Smart Grid Infrastructures

Trend Report 2010/2011

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ISBN 978-3-9812203-6-0. 2010.
XXVI, 356 p.

Benedikt Römer · Julian Sußmann · Christian Menkens
Marie-Luise Lorenz · Philip Mayrhofer (Editors)

Smart Grid Infrastructures

Trend Report 2010/2011

Class 2010 Fall

Center for Digital Technology and Management

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Edited by: Benedikt Römer, Julian Sußmann, Christian Menkens, Marie-Luise Lorenz, Philip Mayrhofer

ISBN: 978-3-9812203-7-7

Biblografische Information der Deutschen Nationalbibliothek
Die Deutsche Nationalbibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über http://dnb.d-nb.de abrufbar.

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Printed in Germany

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The Center for Digital Technology and Management (CDTM) is a joint institution of the Technische Universität München (TUM) and the Ludwig-Maximilians-Universität München (LMU). This report was created by CDTM students and is one element of a comprehensive research project. The CDTM is part of the Elitenetzwerk Bayern.

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Preface

E-Energy and Smart Grids are on everyone's lips. These expressions stand for the convergence of the electricity system with information and communication technologies (ICT) forming a complex cyber physical system. The aim of all the efforts within this area is to increase energy efficiency and to allow for a stable integration of fluctuating distributed renewable energy sources into the electricity system.

This new so-called "Internet of Energy" is one very important step on the way to a sustainable energy system. Germany and the European Union define sustainability by the three targets of energy security, economic efficiency, and environmental impact. One mile-stone on the way to those long-term goals are the European 20-20-20 marks, referring to 20% increase in energy efficiency, 20% reduction of CO2 emissions, and 20% renewables by 2020, with German goals being even more ambitious aiming for 30% renewables by 2020. The German research efforts for the development of a smart grid are bundled within the E-Energy initiative, which mobilized € 140 million of public funds and was declared a beacon project by Federal Chancellor Dr. Angela Merkel.
In 2009 the Center for Digital Technology and Management (CDTM) conducted an initial Trend Seminar on E-Energy supported by the E-Energy accompanying research. Its results have been published in the CDTM Trend Report 2009/2010 giving a broad overview of the trends relevant in the context of E-Energy. In 2010 the CDTM research project ZESMIT (German acronym for future energy systems: market, integration, technology) started. ZESMIT is funded by the federal ministry of economics and technology embedded in the E-Energy initiative. It is carried out by CDTM. Hence, the need for a deeper look especially at the technology side of this new emerging cyber physical system was mandated. Thus, the Trend Seminar class of the fall term 2010 analyzed trends within five distinct areas including four that focus specifically on detailed technology aspects. Those five areas are information technology, communication technology, electric energy related technologies, electric mobility and the changing structure of market players in Europe. These condensed and refined insights represent part one of the present work and aim at providing the reader with an in-depth understanding of the status quo and the most important trends concerning technologies and markets in E-Energy.

Smart grids will affect not only the energy industry, but stakeholders of various industries as well as private households. Thus, part two examines possible future scenarios and matching product or service ideas from five perspectives: from an information service provider's, from a communications company's, from utilities', from the automotive industry's and from the end-consumer's view. Building upon their in-depth knowledge gained from working on part one of the Trend Report, the teams developed five innovative business ideas. Ranging from the so-called “Energy Brain” (aggregating data in a cloud-like approach) and “SCI:LastMile” (enabling the balancing of the low voltage grid) over “SmartMicroGrid” (dealing with areas not yet fully connected to a smart grid) and “Energy&Drive” (taking on upcoming challenges for e-mobility) to “EnergyOnTheGo” (allowing seamless electricity roaming for the future mobile European citizen). Ideas like these that take different future scenarios into consideration need to be found for all participating players of a future smart grid. Without the stimulating power of such creative business models it is hard to convince relevant stakeholders of the great opportunities that lie in a fully developed smart grid.

We highly appreciate that the CDTM investigated this most relevant topic in more depth and lead the students at their deep-dive study into the complexities of the future smart grid infrastructure. We are very happy that the creativity and perseverance of our excellent students once more contribute to the knowledge on smart grids and will help to spread the E-Energy idea. We regard the results of this seminar as remarkable, providing useful information and insights for research, politics and industry. We thank the students for their enthusiasm and dedication and all the guest lecturers for sharing their valuable insights: Andreas Dutz (prevero AG), Peter Esslinger (Technische Universität München), Prof. Andreas Jossen (Technische Universität München), Ludwig Karg (E-Energy accompanying research), Heiko Lehmann (Deutsche Telekom Laboratories), Ludwig Preller (Blue Ribbon CleanTech), Dr. Alexander Vilbig (Stadtwerke München), Heinrich Wienold (EFR GmbH).

We also thank the CDTM assistants Benedikt Römer, Julian Sußmann, Christian Menkens and Marie-Luise Lorenz for the conception and tutoring of this seminar and Albert Feller for his contributions to the final editing of this report.

Munich, Fall 2010

Prof. Arnold Picot Prof. Manfred Broy

For more information about the CDTM and its related projects,
please visit http://www.cdtm.de

The entire trend report was written by CDTM students under the close guidance of research assistants in 2010. The papers compiled here do not claim to be scientifically accurate in every case; they are rather meant to give a structured and broad overview of trends relevant in the smart grid context.

Contents

List of Figures

List of Tables

Nomenclature

AC	Alternating Current
ACER	Agency for the Cooperation of Energy Regulators
ACSR	Aluminium Conductors that are Steel Reinforced
ADR	Automated Demand Response
AMI	Advanced Metering Infrastructure
AMR	Automatic Meter Reading
API	Application Programming Interface
ATC	Available Transfer Capacity
BACNet	Building Automation and Control Networking
BEV	Battery Electric Vehicle
CAES	Compressed Air Energy Storage
CHP	Combined Heat and Power
CPNI	Centre for the Protection of National Infrastructure
CSP	Concentrated Solar Power
DG	Distributed Generation
CT	Communication Technology
DC	Direct Current
DNO	Distribution Network Operator
DNP3	Distributed Network Protocol
DMS	Distribution Management System
DMZ	Demilitarized Zones
DOE	Department of Energy
DoS	Denial of Service
DR	Demand Response
DRAS	Demand Response Automation Server

DRRC	Demand Response Research Center
E-Mobility	Electric Mobility
EDIFACT	Electronic Data Interchange For Administration, Commerce and Transport
EEG	Erneuerbare Energien Gesetz
EEX	European Energy Exchange
EHV	Extra High Voltage
EPEX	European Power Exchange
EPRI	Electric Power Research Institute (U.S.)
ETN	Europena Tranmission Networks
ETS	European Power Exchange Trading System
EV	Electric Vehicle
EU	European Union
FACTS	Flexible Alternating Current Transmission System
FERC	Federal Energy Regulatory Commission
FTTx	Fiber-To-The-X
G2V	Grid-to-Vehicle
GHG	Green House Gas
GOOSE	Generic Object Oriented Substation Events
GPS	Global Positioning System
GPRS	General Packet Radio Service
GTI	Grid Tie Inverter
GW	Gigawatt
HSDPA	High Speed Downlink Packet Access
HV	Hybrid Vehicle
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current

Hz	Hertz
ICE	Internal Combustion Engine
ICT	Information and Communication Technology
IEC	International Electrotechnical Commission
IGBT	Insulated-Gate Bipolar Transistor
IP	Internet Protocol
IPsec	IP Security
ISDN	Integrated Services Digital Network
IT	Information Technology
KNX	Konnex (ADR standard)
LA	Lead–Acid Battery
LAN	Local Area Network
LTE	Long Term Evolution
MDM	Meter Data Management System
MISS	Member Integration System Server
MMS	Manufacturing Message Specification
MPG	Miles per Gallon
MS	Management System
NiCd	Nickel-cadmium
NIST	National Institute of Standards and Technology
OEM	Original Equipment Manufacturer
OSI	Open Systems Interconnect
OFDMA	Orthogonal Frequency Division Multiple Access
OpenADR	Open Automated Demand Response
MIMO	Multiple Input Multiple Output
P2MP	Point-To-Multipoint

P2P	Point-To-Point
PEV	Plug-In Electric Vehicle
PLC	Powerline Communication/Powerline Carrier
PHEV	Plug-In Hybrid Electric Vehicle
PMU	Phasor Management Unit
PV	Photo Voltaic
R&C	Residential and Commercial
R&D	Research and Development
RES	Renewable Energy Sources
RMR	Remote Meter Reading
RTU	Remote Terminal Units
SCADA	Supervisory Control and Data Acquisition
SDR	Software Designed Radio
SMS	Short Message Service
SOA	Service oriented Architectures
SOAP	Simple Object Access Protocol
SSG	SuperSmartGrid
TCP	Transmission Control Protocol
TEN-E	trans-European Network for Energy
TSO	Transmission System Operator
TPA	Third Party Access
TOU	Time Of Use
TWh	Terawatt hour
UCTE	Union for the Coordinated Transmission of Energy
UDP	User Datagram Protocol
UPS	Uninterruptible power supply

V2G	Vehicle-to-Grid
VA	Volt Ampere
VDSL	Very High Speed Digital Subscriber Line
VPN	Virtual Private Network
VPP	Virtual Power Plant
W	Watt
WAPS	Wide Area Protection System
WAMS	Wide Area Measurement SystemMarie-Luise Lorenz
WAN	Wide Area Network
WinCC	Windows Control Center
WLAN	Wireless Local Area Network
WLS	Weighted Least Square
XML	Extensible Markup Language

Part I

Trends

Chapter 1
Information Technology

Veranika Andreyeva, Albert Feller, Johannes Lechner, Kilian Moser

Information technology (IT) plays an integral role for the establishment of smart grid infrastructures. As backbone of the future energy internet, IT applications will tackle major challenges along all parts of the energy value chain. With small decentralized electricity generators joining large-scale power plants, demand response technologies, monitoring and protection systems as well as integrated business applications for real-time energy markets have to be developed to fully benefit from the potential of smart grids. While today's energy consumers barely use IT systems to monitor and control their electricity consumption, the future energy prosumer will be supported by IT to both produce and consume energy at the same time. In this context the adoption of smart home automation technology will accelerate in the future and new IT systems have to be built to connect prosumers to the energy internet that will evolve on top of today's electricity grids. Utilitites will be challenged by a massive increase of data produced by smart meters. Hence business intelligence systems and data warehouse concepts have to be improved to handle this trend.

Today however, the majority of IT applications along the energy value chain is only partially ready for smart grid integration, as developments in the field of information technology are largely dependent on preceeding changes of the physical layer and improvements of the data transport layer.

1.1 Introduction

The term “smart grid” is almost becoming a household name with politicians, television commercials and newspapers talking about this topic almost on a daily basis. We have a plethora of activities where engineers, policy makers, entrepreneurs, and businesses have shown a keen interest in smart grid infrastructures. While general approaches to implement smart grids are frequently discussed, extensive information about information technology (IT) used in the energy industry is scarce. The following report aims at filling this gap by providing a comprehensive overview of current and future IT trends that will impact smart grid infrastructures.

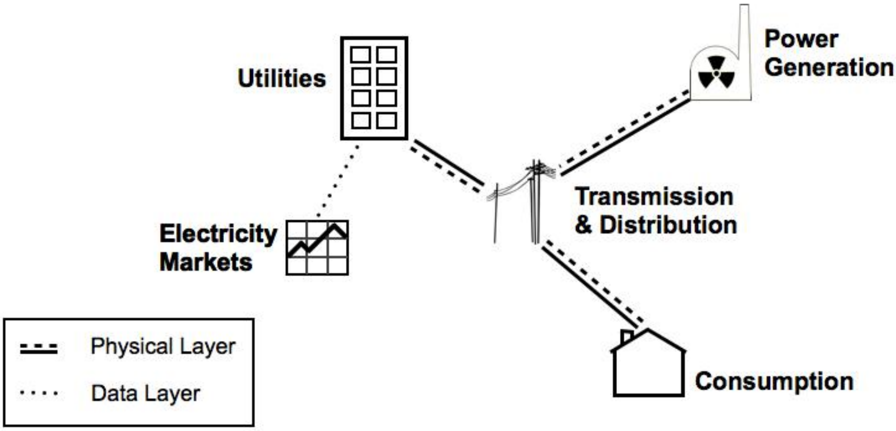

Figure 1.1: Status quo of the IT landscape in the energy industry
Source: own illustration

Most of the world’s electricity grids have been built over decades with the goal of providing a reliable and ubiquitous energy supply. By following this approach, a grid topology was etablished in which the different parts of the energy industry, as depicted in figure 1.1, have been kept apart. The first part of this report analyzes the current status quo of IT along the energy value chain starting with power generation. The intermediate layer has been seperated into a technology layer comprising IT systems used in transmission and distributions grids and an economic layer where the IT systems in electricity markets and utility companies are analyzed. The status quo ends with an exploration of IT used by energy consumers.

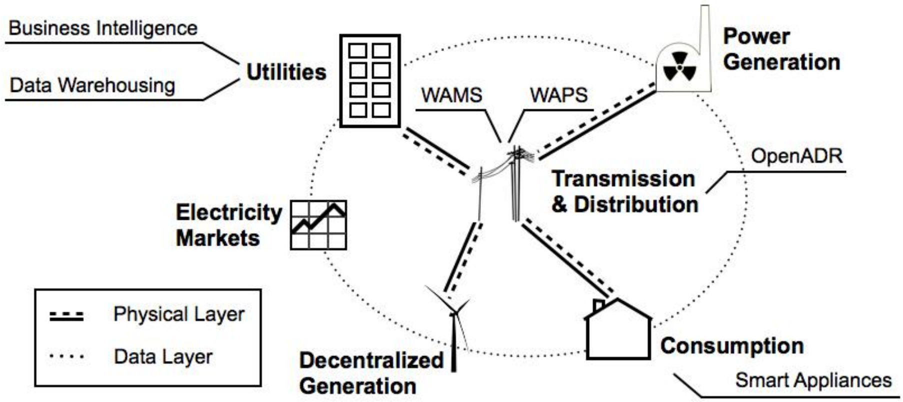

Figure 1.2: Trends within the future IT landscape of the energy industry
Source: own illustration

The second part of this report focuses on IT trends in the energy industry. Future smart grid infrastructures, as described in figure 1.2, interconnect all stakeholders of the energy industry on two layers. Traditionally, all entities are connected in a conventional electricty grid, which becomes smart when all players are connected to an energy internet. Within the energy industry, IT systems will evolve that will push current technologies towards the integrated, smart and efficient grid of the future.

1.2 Status Quo

IT plays an important role in the technological status quo of the electricity grid. Following the approach detailed in the introduction, the most important influences of IT along the value chain are outlined in the following sections. First of all, the current IT support in large and small-scale power generation is discussed. Then, the field of energy distribution and transmission, which connects the supply and demand sides of the grid, is analyzed regarding the deployed IT solutions. Naturally, IT has a great impact on the business as well as the market level of the power grid, which is also outlined. Finally, the current status of energy-related residential IT usage is described.

1.2.1 IT Support in Power Generation

The IT support in the current power generation infrastructure mainly differs between large, industrial suppliers and small-scale power generating entities. Big utility companies use IT for plant automation, operations and forecasting of electricity demand. In contrast, small-scale power generators, which are mostly based on renewable energy sources, have no need for smart information technology since their feed-in tariff is currently fixed anyway.

1.2.1.1 IT in Large-Scale Electricity Generation

Today's large-scale utilities, which generate the majority of electricity consumed, rely on IT in various aspects. Power plant resource scheduling and operations planning for example are supported by IT systems in order to adapt generation levels according to both grid status and power demand in real-time [60, p. 97]. State of the art large-scale power plants are automated by IT systems [34, pp. 1-3]. Forecasting the required amount of electricity is a further area where utilities make use of information technology. Recent examples for the advanced use of IT include applications to forecast the power generation of decentralized units like wind turbines [44, p. 276]. Typically however, utilities feed their software systems with static load profiles matching specific electricity distributions [33, p. 424]. Thus, as of today, the impact of IT used in utility companies is limited to plant automation, operations and forecasting.

1.2.1.2 IT in Small-Scale Decentralized Electricity Generation

Due to the "Erneuerbare-Energien-Gesetz" (EEG) [4], which has been introduced in March 2000, electricity carriers in Germany are required to buy any power generated by renewable energy sources for a fixed price which is regulated by the legislative body [6, p. 34]. Especially small-scale power generators profit from this law since the feed-in tariff, which is guaranteed for 20 years, ensures a protection of the investments [9, p. 28].

