shifting has more potential for sales.

Table 15 Shifting Potential of micro-CHP plants,
Adapted from: (Nitsch 2008), (Droste-Franke et al. 2012, pp. 111–112)

Positive shifting potential [%] for 4 h		Negative shifting potential [%] for 4 h	
Winter	Summer	Winter	Summer
0.5	0.95	0.5	0.05

A possible micro-CHP penetration has been modelled. Assumptions for the modulation can be found in Table 17. The chosen micro-CHP technology system has a power output of 5 kW_e and 11.7 kW_{th}. It is important to note that the electrical efficiency of 26 % is the maximum efficiency and only reached for the optimal rotational speed.

Table 16 Micro-CHP System Data,
Source: Based on Distribution Data of (SENERTEC 2014), Papers and Own Calculations

Characteristics	Value	Unit	Source
Electricity output	5	kW_e	(Simader et al. 2004, p. 56)
Heat output	11.7	kW_{th}	(Simader et al. 2004, p. 56)
Shifting Time	4	h	(Droste-Franke et al. 2012, p. 110)
Runtime Winter (11,12,1,2)	90	%	(Droste-Franke et al. 2012, p. 110)
Runtime Autumn/Spring (9,10,3,4)	50	%	Assumption
Runtime Summer (7,8,5,6)	25	%	(Droste-Franke et al. 2012, p. 110)
Electric Efficiency	26	%	(Simader et al. 2004, p. 56)
Thermal Efficiency	61	%	(Simader et al. 2004, p. 56)
Module Price	13,500.00	€	(Simader et al. 2004, p. 56)
Maintenance Cost (full service)	0.02	€/kWh	(Simader et al. 2004, p. 56)
Lifetime	15	Years	(Simader et al. 2004, p. 56)
Discount Rate	6	%	(Simader et al. 2004, p. 56)
Fuel Costs	0.035	€/kWh	(Simader et al. 2004, p. 56)
Annuity	0.102962		Own Calculations
Full-load Hours	4818	h	Own Calculations
Electricity Production Cost	0.117777	€/kWh	Own Calculations
Households with Micro-CHP	10	%	Assumption

Using the module price, discount rate and lifetime the annuity of 0.103 has been calculated. But as mentioned in chapter 5.3, runtime and fuel are the most important cost factors. Based on the assumption of the runtime in summer, winter and the transition periods, a total of 4818 h full-load hours has been calculated. The assumption was based on literature and similar projects. Including the fuel costs, the total electricity production costs of the introduced micro-CHP system are 0.12 €/kWh. In comparison the electricity price for households in Norway is 0,11 €/kWh (Statistik sentralbyrå (Statistics Norway) 2011). The calculation is optimistic and no energy savings can be expected without additional subsidies or income from DSM. For Germany the situation looks different because of the higher electricity price of 0.29 €/kWh (EUROSTAT 2013a) and additional subsidies, see chapter 5.4.

If energy demand of Florø were to increase in the next year because of EV penetration or other factors, this additional load could be met by micro-CHP plants (5 MW[1] = 300 micro-CHP systems, i. e. equipping 7.5 % of the population). But in case of a problem with the power lines the available capacity

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[1] Electricits output of the introduced micro-CHP system, see Table 16.

on the island could drop to 35 – 40 MW. With this, an additional safety buffer of 25 MW decentralized generation and respectively 1,500 micro-CHP devices would be needed. The resulting investment costs for 1,500 micro-CHP plants are higher than the grid reinforcement costs, whereas 300 micro-CHP plants are a manageable investment. Consequently, micro-CHP systems should not be used to back transmission line failures.

The calculation has been performed with different micro-CHP penetration levels. 1,500 micro-CHP systems, respectively 37.5 % of the customers, lead to energy flows off the island during load time and are therefore highly impractical. If 10 % of the residential customers would install a micro-CHP turbine, these 390 devices could unfold some positive effects. In Figure 18, the dotted line represents the customer's original energy demand and the solid line depicts the new load from the grid with CHP in place. Longer runtimes of the CHP-units during the winter enable a 5 MW demand reduction. The possible DSM is already included in the calculation.

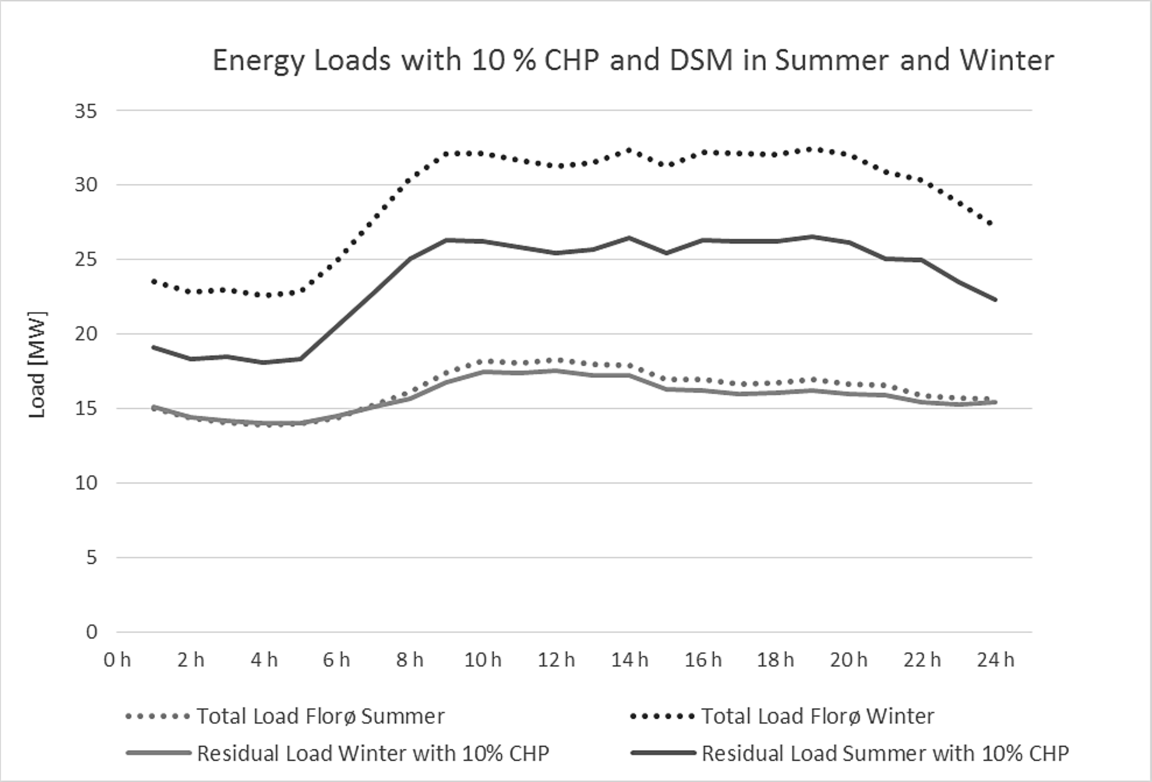

Figure 18 Remaining Energy Demand from the Grid

Figure 19 shows the effect of the realized load shift potential of DSM. The calculation is based on the assumptions of 50 % negative load shift potential for 4 hours to enable a load reduction from 8am to 9pm which is shifted to the time period 11pm to 6am. In this case it doesn't matter whether the load is shifted backwards of wards. The assumptions are based on (Droste-Franke et al. 2012; Aketi, Sen 2013; Houwing 2010; Simader et al. 2004; Nitsch 2008). The calculations show the approximate potential and magnitude of load shifting that an ESCO could realize in a smart grid region.

The decomposition of the energy demand of the customers is posed in Figure 20. In the illustration the resulting energy demand curve is already quite flat (upper edge of dark grey area). If peaks and valleys are more distinct, for instance because of EV, DSM with micro-CHP would be even more effective. The maximum energy demand per hour in the year 2013 was more than 41 MW. With CHP this could be reduced to 35 MW, a reduction of about 15 %.