No smart information technology is needed to meter and bill the produced electricity because of the fixed feed-in tariff. However, there exist various IT solutions, which support the owners of small-scale power generators in monitoring the produced power and calculating the earnings of the power plant. One example in the field of photovoltaic power generation is the Suntrol monitoring system [67]. It consists of a data logger hardware and an internet portal. The data logger monitors the power generation and uploads the data to a web server and the internet portal [68] displays the produced energy, earned money and saved carbon dioxide [69].

1.2.2 IT Enabled Distribution and Transmission

The distribution and transmission of energy connects the supply side, which generates the power, to the demand side, which consumes the electricity. This section focusses on the IT used on the technological level of the power grid. On the one hand, IT for demand response is needed to manage the load of the electricity grid and on the other hand, the monitoring and operations of the functionality and stability of the grid is also supported by IT.

1.2.2.1 IT in Demand Response Management Systems

Demand response (DR) enables utilities to manage the load of their customers in order to facilitate peak load reduction. DR further allows electricity consumers to react faster to both changing market prices and change their electricity consumption accordingly [23, p. 141]. A 2008 survey of the Federal Energy Regulatory Commission (FERC) estimates a potential peak load reduction through DR in the United States of 41 GW. Out of those, 13.6 GW were already realized in 2007 [18, pp. 33-35]. DR programs can roughly be characterized by two categories: incentive-based and time-based [18, pp. 24-26]. Incentive-based DR provides immediate means for utilities to reduce load by shutting down customer equipment via direct load control and by offering incentives (i.e. discounts) to customers. Time-based DR adds price data (Time-of-Use, Real-Time) to this and exposes customers to prices.

As of now, automated IT support of DR is not ubiquitous. Demand response requests are still submitted via phone calls, pager messages and emails and require people to act upon those requests [7, p. 297]. Large-scale pilot projects for automated DR are well underway [18, pp. 57-58]. The Demand Response Research Center (DRRC) currently runs a pilot project focusing on DR IT architectures [38].[1]

1.2.2.2 IT Driven Monitoring and Operation

Most of today's electricity grid monitoring in a control center depends on estimations about the grid status, which are based on data collected via management systems (e.g. SCADA) and remote terminal units (RTUs) [32, p. 4]. Among the systems implemented today, there exist distribution network management systems, Supervisory Control and Data Acquisition (SCADA) systems and graphical information systems that depict the electrical network topology. Currently, SCADA is the key data collection and control system for the operation of distribution systems. Thus companies like ABB, CISCO and TEKLA are continuously working to improve current SCADA systems in existing distribution grids. SCADA is used to transfer grid status information from various measuring nodes to the Distribution Management System (DMS). It includes features that allow control centers to send supervisory control commands like manual overrides from the DMS via the SCADA system to the grid [72, p. 47]. In the status quo however, issues arise. SCADA and DMS based estimations about the grid status require more running time and are less robust, since the data collected from RTUs is not synchronized. Significant effort must be taken for topology checking and bad data detection [32, p. 5]. The present IT systems usually interpret the voltage magnitude in measuring nodes as an indicator for grid stability. If however an electricity grid is stressed and voltage collapse

[1] Preliminary attempts of a DR architecture are discussed in more detail in chapter 1.3.1.1.

represents a recurring threat, the voltage magnitude can no longer be considered a valid indicator for the functioning of the system itself [63, pp. 842-844]. Hence, current systems require a better indicator for margins of voltage stability to improve their monitoring capabilities [29, pp. 2-4].

1.2.3 IT Based Electricity Markets

This section details the IT on the business and market level of the power grid. The IT based electricity trading and purchasing is done between suppliers and distributors on several energy markets but the prices for end-customers are nowadays still mostly static. Various business applications are used by utility providers to manage interactions with customers.

1.2.3.1 IT Based Energy Trading and Purchasing

The trading and purchasing of electricity is done over several power exchanges all over the world [46, p. 47]. The European Power Exchange (EPEX) and European Energy Exchange (EEX) markets are used as explenatory examples in the following paragraph. The electricity can either be traded in the long term on the EEX derivatives market or via the EPEX spot or intraday markets [17]. No automated real-time trading is possible for now. The EEX power derivatives market is run on the Eurex trading system which can be accessed via simple web-based systems (WebAccess, EEX Global Vision Screen) or via advanced trading systems with customer-own MISS-Architecture (Member Integration System Server) which support dedicated secure lines to the EEX back-end [16]. The trading on the EPEX spot market is handled by the EPEX Trading System (ETS) [14] which allows market participants to connect via the ETS Client [70].

1.2.3.2 Business Applications in Utilities

On a business level, utility providers use data warehousing and business intelligence applications to manage their various datasets effectively and draw conclusions for their business practice. Data mining for example presents a common way to generate customer profiles that can be used for target-specific marketing or improved load forecasting [36, p. 632]. A lot of applications are used to manage interactions with customers, e.g. contract management or billing. But software also supports a utility's internal management of employees, assets or further administrative purposes [2, p. 22]. Currently, few of those applications are ready to processes smart grid information. Today's business applications rather serve the traditional business model. Some of those applications however are build on service oriented architectures, thus allowing an interface like data-access across different platforms [2, p. 22].

1.2.4 Energy-Related Residential IT Usage

Traditionally, electricity consumers care little about their household consumption. Home automation technology, that could help to reduce our residential energy usage, is still only implemented in a small minority of residential buildings.

1.2.4.1 IT Supported Home Automation and Home Appliances

Naturally, residential buildings are equipped with power lines and telephone circuits to enable its residents to use standard home appliances like washing machines or refrigerators, allow them to install lighting systems, audio / video equipment and give them access to communication services like the Internet. Traditionally, those services are not able to talk to each other. In order to countervail the lack of central control, home automation technology was developed. A wide range of different concepts from the ICT is combined to empower its users to control their appliances over an single interface or service. While home automation is technically feasible, the diffusion of home automation systems is still impeded by the high costs for such installations [48, p. 13]. Smart appliances, a major component of home automation technology, are literally not existent, because potential customers regard the technology as too expensive or of no immediate use [21, p. 23]. The technology itself however offers intriguing aspects for the emerging field of smart grids. German households for example account for about 33% of the country's total energy consumption [71]. In this context, home automation technologies can be used to optimize the energy usage, but this potential is currently barely exploited. Besides the significant initial investment, the main reasons for missing diffusion of home automation technology originate from different standards and system architectures [43, p. 750ff]. In Europe, the three standards BACnet, KNX and LON compete against each other, effectively impeding collaboration of household appliances across all systems [12, p. 58]. As a consequence, only few appliance manufacturers have equipped their products with controllers that enable smart grid interaction.[2] While industrial facility automation is far more advanced and common, today's home automation technology lacks behind both in implementation as well as in standardization and collaboration [2, p. 14].

1.2.4.2 IT Enabled Electricity Consumption Monitoring

As of 2010, the installation of smart meters has become mandatory by law in Germany for newly built houses [77]. It is not stated however, that these smart meters must enable remote readout of consumption, but merely need to track actual time and amount of energy used [77]. The Germany based

[2] A first attempt towards Smart Grid integration however was made by the German appliance manufacturer Miele & Cie. KG with its technology platform Miele@home [50].

utility provider Yello Strom offers an internet connected smart meter called “Sparzähler” [82]. Consumers are able to track their energy usage from home or on the road using this meter.

Google PowerMeter is a web application that enables customers to monitor and reduce their energy consumption. Google aims to create an open platform with PowerMeter and therefore provides utilities and energy monitoring device makers an open API for integration [25]. Currently, partnerships with ten utilities around the world are in place, including Yello Strom [83].

1.3 Trends

In the near future, power generation will become more volatile and decentralized since renewable energy sources will play a more important role. The grid has to become smarter to handle the more dynamic electricity generation of the future and therefore, the IT used in the transmission and distribution of electricity will be more and more interconnected with the generation of energy. Integrated IT systems for managing Demand Response and wide area monitoring and protection systems will be needed to manage the growing complexity of the power grid. The changing landscape of the energy market will empower electricity consumers to become prosumers and challenges business applications to deal with significantly increasing data volumes. The smart grid will enable new business models through the integration of smart meters and home automation, but is also required to respond to the increasing security and privacy concerns of its users.

1.3.1 Smart Power Generation and Transmission

The increasing decentralization of power generation and the growing utilization of volatile renewable energy sources requires the transmission grid to become smarter. IT in automated Demand Response management systems supports the goal to smooth load curves of the grid and therefore makes additional backup power plants for peak loads unnecessary. IT based wide area monitoring and protection systems help to prevent energy blackouts and support grid operators in guaranteeing a stable power supply.

1.3.1.1 Emergence of Automated Demand Response Standards

In light of the potential peak load reduction possible through (automated) Demand Response (DR), legislation concerning conservation of power in buildings/industry and the fast adoption of smart meters, the creation of a standardized way to exchange Demand Response signals has become a top priority in the United States [64, Sec. 421][55, pp. 82-83][18, pp. 14-17].

Description

The smart grid interoperability effort of the National Institute of Standards and Technology (NIST) picked OpenADR as an initial standard for DR [59]. OpenADR provides two-way communication between utilities and consumers via the internet using established standards such as Extensible Markup Language (XML) and Simple Object Access Protocol (SOAP) [61, pp. 5-6]. It features a comprehensive data model, capable of delivering signals for incentive-based DR as well as time-based DR [61, p. 56]. Central component from an IT point of view is the Demand Response Automation Server (DRAS) which is shown in figure 1.3.

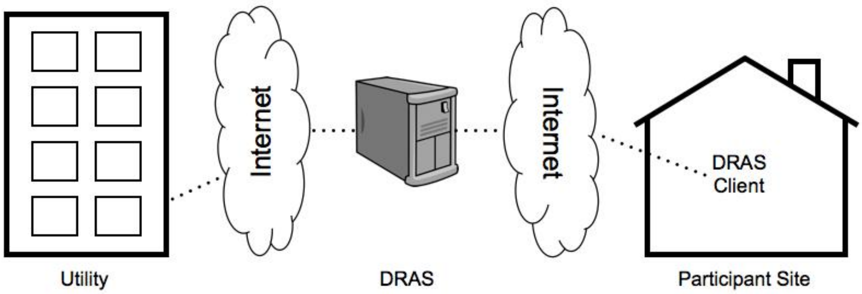

Figure 1.3: Network architecture of the Demand Response Automation Server
Source: own illustration

Due to the open nature of the OpenADR standard, every interested vendor is free to provide its own implementation of a DRAS and/or OpenADR client. An OpenADR client can be a dedicated hardware component (also called Client Logic and Integrated Relay) or a software-based solution, integrated into an existing system [38, p. 2]. Interoperability with BACnet - a well established communication protocol for building automation and control networks - is already part of the OpenADR specification, therefore providing a standardized way for utilities to request load shedding in commercial buildings [28, p. B11].

Impact on Smart Grid

A vivid ecosystem around OpenADR is already coming into existence, ranging from OpenADR client implementations for residential loads [73] to integration software solutions for OEMs [79]. Adding to that, the DRRC is partnering with Utility Integration Solutions, Inc. (UISOL) to provide a Java-based open source implementation of OpenADR that will be available for the public domain [78]. Therefore, chances are very good that OpenADR will emerge as the standard for DR in residential, commercial and industrial settings.

1.3.1.2 Increased Implementation of Advanced Monitoring and Protection Systems

Power systems have become so interdependent that the events in one section of the electricity grid can cascade and have significant impact on other areas in the grid that appear to be relatively remote from the source of the initial event [29, pp. 1-5].

Description

Real-time monitoring enabled by IT systems that allow to construct a comprehensive view of the grid status, will be the future method of choice when it comes to securing the integrity and stability of the grid. This improved monitoring of power grid operation will be achieved through the establishment of a new power sensor system and updates of IT used in electrical grids [58, p. 10] [15, p. 20] [62, p. 1]. Wide-area monitoring as well as control and protection schemes summarize attempts of IBM, CISCO and ABB to fulfill the monitoring requirements of new technologies. Benefits of those IT systems will include measures to avoid blackouts or use real-time data to adjust electricity prices charged to consumers. Real-time monitoring will also be important in promoting the use of renewable energy sources. As renewable energy sources tend to be intermittent, IT-systems must be able to monitor the entire grid and use smart grid data to take intelligent action in order to integrate those fluctuating energy sources [20, pp. 1-2].

Impact on Smart Grid

IT enabled wide area monitoring (WAMS) and protection system (WAPS) technologies will become integral components of future smart grid infrastructures as they will help to use the maximum available capacity of the transmission lines. Integrated with the operation centers of transmission grids, those IT systems will increase the operator's situational awareness and reduce the time needed for transmission algorithms to maximize the grid performance. Thus, IT will provide operators with new tools to better understand existing and projected grid conditions [80, p. 1] [29, p. 1] [32, p. 4]. Integrated through the SCADA network, IT systems will provide performance information about the grid that allows automated, real-time control of grid electricity. IT will be the key to handle tasks such as predicting the grid integrity as well as detecting and repairing grid interruptions and guarantee the safe operation of power systems [3, p. 96].

In the nearer future the grid status information will be obtained from the state measurement modules based on a new technology known as a Phasor Measurement Unit (PMU) [29, pp. 1-8] [49, p. 12]. IT wise these devices are GPS time-synchronized and provide accurate, simultaneous, synchronized data of events occurring across the grid [32, p. 4] [58, p. 11] [29, p. 2]. Using WAMS and WAPS to effectively monitor and protect the future smart grid, will help to avoid or mitigate power outages and quality problems. Future IT systems have the potential to provide early warnings to grid operators about imminent failures, stress, potential instabilities or service disruptions [3, p. 94][53, p. 4].

1.3.2 Real-Time Electricity Markets

The availability of smart meter data and the introduction of a so called energy internet will increase real-time energy commodity trading volumes. Electricity prices will become more elastic and create the need to optimize business intelligence software that is capable of supporting utilities in making prompt and sound business decisions. Data volumes created by smart meters and other measuring nodes will increase significantly in the future. Consequently, IT will be challenged to optimize enterprise architectures and push IT systems towards real-time interactions. The following chapter focuses on IT trends in the business level of the utility industry.

1.3.2.1 Shift towards Real-Time Electricity Trading and Purchasing

The change in the market for energy is caused by three major driving factors: The liberalization of the market (e.g. in the EU) which leads to an increased competition, the growing decentralization of power generation especially in the field of renewable energy sources and the necessity to use energy efficiently to reduce the emission of greenhouse gases [81, p. 1].

Description

The growing market share of decentralized and volatile renewable energy sources (for example wind turbines, which are dependent on weather conditions), leads to elastic prices on the electricity markets [66]. The market structure even allows negative prices [3] when the power supply exceeds the demand [13, p. 7].

To overcome the challenges of the changing energy market, the German Federal Ministry of Economics and Technology started the funding program “E-Energy: ICT-based energy system of the future”, which addresses the issues security of energy supply, environmental compatibility and economic efficiency [5]. The program has three main goals: creation of an E-Energy marketplace, interconnection of all systems to ensure independent monitoring, control and regulation and real-time digital interaction of business and technology operations [19].

[3] The exceptionally strong wind in the night of October 4 2009 combined with a very low power demand led to a negative record price of -500 EUR/MWh on the European Energy Exchange (EEX) market [13, p. 7].

One ICT architecture for an IT based marketplace for energy, is proposed by the E-DeMa project which is supported by the E-Energy program. R&C (residential and commercial) customers have (smart) metering points installed which measure their energy consumption. Metering and billing data, along with time series of measurement values are exchanged via the ICT infrastructure (e.g. using the EDIFACT message standard [1]) [40, p. 80]. Smart home appliances (see section 1.3.3.2) have to be installed in households to allow automated demand response (see section 1.3.1.1) management using pricing signals.

Impact on Smart Grid

The current electricity market will evolve into a highly interconnected electronic marketplace. All market participants will be connected via ICT gateways to an "Internet of Energy". Consumers will be able to adapt their energy demand automatically to the very elastic supply-based pricing because of real-time pricing signals exchanged and computed via IT [31]. Producers will be able to adapt their energy production to the demand of the market because of demand signals which allow consumers to announce their present and future demand. Furthermore, energy consumers will have the opportunity to become prosumers who can actively participate in the marketplace and both produce and consume energy [40, p. 75][19].

1.3.2.2 Enhanced Business Applications in Utilities

IT has experienced a significant increase in the data volume to be processed. Data mining technologies have been developed for various fields to cope with the threat of information overload [26, p. 3]. This trend will continue in the future and will become even more relevant to utility companies.