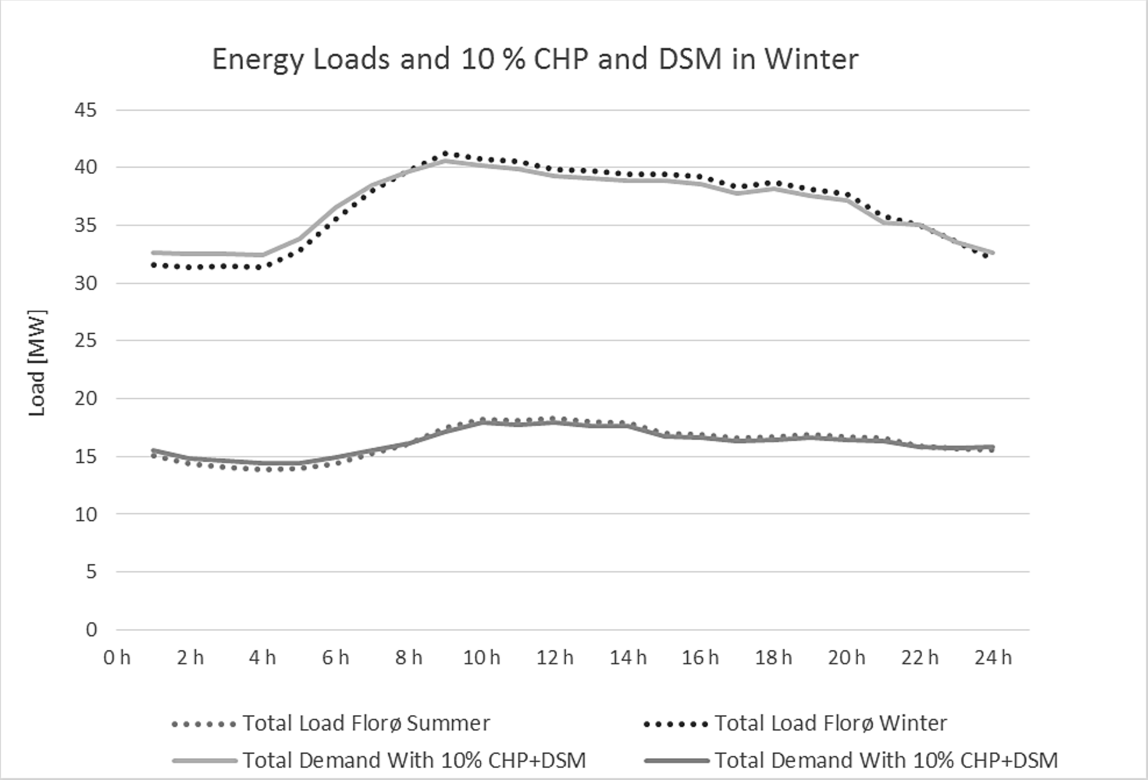

Figure 19 Effect of DSM with 10% Micro-CHP Penetration

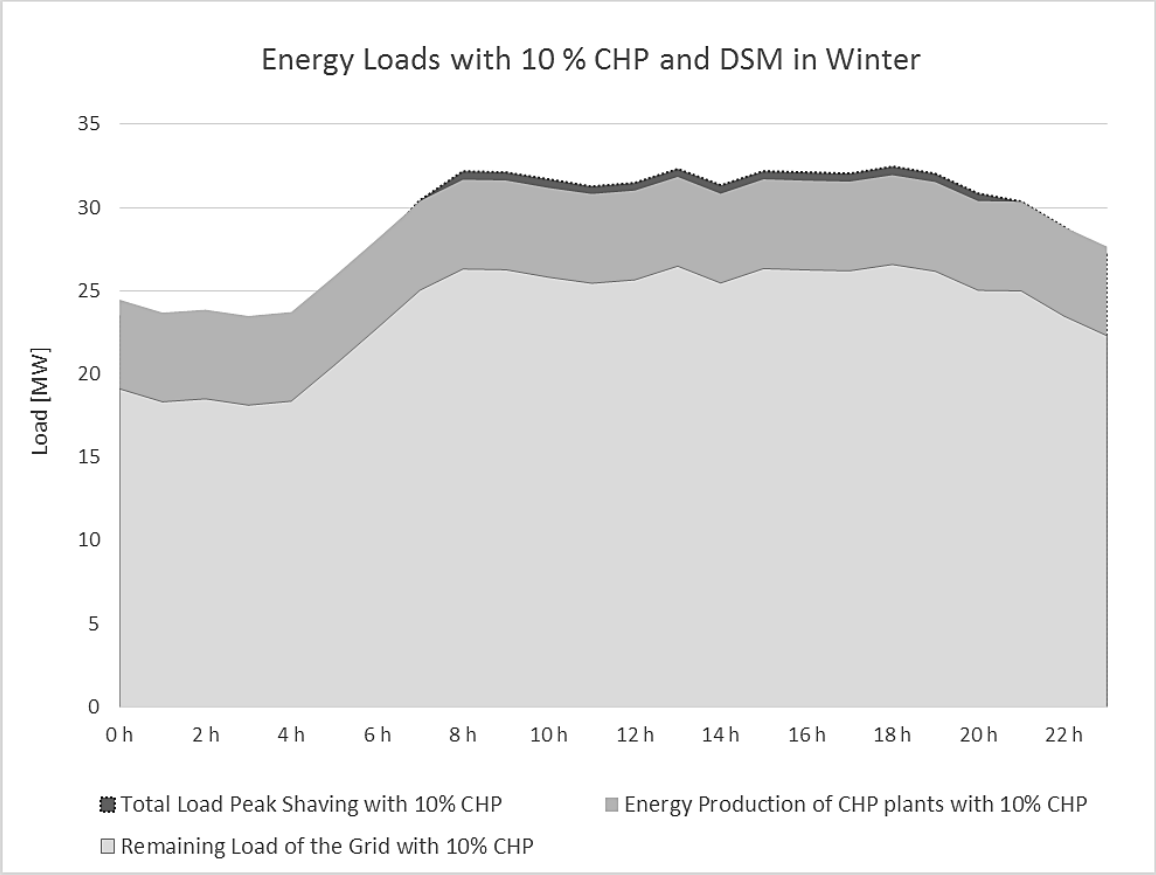

Figure 20 Decomposed Energy Loads with 10% CHP in Winter

As seen in Table 16, micro-CHP systems are not competitive in Norway without subsidies or other incomes. Table 16 contains the results of the calculation based on the data from chapter 5 and on own assumptions.

Table 17 Energy Supply Costs with 10% Micro-CHP

	With 10 % Micro-CHP	Base Case
CHP-Costs	2,532,461.09 €	-
Electricity (Spot Price)	6,568,035.62 €	7,386,800.54 €
Grid Rent	5,671,418.38 €	6,380,985.16 €
Total	14,771,915.09 €	13,767,785.70 €
Savings per Household and year	- 253.38 €	-

7.2.2 ENERGY SAVINGS

Energy savings are the most effective way for customers to save money and to reduce greenhouse gases. Furthermore they can be used as negative load shift potential, by reducing the energy demand at high prices without consuming more during lower prices. The energy consumption should be reduced in times of expensive energy or when transmission limits are reached. As mentioned, the demand reduction has a direct influence on the savings of the customer. Although also easy to realize, none of the today's market participants, except customers, have an interest in realizing this potential. The higher the sales, the higher the profit. That counts for TSO/DSO, power producers and power suppliers.

The ESCO, however, is interested in the energy efficiency and energy savings after all. The aim here is a comprehensive offer. Energy savings that can be used as load shift potential will be discussed in the following chapter 7.2.3. Other energy saving measures are information brochures, energy saving apps, personal consulting and constructional heat insulations. Apart from the latter, these measures will not influence the revenue significantly and the costs are limited. In a comprehensive offer these aspects should be included to some extent. The last point, heat insulation, will not be discussed here. Nevertheless a few ESCOs have successfully focused on renovation of public buildings. The revenues derive from sharing the energy savings with the principal. This business model can on the one hand be added to the introduced ESCO easily because it is independent of the other offers. But on the other hand it also does not benefit from synergies like ICT installations.

7.2.3 LOAD SHIFT POTENTIAL

The most important factors to realize DSM are tariffs and information in accordance to chapter 3.1. A list of interesting Smart Grid projects in Europe with their respective internet presence can be find in the Appendix. The European projects that already delivered useful results in the area of load reduction and demand shift potential, together with some broad studies in the USA, are listed in Table 18. The load shift potentials were additionally categorized by how it has been realized (Dütschke et al. 2009).

Table 18 Realized Load Shifts in Smart Grid Projects

DSM Programs	Description	Load Shift Potential	Test Region / Institution
Flat rate	Same rate all times	+- 0 %	Everywhere
Critical peak pricing (CPP)	During critical peaks very high rates	- 4 %	(Federal Energy Regulatory Commission (FERC) 2009), National Assessment USA
Time of use (TOU)[1]	Variable pricing for prescheduled blocks of time	- 12 %	(Federal Energy Regulatory Commission (FERC) 2009), National Assessment USA

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[1] In the project region Swabia and Waldshut-Tiengen in Germany a project focusing on time-of-use tariffs has been introdued in 2014 (EnCT, Intelligent Energy Europe 2014).

Real-time pricing (RTP)	Variable pricing at all times, customer informed almost instantaneously		
Direct load control (DLC)	Centralized control of e. g. thermostats, home energy controllers	- 3 %[1]	(Federal Energy Regulatory Commission (FERC) 2009), National Assessment USA
Emergency Demand Response	Centralized control in emergency		
Curtailed load	Agreed upper limits for energy consumption		
Provision of information	Information on in-home display, software compares usage with similar households in size and attributes	- 5.9 % to - 7.5 %[2]	Follo (east) and Askøy (west), Norway
		- 6.5 %	Opower, Canada
		- 3 %	Sacramento Utility District, USA
Combined	Combined peak demand reduction with DSM	+- 10 %[3]	Smart Grid Gotland, Sweden
		+- 10 %[4]	E-Energy, whole project, Germany
		- 8.4 %[5]	DeViD Steinkjer and Hvaler, Norway
		- 20 %[6];	(Federal Energy Regulatory Commission (FERC) 2009), National Assessment USA
		+32 % and -26 %	MeRegio-field test[7], Germany

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[1] Dirct load control just of the airconditioning.

[2] Pilot study: 91 households with In-home display, mostly reduced their energy consumption for lighting. SINTEF und Intelligent Energy Europe 2012

[3] Prüggler et al. 2014: Active customer will contribute to a load shift of +/- 10 %.

[4] Federal Ministry of Economics and Technology (BMWi), Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) 2014, Private households shifted due to intelligent systems coupled with special legal contracts 10 % to low demands. For industrial estates 20 % has been reached respectively.

[5] Sæle, Grande 2011, Demand response form households, utilizing smart metering, remote load control, pricing based on the hourly spot price combined with time of day network tariff and information provision. A potential of 4.2 % of the whole peak load response is reached if 50 % of the Norwegian household participate.

[6] Federal Energy Regulatory Commission (FERC) 2009, A US-wide study with 4,039,005 residential customers and more than half a million commercial and industrial customers.

[7] Hillemacher et al. 2011, MeRegio is part of the E-Energy project of the German Federal Ministry of Economics and Energy and the German Federal ministry for the Environment, Nature, Conservation and Nuclear Safety. The project uses ICT, real-time communication, multiple distributed energy resources as well as smart storage devices. 1,000 private and commercial energy customers participate. (Prüggler et al. 2014)

		+- 13 %	VDE[1], Germany

An up-to-date business model should learn from experiences of smart grid studies and ought to implement the most successful schemes in terms of cost structure and revenue stream.

7.2.3.1 In-home displays

For example the provision of information with an in-home display led to significant reductions in demand like in the Norwegian pilot project (Sæle, Wilber 2014). Less energy has been used in such households mainly through visible savings like switching off lights. It is worth considering that this scheme just aimed to reduce the 20 % of the electricity demand that is not used for space and water heating and that this scheme generated more than 5 % overall energy reduction. The remaining 80 % still leave immense room for improvement; using automated control.

As mentioned, the average electricity consumption per household in Norway is around 16,000 kWh/year (SINTEF, Intelligent Energy Europe 2012). The installation of in-home displays could lead to an energy demand reduction of 5.9 – 7.4 % (Prüggler et al. 2014; Sæle, Grande 2011); the energy savings are respectively approximately 944 to 1184 kWh per year. The average electricity price in the 4th quarter of 2013 was 0,109 €/kWh (Statistik sentralbyrå (Statistics Norway) 2014). Accordingly for the case study in Florø, savings per household and year are 130.92 €, see Table 19.

Table 19 Supply Costs with In-home Display

	Load with In-home Display	Base Case
Electricity Load	193,363 MWh	188,594 MWh
Savings per Household per year	130.92 €	-

7.2.3.2 Other DSM

The Norwegian DeVit project realized the smallest peak load shift potential (8.4 % negative load shift potential, see Table 18) of the analyzed smart grid regions. It used metering, remote load control, pricing based on the hourly spot price combined with a time of day network tariff and a token provided to the customers indicating peak hours (Sæle, Grande 2011). Although for example in Germany heating of water and space is predominantly gas based, two or three times higher load shift potentials have been realized in such regions. One of the reasons could be that German customers were given additional incentives to shift their load (Paetz, Dütschke 2011), which were higher than the spreads

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[1] Association for Electrical, Electronic and Information Technologies, VDE 2012

given by the respective spot prices. Furthermore even with the installation of in-house displays and software 7.4 % energy demand reductions have been achieved. Therefore, on the one hand the 8.4 % of the DeVit project can be seen as a downward limit and on the other hand the other realized numbers should be treated with caution because they seem quite optimistic. The magnitude of the Hawthorne-effect[1] in most of the DSM studies is barely investigated.

The load shift potential basically depends on the demand elasticity (own-elasticity and elasticity of substitution) of the end-customer. 281 smart grid projects in the EU (Institute for Energy and Transport (IET) 2014), and even more simulations and modulations reveal a bouquet of possibilities differing in size and shape as well as demanding most diverse requirements from its environment.

As a calculation basis for this case study a realistic but rather simple load shift potential is assumed: Following the average achieved in Europe and the world (see Table 18); 20 % load shift potential, a 50 % share of participating households and a shift time of 2 h will be applied here. Again assumptions are made in order to show the range of possibilities and the amount of possible profits for the end-customer. The results of the calculations can be seen in Table 20 and are illustrated in Figure 24.

There are different possibilities of how to use this flexibility. The generated flexibility can be bid in the day-ahead market (e. g. in Scandinavian countries: Elspot), the intraday market (e. g. in Scandinavian countries: ELBAS) or in the balancing market. Here the potential is just bid exemplary in the spot market.

Table 20 Energy Supply Costs with 20% Load Shift Potential for 2h

	With DSM	Base Case
Electricity Load	193,363 MWh	193,363 MWh
Electricity Costs	7,380,519.96 €	7,386,800.54 €
Savings per Household per Year	1.58 €	-

Because of the very low variation of the spot market prices in Norway the customer earns the negligible amount of 1.58 € per household and year. Figure 24 shows an exemplary day in summer and winter. The sport market prices are over articulated using a stretched price scale to demonstrate the DSM effect and the demand as a function of the price. It can be seen that the energy demand is reduced over the day and exactly the same amount of energy is additionally consumed at night during low price hours.

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[1] The Hawthorne effect is also referred to as the observer effect. It deals with the phenomenon that participants of studies change their natural behavior because they know that they are observed (Jasper 2012).

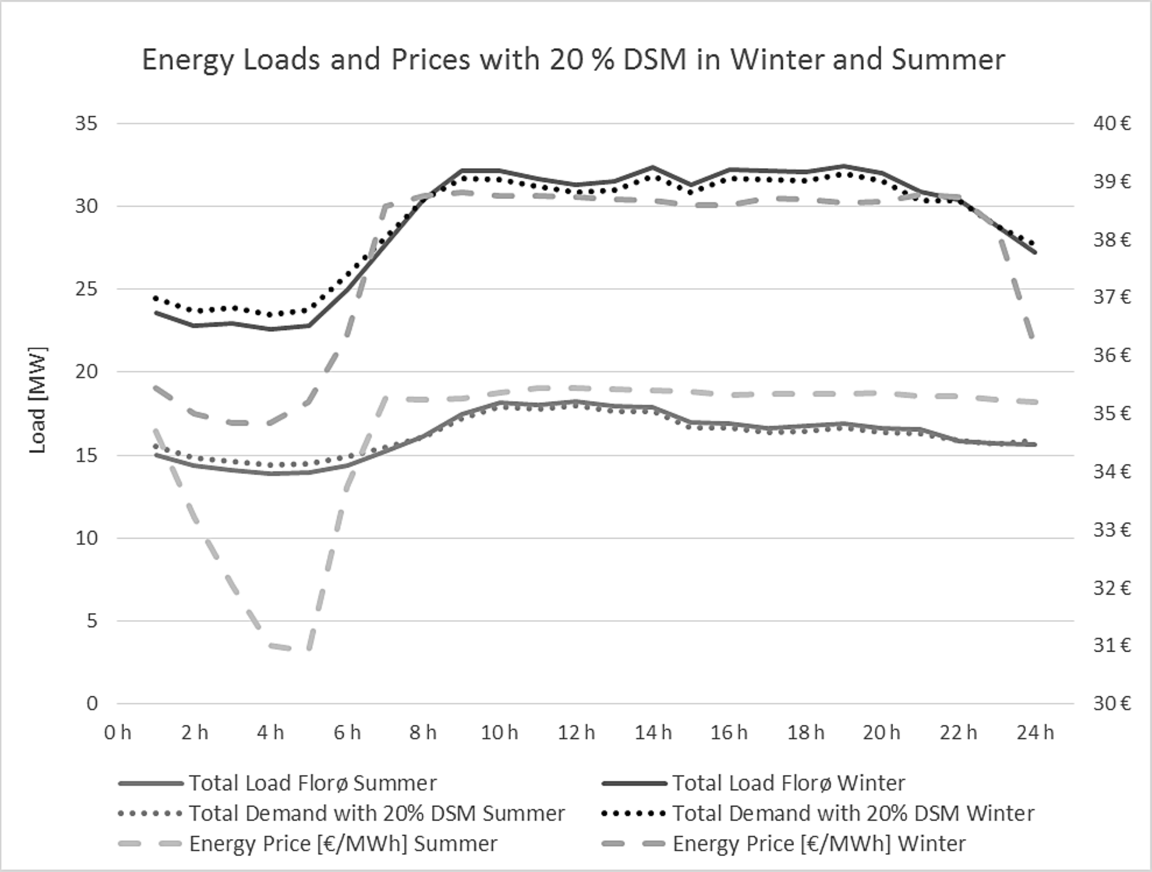

Figure 21 Energy Loads and Prices with 20 % DSM in Winter and Summer

7.2.4 ELECTRIC VEHICLE

As introduced in chapter 4, EV are an important topic in Norway. Because of sweeping incentives the number of EV is strongly increasing, even though the penetration mainly takes place in the agglomeration areas of big cities like Oslo, Bergen, Trondheim and Stavanger. This is because of on average shorter ways of the road users and the perfect conditions for EV in cities in general. In rural areas EV are not yet that prevalent. But persistent subsidies and increasing range make EV more and more attractive also for the countryside.

The modulation considers this development: The energy demand enhancement is calculated for 5 %, 10 % and 20 % EV share in Florø. It has been analyzed what repercussions come along with the energy demand of households when the EVs are charged up using a dumb or smart charging strategy. Dumb charging refers to a charging strategy where the EV is immediately fully charged after plugged-in; normally after the owner comes home from work. Smart charging strategies are more diverse: Here a centrally controlled charging of the EV makes it possible to firstly load the battery slower to improve its lifetime (see chapter 4.2), secondly use cheaper off-peak electricity and thirdly relieve the grid with more distributed demand (see chapter 4.4). The scenarios 5 %, 10 % and 20 % EV share refer to the number of cars in a country. For the scenarios it has been assumed that also the commercial customers switch to electrified vehicles in the same dimensions as the private customers. A summary of the assumptions can be found in Table 21.

Table 21 EV Data,
Source: Based on Own Calculations and Literature

Characteristics	Value	Unit	Source
EV Energy Demand	4	kWh per day	(Jochem 2013)
Persons per Household	2,2		(http://www.ssb.no/en/familie)
Households in Norway	2258794		(http://www.ssb.no/en/familie)
Plug-in Time EV Charging (Dumb)	17-18	time	
Plug-in Time EV Charging (Smart)	23-00	time	
Battery Capacity of Average EV	20	kWh	(Jochem 2013)
Charging Power AC (230V,16A)	3,7	kW	
Charging Duration Charging (Dumb)	2	h	
Charging Duration Charging (Smart)	7	h	
EV Market Penetration Scenario 1	5	%	
EV Market Penetration Scenation2	10	%	
EV Market Penetration Scenario 3	20	%	

Fehler! Verweisquelle konnte nicht gefunden werden. and the Figure 23 show the results of the 20 % scenario calculations. The black solid lines show the electricity spot price of the respective region. The grey dashed line shows how the plugged-in EV increase the total energy demand in Florø between 5 pm and 6 pm. This is the so called dumb loading strategy that leads to around 5 MW additional load during already high load times in the evening. The grid in its status quo is not prepared for this. Even without power line problems the demand could overtake the load capacity of the grid during cold snaps; which means blackouts - a worst-case scenario to be avoided. For the rest of the day the demand with EV coincides with the originally demand.

As opposed to this the dotted line shows the energy demand using a smart loading strategy. The energy demand of the EVs is met during an elongated load at night when the energy is cheap and the grid has free capacity. The maximum transmission capacity is not reached. This is the manifestations of DSM, using the load shift potential of EV.

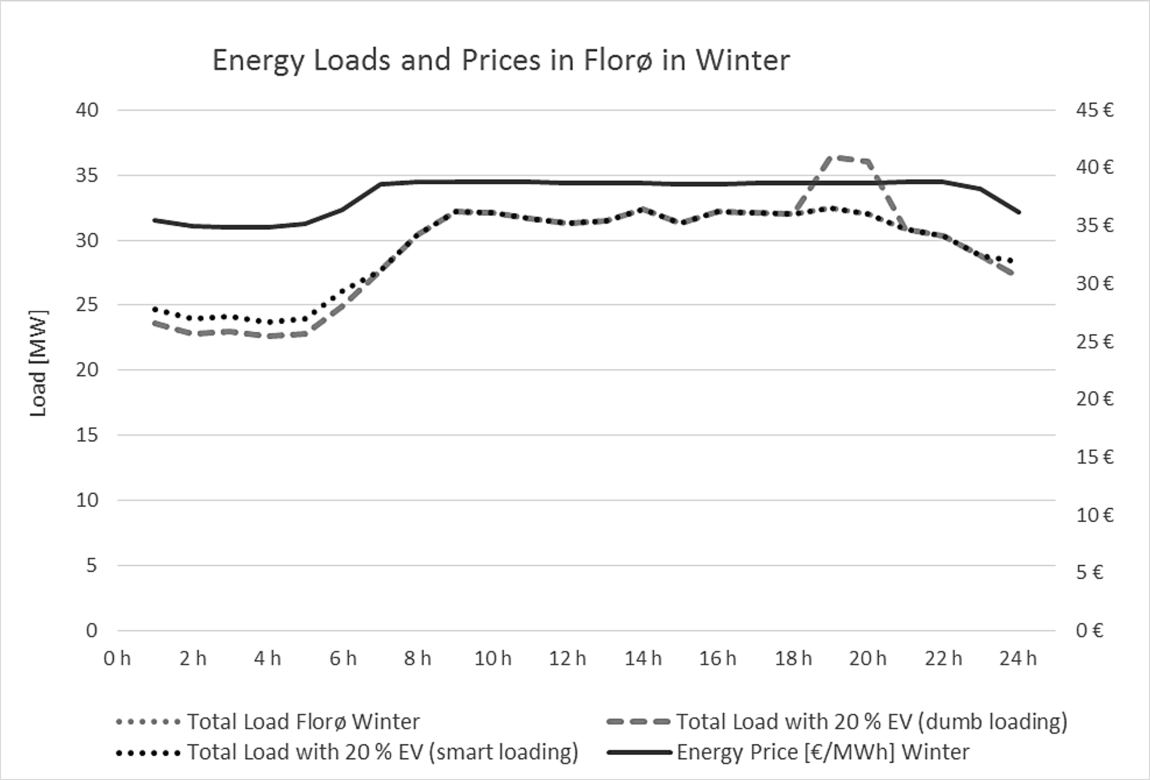

Figure 22 Energy Loads in Florø with 20% EV Share in Winter

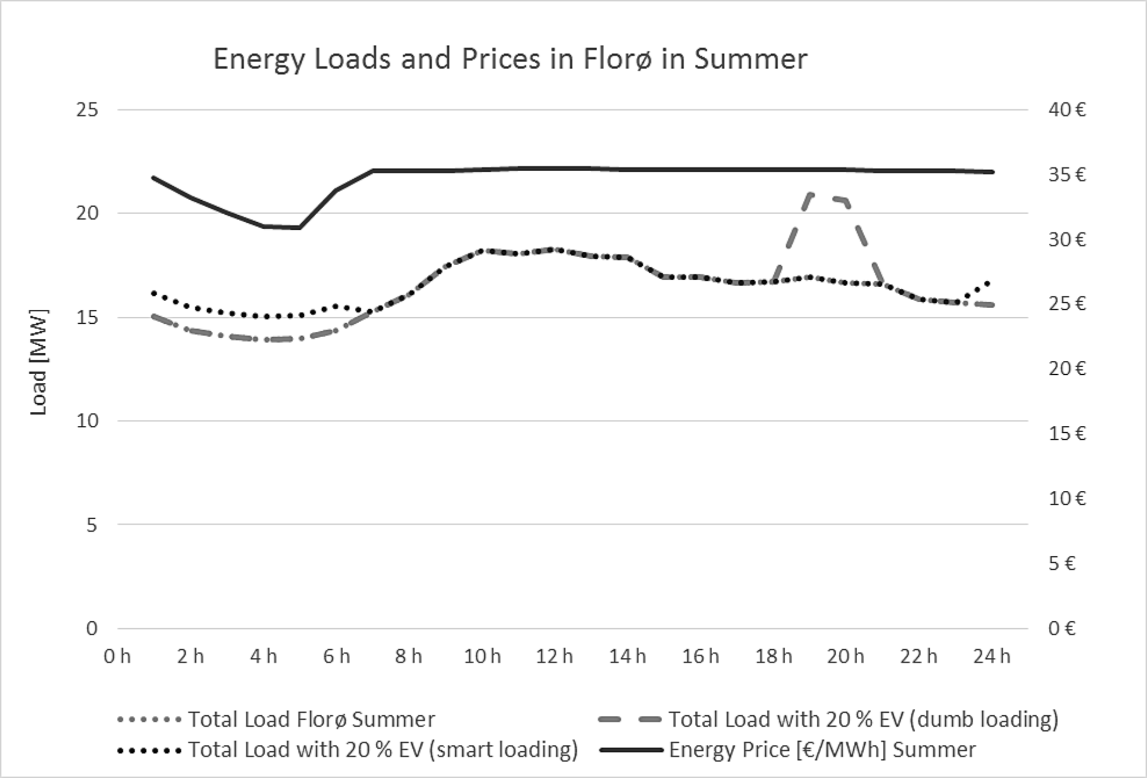

Figure 23 Energy Loads in Florø with 20% EV Share in Summer

Further tests were conducted to assess the influence of using EV as storage. More precise, how much money could an EV owner make by a 3 kW feed-in to the grid when the price is the highest and charge 3 kW when the price is the lowest? As an illustration, assume, the owner returns home from work and plugs-in his EV. The battery is still three-quarter charged because the owner directly drove home from work. During this evening hours the energy is quite expensive before the price will drop during the night. In this case the EV would not start loading, it would first feed the remaining energy in the battery into the grid and only charge the battery at night. In practice, SOD and user behavior need to be considered as well as the normal load shift process. As seen in the results in Table 22 the savings in Norway are again fairly small due to little changes of the spot prices.