Description

The U.S. Electric Power Research Institute (EPRI) predicts an increase of data intake upon full smart grid penetration from 200 Terabyte to approximately 800 Terabyte on an annual basis for an average U.S. based utility company [22, p. 59]. As depicted in figure 1.4, the data volume will rise exponentially along the introduction of new technologies that enable smart grids.

Confronted with information overload, ICT will develop new ways to manage its ever larger data marts. Technology wise, IT architectures will more and more incorporate concepts like in-memory databases to speed up the data handling [8, p. 295]. Increasingly sophisticated modeling of software architectures coupled with algorithms based on artificial intelligence will help to canalize (smart grid) data in a meaningful way [52, p. 5]. Besides storing the smart grid data, analytical streaming applications present another promising way to process data in real-time [24, p. 1].

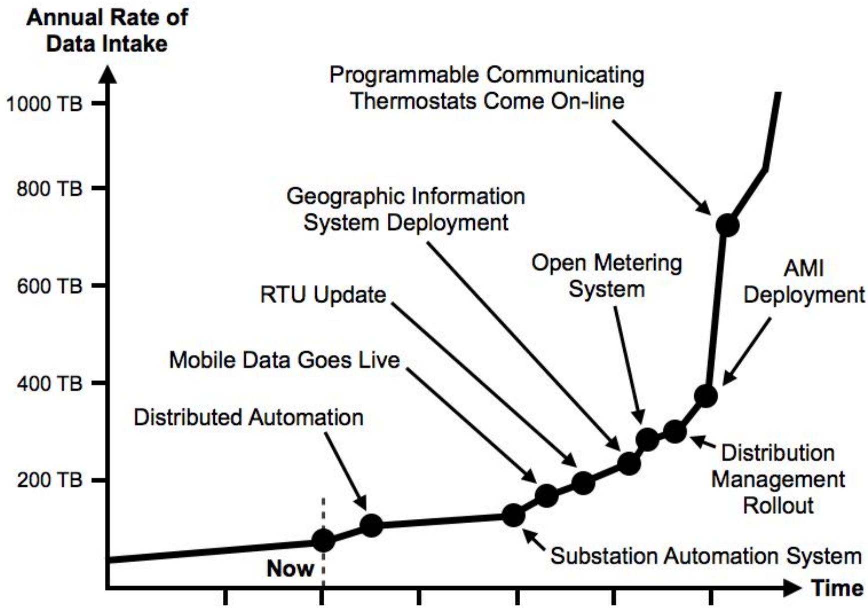

Figure 1.4: Development of data intake upon smart grid implementation
Source: adapted from EPRI [22, p. 59]

Business intelligence relying on streaming technologies has the advantage that real-time events are processed on time and immediate action can be taken. Implementation of this concept in other areas has proven that those systems are capable of handling huge data streams [57, p. 77]. Thus applying this concept in utilities could help to handle the massive data volumes that smart grids will create.

Impact on Smart Grid

Before smart grids have been established as the future of today's electricity grids, power plant operational information was isolated from business information systems. Further increasing trading activity of electricity commodities and the integration of distributed generation will require holistic enterprise solutions to optimize financial trading results as well as the operational grid integrity [10, p. 1209]. Thus, enriched business intelligence applications and clever data warehousing concepts are required and will impact utilities in several ways. As utility's customer care services will improve, customers can be offered a variety of new services bundled under the term "proactive customer communications". This includes for example billing, load-limiting or outage notifications. Furthermore, integrated enterprise architectures will increase an utility's operational efficiency and capacity utilization [74, p. 2].

In this context, a close cooperation between utility companies and providers of business applications is required to guarantee a smooth transformation of current IT systems towards future smart grid enabled enterprise solutions [35, p. 4].[4] On their way of integrating power plant information systems with business information systems, those companies will be challenged by different data-models, heterogeneous information sources across geographical boundaries and time stamped data volumes [10, p. 1209][35, p. 3].

1.3.3 IT Integrated Energy Users

It is out of question, that energy users play an integral part in realizing the full benefits from future smart grid infrastructures. In this context, smart home automation is seen as a cornerstone to success. At the same time, smart grid infrastructures are human built systems and thus error-prone. Consequently, future IT systems have to make sure to make smart grids reliable and secure while keeping in mind privacy concerns raised by IT-integrated energy users.

1.3.3.1 Increasing Awareness for Security and Privacy

The IT and telecommunication infrastructure used in the smart grid will make the power grid subject to new security risks and threats [41, p. 1].

Description

Attacks on SCADA systems are real [76], e.g. most recent in 2010 with a malware worm infecting several Siemens SIMATIC WinCC systems [51]. The software running on smart meters can be equally vulnerable to attacks. A proof of concept smart meter worm that spreads itself through the wireless software update mechanism has been demonstrated by IOActive at the Blach Hat security conference[11].

While there lies an undeniable benefit in the detailed energy use information a smart meter can provide, this very data can pose a breach in customer privacy. The extraction of detailed personal information out of a load curve sampled by a typical smart meter (at 15 second resolution) has already been demonstrated [45]. It is possible to tell with high confidence the presence, sleep cycle and appliance usage patterns of an inhabitant [45, p. 18]. This information is not only useful for utilities, but can be abused by law enforcement agencies, marketing partners (e.g. "What kind of appliances are in use?") and criminals (for example "What is the best time for a robbery?") [45, p. 13]. Experience from other areas (like cable TV signal hijacking) suggest that inexpensive solutions to make illicit use of this data will be available if this issue is not taken seriously [47, p. 76].

[4] As a first ERP-provider SAP announced a cooperation with seven major utility companies to work together on the integration of AMI into business intelligence software [65].

Impact on Smart Grids

Inadequate security and privacy measures can lead to serious reliability and trust issues within the smart grid. Luckily, the NIST has already recognized the importance of this topic and has formed the Cyber Security Coordination Task Group [41, p. 4]. Furthermore, solutions for enhancing the privacy of smart meter customers, like aggregation of load data and anonymization, are being discussed [54, pp. 359-364][45, p. 19]. The rising awareness for security and privacy could still slow down the rollout of the smart grid, with the U.S. Department of Energy (DOE) currently considering not to fund otherwise promising projects that lack in the area of security [27].

1.3.3.2 Accelerating Adoption of Smart Home Automation

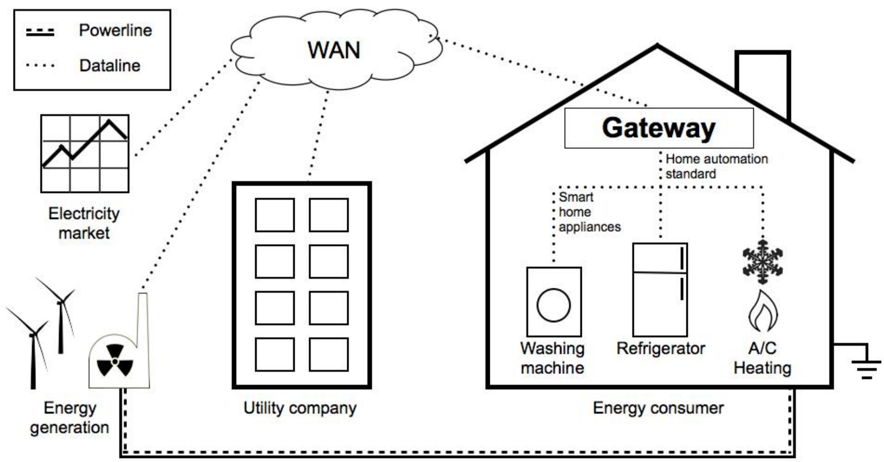

Figure 1.5: Model architecture for smart appliances integration in home automation systems
Source: own illustration

Description

The nearer future will bring a growth of smart appliances and an increasing automation of households. This growth is directly linked to the growing number of smart meter installations in residential buildings.[5] Smart meters can be seen as the first step towards a smart grid, which will require new technologies that

[5] Germany for example dictates the installation of a smart metering devices for entities connected to the electricity grid for the first time or after significant renovation processes [77].

put the available information about the grid status to effective use [33, p. 424]. Already today a large number of potential smart appliances users consider this emerging technology to play a bigger role in the future as they are convinced that good technical solutions are required to reduce energy consumption [48, p. 17]. From an ICT perspective, service oriented architectures (SOA) of smart meters will empower appliances manufacturers to implement smart grid functionalities in their devices in the future [33, p. 424][2, p. 21]. The growth of smart appliances is further supported by the evolution of smarter and more user-friendly remote control possibilities using e.g. smart phones or web interfaces [42, p. 324][30, p. 110]. Additional smart home appliances combined with home automation technology allows a price-sensitive operation of smart grid connected technologies [56, p. 85]. In theory, this would help to counterbalance the high initial installation costs of such devices.

The ICT industry is currently discussing several approaches to realize this trend and implement smart grid connectivity in households. If a home automation system is already in place, it is suggested to upgrade it to include energy management functionalities [12, p. 35]. Home automation standards like KNX are already trying to include smart meter data in their current systems, thus effectively providing a solution to upgrade existing systems [37, pp. 10-20]. Other approaches include the installation of separate energy management systems, either within the devices itself and thereby making them smart on their own, or providing a gateway to link the appliances to a decentral intelligence managing the devices [12, p. 36]. Consequently, smart appliance networks or smart home automation systems will require some instance to process grid information like load-data or electricity prices. Here, a trend towards a server-like architecture can be identified. A smart box will take over all necessary energy management functionalities like switching on and off the different appliances, processing price signals and load-curves in order to effectively communicate with utility companies about the optimal time-frame for operations [42, p. 323][39, p. 1]. This scenario is also depicted in figure 1.5 where a smart home automation gateway processes all household information and communicates over a wide area network (WAN) with utility companies, the electricity market and power generators.

Impact on Smart Grids

Smart appliances and increasing household automation impacts the smart grid on various levels. Smart appliances offer the potential to reduce the total energy consumption. For Germany alone, a savings potential of 9.5 TWh per year is estimated [2, p. 15]. The information about the current and expected load, that smart appliances provide to its users and utility companies, can be used to extrapolate estimations about the future load-curve of the grid. This would allow utilities to manage their power plant mix more effectively and stabilize the grid integrity [2, p. 13]. By using smart appliances for intelligent scheduling of household electricity demands, a virtual buffer could be implemented [75, p. 95].

1.4 Conclusion

This report has analyzed the status quo of information technology with impact on the energy industry from various angles along the value chain. The current IT support of power generating units largely differs depending on the size of the generating entity. While large-scale utility companies incorporate IT systems for plant automation, load forecasting and administrative purposes, small-scale electricity providers largely refrain from using IT systems. This however, will change in the future. Integrating both centralized and decentralized power generation in smart grid infrastructures will be one key challenge of future IT systems for smart grids. Along this trend, energy market places will comprise real-time trading platforms, where IT systems will empower all market players to trade energy in an elastic electricity market. Integrated IT architectures for enterprises are planned to handle the trend of increasing data volumes and support utility companies in making thorough decisions and taking appropriate actions. Transmission and distribution grid operators will upgrade their current monitoring systems and combine currently separated architectures like DMS, SCADA and DR in single platforms capable of real-time monitoring, operations and control to ensure grid integrity. As an integral part of the energy value chain, electricity consumers will evolve to prosumers that will both produce and consume energy at the same time. Today's home automation technology will evolve to a smarter IT architecture that connects smart appliances to smart grids and thus follows the trend of linking all IT systems to smart grid infrastructures. Already today, energy consumers raise concerns about security and privacy within smart grids. This trend plays an important role in shaping the IT architectures of smart grid components and has to be addressed by future IT systems.

Information technology influences the energy industry on several layers. Most of the applications currently used in those layers are not yet ready to fully support smart grids. Major improvements in the data transport layer and the physical layer are required to allow IT systems to fully benefit from smart grid infrastructures.

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Chapter 2

2 Communication Technology

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The current energy grid was originally designed to transport energy in one direction: From a central supplier to a consumer.

Today, with more and more decentralized energy generation, load balancing and smart consumption, communication is becoming an increasingly crucial and worrisome factor. Independently organized communication networks are not a sustainable solution. DSL, powerlines and wireless communications like terrestrial and 3G and 4G wireless communications reliably provide high bandwidth and low latency and will therefore be increasingly utilized. Furthermore, the need for fewer but more fexible standards will lead to an increased adoption of IP-based communication infrastructure and the IEC 61850 protocol family. For smart meters, standards like the EEBus and M-Bus provide clear specifications and will be adopted in more and more industrial scenarios as well as private households in the future.

Security is a primary concern as the energy grid communication systems get connected to the Internet but are not prepared for cyber attacks from the outside. Technologies like VPN that were developed to address vulnerabilites of the Internet can also improve electrical system security. But the electricity infrastructure will also require power-system specific advanced technology.

2.1 Introduction

The current power grid could be considered a 'dumb grid'. This is because although numerous break-throughs have been made in the field of energy generation and distribution, due to the lack of ubiquitous and flexible communication networks it is impossible to integrate sustainable energy resources. However, modern communication technologies fulfill the requirements necessary for accomplishing such a complex task. By combining transmission technologies, protocols and security measures the current infrastructure can be turned into a truly intelligent grid - the Smart Grid.

2.2 Status Quo

In Figure 2.1, the four basic levels of the energy grid are displayed. Currently, CT exists mainly on generation, transmission and distribution levels, although energy providers and single transmission system operators have their own standards. Interfaces like for example the one used for the European Energy Exchange (EEX) in Leipzig operate partly manually and are therefore slow and inefficient.

The generation and transmission levels and their corresponding communication protocols are covered in the status quo of this report. Additionally, the last part of this section displays an outline of the current security measures in grid CT.

On the consumption level, CT standards have yet to be established and are therefore not covered.

2.2.1 Communication Technologies in Energy Management Systems

The communication technology currently used in the power grid is not limited to a specific medium or a single message protocol specification. In contrary, a variety of communication technologies and protocols are applied concurrently.

2.2.1.1 CT on Generation and Transmission Level

Power generation facilities and their monitoring components were originally connected via serial communication technologies (RS232). However, control and process optimization required more data to be sent over the network and the Ethernet based local area networks (LAN) are nowadays linking different sub-systems with the control center in most power plants [117, p. 1].

The merge and expansion of regional power grids led to larger distances between substations within the infrastructure of single transmission system

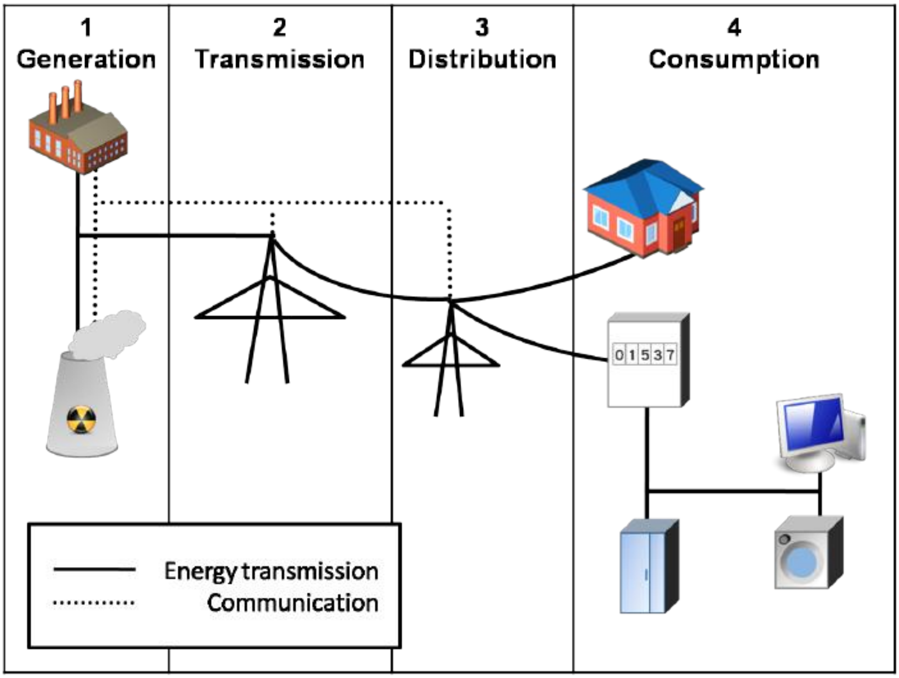

Figure 2.1: Structure of the current grid communication infrastructure
Source: own illustration

operators (TSO) which required the following technologies to connect the nodes of the transmission layer.

Carrier Wave has been used by utility companies for network control for more than eighty years . The alternating signal in high-voltage transmission lines is being modulated to carry information in the same medium as the energy and can be used for distances up to 500 km [122, p. 34].