Table 22 Energy Supply Costs with EV Penetration

	With 5% EV	With 10% EV	With 20% EV
Additional Electricity Demand	726 MWh	1,444 MWh	2,902 MWh
Max Additional Load (Dumb)	1.41 MW	2.82 MW	5.65 MW
Max Additional Load (Smart)	0 MW	0 MW	0 MW
Electricity Costs per EV (Dumb)	60.30 €		
Electricity Costs per EV (Smart)	53.91 €		
Savings per EV (Smart)	6.11 €		
Savings per EV (Smart + Storage)	8.47 €		

7.3 Results

This chapter gave an overview of the results of the model based on the electricity that flows through the transmission lines towards the island Florø. The biggest drawback is the small differences in the sport price, which diminishes possible profits from DSM. Table 23 gives a numeric outline of the results.

Table 23 Overview of Saving Potentials in Florø

Savings per Year	Amount
Household with DSM	1.58 €
Household with In-home Display	130.92 €
Household with Micro-CHP System	- 253.38 €
Household with EV (Smart Charging)	6.11 €
Household with EV (Storage)	8.47 €

Higher savings are possible if the aggregated load shift potentials are large enough to be bid in the balancing market. The other possibility is to sell the flexibility to the DSO or an aggregator via an innovative market mechanism.

8 ESCO

> “The only way of discovering the limits of the possible
> is to venture a little way past them into the impossible.”
> - Arthur C. Clarke

8.1 Introduction

An ESCO is manages comprehensive performance-based projects, which includes: developing, installing and financing in order to improve energy efficiency, load reduction of facilities (Cudahy, Dreessen 1996; Goldman, Dayton 1997; Goldman et al. 1998; Lockhart, Singer 2002; Vine et al. 2003). Projects have a typical duration of 5 – 10 years (Vine 2005). A broad variety of ESCO exist since the late 1980s and the 1980. The first ESCO started even in the 1970s (Vine 2005). Today, ESCOs can be found around the world, especially in countries with increased competition and privatization. Studies conducted by Vine (2005) and Okay, Goldman et al. (2005) showed that the growth potential is still huge. Most business models focus on the industrial, commercial and municipal sectors (Vine 2005).

The here introduced business of an ESCO is not a singular, but rather a smart combination of already existing and new offers with the focus on residential customers. This ESCO is supposed to be a one-stop shop and partner for the customer helping him to save energy, money and time by integrating local production, EV, DSM with smart connections and control of his devices and independent billing. An ESCO is supposed to tie in already existing offers and put together a comprehensive package for the customer.

In the preceding chapters, necessity for a new player in the energy value chain was derived, that should help the end-customer to “get the job done” and save money by managing complicated processes and bundling resources. Furthermore it will be outlined in the following that quite some successful ESCO business models already exist, although most of them are not active on more than a regional level.

This chapter develops new ESCO business models based on experiences of existing ESCOs, developments in the Norwegian and German markets as well as information from the case study region Florø, focusing on the great potentials of DSM, EV and micro-CHP.

8.1.1 Included Business Models

As mentioned, an ESCO combines different services to offer the customer a comprehensive package and meanwhile giving useful flexibility to the grid operator. A great advantage of an ESCO is his ability to generate synergies by including or combining the following business models:

- Installation of micro-CHP systems
- Delivery of renewable energy
- DSM
- Load management of EV
- Energy saving recommendations

The mentioned business models are analyzed in the following with help of the business model canvas (Osterwalder et al. 2010). Resulting synergies are identified afterwards and a comprehensive business model is developed.

8.1.1.1 Installation of Micro-CHP Systems

The **key partners** for the installation of micro-CHP systems are on the one hand side the DSO that gives information about capacity limits in the grid and on the other hand side the manufactures of the micro-CHP systems (chapter 5.1) that most likely also undertake the installation of the system.

The **key activities** concentrate on the management of the micro-CHP system that includes planning, investment and maintenance as well as optimized control. Using the constraint which the provision of heat for the customer is always sufficient; the system is operated to maximize the electric energy output. The output is maximized when the time of feed-in and maximum load of the grid or high prices on the stock are in line.

The offered **value proposition** is lower costs of electricity for the end-customer and a postponement or avoidance of grid reinforcements for the DSO.

The **customer relationships** are based on personal consulting and case-by-case calculations and change over to an automated relationship of billing and control.

The **customer segments** are mainly based on the DSOs with capacity problems in their grid that are willing to buy flexibility to cut off peaks and to postpone investments into their grid. The other important segments are energy consumers although it is not clear whether they are customers or partners. EV owner, energy users at critical places for the grid, as well as proactive users - with the desire to set an example towards eco-friendliness - are part of this group.

The **key resources** for a business model that installs micro-CHP systems are financing and knowledge. Whereas knowledge on CHP technology, smart control schemes, contracts and energy procurement is mandatory. The staff need to be trained accordingly.

Channels between customers and the company are the internet, apps as well as a personal contact depending on the status of the project.

The **cost structure** has two big areas. The investment in ICT plus the micro-CHP system and the fuel costs. Additionally, the cost for marketing, employees, education, programming of apps etc. need to be considered.

The **revenue streams** are based on two pillars. Firstly, selling the produced heat and power to the customer taking into account investment, risk and fuel costs and secondly, selling flexibility to the DSO or on the stock market.

Similar business models exist with different service levels. The profitability is mostly based on the heat demand, respectively the full-load hours of the system and the fuel costs. If the business model is strongly based on selling flexibility to one monopolistic DSO this can be critical because of information asymmetry and sunk costs. Usually these problems can be solved with sufficient contracts. In most of the EU states micro-CHP plants receive extensive subsidies (see chapter 5.4).

8.1.1.2 Delivery of Renewable Energy

Key partners are energy generators that sell renewable energy on a long-term contract basis. More critical is to buy the energy on the energy exchange and to acquire (Renewable Energy Certificate System (RECS) certificates separately.

The **key activities** are mainly the procurement of renewable energy either bought over-the-counter, on the energy exchange or self-generated and further sold to the customer.

The **value proposition** is clearly to deliver renewable energy and get a mark-up for that service.

The **customer relationship** is based on the “getting the job done” philosophy. The customer will get a regular bill and a transparent proof of origin.

The **customer segments** include all energy customers while the focus is on ecologically aware people and holders of EV.

The **key resources** are knowledge of trading, billing and marketing as well as access to the energy exchange.

The **channels** are very limited. Customer contact costs money and is therefore limited to hotlines and apps.

The **cost structure** is composed of the energy procurement costs as well as marketing and billing costs. In Norway the transmission costs are paid by the customer in a separate contract. In Germany they are paid by the energy supplier that passes the costs on to the end-customer. This includes taxes and other charges, for example for the transmission capacity reservation.

The **revenue stream** is simply based on the payment of the customer for the delivered renewable energy. The customer should be able to choose between fix and variable contracts.

Delivering renewable energy is very common in Germany and nearly every energy supplier offers its customers renewable energy contracts. Generally the surcharge for renewable energy is rather small because RECS[1] certificates for renewable energy can be bought on the market fairly cheap (RECS International 2013). Norway for example sells a major share of their hydropower guarantees on the RECS market. Renewable energy tariffs itself are rare or not available in Norway.

8.1.1.3 Implementation of DSM

The **key partners** are producers of ICT as well as companies that install the ICT. Further, the DSO or grid regulators can play an important role by delivering data about customers living in critical areas of the grid.

The **key activities** are based on realizing flexibility in the customers' energy demand, to aggregate this load shift potential and to sell it to the DSO or on the spot or regulation

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[1] RECS stands for Renewable Energy Certificates, also known as Tradable Renewable Certificates. RECS represent the environmental attributes of electricity that are sold separately from the commodity electricity itself. RECS represents a quantity-similar certification system. Untill 2016 the RECS system will be replaced be the EECS-GoO system (Guarantee of origin) which is based on the EU guideline 2009/28/EG.

power market. For the realization of the flexibility different incentive systems for the customer are needed.

The offered **value proposition** is cost advantage and smart control for the households and flexibility for the grid to postpone investments.

The **customer relationships** are based on an app and/or a monitor, providing information that keeps the user up-to-date.

The **customer segments** are firstly TSO/DSO with capacity problems in their grid. Secondly, all households are possible customers. Special focus should be on holders of EV, customers with micro-CHP systems and households with electrical water boilers because of their superior load shift potential.

The **key resources** are basically knowledge about: DSM, contracts, critical users and access to energy exchanges.

The **channels** to reach the customers are web sales and the DSO, based on the existing DSO customers.

The **cost structure** is based on the installation costs of ICT and monitoring, the payment for the customer to provide flexibility, marketing as well as programming the homepages and apps.

The **revenue streams** consist of a mix of selling flexibility to TSO/DSO or to the energy exchange and the achievement of cheaper prices on the spot market.

The profitability of existing businesses is questionable because the differences on the spot market provide not enough incentives and profit to change the customers’ behavior. But the spot market also does not reflect the real demand for load shift potential. Further cash flows can be generated if the flexibility demand of DSO or the regulating market (market for ancillary services) can be satisfied. However, selling ancillary services to DSO is subject of strict regulations (see chapter 2.3.2).

8.1.1.4 Load Management of EV

The **key partners** are TSO/DSO, the car manufacturers that can help to provide information on battery and possible customers as well as partners that can help with the installation of load infrastructure and ICT.

The **key activities** are the smart load management of EV, based on the following goals: Improvement of battery life-time, realization of flexibility and providing additional comforts to customers.

The offered **value proposition** for the end-customer are cost savings and improved services. In some cases, e. g. in Norway, loading of the battery can be cheaper because of arbitrage values of the flexibility disposal.

The **customer relationships** are based on app and or in-home displays, which provide information that keeps the user up-to-date. Another simpler version is just a timer at the load device.

The **customer segment** is based on owners of EVs or households with a great energy demand.

The **key resources** are knowledge on: life-time improvement of the battery, load management and communication with the TSO. Further, the possibility to aggregate a lot of customers to build up a unit that can be sold on the market.

The **channels** are basically limited to web sales but the demand will determine the way of communication with the customers.

The **cost structure** breaks down into installation costs for ICT and load infrastructure, programming of apps and homepages, marketing and payment for the EV holder for flexibility provision.

The **revenue streams** can be itemized into buying the needed energy on the energy exchange in low-price periods as well as selling the flexibility on the energy exchange or to the DSO.

After the detailed analyze of the business models it can be seen that they have similar structures. Nearly all rely on expansive ICT that can inhibit their implementation. As explained in chapter 3.1.1, by combining these existing business models, e. g. in one ESCO, significant cost advantages and synergies can be generated.

After this introduction of existing business models the business model of an ESCO will be analyzed in detail in the following.

8.2 Market Situation and Competitors

The relationship of an ESCO companies of the energy sector can generally be split into cooperation and competition.

The **key partners** for an ESCO are essential to keep the business running. Such key partners are local DSOs, network regulators, installation companies and partners from sub-business models. Households can also be seen as key partners.

The **competitors** are companies that offer a similar value proposition to the customer. Additionally they could be interested in adopting the business model. A good business model learns from competitors without letting them copy their ideas.

Key partners have already been listed in the previous chapters and are just shortly repeated here. Competitors – including with existing business models – are discussed and underpinned with some European examples followed by a critical analyze and classification in the last part.

What can be seen is, that most of the business models have a focus on either

a) capturing potential through improvements in the combination of products and services,
b) incentives that lead to reduced costs that are split up between provider and customer,
c) or risk management based business models using risk pooling in order to reduce and share risk.

A lot of examples are following the logic of **product service systems** where the focus shifts away from delivering traditional products towards delivering functionality to satisfy the customer’s needs (van Halen, Vezzoli 2005, p. 21). A product service system is a pre-designed system of products, services, necessary networks and supporting infrastructure to jointly fulfil the user’s needs (COWI 2008, pp. 3-4, 102).

Examples for product service systems are for example:

a) Resource management
b) ESCO (design, build, finance, operate)
c) Car-sharing (COWI 2008, pp. 3–4)

8.2.1 EXISTING BUSINESS MODELS

This chapter analyzes business models that are innovative, bring substantial environmental and economic benefits and have the potential to create multi-billion euro markets in Europe (COWI 2008, p. 3). Since the turn of the millennium, the energy market is supposed to be liberalized. Nevertheless all business models introduced here have in common that they have been utilized very limitedly and unequally distributed between different countries and industries.

In Canada, the United Kingdom and Sweden the first ESCOs were created in the late 1970s. Nevertheless the most ECSOs actively occurred twenty years later in the early 1990s (Vine 2005, p. 692). Most of the ESCOs are local players. The number of ESCOs per country varies strongly form just a few to more than 50 (Vine 2005, p. 692). Nevertheless, the energy service market still contains high potential (Marino et al. 2010). ESCOs can generally target the residential, commercial, industrial, municipal and agricultural sector. ESCOs normally operator on different sectors. Many ESCOs do not target the residential sector or just have limited activities there. (Vine 2005, p. 694)

ESCO handling supply and installation of energy efficient equipment, supply with energy and heat, smart control, operation and management of all energy flows, EV management, building refurbishment, maintenance, facility management and energy service contracts. The latter are part of nearly every business model and help to overcome financial constraints like investments in energy efficiency and ICT by paying off initial costs with help future cost savings. Cost savings are realized by reduced energy consumption. (COWI 2008)

a) An examples for an ESCO is the Swedish utility Vattenfall. Vattenfall closes personal deals with end-customers taking over the responsibility for heating, cooling, climate control as well as compressed air and electricity provision. Maintenance, fuel and installations are provided by Vattenfall and the customer does not need to be concerned about anything. To make every customer a personal and an appropriate offer the pre-contracting phase needs time and expertise. (Zaring 2001)
b) Another example is the energy management system of Scottish Power for London’s suburb Hendon. In 1997 a new CHP plant has been installed to provide 1000 homes as well as community buildings with electricity and heat. The 10 year contract secures the investment for Scottish power and guarantees low energy prices for the end-customers. Reductions of 1,500 tons per annum of carbon dioxide emissions in comparison to the old installation were achieved. (Zaring 2001)

Energy Performance Contracting (EPC) is an important instrument for a lot of ESCOs and is used to finance retrofitting of public buildings. The economic gain from the realized savings are usually split up between the contracting parties. Not uncommonly a no-cure-no-pay agreement is set, in which the ESCO relinquish the payment if the actions failed to succeed. (COWI 2008)

a) An example for EPC is the contract between the ESCO TAC and the Danish municipality Middelfart. The project was successful and has been adopted by other Danish municipalities.

b) There are also ESCOs focused more on the end-customer segment, such as the ESCO Modestrøm; a new power provider on the Danish energy market that assists costumers with counsel on energy savings.

c) Another group of possible competitors are utilities, like the British company Eastern Energy that extended its business from providing electricity to their customers or additional services such as monitoring and saving energy. This includes energy management, data of load and consumption, profiling, process monitoring, sub-metering as well as training in utility awareness.

d) But is also possible that a governmental organization like the Energy Agency Berlin/Berliner Energieagentur participate in projects where they take over the energy management system of a company like Bartel & Sohn. The aim was to reduce the energy demand of offices and the production facilities. The Energy Agency Berlin participates in the realized savings.

e) Mentionable is also a business model for building-integrated solar energy. This is a project of a German architect, who planned houses which produce more energy than they use, so called “plus-energy houses”. This is possible by combining energy efficiency, heat insulation and large-scale photovoltaic panels. (COWI 2008)

8.2.2 DISCUSSION

As mentioned in the beginning of this chapter, all introduced business models combine that they have been utilized very limited (COWI 2008, p. 3) and if they are successful, only in a particular country or industry.

This infers the following conclusions:

1. The market is still quite regulated with high subsidies for the established and discrimination against new businesses. New market entrants experience difficult market entry conditions. This could be underpinned by the plummeting profits and market values of German energy utilities due to their inability to find and implement new profitable business models to compensate the shutdown of nuclear power plants and unprofitable gas and coal power plants (Braun 2012).
2. It is uncertain if there actually is a need for new market services. Not all customers per se want more than a “getting the job done”-relationship. However, the energy market is more sophisticated and new business models need to count that in. Another point is, how strongly the traditional operators edge into the market for new solutions.
3. Generally, new market entrants and start-ups face man-made problems like limited knowledge, communication problems, complexity and an uncertain future regarding policies and regulation changes.

8.3 Unique Selling Proposition and Customer Benefit

The unique selling proposition deduces from the key resources and the key activities a company performs. Consequently an offer is made to respective customer groups, which will be discussed in the second part of this chapter. This offer can be described as the value proposition which fulfils the customer needs and is described in the chapter 8.3.1.

The **key resources** of the business are mainly knowledge on: smart control, smart EV charging, energy procurement, DSM, contracts, micro-CHP technology, trading and billing. Also important is a network of partner companies that together set the basis for the ESCO. If the ESCO enters the floor of the energy exchanges, suitable securities and know-how are crucial but could easily be outsourced to trading companies.

The **key activities** are focused on the combination of the different energy business models that include generating synergies, especially for ICT investments, combined app development and aggregate flexibility for more market power and energy exchange access.

8.3.1 CUSTOMERS

The customer that are crucial for the business model of the ESCO are divided into **customer segments**. This chapter describes the most important end-customer segments. Especially (Hillemacher et al. 2013; Flaig 2013; Sæle, Grande 2011) reveal two different kinds of customer segments: On the one hand side households with the need for energy as well as auxiliary services like smart loading of their EV etc., and on the other hand side DSO that have problems securing grid stability and are a potential customers for flexibility of the customers.

8.3.1.1 Households

Households are a vital component of the business model. But households also have different needs and qualifications to participate in DSM or energy saving measurements. Figure 24 structures the energy end-customers. Every box symbolizes a sub customer segment. It is important to break the group of customers further down, in order to focus on the highest saving potentials and therefore highest profitability. At the top of the scale are proactive customers that already invested in EV or smart meters and are willing to participate in innovative programs – ideally because of intrinsic motivation. Of lower interest are passive customers that have a low awareness for the topic and prefer to stay with a secure fixed-rate tariff. Another dimension that plays a role is the location of the household. Customers from rural, isolated regions, where load reaches the capacity limits of the grid are more interesting than customers from regions without grid problems. This is because such customers can generate benefits for grid operators enabling postponing network reinforcements. Generally, the main advantages tools for a customer to save money are: EV, electrical water boiler and micro-CHP systems. Minor advantages are a location within an area with grid capacity limits or interest and data awareness.

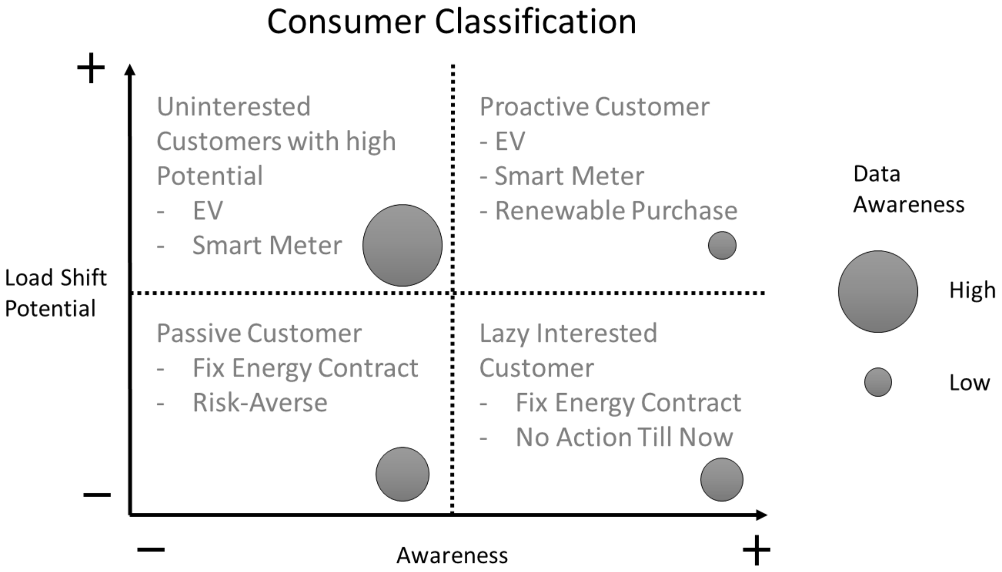

Figure 24 Classification of Energy End-Customers

It is also important to know which channels are used to reach customers and what the relationship look like.

The **channels** are used to stay in contact with the customer. This is done via well-organized and attractive online communication, using apps and further software to provide the customer with all necessary information. Additionally, personal communication will be provided. The channels are determined by the customer's wishes.

The **customer relationship** is self-service, the loading and generation of flexibility is automated and the customer is provided with necessary information to help themselves via app and monitor. Extended offers, including the utilization of micro-CHP, need personal contracts.

8.3.1.2 Grid operator

DSO are potential candidates for another customer segment. As mentioned in chapter 2.2 the electricity demand in Norway is in some regions increasing, often due to electric mobility. In Germany grid problems accrue due to rural feed-in and a north-south production discrepancy. These DSO have power lines and transformers within their portfolio that face capacity limits, are grouped in one customer segment. They all expect selected investments in grid expansion, security measurements and new transformer stations.

The channels to reach the grid operator and the relationship are important and different for every customer segment.

The **channels** to stay in contact with the grid operator is via personal communication, especially the negotiations between DSO and ESCO.

The **customer relationships** should therefore be on a professional and positive level. Most of the offers an ESCO makes are just profitable if the cooperation with the DSO works well.

8.3.2 VALUE PROPOSITION

The offered **value proposition** can contain a lot of different services. Cost advantages for households and DSO, smart control of household devices, auxiliary convenience services, delivery of renewable energies, energy savings tips, optimized control of the heating system, steering of other electrical devices, smart home realization and so on.

But to build up a tailored offer, the needs and wants of customers need to be identified and classified. A goal of every company should be to understand its customers, and to determine what the customer wants and for what values he or she is willing to pay. Millions are spent to understand customers and develop products and services accordingly. Talking to customers and making polls is the most common way and to adopt the customer perspective is a guiding principle for the design process of the business model (Osterwalder et al. 2010, p. 128).

This can be done for example with the empathy map, a tool to analyze and structure the customers' needs. By taking the customers stance, falling back to habituated thinking patters can avoided. In the following, this is applied on the two identified customer segments: households and grid operators. Figure 25 shows the empathy map as it has been applied to households as energy end-customer and later on the grid operator. In the upper part the interaction with the environment is described. This includes what he or she thinks, feels, hears, sees, says and does. In the lower part the customer-centric 'gains' describe what he or she wants and needs. The 'pain' describes fears, frustration and obstacles.

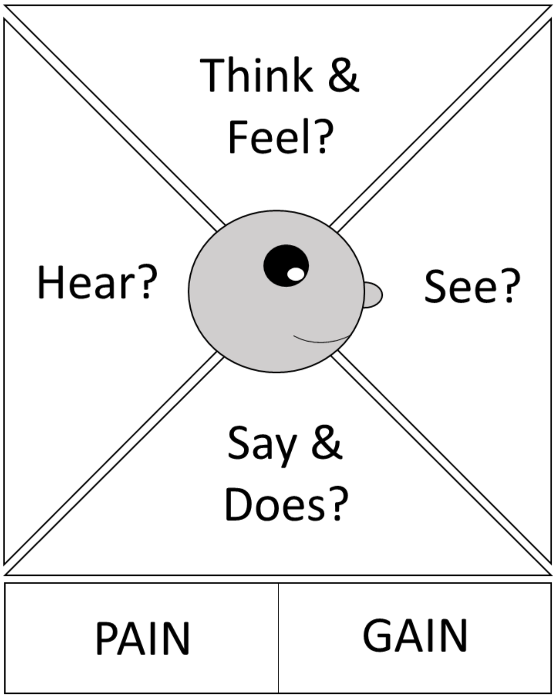

Figure 25 Empathy Map

8.3.2.1 Households

Households basically want a cheap and secure delivery of energy. The need for decentralized energy generation and DSM are no end-customer needs. But the German customers see that generation of electricity needs to become more environmentally friendly. The end-customer also sees more and more EV, wind mills and PV modules on the roofs. The people hear that this could cost more and while they are willing to pay a little bit more, they also want the industry to pay more too. But the customer would say that if his or her help is needed to stabilize the grid or meet new energy mix requirements he or she expects something in return. How do the customer want to be approached? The empathy gives basically the same answers as field tests that have been revealed. Customers generally avoid risk, prefer easy tariffs and favor to have one single contract partner (Paetz, Dütschke 2011). Households are afraid that the energy could get more expensive and on the other side want to gain from renewable and environmentally friendly energy. Especially in Germany, the households fear cost and waste of nuclear power plants.