Dedicated Leased Line and Dedicated Microwave links are a very common way to connect substations and control units over long distances [129, p. 1].

2.2.1.2 CT on Distribution Level

The distribution system is controlled independently from the transmission layer and often operated by a different party. To synchronize the nodes of the middle-voltage and the low-voltage transmission lines there are three communication technologies used for data transmission.

Ripple Control uses frequencies in the middle and low-voltage distribution system for unidirectional communication from control centers to substations and meters.

Modem/ISDN uses the widespread telephone communication infrastructure for data transmission.

Cellular communication technologies like GSM use the network infrastructure of mobile communication operators to connect remote sites to the control centers of utilities via Short Message Service (SMS) or General Packet Radio Service (GPRS) [122, p. 34].

2.2.1.3 Communication Protocols in Energy Management Systems

All information is being transmitted according to a number of protocols. These are usually either data transmission protocols, typically representing the lower layers of the Open Systems Interconnection (OSI) model, or application layer protocols, which carry the actual information between two nodes. Additionally, the application protocols themselves are generally accompanied by data format definitions, which specify the structure of the transmitted messages so other systems are able to interpret the data correctly.

Ethernet is one of the most common lower layer communication standards. Because it has seen such a wide spread use in the past 20 years it is now often an integral component of the communication infrastructure used in the power grid [105]. The reasons include cost reduction by reusing components and less complicated infrastructure by focusing on a common standard. The fact that it has been specified for a wide range of actual physical layers makes it extremely versatile and extensible, offering a number of possible maximum ranges and transmission speeds [84, p. 6].

The need for more flexibility in the transition towards a Smart Grid and the fast development of the Internet has led to the introduction of the proven **TCP/IP** (as the stack, consisting of the Internet Protocol (IP), Transmission Control Protocol (TCP) and User Datagram Protocol (UDP) is commonly referred to) into the communication infrastructure of power utilities. It is now very common, thereby harmonizing previously independent systems and reducing cost and overhead [94, p. 28].

International Electrotechnical Commission (**IEC**) **standard 60870** is a family of standards specifying application layer communication protocols and information elements. Various companion standards are each more specialized for a range of sub-tasks. These protocols are commonly used to exchange information between the control centers in the higher hierarchy levels of the power grid communications infrastructure [92, p. 6]. Some European countries even made IEC compliance mandatory [132, p. 4]. Competing standards such as **MultiSpeak** and the Distributed Network Protocol (**DNP3**) are mainly used in the United States of America and Southern America and play only a minor role in Europe [130, p. 4].

MODBus is the most widely known of a number of related protocols such as

M-Bus, **CAN-Open**, **OPC**, **Interbus**, **SMA-Net** or others, some of which being proprietary. They are highly specialized, which makes them often more efficient than more general protocols. In Germany, the M-Bus has been selected as the standard by the metering industry. It is responsible for transmitting data from gas-, heat-, water- or other meters [99, p. 1].

2.2.2 Communication Security in Energy Management Systems

The basic elements of interconnected power monitoring systems like SCADA were established in the 1960s. At that time the security of the SCADA infrastructure was ensured by protecting the physical access to the computers of the systems. Even 20 years later, the same control systems were used, without adding much technology [125, p. 1][98, p. 3][102, p. V]. Although today software is used for planning, local control of equipment or processing of field data, the coordination of the power network is still mainly based on telephone calls between system operators at utility control centers [115]. Due to the manual reading of meters at customers' premises, data security has been of minor concern [122, p. 46].

Since 1990 there have been several cases in which existing control systems, originally designed for use with proprietary, stand-alone communication networks were indirectly connected to the Internet. Without added security technologies, a system is exposed to various threats [115]. This includes attacks such as accidental cyber-related incidents, as well as deliberate events such as external hacks, Denial of Service (DoS) attacks and virus or worm infiltrations. [121]. During the last years security technologies like VPN, Firewalls and authentication mechanisms which are well known from the Internet are more and more used in SCADA systems [125][98, p.3].

2.3 Trends

With the increasing convergence of the Internet and the formerly dedicated energy grid communication systems, it is possible to use a single network for all nodes, from generation to consumption. The following discussion of trends in CT and their impact on the Smart Grid will be segmented according to the illustration in Figure 2.2. Finally, upcoming trends in communication security are being outlined, which are important for all sectors.

2.3.1 Upgrade to Ubiquitous Broadband Availability

An important step towards an optimized energy grid is to measure its parameters at high resolution. The large number of meters that will be deployed require a data connection wherever they are installed. Therefore changes in the present communication network infrastructure are necessary.

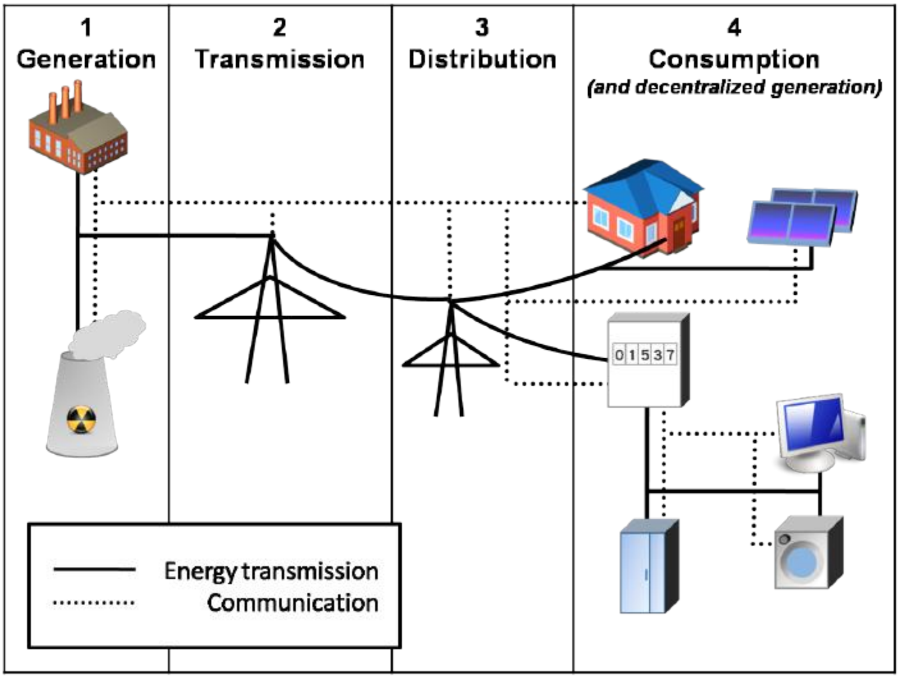

Figure 2.2: Structure of the future grid communication infrastructure
Source: own illustration

2.3.1.1 Expanding Backbone Capacity

Metering on all levels of a future Smart Grid and the use of new media over the Internet will cause growing traffic on data networks. Therefore it is necessary to expand existing backbone capacities to enable near real-time monitoring of the Smart Grid. Low latency and high bandwidth of the communication channels are important to operate the Smart Grid with good temporal resolution [100, p. 6].

Description

Fulfilling the mentioned requirements is particularly crucial on high levels of the grid. The large number of data links that converge in the backbone networks need to be routed to the control centers without being congested. For moderate distribution systems, 100Mbps of traffic have been predicted [88, p. 4].

Optical Fiber has been upgraded with new developments like Wavelength Division Multiplexing (WDM) which has led to very high transportation capacities with speeds of several hundred gigabits per second [123, p. 51].

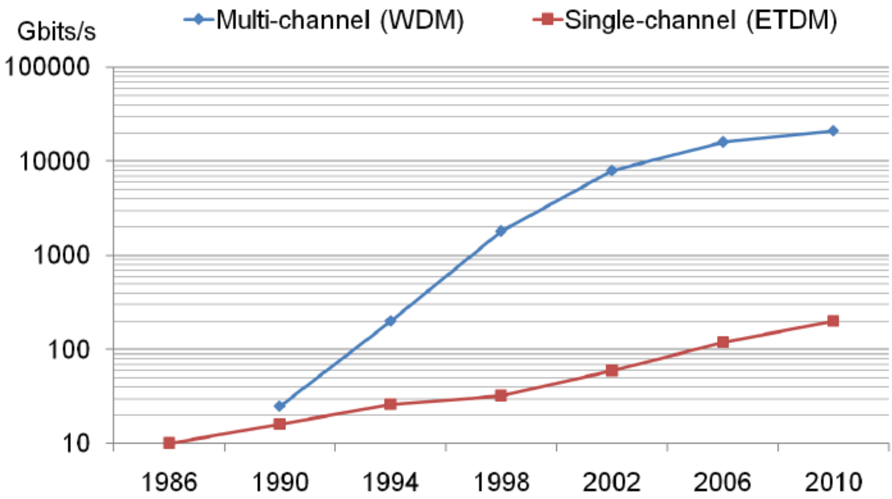

Figure 2.3: Evolution of capacity in optical fiber communication systems
Source: [96, p. 13]

WiMAX with the IEEE 802.16 standard offers promising characteristics for a wireless technology especially in terms of latency and can be used to build multi-hop relays for substations. [126, p. 5][108, p. 14].

Impact on Smart Grid

The mentioned technologies provide the necessary characteristics to establish highly interconnected energy management systems in which substations are distributed over a large area. During an introduction period of the Smart Grid, most monitoring and control units will be connected using shared network infrastructure based on existing networks. The technologies described, especially optical fiber as shown in Figure 2.3, expand the capacity of data network backbones. The availability of different technologies enable the Smart Grid later on to operate on dedicated infrastructure [117, p. 1 ff].

2.3.1.2 Providing Consumers with Access to the Smart Grid

Interacting with energy consumers makes it necessary to propagate suitable communication technology to all premises. In the following, different transmission technologies known from the development of the Internet will be discussed for use in Smart Grid.

Description

Figure 2.4 illustrates the two different topology types Point-To-Point (P2P) and Point-To-Multipoint (P2MP) which are most common [90, p. 38].

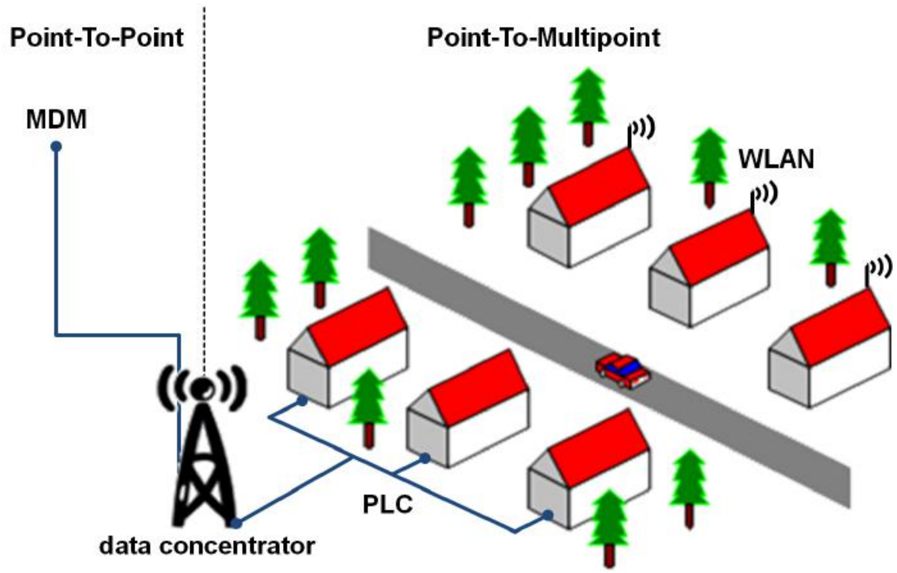

Figure 2.4: Point-To-Point and Point-To-Multipoint concepts
Source: own illustration

In the Point-To-Point (P2P) concept, each meter or gateway transmits its data directly to the meter data management system (MDM) making use of the following technologies:

- DSL (Digital Subscriber Line) technologies have the highest availability among fixed line networks, covering 95% of the households in Germany [120, p. 10]. Having 22.4 million subscribers [91, p. 81], this technology was selected for most German smart metering projects [131, p. 4][85].

- Cable Modem Internet Access increased between 2008 and 2009 by 44% up to 2.3 million subscribers in Germany [91, p. 84]. Even though installation started only two decades ago, cable networks have already reached a coverage of 58% [120, p 19].

- FTTx (Fiber-To-The-X) as fiber to the curb or all the way to the premises currently gains momentum in some European countries. This technology outperforms most copper based communication means in terms of available bandwidth but is up to now rarely available in Germany [120, p. 25].

- Wireless Terrestrial Communications (2G/3G/4G) have also benefited from numerous improvements in terms of coverage and bandwidth, making mobile communication channels more viable for Smart Grid. Software Designed Radio (SDR), cognitive radio and Multiple Input Multiple Output (MIMO) antennas will further increase available bandwidth [123, p. 50].

In the Point-To-Multipoint (P2MP) concept, meters and gateways transmit their data to a data concentrator which collects the information from sensors in a larger area (e.g. neighborhoods) and provides it to the MDM:

- Power Line Communication (PLC) has the advantage that separate infrastructure is not required and in-house locations that can not be connected through a radio link can be reached. New developments like Orthogonal Frequency Division Multiple Access (OFDMA) help to overcome present reliability and throughput issues [127, p. 1][89, p. 1].

- Wireless Local Area Network (WLAN) is an alternative technology for transmitting data between end-user premises to a near data concentrators [97, p. 57][122, p. 30].

Impact on Smart Grid

The technological trends described build up the physical base for the transformation of the current distribution system towards an interactive measuring and load balancing grid. In order to reach full broadband connectivity in reasonably short time, existing communication infrastructure plays the most important role. As dedicated data networks require large investments, the first steps towards a Smart Grid can only be achieved by sharing network capacities with Internet usage. New developments like Very High Speed Digital Subscriber Line (VDSL), High Speed Downlink Packet Access (HSDPA) or Long Term Evolution (LTE) upgrade existing communication channels for use in Smart Grid. As DSL and GSM/GPRS reach full coverage in Germany, these technologies are most important for first deployments of smart meters. With the latest upgrades, full coverage and first field tests [109, p. 7], PLC can serve as a dedicated communication channel in certain areas. Optical fiber provides the best characteristics for communication networks and will certainly be the long-term solution for evolving needs of Smart Grid [88, p. 4][123, p. 50][97, p. 28 ff][122, p. 26 ff].

2.3.2 Commoditization of the Communication Infrastructure

The communication infrastructure of the power grid is in a process of moving towards fewer, commonplace and standardized protocols which help to mask the actual underlying infrastructure so that it can be modified independently of the actual applications by which it is used.

2.3.2.1 Increasing Deployment of Internet Protocol-based Infrastructure

Although pre-existing systems are used as long as possible, the current transition to a radically different grid structure leads to new devices replacing legacy systems at an increasing pace.

Description

Most manufacturers of hardware are focusing on IP-based networks, which have proven their flexibility and scalability in the Internet. Because the latter is slated to be tightly integrated into the future Smart Grid infrastructure, choosing IP as a common transport mechanism is even more convenient. With the current investments being made in the grid network infrastructure, IP-based communication will become even more prevalent [94, p. 6].

Impact on Smart Grid

This development will influence the future of the grid in several ways: For one thing, gravitating towards a standardized network architecture will make the details of any single specific network much less important.

Also, the overall efficiency of communication will improve, because instead of having to translate information between different protocols and data formats, data transfer can now be accomplished directly between all connected nodes [114].

An important issue is that the Internet Protocol itself is in a state of transition, meaning that by using it all the transition problems will affect the grid as well. One of the biggest problems today is the shortage of available IP version 4 (IPv4) addresses due to design limitations and ever-increasing demand, with current estimates placing the exhaustion sometime before the end of 2012 [101]. In order to fix this shortcoming, a newer version of this protocol has been developed (IPv6). It brings numerous other advantages as well, e.g. better support for automatic configuration and new security features. But even so, the infrastructure will have to support already installed IPv4-only devices as well [114].

2.3.2.2 Convergence Towards IEC 61850 as a Standard Protocol

Whenever systems use incompatible communication protocols or data formats, automation is impossible. That is the primary reason why vendors seek to implement a common standard. However, this standard has to be flexible enough to cover the needs of all interested parties [118, p. 1].

Description

The IEC 61850 standard fulfills this need for a common protocol. Together with other associated IEC standards it also defines special communication methods such as the Manufacturing Message Specification - mainly used to communicate real time data - and Generic Object Oriented Substation Events. The latter are extensions to lower layers of the communication infrastructure in order to ensure peer-to-peer message delivery within a specified, very low time-frame (typically $<$4ms) [118].