8.3.2.2 Grid operator

The transition between a key partner and a customer is sometimes fluent. The gird owner in the form of DSO/TSO is seen here as a customer because a service - the provision of flexibility - is delivered in exchange of a monetary payment. The grid operator knows that to keep the total load below the grid capacity is the most important thing. But the grid operators also see that increasing electricity demand requires greater transmission capacities and therefore either a need for grid expansion or some kind of load smoothing or additional distributed generation. The grid operators see on the one that a grid reinforcement is quite expensive, and on the other that it is possible to buy the flexibility of the end-customers to postpone or even avoid the grid investments. Grid operator generally think that it is not their job to enable flexibility because they prefer to stay and invest in their core business[1]. Dependent on what is more profitable they either prefer to upgrade their grid on their own or to outsource peak load relief measurements to the ancillary service providers. Such relief measurements like DSM and distributed generation could also be offered by the ESCO. The grid operator fears that the high standards of grid stability is not guaranteed. But the grid operator also sees the chances to gain additional profit using cheap flexibility instead of expensive grid constructions.

The two customer segments are completely different and whether a separation of the business model could make sense can be discussed.

8.4 Financial Plan

The **cost structure** is mainly the investment in ICT and, if demanded, load infrastructure for the EV and a micro-CHP system. Furthermore marketing, programming costs of app and homepage and the provision of an in-home display. Payments to the customer for providing flexibility will play a significant role. If a micro-CHP system has been installed, fuel costs and maintenance will be cost factors too.

The **revenue stream** is split up. One stream is the bundled procurement of the flexibility to the DSO or on the energy exchange. The other revenue stream is the procurement of households with heat, electricity and ancillary services.

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[1] This statement is based on conversation with experts.

9 ESCO in Practice

> "There is no reason for any individual to have a computer in his home."
>
> - The founder of Digital Equipment Corp. Ken Olson

In chapter 8 a modified ESCO has been introduced. This ESCO was especially tailored to focus on the end-customer market. It was also important that the load is smoothed in order to postpone or avoid extensive grid reinforcements. In chapter 9.1 the profitability of an ESCO in Norway is tested. For this financial blue print the calculated data from the case study in Florø is used. The two sides cost structure and revenue steam are compared and evaluated here. In chapter 9.2 similarities and differences to Germany will be worked out.

9.1 Norway

9.1.1 INTERNAL COMMUNICATION TECHNOLOGY

The first step towards an ESCO is the installation of ICT that includes mainly smart meter and control devices. As a general rule, the smarter the devices the more possibilities there are to save energy and money. A lot of countries already require customers to install smart meters, e. g. Sweden and Italy (Hierzinger et al. 2013). For every business model ICT is needed but the investment depends on how much is already available.

A list of Capital Expenditures (CAPEX) needed to install ICT can be seen in Table 24. The investment and installation costs of in-house displays are included because the installation of a smart meter should come together with an in-home display. Such a display is not only the easiest way to realize savings with smart meters, but also the cheapest. They can be purchased and installed for around 60 €. In-house displays normally have a home area network (HAN) interface with a smart meter gateway to the measurement system of the smart meter. The HAN is set up via personal computer and LAN/WLAN router (Ernst & Young GmbH 2013) and broadcasts the data to the in-home display as well as available tablets and smart phones.

Table 24 CAPEX of Different ICT,

Source: Expert Talk and Survey of (Ernst & Young GmbH 2013, p. 145)

CAPEX	Amount	Depreciation Period
In-house Display	40 €	13 years
Installation In-house Display	15 - 25 €	13 years
Smart Meter (incl. Communication Module and Adapter)	80 €	13 years
Smart Meter Gateway (incl. Measuring device, Communication and Security Module)	175 €	13 years
Installation Costs Smart Meter and Gateway	40 – 110 €	13 years
Communication Module DSL	20 €	13 years
Installation Communication Module DSL	5 – 20 €	13 years
IT System Development (<100,000 Meters)	100,000 €	8 years
IT System Development (>100,000 Meters)	2,000,000 €	8 years

The operational expenses (OPEX) are displayed in Table 25. They mainly include maintenance, operation, billing and the costs for the data transfer.

Table 25 OPEX of Different ICT,

Source: (Ernst & Young GmbH 2013, pp. 150–153)

OPEX	
Maintenance and Operation of IT[1]	15 % of IT-Investment p. a.
Operation of Smart Meter and Software Maintenance	0.5 € per Meter p. a.
DSL Information Transmission	144 € p. a.
Replacement of Defective Systems	10 % of Investment
Reading of a Smart Meter	0.06 € per Meter p. a.
Customer Service and Call-Center Costs	2 € per Meter p. a.[2]
Billing Process	3.75 - 11 € p. a.

If the installation of a smart meter takes place instead of the installation of a conventional meter e. g. in a new building, building refurbishment or in case of regular replacement, around 90 € are saved, see Table 29. The automated reading of meters results in further economization. Especially the rate of

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[1] The maintenance and operational costs of IT include also energy costs, labor costs, cleaning and maintenance of hardware and software.

[2] Customer Service and Call-Center Costs are higher after new installation. In this pilot study they led to 5 € per Meter p. a. in the first year and abated to 2 € per Meter p. a. in the following years.

failure will be reduced from 3 % for conventional meters to 0.5 % for smart meters (Ernst & Young GmbH 2013, p. 154).

Table 26 OPEX and CAEX Conventional Meters,
Source: (Ernst & Young GmbH 2013, p. 154)

Cost reductions	Amount	Depreciation Period
Costs of Conventional Meter	25 €	16 years
Installation of Conventional Meter	50 – 80 €	16 years
Reading of a Conventional Meter	3.6 € per Meter p. a.	
Customer Service and Call-Center Costs	7.5 € per Meter p. a.	
Billing Process	15 € p. a.	

Not taken into account here is the higher energy consumption of a smart meter system (15 W) in comparison to a conventional meter (3.4 W), the maintenance cost of the measuring system, which are 1 € for the smart meter in comparison to 2 € for the conventional meter, as well as the economical welfare of increasing the energy security by 1 % with smart meters (value of lost load = 10,000 €/MWh) (Frontier Economics 2008; Ernst & Young GmbH 2013, p. 157). As calculated in chapter 7.2.3, the savings with DSM and in-home displays are shown in Table 27.

Table 27 Energy Supply Costs with 20% Load Shift Potential for 2h

	Savings
Savings per Household using DSM	1.58 €
Savings per Household using In-home Display	130.92 €

Based on all gathered data and previous calculations, the average smart meter owner with intelligent measuring system and in-home display has a negative net present value (NPV) of – 34.84 € per year in case of a regular replacement of an old electric meter. If the meter is replaced before expiration this value can decrease down to - 42.85 €. These numbers also include costs for DSL information transmission of 144 € per year.

A mandatory installation of smart meters, at least in Germany, is unlikely because of the negative NPV, high financial risks and security aspects. The green technology rollout like in the EU scenario with 80 % smart meters by 2020 cannot be expected. Since the installation of smart meters is crucial for this business model, the investment into smart meters has to be economical without governmental support, at least in Germany and up to know also for small residential customers in Norway.

An important point not mentioned so far, is how to make the customers participate in DSM programs. A German survey showed that the most important driver to participate in DSM programs are monetary incentives. Following this approach, a van-Westendorp-analysis concluded that the yearly savings must be between 65 € and 120 € to provide sufficient stimulus. (Paetz, Dütschke 2011, p. 48) Since the wage level in Norway is significantly higher than in Germany, at least 100 € stimulus should be paid.

It is not easy to make energy end-customers participate in DSM. The ESCO business model should therefore at least calculate to spend around 100 € on whatever mannered incentives for the customers. This leads to a final NPV of – 134.84 € per year.

9.1.2 ELECTRIC VEHICLES

Using the calculations from chapter 7.2.4, an EV owner can save money by using a smart charging strategy employing the optimization points' costs, battery life-time and grid stability, as mentioned in chapter 4.

Table 28 shows costs and saving potentials of EV owners. Generally it can be expected that when a customer owns an EV he or she is also in possession of a charging station. Smart charging stations can automatically communicate with a central control unit (e. g. utility), while standard chargers cannot. Nonetheless, even the standard charger can be controlled internally, if ICT is installed. This needs to be checked case-by-case but normally no new charger is needed.

Table 28 Energy Supply Costs with EV Penetration

	Cost/Savings per EV
Standard EV charger[1]	350.00 €
Smart EV charger[2]	700.00 €
Electricity Costs per EV (dumb)	60.30 €
Electricity Costs per EV (smart)	53.91 €
Savings per EV (smart)	6.11 €
Savings per EV (smart + storage)	8.47 €

Expecting that no additional chargers are needed the annual NPV is positive although small. 14.58 € can be saved every year when the EV battery is used for DSM and storage. The installation of a charging station would turn this around and leads to an annual NPV between - 29.65 € and - 73.89 €.

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[1] Taken from Tweed 2013

[2] Product offer on Leviton 2014 homepage and taken from Tweed 2013.

9.1.3 MICRO-CHP

Many important factors will influence the costs of a micro-CHP plant. Among these, the time in operation, and fuel prices are the most important, followed by investment, discount rate, planning, plant manufacturing, financing, connection to the grid, billing, energy purchase, maintenance and insurance. The highest heat demand usually determines the size of the hot-water boiler and the plant itself. For the case study micro-CHP systems with an electric power output of 5 MW has been chosen. Table 29 shows the most important results. All costs are included in the micro-CHP electricity production costs per kWh as calculated in chapter 7.2.1. The annual NPV is – 253.38 € per year.

Table 29 Energy Supply Costs with Micro-CHP

		Unit
Micro-CHP Electricity Production Cost	0.117777802	€/kWh
Loses Household in Florø with Micro-CHP system	-253.38	€/year

9.1.4 FURTHER INCOMES

Beside the arbitrage incomes of the energy exchange, other means of income need to be reviewed. The local electricity distributor and retailer, SFE, is responsible for the grid infrastructure and its performance, see chapter **Fehler! Verweisquelle konnte nicht gefunden werden.**. SFE plans a reinforcement to stabilize the grid and extend the transmission capacity in a few years. The costs of the project are expected to be 16.5 million €.

If SFE could postpone the grid investment because of DSM it could save 742,500.00 €[1] every year. The DSO SFE has two possibilities: Either the company spends the above sum to reinforce the grid or a minor amount encouraging end-customer participation in DSM and energy saving programs. If the ESCO were able to negotiate on behalf of a big group of customer, it can be expected that they obtain more than half of the savings of SFE. On the other hand, SFE run a risk that the ESCO neglect their promises. For this calculation it is assumed that SFE pays the ESCO 400,000.00 € for keeping the demand for instance below 45 MW in winter and below 40 MW in summer (temperature dependent transmission capacity, see chapter **Fehler! Verweisquelle konnte nicht gefunden werden.**). These assumption are made to show how a payment from a DSO towards an ESCO can work as a leverage making the business model profitable.

---

[1] $Investment \cdot Discount\ Rate = 16.5m€ \cdot 0.045 = 0.7425m€$

To check the load factor of a network, the maximum transmission is crucial, rather than the average transmission. Therefore the calculations revealed the following: In Florø the maximum load of the year is increased by 1 MW with 20 % EV share. With a smart charging strategy and the usage of EV as a storage, this effect can be turned around and the maximum load can be reduced by 2 MW. With 50 % participation of residential customers in DSM programs also the maximum load of the year can be reduced by 1 MW. The installation of in-home displays in a wide range of households could also reduce the maximum load by 1 MW because of energy demand reductions. Already the mere installation of micro-CHP systems leads to a significant reduction of maximum load up to 6 MW, see Table 30.

The number of households on Florø is 3963. If just one of the four possibilities would be realized, the profits could be shared among the participants. To realize the calculated DSM, 50 % of the households need to participate. This would lead to 200 € per participating household and year. 20 % EV penetration would lead to 370 € per customer (industry and households), whereas this scenario requires an existing EV fleet which is not the case. As a last resource just 10 % of the households fitted with micro-CHP plants would be assigned 1,000 € each.

Table 30 Overview of Saving Potentials and Total Peak Load Reduction in the Grid in Florø

Share of Households [%]	With	Savings per Year	Peak Load Reduction by
50 %	DSM	1.58 €	1 MW
50 %	In-home Display	130.92 €	1 MW
10 %	Micro-CHP system	- 253.38 €	6 MW
20 %	EV (smart loading)	6.11 €	2 MW
20 %	EV (storage)	8.47 €	

9.1.5 CONCLUSION

The average Norwegian energy customer spends 1,850 € on electricity every year. The ESCO focuses on the most profitable measurements. For the further calculations a return on equity (ROE) of 10 % has been employed. Every participant creates costs for the installation of ICT as well as the software 56.38 € per year over the next 13 years. Further cost are listed in Table 31. It needs to be concluded that without additional money from a DSO, micro-CHP and DSM are not profitable, EV charging only limitedly and in-home displays only just.

Table 31 Minimum Cash Inflow per Customer

	Minimum Cash inflow per Customer		
	ICT + Software	+	Additional Installation
In-home Display	56.38 €	+	6.74 €
EV	56.38 €	+	0.00 €
DSM	56.38 €	+	0.00 €
Micro-CHP	56.38 €	+	537.11 €

The following offers should be made to the customers:

1. The basic package:
   The customer can choose to buy a package or 900 € consisting of ICT, software and an in-home display, leaving it to the customer to shift or reduce the demand and to profit from gain. The amortization period for the customer is about 6.5 years. If the customer wants a payback upon day one a monthly amount of for example 11 € over seven years is also possible. Payback after day one means that the savings per month are higher than the amount paid to the ESCO, which means the end-customer has a positive cash inflow upon day one of the contract. For the ESCO the profits are limited based on the 10 % ROE but nevertheless the risk is quite low. This basic package can open doors for other offers.
2. Advanced DSM package:
   Additionally to ICT, software and display the customer will participate in a controlled DSM program. 100 € participation incentives will be paid. The expenses of 156.38 € will be covered by a 200 € payment per customer, paid for postponing the grid reinforcement. This second package therefore offers 50 € additional profits per contract sold but also contains far more risks. The contract would have to run over 13 years. Over this whole period the contractual agreements about the grid stability need to be granted.
3. Advanced EV package:
   Additionally to ICT, software and display the customer does not need further installations when he or she already owns a charging station. The controlled charging management helps the customer to increase the lifetime of his battery. The expenses of 56.38 € are covered by savings to the customer of 14.58 € and the rest from the postponement of the grid reinforcement. The whole service is free for the customer and still 150 € are left as additional profit. The additional profit could also be used to shorten the contract form 13 to for example 6 years which is more realistic, reduces the risk and still leaves additional profit of 100 €.
4. Advanced EV and DSM Package:
   This is the level on which it becomes more interesting for the ESCO. The investments in ICT, software and display amortize much faster. Customers could be paid about 150 € and the

ESCO is still earning 150 € per customer in a 13 years contract and 100 € in a 6 years contract. Again the 13 years contract is rather unrealistic, especially when the customer cannot expect the battery of his EV to work that long.

5. Advanced Micro-CHP package:
   The installation and management of micro-CHP systems needs profound know-how. If the ESCO cannot provide that it should draw on CHP contracting companies. Such a contract could describe the ESCO paying a monthly amount for installation and maintenance while still maintaining control of the device. About 250 € losses and 250 € ROE need to be recovered. The contract would need to run 15 years. However, the possibilities to reduce and shift load are so enormous that about 500 € remain every year as additional profit. The long running time contain risk and the life cycle assessment with the use of natural gas is suboptimal. If biogas could be provided, the micro-CHP is a reliable option.
6. Full package:
   The full package is a combination of ICT, software, DSM, smart EV charging and micro-CHP. Such a combination would need individual calculation. Nevertheless the advantages for end-customer and ESCO would be at least as much as package four and five together.

In case of 10 % EV penetration and additional 5 % of residential customers with micro-CHP system, the peak load of the grid could be reduced by 4 MW when expecting that all 10 % EV owner and all 5 % micro-CHP system owners participate and take the respective package of the company’s offer. The additional annual profit – beside the ROE of 10 % - would be 193,195.00 €. This is about half of the money that had to be invested by the grid owner to postpone grid investments in the first place, following the assumptions in chapter 9.1.4. This can give a good insight in how far earnings from grid postponement can be split for mutual benefit. Of the 742,500.00 € SFE saves per year because of grid investment postponements, at least 206,805.00 € are needed per year to enable flexibility and is therefore a theoretical lower negotiation limit for the ESCO. The upper annual limit is nevertheless the 742,500.00 €.

The ESCO will face the dilemma that negotiations with DSO will be quite difficult, especially, when the number of customers is unsure and therefore the maximum load reduction a point of discussion. A solution for this could be a contract similar to crowd funding[1] but just the other way around. For crowd funding a common system is that the crowd has a timeframe to invest in the offered business model in return for silent partnership. The proposing organization sets itself a target how much money they want to collect. When they reach their target and they collect enough funds to meet their target, the crowd funding was successful. If they do not, the crowd funding failed and they get nothing. This can be

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[1] Crowdfunding is a way of financing. Generally over the world wide web, donations are collected from the “crowd” to fund business ideas. (Wikipedia 2014a)

called the decision of collective intelligence. Transferred to the case here a possible contract between DSO and ESCO could be structured similarly. DSO and ESCO sign a deal that the ESCO reduces the maximum load by a certain amount and gets a respective remuneration for that. Afterwards the ESCO has a timeframe, e. g. one year, to collect enough customers in the respective region to realize the promised maximum load reduction. If the ESCO reached the agreed threshold the contract is effective, otherwise the contract is off the table. This way of contracting could reduce the risk for both parties.

9.2 Germany

Chapter 9.1 simulated an ESCO on the basis of the case study data of Florø in chapter 7. The implementation of a similar business model in Germany is generally possible. The differences are the structure of the revenue stream and different customer privacy settings.

The Norwegian ESCO has two important revenue streams: DSO payments, responsible for the biggest share, and spot market arbitrage. A German ESCO would have to focus on arbitrage possibilities because the income from DSO payments is normally not available. German DSO do not face extensive grid reinforcements. Due to bigger variances of the prices on the spot market in Germany the income stream should be higher.

The prices on the Nordpool Spot in the year 2013 were quit constant with a standard deviation of 17.48 € and an average price of 37.34 €. The prices were in a range between 1.38 € and 109.55 €. The EPEX Spot intraday energy trading prices in 2013 had a standard deviation of 544.67 € and an average price of 38.58 €. The prices were in the range between – 83.25 € and 155.61 €, see Figure 26.

Figure 26 also shows that in 4117 hours in 2013, which is 47 % of the time, the energy spot price in Germany was cheaper than in Norway. A direct power line between Norway and Germany could reduce the energy costs on both sides of the sea. Norway would import energy when the German energy price is below the Norwegian and Norway would provide flexible hydro power capacity when the prices in Germany are the highest.

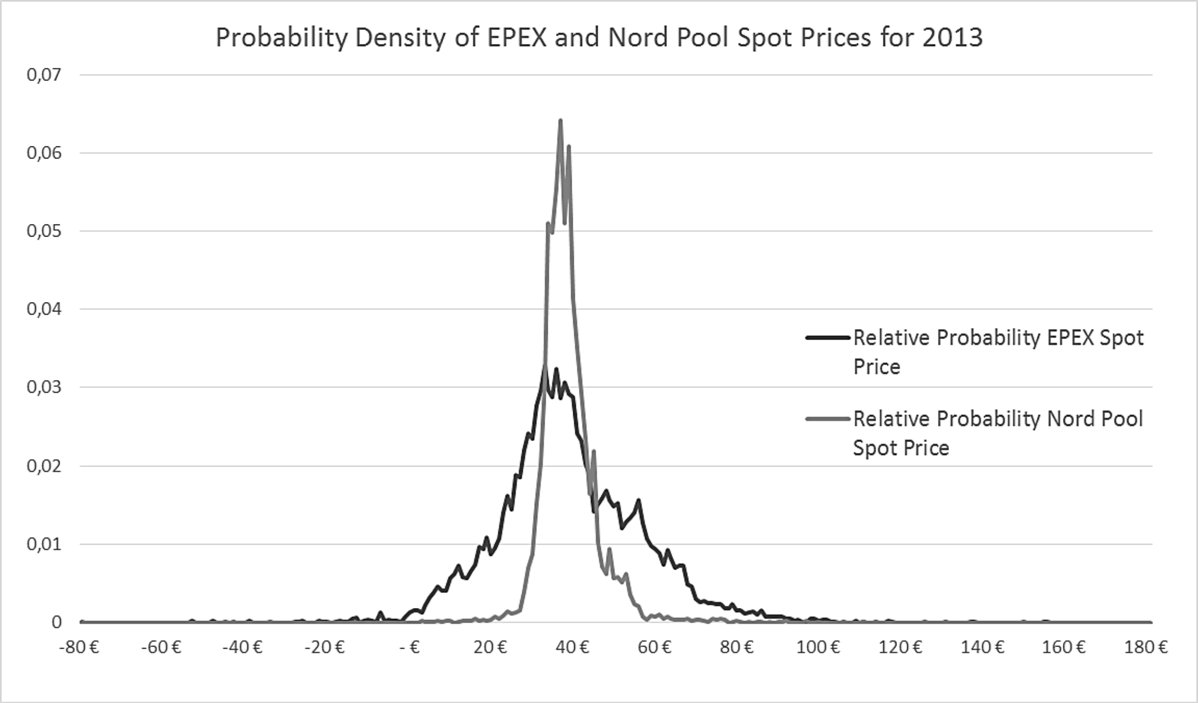

Figure 26 Energy Prices of EPEX and Nord Pool

The varieties on the German energy spot market are high due to a high penetration of wind power and PV. On the German energy market, a wind power capacity of 35 GW (Bundeskartellamt 2014, p. 3) is installed. During strong wind and production at full capacity the energy prices at the EPEX spot can be pushed well below zero, as can be seen in Figure 27. During low wind times the energy prices are generally higher. The average German energy load is 68 GW (Statistisches Bundesamt 2013).

The German capacities of PV is 36 GW (Bundeskartellamt 2014, p. 2). The German price curve used to have a high during 11am and 2pm. This regular high price time cannot be seen anymore due to strong PV penetration. The difference between a sunny day and a normal day can be seen in Figure 28. Since this regular high price period does not exist anymore, a lot of gas power plants are not profitable anymore. This general tendency also decreases the arbitrage possibilities of DSM, micro-CHP or smart charging of EVs.