This standard is already being implemented and deployed in commercially available devices [93, p. 7].

Impact on Smart Grid

Having been very broadly defined, IEC 61850 includes almost all types of messages which are needed for communication in the power grid, covering most use cases. Economies of scale will lower costs of power grid controlling devices by making reuse of IEC 61850 implementations easier [118].

2.3.3 Higher Demand Response Efficiency Through CT

With an efficient Demand Response (DR) System in the hierarchy levels it is possible to obtain an even higher efficiency in the Smart Grid. In the future, private and industrial consumers will be able to benefit further from automated price and availability broadcasting over quick and efficient communication systems [116, p. 1]. While there are few standards already available, the market for systems like Open Automated DR (OpenADR) and Konnex (KNX) will be rapidly expanding in the upcoming years [116, p. 7].

2.3.3.1 More Demand Response CT in Private Households

Since January 2010, it is obligatory to install smart meters into newly built houses in Germany [112, §21b, Abs. 3b]. Although most meters do not support remote data collection yet, some energy providers like Yello Strom have started deploying communicating meters which send the data to Yello Strom servers. The customer can then monitor the energy consumption via online services [85].

Description

Yello Strom and the German EnBW use DSL technology to transfer the meter data to their servers. In-house bus standards like KNX are gaining importance in home appliances as well. The communication is based on twisted pair cables, radio frequency and powerline data transmission [122, p. 23f] (e.g. Miele and Liebherr @home appliances). Another standard is OpenADR. Its communication interfaces to the Smart Grid are not finalized yet, but one of the standards being tested is OPC-UA Industrial, which relies on TCP/IP and binary/XML-schemas [113, p. 57].

Impact on Smart Grid

The most important step into connecting home appliances to the smart grid is transferring usage data to the energy provider. For these transmissions, Energy Information Gateways (EIG), in private homes specifically called Home EIG (HEIG) will be used [122, p. 13]. These aggregating gateways communicate via the established channels: Wired (DSL, Powerline) or wirelessly (M-Bus, WLAN or Zigbee[122, p. 24]). The Smart Grid will have to account for the different standards currently employed, although there are efforts to agree on a single standard on a European level by KEMA (association of Dutch energy providers) and, parallely, the ESMIG (European Smart Metering Industry Group) [128, p. 19].

A customer energy information network system (CEIN) [122, p. 19] then transmits information from the energy provider to the customers' HEIG and vice versa. Efforts for standardisation are being conducted by the IEC, to which the German research program E-Energy contributes as well [122, p. 32]. CEIN communicates via DSL, Powerline or mobile radio.

The KNX in-house ADR standard will be widely employed as well. For communication, KNX uses the Building Automation and Control Networking Protocol (BACnet), which itself relies on IP networks [103, p. 1193]. KNX then communicates via twisted pair cable, Powerline (KNX-PL) or radio frequency (KNX-RF).

While KNX controls the in-house optimization, the E-Energy program [124, p. 255] developed an interface standard called EEBus for the communication between the Smart Grid and in-house grid. It provides a unified interface for transferring information about current price and type of the supply [86], enabling the energy management of the KNX system to adapt the Smart Grid. Appliances using these standards are developed, partially even on sale right now, and will be implemented in German grids in the upcoming years.

2.3.3.2 More Demand Response CT in Industries

While DR systems will eventually be implemented in private households, greater benefit can be achieved on an industrial scale. It has been proven that cooling houses can reduce grid load by 18% to 24% [110, p. 44] with the technology already available today. These systems have only been controlled locally so far and will have to be attached to the Smart Grid.

Description

Today, DR systems are mostly utilized in industrial environments. Efforts to connect them to the Smart Grid information systems are currently being conducted especially for energy-intensive industries. One of those project setups is the eTelligence in Cuxhaven as part of the E-Energy project. It consists of cooling houses with a total load of 43 MW communicating with the decentralized energy providers and their voltage transformation substations via fiber optics [107, p. 10]. For the data transfer eTelligence uses the IEC 61970 Common Information Model to keep standardization at a high level [106, p. 49].

Other potentials lie within the automatization of DR systems in wastewater treatment facilities: About 20% - 30% depending on the size and load of the facility [111, p. 71ff].

Impact on Smart Grid

As in private households, the most important step is to give industrial energy consumers the opportunity to know the price and shift their load accordingly. DR systems are more common in industry environments than households. Although a communication standard has still to be agreed upon, international research initiatives like the IEC have identified the gaps in intersystem-to-subsystem communication [87, p. 32]. Although these will not be implemented on a global level by 2015, the model regions show a high potential even for implementations on a smaller scale.

2.3.4 Enhanced Grid Security with Standard IT

Since SCADA systems get more and more connected to the Internet they are exposed to threats and vulnerabilities they have never been exposed to before - for instance viruses and worms, DoS attacks, spoofing, falsification of data or sniffing [125, p. 4]. The need for treating security issues has become more evident among utilities, vendors, standardization bodies and regulatory bodies all over the world [125, p. 2]. A large number of recommendations and guidelines have been developed that describe matters specifically related to SCADA security, for instance [98][119][95][102][104]. These recommendations focus on technical countermeasures that have been developed to address the vulnerabilities of other systems [125, p. 2]. The most frequently mentioned technical countermeasures are authentication, encryption and firewalls [125, p. 3].

Description

Authentication e.g. by PIN number or password, key, dongle, smart card or fingerprint is a security measure which is getting more and more integrated in control systems [102, p. iv]. In advanced SCADA systems an authorization technology is used which allows very specific control of user capabilities. [102, p. 21][104, p. 6-32].

Encryption ensures that critical data pertaining to a SCADA system is stored and communicated securely. Therefore various encryption algorithms can be used as well as VPN for remote log-in processes [133][98, p. 11]. A suitable software security solution is IP Security (IPsec), which provides the ability to authenticate and encrypt IP traffic within the protocol stack [102, p. 59]. For wireless networks Wi-Fi Protected Access (WPA) and WPA2 are used[133][102, p. 66].

Firewalls protect modern control systems as well as demilitarized Zones (DMZ) which are a buffer between a trusted network (SCADA network) and the corporate network or Internet, separated through additional firewalls and routers which provide an extra layer of security against cyber attacks. Utilizing DMZ buffers is becoming an increasingly common method to segregate business applications from the SCADA network [133].

Impact on Smart Grid

Besides authentication, encryption and firewalls, more advanced technologies like intrusion detection, auditing and vulnerability scanning, anti-virus and backup are increasingly used [125, p. 3]. Commercial products provide improved protection for industrial protocols used in control networks, as manufacturers respond to market demand [102, p. 13][98, p. 9].

The widely used standards and solutions for securing IT systems are still often inappropriate for the process control environment, even though process control systems are now frequently based on standard IT [125, p. 1]. For example, in a business system environment, access to the server is typically the key focus, whereas in a SCADA environment the access focuses on the operator console level. Consequently, the highest priority to safeguard against security breaches differs [133]. While some standard security tools and techniques can be used to protect process control systems, the electricity infrastructure will also require security technologies developed specifically for the energy grid [115].

Security testing on process control systems must be approached with extreme caution as security scanning can seriously affect the operation of many control devices. Furthermore, there is often a lack of training and awareness by organizations. Installing modern communications and control equipment can help, but security must be considered in the design of the system right from the start [115].

2.4 Conclusion

To summarize the key findings, the current trends in communication technology regarding the future of the power grid can roughly be split in two main areas:

Firstly, the increasing demand of communication in the grid necessitates a robust yet flexible infrastructure. It will be increasingly standardized and thereby less important as a distinctive characteristic as such. Otherwise, quickly responding automated systems cannot be established. One can already see an increasing adoption of commodity technologies which have been established before in the Internet: Broadband connectivity - wired and wireless - as well as ubiquitous IP-based connectivity are the two most visible technologies. But also power grid related industry sponsored standards have proven to be of high value, such as the accelerating movement towards the IEC 61850 standard, which promises to become the single most important protocol and data format definition used for information exchange.

Secondly, it is becoming apparent that security cannot be only an afterthought as for example in some technologies used in the Internet (like E-Mail). In the past decade attacks on the energy infrastructure have risen sharply. Now and in the near future, with more and more parts connected directly or indirectly to the Internet, the potential attack surface continues to increase. Modern security technologies originating from the communication sector are already beginning to see widespread usage in the power grid. But it is also important that simple technology transfer alone will not be enough. It will be crucial for vendors and the industry in general to develop a comprehensive security concept and specialized security measures in order to secure the energy grid communications. This means not only finding technical securities, but to establish mindsets and management principles.

With these trends currently emerging, one of the basic prerequisites for the Smart Grid is being put into place: a solid communication infrastructure which can reliably and securely serve the needs of the Smart Grid.

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Chapter 3

3 Technologies along the Electricity Value Chain

Mariam El Sayyad, Christoph Neyer, Pascal Nolle, Victor Petcu

Power plants can be distinguished between centralized and distributed powerhouses. Due to the shortage of fossil fuels, renewable energy sources and combined heat and power plants, which are often decentralized, become more and more important. Volatile power supply of renewable energy sources and the lack of power quality make the need of virtual power plants that can be controlled centrally obvious. Governmental incentives for electricity producers promote and encourage energy self supply. For establishing stability and security in the electricity network, the implementation of microgrids will become essential.

As demand on the transmission and on the distribution grid increases globally, new methods for an effective grid capacity, such as dynamic reactive power compensation will have to be employed. In addition to the existing infrastructure, new High Voltage Direct Current (HVDC) lines will be constructed as they have fewer losses over greater distances compared to HVAC lines. Furthermore, as electricity generation becomes more decentralized, an information-driven grid, with sensors throughout will come into use to regulate the electricity flow to ensure grid stability.

Electricity storage systems have to be able to balance out volatilities in decentalized production. In addition, large scale storages are required to compensate the temporal gaps between renewable energy generation and demand. According to this, international cooperations are needed to share available storage capacities.

The real-time and bidirectional exchange of data available in a smart meter will encourage consumers to save energy. The installation of energy-management capabilities to the measuring devices and power quality monitoring will increase the reliability, controllability, and predictability of the power grid. Because of the growth of decentralized energy production and renewable energy sources, net metering allows the customer to use any excess electricity to offset electricity used at other times during the billing period. The implementation of the contemplated electricity measuring technologies and policies will reduce energy costs and increase consumer awareness.

3.1 Introduction

Today's electricity grid is the largest machine in the world. Thousands of people every day keep an eye on the complex workings of the thousands of substations and of the millions of kilometers of cable that cross borders and connect people's lives. To put it into perspective, the combined length of the transmission and the distribution network in Germany alone would be enough to circle the world forty four times. Even though this machine seems to be indestructible, cracks are beginning to appear. Rolling blackouts and system failures are becoming more common, as the machine struggles to keep up with greater loads, which more and more people put on it with new technologies that require an exact voltage supply with almost no tolerances. To add insult to injury, end-users are now beginning to take part in the electricity production game with a large number only interested in the monetary gain, due to government incentives. While renewable energies provide a healthy alternative to burning scarce resources, they are often unpredictable since nobody can guarantee that the sun will shine or that the wind will blow. Figure 3.1 illustrates the structure of the following chapter. The top-down electricity supply chain of electricity generation, which is transmitted and distributet to the customers and storage systems is not valid anymore. The new concept, which will be discussed in the trends, is a smart interaction and communication between electricity generation, distribution & transmission, storage systems and smart meters.

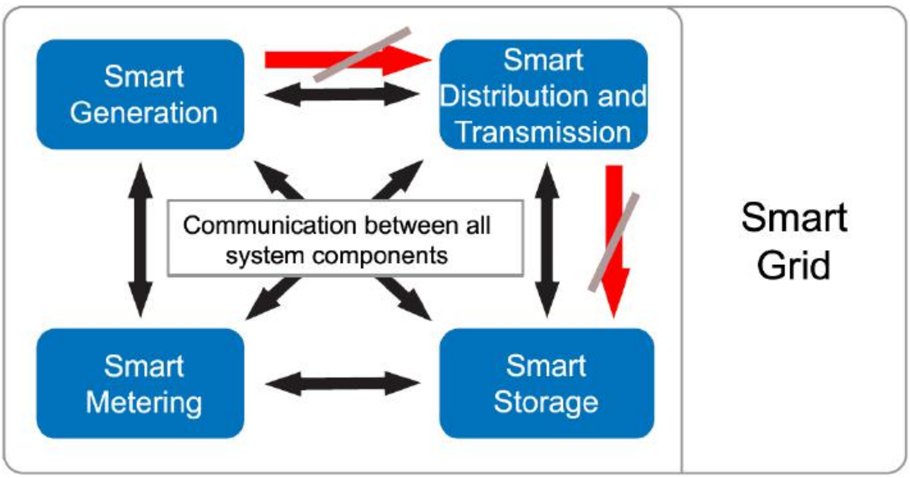

Figure 3.1: The vision of the smart grid compared to the traditional grid
Source: Adapted from DKE [149, p. 14]

3.2 Status Quo

Many technological concepts and policies are in the process of being applied to today's power grid as the usage of world-wide electricity is changing.

3.2.1 Electricity Generation

When the British scientist Michael Faraday discovered how to produce electricity by electromagnetic induction in the 1830s [138], he could not imagine which beneficial influence this innovation would have on the development of the modern society. Electric energy is omnipresent in our daily lives; we need it to have light, to cook, to work, or even to watch TV. The basic principle of a moving loop of wire, or a disc of copper between the poles of a magnet, is still the most common way to produce electricity nowadays. Besides huge power plants that produce gigawatts of electricity more and more decentralized powerhouses have been developed over the last few years. The challenge is to have a grid which is smart enough to supply the consumers reliably with electricity, while managing the growing number of electricity producers. This section focuses on the most common ways of generating electricity and categorizes them by comparing their sizes and controllability.

3.2.1.1 Comparison of the Different Electricity Production Types

As illustrated in Figure 3.2 the biggest proportion of electricity is generated by fossil fuels, second are renewable energy sources, and third is nuclear power. In 2007 the overall electricity generation in the world was at 19,771 TWh, which is more than three times as much as in 1973. About 18.2 % of the generated electricity is produced out of renewable resources. The biggest proportion (15.6 %) is produced by hydro power plants and 2.6 % by using geothermal energy, solar energy, wind energy, combustible renewables & waste and heat energy. The remaining 81.8 % are generated by fossil fuels (68 %) and nuclear energy (13.8 %). The largest proportion of the electricity production is generated by coal or peat (41.5 %). Other fossil fuels are natural gas (20.9 %) and oil (5.6 %) [134, p. 24].

Power plants can be classified in centralized and decentralized power plants. Coal, oil, gas, nuclear, and hydro power plants are typical examples for big and centralized power plants, producing power of several hundred megawatts. Decentralized power plants generate power with an order of magnitude of kilowatts up to few megawatts and are more likely to use renewable energies like wind, photovoltaic, biogas, or small hydro power. Small Combined Heat and Power plants (CHP) are examples for local power plants that use fossil fuels. The CHP co-generation is a highly efficient way to produce electricity and to use the waste heat for domestic or industrial heating purposes. The overall efficiencies of CHPs reach up to 95 % [158].

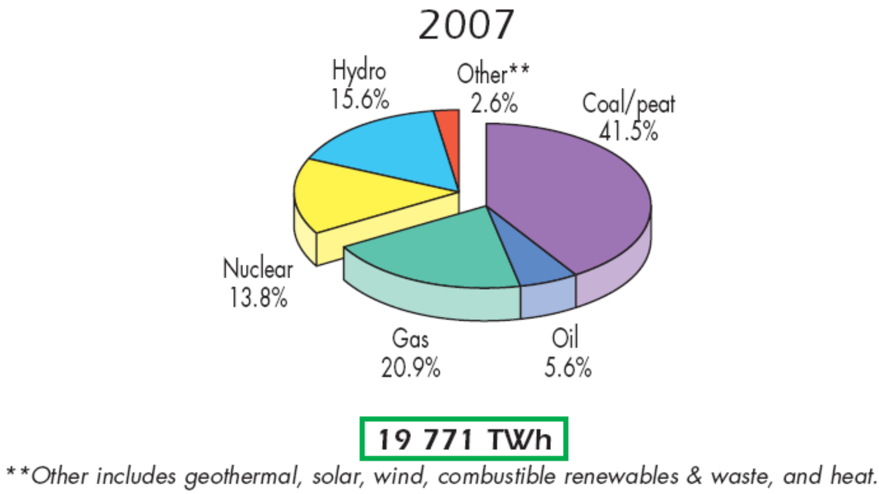

Figure 3.2: Fuel shares of electricity generation
Source: Adapted from International Energy Agency [134]

3.2.1.2 Dynamics in Electricity Generation due to a Fluctuating Electricity Consumption

Electricity cannot be stored on a larger scale to guarantee electricity supply. Therefore, the demanded power has to be supplied by the power plants at any time, even when production is fluctuating. To guarantee this, power plants are distinguished by the usage between base-load, middle-load, and peak-load electricity generation plants [160, p. 43].