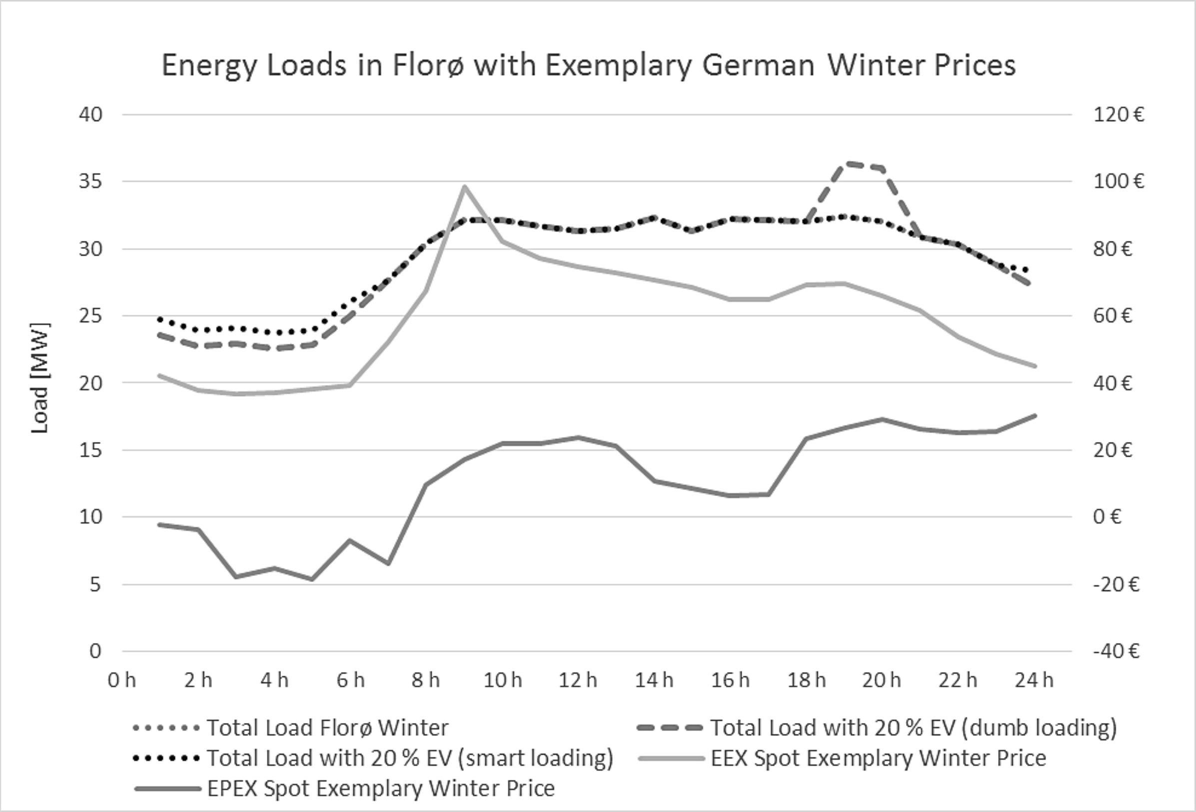

Figure 27 Energy Loads in Winter with EPEX Prices

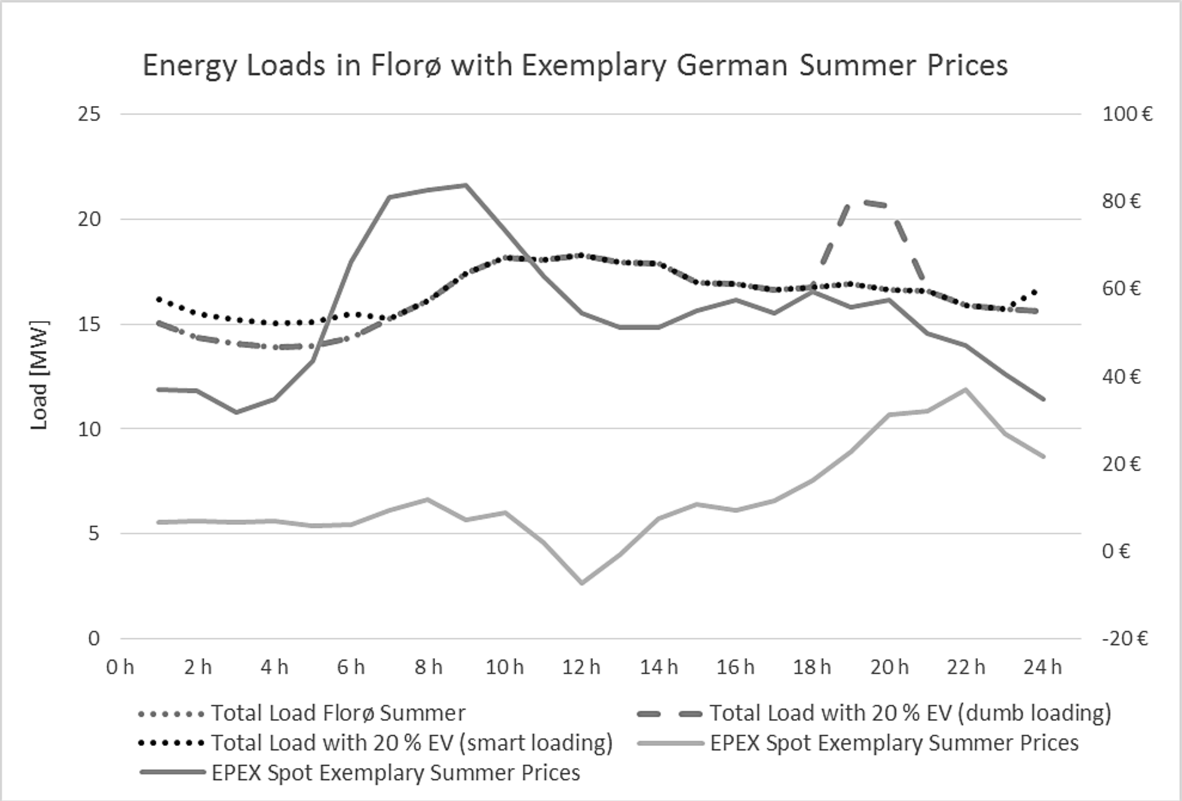

Figure 28 Energy Loads in Summer with EPEX Prices

As presented, the chances for arbitrage in Germany are much higher than in Norway. Nevertheless the variability of prices is not enough to make an ESCO profitable in Germany.

The revenues for an ESCO the case study region Florø with German energy prices has been calculated. E. g. the revenues of EV are 43.29 € per year and household and for DSM 35.42 €. These numbers are significantly higher than the results with Norwegian energy prices. Nevertheless the results are not comparable because assumptions and circumstances do not fit a German case. Further, the calculation have not been designed for the high variations of the EPEX prices. An optimization in Germany would be far more difficult because external information like wind and solar radiation are very important. Further research should be done on this field.

A substantial profitability contribution could be achieved with micro grid management, see chapter 3.2.1. Also this topic contains a lot of room for further research.

10 Conclusion

This thesis showed that the business model of an ESCO – under certain conditions – can operate profitable. This is especially because of the assumption that the local DSO is willing to pay for provided flexibility. Using this flexibility, grid reinforcements can be postponed. The business model of the ESCO can easily be applied on other regions with bottlenecks, shortages or similar problems. Operating in more than one region will generate economies of scale. In the following a short overview about the thesis will be given. Every chapter will be revised and discussed how it contributed to the results as well as possible obstacles and results will be worked out.

Chapter 2 gave an overview about the electricity supply chain and what is important when implementing a new player on the market. Chapter 3 dealt with smart grids including DSM potential, smart homes and already existing new players on the energy market. Chapter 4, e-mobility, considered positive and negative aspects of EV and their integration into the grid; a special focus was on the battery. Chapter 5, micro-CHP, gave an overview about the wide and complicating flied of CHP technologies and their possibilities for DSM. A short calculation revealed that CO_2 reductions of micro-CHP systems are at least questionable. From an environmental point of few, CHP plants should generally run on biofuels.

Subsequently, after the information about the supply chain and smart grids as well as the new technologies EV and CHP also an introduction into business models has been given in chapter 6. A wide range of definitions, models and frameworks is known from the literature. Especially the business model canvas was introduced due to the fact that it is the most widely used model and especially in entrepreneur circles very common. Therefore it was used to generate the business model of the ESCO and helped especially during the creativity process.

Chapter 7 described the results of the modulation in the casestudy region Florø. The influences of micro-CHP, energy savings, DSM and EV on the energy demand were presented and discussed. Challenges accrued from collecting data, building up the model and to replace missing data by smart and reasonable assumptions. Most assumptions refer to similar projects and models and were chosen conservatively. Increasing demand and fluctuating energy demand stress the grid. A need for DSM or a grid reinforcement was identified.

A business model of an ESCO that fits the requirements of the test region was developed in chapter 8. The market situation, competitors, the unique selling proposition, the customer benefits and the finance plan were worked out.

Chapter 9, the ESCO in practice, used the simulation results of chapter 7 and compard the revenue streams of EV, mico-CHP and DSM with the corresponding costs of ICT, charging station, smart meter, DSM and micro-CHP. The cost side was represented very detailed to identify synergies. The ESCO generated synergies when its customers installed more than one technology. This influenced the selling offer. Offers that just contained DSM were basically unprofitable. The more technology a customer installed the higher the savings for him or her and the higher the profits for the ESCO. The practicability of an ESCO in the German context was identified as critical due to missing DSO payments. More elaborate optimization models might use the variations of the German spot price in order to generate enough profit.

Appendix

Table 32 List of Smart Grid Regions in Europe

Agios Efstratios – Green Island – Smart Grid (Greece)	GRES
DeVID (Norway)	www.sintef.no
DG DemoNet project chain (Austria)	www.ait.ac.at
DREAM – Dynamic real-time control of energy streams in buildings (The Netherlands)	www.utwente.nl/ctit/energy/projects/dream.html
EcoGrid EU Project (Denmark)	www.eu-ecogrid.net
E-Energy, Smart Grids made in Germany (Germany)	www.e-energy.de
Flexible EV Charging Infrastructure (Croatia - Denmark – Norway)	http://www.et.aau.dk/research-programmes/microgrids/research-activities/Flexible+electric+vehicle+charging+infrastructure_Flex+%E2%80%93ChEV/
Gredor (Wallonia)	University of Liège
GridBox – Open real-time distribution grid control system (Switzerland)	Supercomputing Systems AG
IN2VPP (Germany - Austria)	www.in2vpp.de
INFRAPLAN (Austria – Germany)	www.infra-plan.eu
INTEGRA (Austria - Germany)	www.smartgridssalzburg.at
Kostredin - Cost reduction MV/LV Instrumentation (The Netherlands)	www.enexis.nl

Linear – Local Intelligent Networks and Energy Active Regions (Flanders)	http://www.linear-smartgrid.be
North Sea Offshore Networks (Norway)	www.sintef.no
OGEMA 2.0 - Smart Grid meets Smart Home (Germany)	www.ogema.org, www.openmuc.org
Power Networks Demonstration Centre (Scotland)	www.strath.ac.uk/pndc/
PowerMatching City II (The Netherlands)	www.powermatchingcity.nl
PRICE Project (Spain)	www.priceproject.es/en
Promotion of Energy Efficiency in Households with Smart Technologies (Latvia)	http://www.latvenergo.lv/lat/viedie_skaititaji/viedie_skaititaji/
SGEM – Smart Grids and Energy Markets (Finland)	www.cleen.fi/en/sgem
Smart City Kalundborg (Denmark)	www.smartcitykalundborg.dk
SMART GRID Gotland (Sweden)	www.smartgridgotland.com
SMART GRID HYLLIE (Sweden)	www.hyllie.com
SMART GRID Stockholm Royal Seaport (Sweden)	www.stockholmroyalseaport.com/en/srs, www.stockholmroyalseaport.com/en/srs
Smart Grid Ulm in Baden-Württemberg (Baden-Württemberg)	Municipality Ulm
Smart Grid Vendée (France)	www.smartgridvendee.fr
Smart Grids Model Region Salzburg (Austria)	www.smartgridssalzburg.at
Smart transmission grid operation and control (Nordic Region)	http://www.nordicenergy.org/project/smart-transmission-grid-operation-and-control/
Swiss2Grid: Algorithm based load management (Switzerland)	www.s2g.ch
The FlexLast Project (Switzerland)	www.zurich.ibm.com/flexlast/
TÜDOSİS Project – Feeder Automation System (Turkey)	TÜBİTAK Marmara Research Center Energy Institute
VENTEEA (France)	ERDF

Wind Power Monitoring and Forecasting System of Turkey (Turkey)	http://www.ritm.gov.tr/

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