- Base-load power plants run efficiently at high utilization time due to low running costs and high fixed costs. Examples are river-, nuclear-, brown coal power plants and also cheap imported electricity is used for base-load power [160, p. 43].

- Middle-load power plants are characterized by medium running costs and the ability of frequent power changes and daily shutdowns. Examples are hard coal, oil and gas power plants [160, p. 43].

- Peak-load power plants are characterized by high running costs, high controllability, fast starting time, fast switch-off, and high power changing speed. Examples are storage, pumped storage, and gas turbine power stations [160, p. 43].

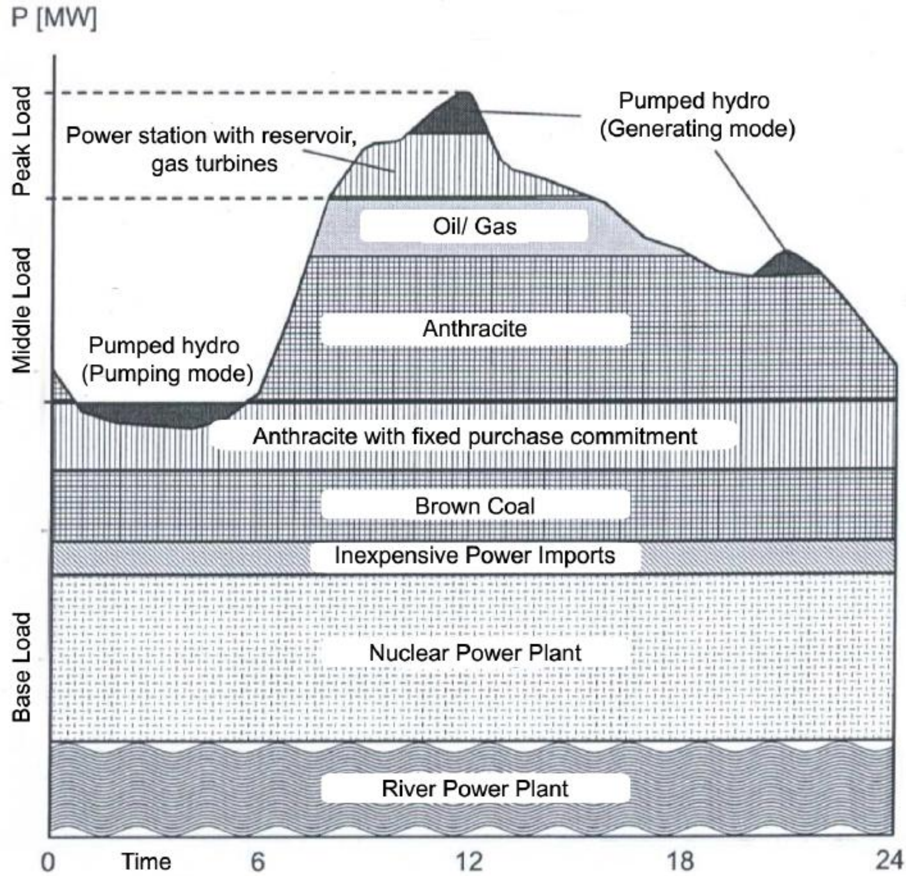

Figure 3.3: Usage of the different power plants
Source: Adapted from Kindersberger [160, p. 44]

Looking at the load curve of the daily electricity consumption (Figure 3.3) makes controllability an obvious goal for power plants and why it is important to talk about fast power controllability of power plants. During one typical day there are two peak times; one at about noon time and another at about 9 p.m.. If one didn't adjust the produced power to the consumption as accurately as possible, the net frequency would change and the power quality would drop. To accomplish the goal of constant frequency some combined heat and power plants run at half throttle and can be powered up if needed within seconds [141]. Gas turbine power plants can also be started and shut down within several minutes. To generate electricity in the very peak- and bottom times pump storage water plants can be used flexibly as described in 3.2.3.

3.2.2 Electricity Transmission and Distribution

Transmission and distribution of electricity is the most vital aspect of any electricity network and with this, the electricity gird is under immense pressure to be reliable under all conditions. The basic layout of the grid has not changed significantly in the last one hundred years and it will have to change in the upcoming years to meet the growing demand of future consumption.

3.2.2.1 Transmission and Distribution Grid

Current transmission systems worldwide have the same structure; power is transferred in a top-down hierarchy using Alternating Current (AC). This is vertical alignment, where power is generated at one end of the system by power plants and then transmitted using high-voltage power lines to different grids or substations. Power is generated at centralized power stations at either 50 Hz or 60 Hz and at a set voltage, passed through a step-up transformer and then sent over transmission lines. This high voltage is required to minimize losses over the transmission wires as the power is lost in proportion to the square of the current through a wire $P_{loss} = R \cdot I^2 = R \cdot \frac{P_{use}}{U^2}$ [192, f. 2.108].

The power grid is divided into different voltage layers. As seen in Figure 3.4, power plants above 200 MW, such as hydroelectric, coal and nuclear power plants, are connected to the Extra High Voltage (EHV) transmission lines as they provide the bulk of energy required. These EHV networks vary in voltages across different countries, but are defined above 200 kV. The Union for the Coordinated Transmission of Energy (UCTE) in continental Europe utilizes 380kV for EHV networks with 400kV common in Scandinavia and the UK [165, p. 9].

Similarly, the distribution grid interconnects substations to customers at a much lower voltage level. This gird operates between 200 V and 150 kV. Between 10 kV and 150 kV distribution grids are used to transmit energy between cities and between rural areas. At the bottom end of this cascade, the low voltage city grid is connected directly to homes and generally operates between 100V and 400 V [176, p. 13-30]. This lower voltage allows electrical cables to be buried cost-effectively, as the cables require less insulation and less safety clearance.

Transmission over high voltage overhead power lines use Aluminium Conductors that are Steel Reinforced (ACSR) with an aluminium to steel factor of 6:1 [160, p. 121] due to their lower resistivity/ weight factor compared to copper as well as the lower cost. Transmission via underground cables is far more complex and costly, as the cables need to be specially insulated. With the absence of air cooling, excessive heat is generated which cannot be dispelled quickly and thicker conductors are needed [165, p. 12]. Penetration of High Voltage Direct Current (HVDC) connections to transfer the bulk of electrical power is much lower than that of AC links due to the high cost of initial set-up. On the one hand, this is determined by the power electronics required for switching and

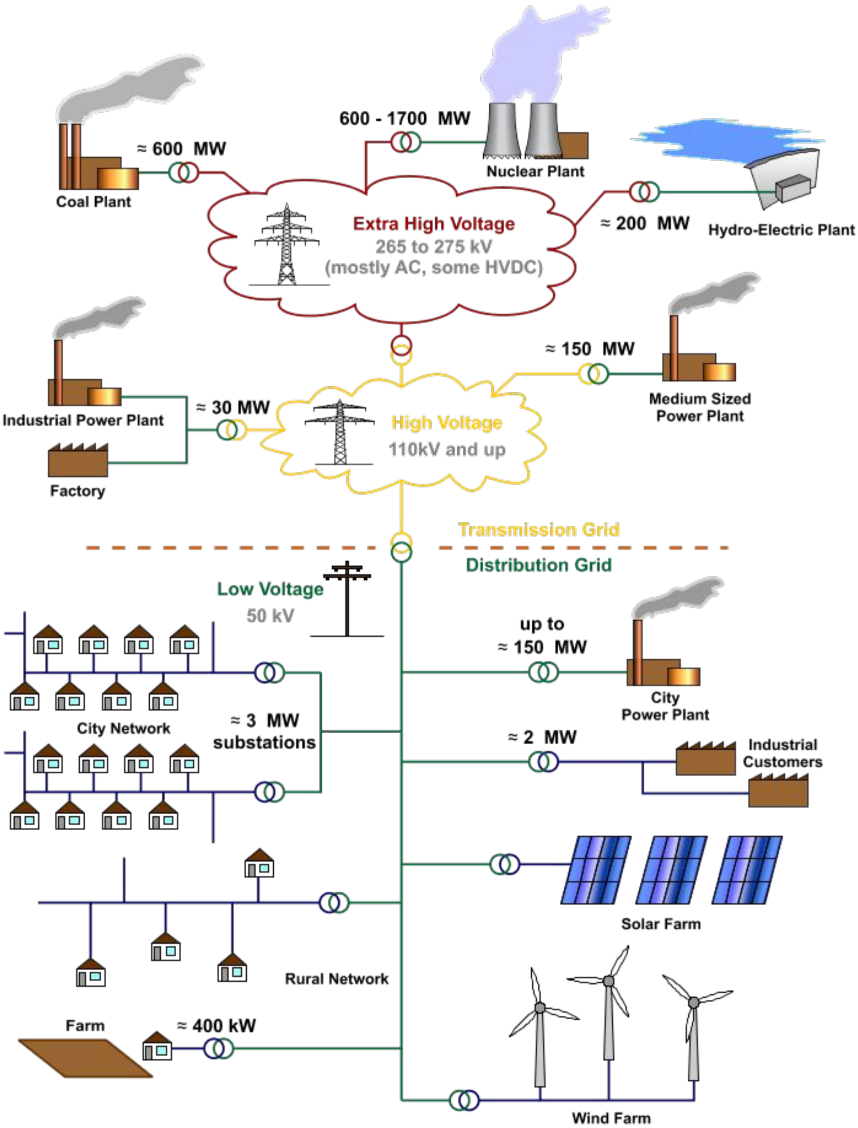

Figure 3.4: Layout of a typical transmission and distribution grid found in Germany
Source: MBizon [168]

on the other by the distance needed to be covered. Over distances greater than 600km or for undersea transmission HVDC is more efficient than its AC equivalent due to significantly lower losses over greater distances, namely 3% vs. 7% [182] as it does not need to be compensated for unusable reactive power. While real power is the product of current and voltage as seen in Figure 3.5, reactive power is generated as a byproduct of AC transmission due to the angle offset between the voltage and the current which is visible in Figure 3.6 and furthermore by inductive loads on the grid, such as electric motors [135, p. 1].

3.2.2.2 Shortcomings of the Current Infrastructure

Today's electricity grid has remained largely unchanged since the late 19th century [144, p. 3] by retaining its unidirectional power flow structure and its electromechanical switchgear, which in some cases is up to 50 years old [136, p. 1]. Due to the thermal and resistive characteristics of transmission cables, increasing the current in the lines generates more heat. A typical 380kV overhead power line has a power limitation of 1700 MVA due to its thermal characteristics, which if crossed, will cause the power line to sag to the ground and exceed safety margins [165, p. 13]. This limitation is largely due to the natural phase shift of the sinusoidal current and voltage waves, which generates unusable reactive power [184]. Further complications arise when electricity does not choose the most direct path from the source to the destination [165, p. 14]. These loop flows, which are governed by Kirchhoff's Law [143, p. 2] and which occur naturally as electricity flows according to the path of least resistance, cause congestion on the electricity network that leads to limited capacity and throughput [188]. Power quality, which is defined by the constant voltage and frequency levels, becomes a more important aspect of transmission the higher the usage of digital equipment, as this equipment is particularly sensitive to voltage variations [154, p. 3]. With only a limited number of Phasor Measurement Units (PMUs) installed in an electricity grid [167, p. 7], a provider cannot always guarantee the quality of the electricity. As the production of renewable energy increases, power quality needs to be maintained as irregular power feed-in can damage devices connected to the grid.

3.2.3 Electricity Storage

In today's energy grids, storage technologies are used to balance out short term and long term volatilities in electricity demand and supply. Thereby in the overall grid, only a small percentage of energy is stored at all. For example in the USA, 99% of energy is used in the same moment it is produced [170]. This is mainly due to the fact, that every way of storing energy is connected with a certain percentage to be lost in that process. In addition, storage systems require a high investment and produce ongoing maintenance costs [157, p. 393, 396]. It is therefore best to produce electricity exactly when it is needed. Accordingly,

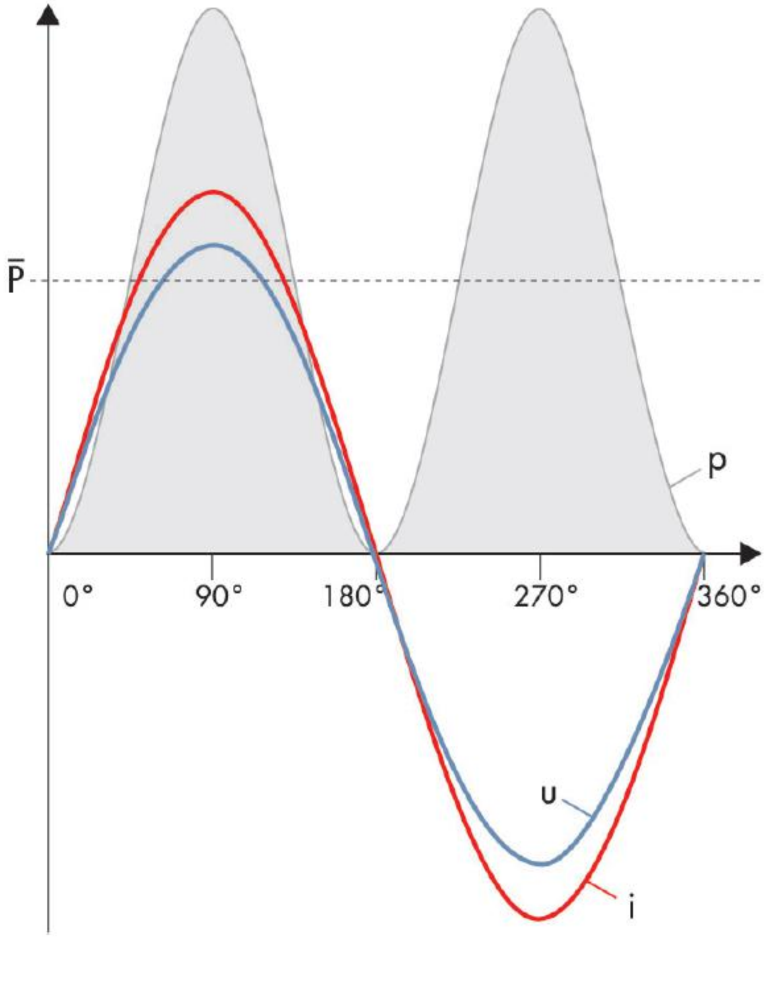

Figure 3.5: Real power, characterized by its positive sign is a product of current (i) and voltage (u)
Source: SMA [186]

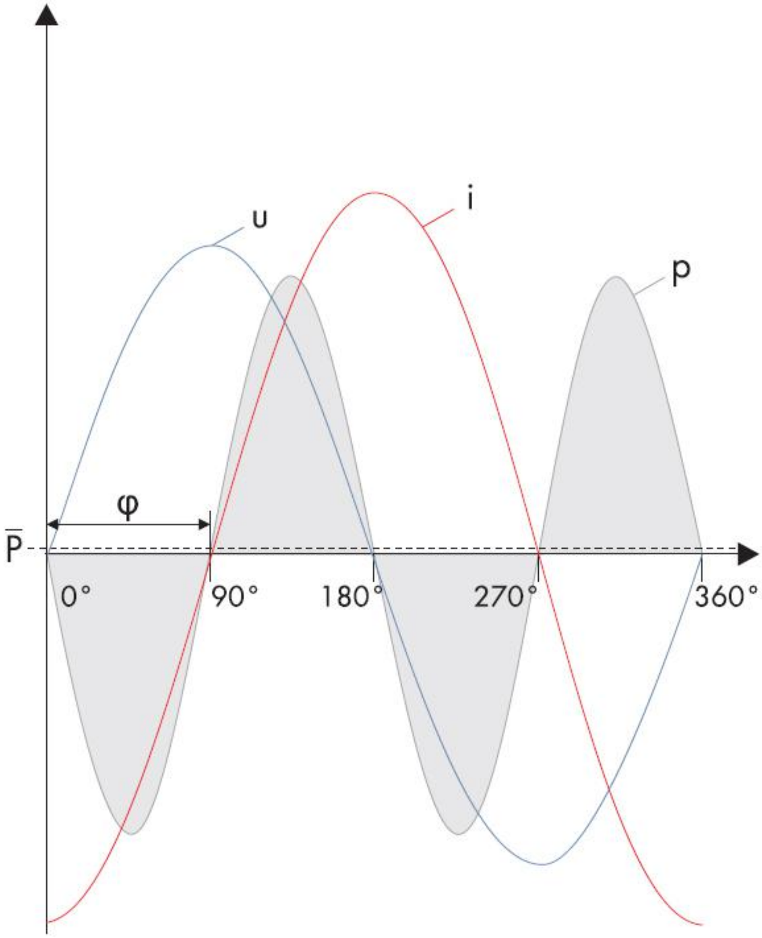

Figure 3.6: Angle offset of 90º between power and current causes pure reactive power

Source: SMA [187]

in today's grid infrastructure it is most economical to align supply and demand by adjusting the capacities of the existing, mostly large scale, power plants. In addition, the current electricity generation is highly reliable in terms of volatility. The output of the commonly used power plant technology produces a constant output and usually does not require as high storage capacities to compensate variabilities in electricity production as it might be the case with a mainly decentralized power generation [157, p. 393].

3.2.3.1 Introduction to the Different Storage Technologies and their Typical Fields Of Application

The diverse storage technologies have different strengths and weaknesses. The focus for the current grid infrastructure thereby lies on the use of large scale storages. These various technologies can fulfill different requirements of the grid. Typical storage applications can be classified as follows:

- Power Quality Applications: Energy storages can contribute to a more constant power frequency and voltage. This requires highly dispatchable storages which can balance volatilities within sub-seconds. They can provide an Uninterruptible Power Supply (UPS) [173, p. 310].
- Bridging Power Applications: Bridging power storage solutions provide a certain capacity for a fixed amount of time. They fill gaps in power supply up to several minutes until other applications can be organized [173, p. 310].
- Energy Management: High Energy Storages are compensating peaks of production and consumption. Therefore they store energy in low consumption times and give it back to the grid in high demand phases. Energy management can range up to several days, for example to level out changing weather conditions [173, p. 310].

Nowadays various technologies exist which are best suited for these different applications (see Figure 3.7). The graph shows that various storage solutions are preferable for different types of application. On the one hand, storage solutions which have discharge times up to several hours are best suited for energy management. On the other hand short time storages are commonly used to guarantee a constant power quality and USP. For example, high power flywheels can feed in up to several megawatts but only for few seconds.

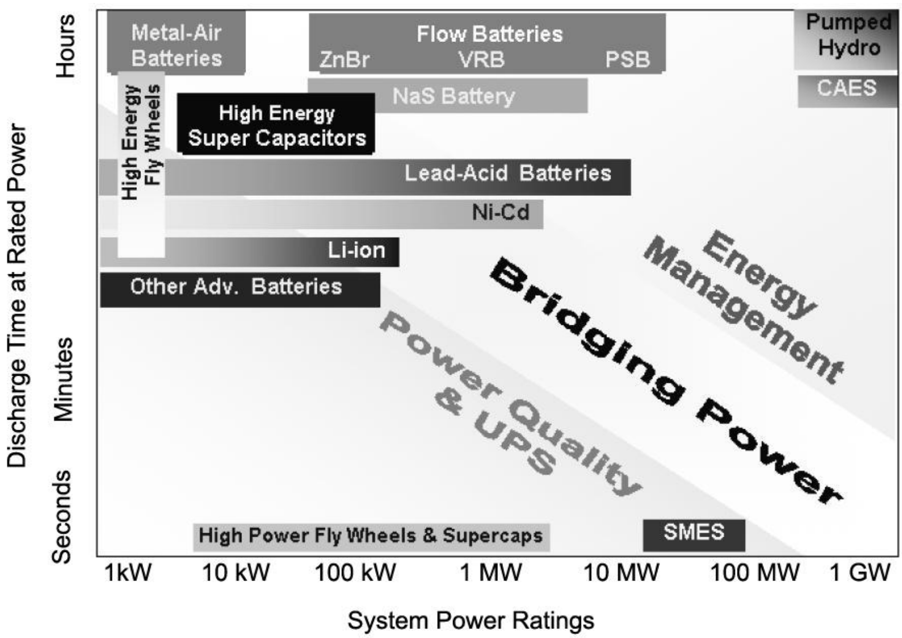

Figure 3.7: Overview of different storage technologies and their typical fields of application
Source: Adapted from Nourai [173, p. 311]

3.2.3.2 Current State of Use of Different Storage Technologies

Many of the technologies which are illustrated in Figure 3.7 are at the current state either not fully developed or in the current grid infrastructure not economic to use. According to the aforementioned different storage applications the following technologies (see figure 3.8) are most commonly used in the grid of today [156, p. 27, 31].

	Typical Time Horizon of Storages	Typical Applications	Maximum Capacity (in MW)	Efficiency (in Percent)
Flywheels	Seconds-minutes	Power quality	10	80
Lead-Acid Battery	Seconds-hours	Power quality	100	80-85
Pumped Hydro	Hours-days	Energy management	5000	70

Figure 3.8: Comparison of commonly used storage technologies
Source: Adapted from: Makarov[166, p. 2]; Electricity Storage Association [148]; Nourai, Schafer [174, p. 45]; Sauer, Kleimaier, Glaunsinger[180, p. 2]; Ragheb [178, p. 4]

As seen in Figure 3.8, all commonly used technologies are characterized by a high degree of efficiency. The flywheel and Lead-Acid (LA) Battery storages are mainly used for short term ranges, and therefore especially for USP and power quality applications [156, p. 14, 17]. In some cases they are also used in off-grid solutions. Pumped hydro storages are the most common large scale energy storages worldwide providing 90 GW of capacity. This is about 3% of the global generation capacity [177, p. 529].

3.2.4 Electricity Measuring

Key to managing our decreasing energy supplies is meticulously measuring usage. Measurement is one of the important steps toward proficient management and improving consumer behavior. It is necessary to efficiently balance power consumption and production.

3.2.4.1 Types of Electric Meters

The Thomson electric meter is most common. Solid state electric meters use an LCD screen which displays the consumed energy. Next to the calculated amount of power used, solid state electric meters are capable of documenting other factors of the load and supply for instance the highest possible demand, power factor and reactive power consumed. An electronic meter is one of the most recent electrical meters which is able to read automatically [161].

3.2.4.2 Applied Technological Concepts

Automatic Meter Reading (AMR) and Remote Meter Reading (RMR) describe diverse systems that permit meters to be checked without sending a meter-reader out. The AMR system refers to the technology used for automating the collection of data that describes the energy used. This data collection is for the sake of real-time billing and usage analysis. At any point of time, the AMR system gathers real-time data and transports it to the central database. The readings are sent out automatically by telephone line, GSM, GPRS or radio to a central billing agency. The major advantage of this technology is more accuracy and a defined measurement of electricity consumption. Users will be billed the amount that precisely matches what they have consumed. Electricity agencies will thus have more efficient operations. Less manpower and fewer resources are required in meter reading and data gathering. The agencies simply require access to the main database to get the information that they need for billing, electric charges and analysis [193]. For more details, see 2.

A more developed technological concept is the PMU. This technological concept is used to measure system parameters from generators, lines or transmission facilities. The data is utilized to evaluate the performance of the generators and the interconnected power system during steady state and transitory conditions.

This evaluation and assessment proposed by the PMU will further be used to compare the actual performance of transmission facilities to results predicted by analytical models. The goal of the application of PMUs is to increase power quality by exact analysis and automatic correction of the system [175].

3.2.4.3 Characteristics of Current Technologies for Measuring Electricity

The shortcoming of the current situation of electricity measurement is the lack of consumer awareness. The economic, energy and ecological efficiency is missing due to the lack of precise measurement, high power consumption, high energy costs, shortage of fuels and global warming. Moreover, the traditional monitoring is based on Weighted Least Square (WLS) which is very frail, not precise enough and prone to failure when topology, measurement or parameter errors are present. As a result of these shortcomings, new technologies for energy monitoring and managing are needed to achieve the goals of the smart grid.

3.3 Trends

By observing the current situation of the electricity system where efficiency is not guaranteed due to the lack of information, certain technological developments such as the precise measuring of electricity quality at different interconnections are starting to affect the entire grid system, which will make the grid smarter over time.

3.3.1 Electricity Generation

In the last years the trend towards distributed energy generation has gained strength. Due to ongoing political measures and rising prices for fossil fuels [185, p. III.46], this trend will intensify in the upcoming years. Moreover, the consumption of electricity will strongly rise especially in developing countries [190]. This shows the necessity to produce electricity more efficiently and to use renewable energies.

3.3.1.1 Rising Importance of Virtual Power Plants due to Increasing Distributed Electricity Generation

An increasing number of electricity producers, which will be mostly situated locally, will result in innovative management systems. To use the distributed renewable energies sources like biogas-, wind-, solar-, or geothermal power, we have to situate the power plant at those areas, too. By trend, renewable power plants are smaller and produce power with a magnitude of several kilowatts up to few megawatts, which results in a higher number of electricity stations.

But there are also ways to use fossil fuels more efficiently than in centralized production by implementing combined heat and power plants (CHP).

Description

As previously described, CHPs achieve high efficiencies because the produced heat is consumed in addition to the generated electricity, as well. Both the trend of having more renewable energy power stations and small CHP plants will increase the number of electricity producer dramatically [153, p. 4].

Having more electricity producers connected to the grid is not the only challenge, but also the volatile way of producing electricity, which especially wind and solar power plants bring along. The networks have to manage the resulting fluctuating power feeding-in. Wind turbines must often even stay switched off to avoid oversupply or to stabilize the grid. Furthermore, the network operator has to control and organize the power quality, which is primarily governed by conventional power plants. This results in a suboptimal operation of these power plants and higher running costs. Conventional plants, for instance, operate in the area of several gigawatts, whereas decentralized generators often just produce some kilowatts. In order to reduce the regulating energy it would be a big advantage, to have decentralized powerhouses that coordinate their operations. In addition, the current electricity network is organized top-down and is not designed for a large amount of decentralized power producers [194, p. 2].

To coordinate the operations of decentralized power producers Virtual Power Plants (VPP) can be implemented. VPPs connect several hundred or thousand distributed small power generating facilities by one centralized energy management system. The goal of VPPs is to reach almost the same controllability as with conventional power plants. Two main effects contribute to achieve this goal:

- The bundling of different volatile systems with different fluctuation patterns will result in a decreasing overall volatility. This particularly applies to power generation out of renewable energy sources. For instance strong winds and sunshine typically do not appear at the same time. As wind is more likely to be present during the winter months and the sun is more present during the summer months (Figure 3.9). Using both energy sources at the same time flattens the overall power supply, as illustrated in Figure 3.9. Furthermore, VPP can combine power generators from different geographical regions with different weather conditions, which flattens the power supply curve, even more [163, p. 12].

- The controllability and the remaining volatility can be managed by including selected controllable generators into the system. For instance, it is not possible to control distributed CHPs, because the owners decide upon their infeed. But if one has several CHPs that are all connected to the same VPP, the centralized management system is able to shut down certain facilities in case of oversupply. Besides CHPs, also pumped hydro storage facilities or biogas plants can be used to compensate the remaining volatility of the system [163, p. 12].

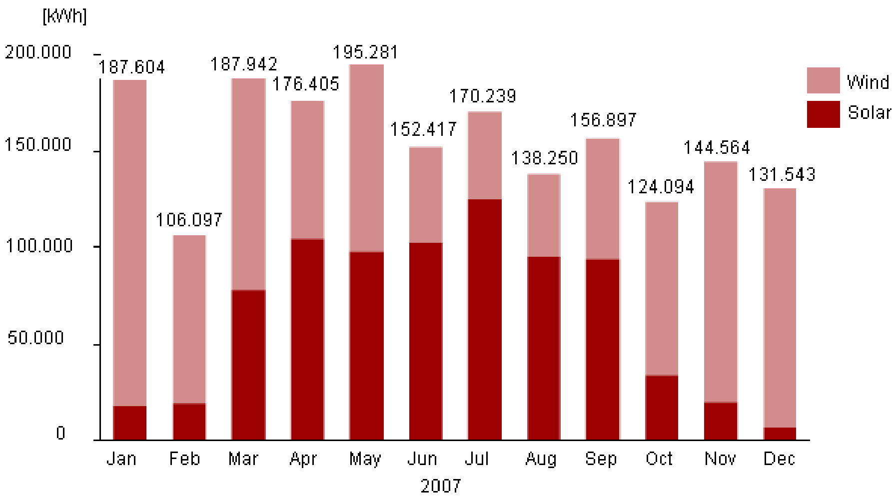

Figure 3.9: Power generation from solar and wind energy in a virtual power plant
Source: Adapted from Knab, Strunz, Lehmann [163, p. 13]

Impact on Smart Grid

The consequence of having more and more decentralized and volatile power producers is the bundling of those to bigger VPPs. The grid can consider the VPPs as single power generators, which have almost the same impact as conventional power plants. This reduces the complexity of the electricity network dramatically, because it does not have to manage a huge number of small powerhouses.

3.3.1.2 Increasing Self Supply by Using Microgrids

There are two main motivations to consume the produced electricity on one's own. Firstly, in Germany the Renewable Energy Law encourages photovoltaic power producers to consume parts of their own electricity production by higher incentives. Secondly, for some electricity consumers it is very important to have a secure and stable power supply. Producing it independently is one opportunity to accomplish this goal.

Description

It is becoming more and more profitable for power generators to consume their own produced electricity. The German government, for instance, incentivizes photovoltaic power generators, which consume parts of their own electricity production [146, § 33 Abs. 2]. Since the consumption of the self-produced power substitutes the external power supply, a small supplementary bonus of about 3.5 Euro-Cent remains, compared to the incentive for electricity fed into the grid [139].

Another possibility of self supply are so called microgrids. Microgrids are groupings of electricity sources and loads, which are connected to the traditional grid (also: macrogrid) through a single point of common coupling. The macrogrid considers microgrids as single consumers or producers, which can be switched on and off within seconds. The advantage of a microgrid is its independence in case of a breakdown or in accident situations. This is especially important for companies that rely on safe electricity supply. If the traditional grid offers cheap power, the microgrid can draw electricity from there. However, if the power gets too expensive or if it breaks down, the microgrid disconnects and supplies its consumers autonomously. The microgrid can also react to bottlenecks in supply by disconnecting unimportant consumers to assure the power supply to critical consumers. Moreover, the microgrid is one possibility to make CHP plants insertable to the macrogrid, since the heat is not too concentrated and can be bought-off [145].

Impact on Smart Grid

Having microgrids and single self supplier in the traditional electricity network requires smart metering of injected and consumed power at the interface between macro- and microgrid and at each single part of the microgrid. Smart meters also decide if it is more reasonable to buy power from the traditional grid or produce power on its own. It can even feed in power into the traditional grid if less energy is needed within the microgrid. This will be discussed in more detail in chapter 3.2.4.

3.3.2 Electricity Transmission and Distribution

The load on the transmission and on the distribution network infrastructure world-wide has been increasing over the last years rapidly. This poses a challenge on the grid to adapt itself to new distribution methods as well as to utilize grid information efficiently.

3.3.2.1 Growth in Bi-directional Electricity Feed-in

Unlike in the past, where power was only produced by large powerstations and sent in a uni-directional form to customers, the proliferation of renewable power production (3.2.1), which is fed into the grid from both electricity providers and customers in a bi-directional fashion, is causing the existing electricity grid to change its current shape.

Description

In Germany, energy producers are required by law to expand their electricity network to be able to handle the influx of power and current in the network from end-users generating their own power and feeding it into the grid [146, § 9]. Not only is electricity produced on a small scale at home with PV panels and fed into the grid with Grid Tied Inverters (GTIs), which ensure that the electricity is fed into the grid at the same frequency (50Hz in Europe), same phase and same voltage as the electricity company [142, p. 1], but also large offshore wind parks are being erected in the North Sea [181, 5.5.]. Further plans include the expansion of Concentrated Solar Power (CSP) sites in the Sahara desert [151]. These factors pose new technological challenges to the grid. Utilizing High Voltage Direct Current (HVDC) cable technology to transfer power over great distances or from offshore wind parks is becoming a vital requirement for the current grid infrastructure. However, HVDC links are expensive to erect due to their inherent need of Insulated-Gate Bipolar Transistors (IGBTs), which provide the switching at up to 2000 Hz [164, p. 32] and their more complex converter station requirements. Unlike their AC counterpart, HVDC links do not suffer from grid instability issues over long distances due to the absence of frequency and phase shift of current and voltage [164, p. 5].

With increasing electricity demand, more current has to be moved through electrical cables. Current ACSR cabling has its own limitations when it comes to capacity. Firstly, a safe operating temperature is required which is linked to the width of the conductor. Secondly the increasing reactive power with increasing cable length limits the capacity. Developing superconducting DC cables will enable the flow of massive amounts of energy, up to five times the amount of HVAC. These cables will be able to carry up to 10 gigawatts (GW) of power over a distance of up to 1500 km [140, p. 1]. Figure 3.10 demonstrates the space and clearance advantages that can be obtained by HVDC cabling. Not only will these cables transfer more power than HVAC cables, they will do this more discreetly as the need for overhead power lines using HVDC is not necessary.

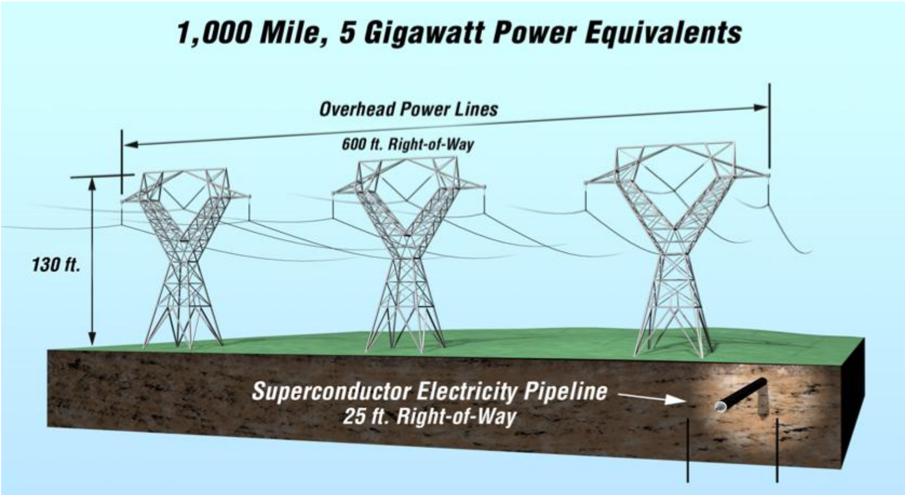

Figure 3.10: Clearance required by a superconducting DC cable
Source: Wires [196, p. 40]

Impact on Smart Grid

As stated in part 3.2.2.2, electricity providers have to compensate for reactive power. As such, having a large number of electricity producers, each with appropriate GTIs, the production of reactive power will increase the grid stability [171]. Risk of over-production by the large number of electricity generators is also a major concern as the excess of power in the distribution grid can cause stability issues as well as overheating. The HVDC technology is superior to the High Voltage Alternating Current (HVAC), as seen in Figure 3.11 , it is more efficient at transferring electricity over great distances, creates less interference with televisions, radios and telephones, and has less of an effect on the human body and the environment [169, p. 1-2, 4-5]. More importantly, an HVDC system is decoupled from the grid frequency and so is able to be connected to any grid infrastructure [164, p. 34] and does not need to be compensated for reactive power [140, p. 1].

3.3.2.2 Increase in Data-driven Grid Management and Control

With electricity consumption rising and with the addition of a bi-directional feed into the grid, the electricity grid has to become 'aware' about its state to deal with outages, power fluctuations and demand. The dynamic utilization of transmission and distribution resources, where demand and supply are matched, will make the grid more flexible and inherently more stable, which will help it cope with the increasing load on it.

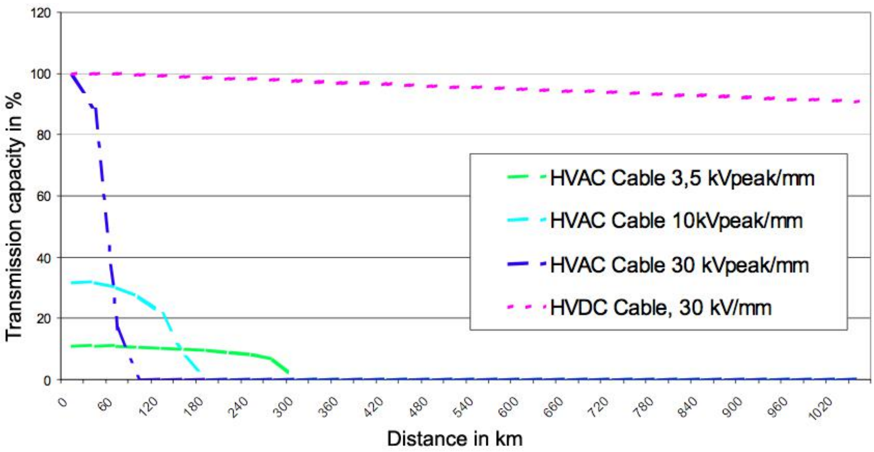

Figure 3.11: Transmission capacity of different HVAC cables in comparison to HVDC
Source: Adapted from Asplund [135, p. 2]

Description

To effectively manage all resources and the load on the transmission and distribution lines, a largely automated control system is required. For this, Phasor Management Units (PMUs) are being put into place world wide to monitor the power quality of electricity networks. The power quality of an electricity grid is vital to the correct functioning of modern digital electronics [195, p. 8]. PMUs measure the angle and the magnitude of the sine waved found in AC systems. To ensure high power quality throughout the grid, PMUs are to be spaced over the electricity grid and synchronized using GPS technology. A Supervisory Control And Data Acquisition (SCADA) system, that is located at the end of the chain of PMUs, can detect a network anomaly. A voltage drop or network instability would cause SCADA to use PMUs to re-route the electricity flow to either avoid certain parts of the network, or to provide compensation for reactive power. China is spearheading the expansion with an already existing 300 PMUs [198, p. 1]that are technologically superior to other PMUs as they offer a five-fold increase in accuracy of frequency in comparison to other PMUs while sampling at twice the data rate [199, slide 8].

Impact on Smart Grid

Due to the tendency of the grid to become more deregulated throughout the world, effective management of the grid's Available Transfer Capacity

(ATC) is essential as most of today's AC infrastructure is operated below its thermal rating [197, p. 305]. To manage this, a Flexible Alternating Current Transmission System (FACTS) will be used by the smart grid to exploit the existing infrastructure and to dynamically adapt itself to load changes. FACTS utilizes power electronics, which are readily available due to advances in semiconductor technology [164, p. 32], to redistribute line flow and to regulate nodal voltage. By using circuit reactance, voltage magnitude and phase angles as controls and in combination with PMUs, ATC can be increased while mitigating the critical situation [197, p. 305].

3.3.3 Electricity Storage

At the current state storage solutions are often not efficient to use. The top-down electricity grid, which relies on centralized energy production, can guarantee constant grid stability by regulating big power plants [157, p. 393]. For example, if additional energy is required, big power plants usually have remaining capacity to compensate the change in demand. However, the importance of storage solutions will grow in the future. The ongoing rise of decentral, volatile renewable energy production (3.2.1) will spur the need for both big mass power storages in the transmission grid and small decentralized storage solutions. Especially in off-grid systems those flexible storages will become more important, also relying on new and innovative storage concepts. For the usage of electric cars as energy storages see 4.3.5.

3.3.3.1 Increasing Application of Mass Energy Storages

In the future there will be a growing gap between production and consumption, which means that at some occasions of a day the energy which could be produced is higher than the demand at this time. The same can happen vice versa if demand is higher than production at other times of the day. This will lead to an additional need for mass energy storages. It will become efficient to store energy, for example from renewable energy sources instead of shutting down overcapacities.

Description

The volatility of production, especially of wind power, leads to a growing demand in mass power storages. For example, in Germany, a study of the "Sachverständigenrat für Umweltfragen"[189], which proposes a massive use of renewable energy sources until 2050, predicts an enormous need of additional storage solutions to cover overcapacities. Germany's required storage capacity only for wind and solar energy grows from 1GW to around 10 GW in 2015 [189, p. 65]. This clearly shows a trend towards an additional demand for mass energy storages. As other large scale storage technologies, such as the Compressed

Air Energy Storage (CAES), are not mature yet, the need for pumped storage hydroelectricity will rise. However, the capacities in most countries are very limited. Therefore, available storage potential in other countries might be shared in the future. For instance in case of a growing offshore-production in Germany, the above-mentioned outlook proposes to cooperate with pump storages in Norway. These could be utilized to balance out overcapacities from Germany and feed them back during peak cycles, provided that a sufficient transmission infrastructure is available [189, p. 62].

Impact on Smart Grid

For international projects like these the transmission grid needs to be extended to connect large scale storages and generation. This requires an international and standardized communication system within the large scale transmission grid. International standards such as the EDIFACT (see 1.3.2.1) are a good starting point. Data and operational instructions need to be securely sent over long distances between storages and large scale generation sites.

3.3.3.2 Growing Use of Decentralized Storages

Besides the need for mass energy storages, the distributed generation as described in 3.3.1.1 will also lead to a growing use of decentralized storages.

Description

Another trend, which comes along with the rise of distributed generation, is the growing use of decentralized storages. The volatile output of many renewable power plants is an enormous challenge for maintaining a constant power quality in the grid. A problem which can be approached by the usage of storage technologies [150, p. 1]. For example, different solutions are developed to provide volatile wind power plants with local storages. This would allow a more constant output of electricity, even in times of low wind conditions. A proposed solution is to combine a short term storage in form of a flywheel with a medium/long term Vanadium Redox flow Battery (VRB) storage. The system also provides a smart grid interface [137, p. 1-2]. Solutions which combine solar power and storages are also possible in order to balance out volatilities which can for example be caused by clouds.

In addition, decentralized storages play a vital role for VPPs [191, p. 5], and microgrids as described in 3.2.1. New technologies such as high-speed flywheels or mature versions of redox flow batteries might become important decentralized storages for those systems. Nevertheless it is still difficult today, to foresee which storage technologies will finally be widely spread in the future [152].

Impact on Smart Grid

For the aforementioned systems and other new decentralized storages for example in VPPs and microgrids, smart solutions which guarantee an intelligent communication of the different devices need to be found. For the overall grid this task might be fulfilled by new market players, which provide embedded central and decentral communication systems [191, p. 6]. Therefore, with the implementation of the smart grid, it will also be decisive that several new market players (e.g. electricity producers and communication companies) are working together, to provide intelligently linked devices and solutions. Different types of storages must learn to work hand in hand in a smart and coordinated way to provide a smart storage management.

3.3.4 Electricity Measuring

Efficient power consumption doesn't only need the management of the supply side but the demand side as well. That advanced management can only be achieved through power quality monitors and meters with "energy-managing skills". Many technological developments are necessary for monitoring and controlling energy consumption and the eventual the implementation of the smart grid.

3.3.4.1 Increasing Usage of Power Quality Monitors

Peak load management/ shifting electrical demand to low-use periods is getting significant attention. Figure 3.12 demonstrates the crucial development of the European energy exchange spot prices from the year 2008 to 2010 according to daily maximum and minimum prices. This huge development in the prices reflects the critical situation of peak loads in energy systems. The prices of the European energy exchange per megawatt-hour have depreciated over the last two years.

Description

The increasing energy demand is starting to exceed the available transmission system's capacity. Through peak load management one can reduce the need for additional transmission capacity and improve the transmission system reliability during time periods of high demand. Hence, reducing peak electrical demand can save huge amounts of money for companies, power agencies and the industry.

There are daily and annual cycles of demand. As Figure 3.13 illustrates that there are usually two peak times during a day. Shifting loads away from that time period reduces peaks.

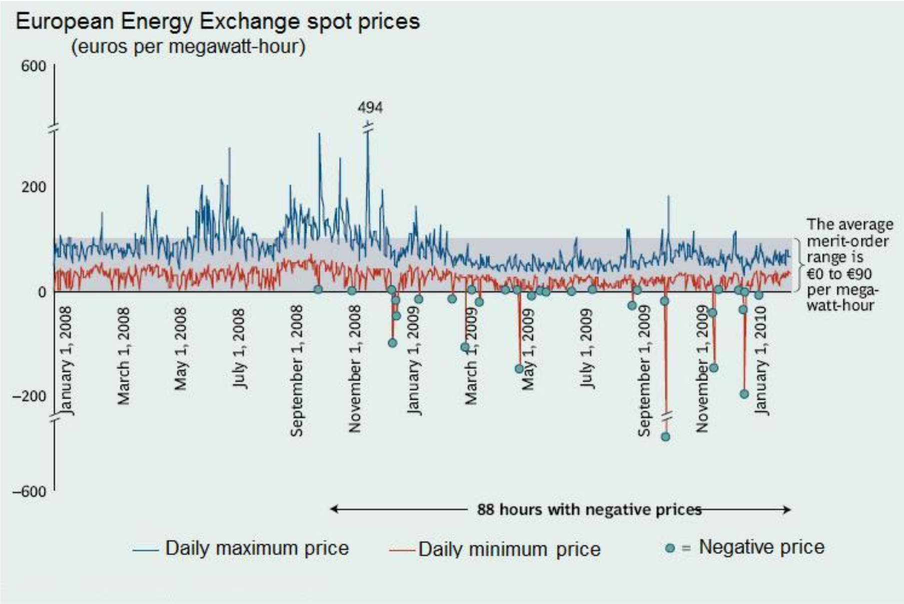

Figure 3.12: In Germany, Energy Systems are showing the first signs of stress
Source: Adapted from BCG [162]

High increase in demand, matched with very small growth in transmission capacity is eliminating the margin of extra capacity that guarantees the supply system's reliability. A failure of a major under sea transmission line during periods of high demand could lead to a major voltage collapse and consequentially causing loss of power. Another reason for shifting peaks is the issue of energy losses due to the low efficiencies of energy storages. Since it is costly to store huge amounts of electricity, it should usually be generated when it is needed [147].

The Time of Use meter (TOU meter) can be utilized so that you are charged cheaper electricity rates at off-peak times, for instance at night. The attempt is making it possible for energy providers to charge varying electricity rates so that charges would reflect the big differences in cost of producing electricity during peak or non-peak periods. These abilities permit load control switches to control energy consuming devices such as water heaters so that they consume electrical power when it is cheaper. Due to this, users are encouraged to shift their electricity consumption away from peak hours [172, p. 2]. Figure 3.14 shows the shifting of peak loads after installing TOU meters.

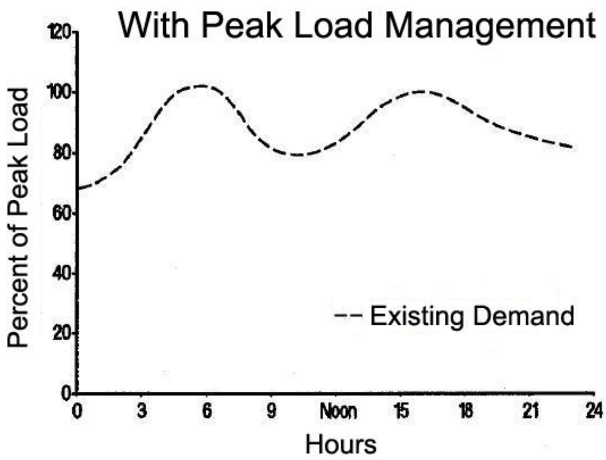

Figure 3.13: Percentage of Peak Loads during a day
adapted from Doe [147]

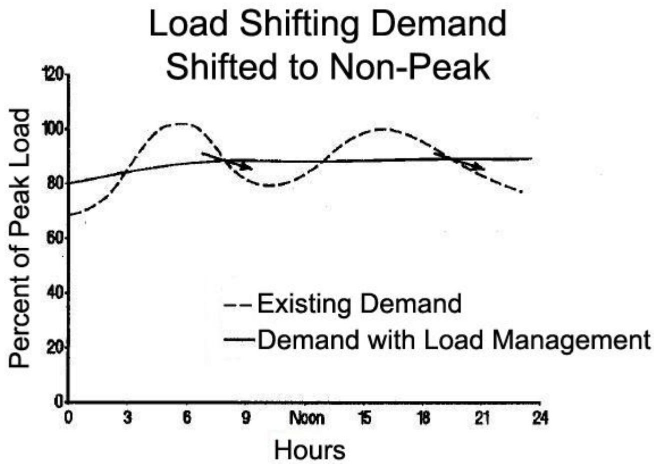

Figure 3.14: Percentage of Peak Loads with Load Management
Source: Adapted from Doe [147]

The newest development of electronic meters is the smart meter which is based on an Advanced Metering Infrastructure (AMI). AMI is an infrastructure for automated, two-way communication between a smart utility meter with an IP address and the electricity company. Smart meters enable bidirectional data exchange (with power providers or grid management), time-based consumption information, advanced power measurement and management capabilities. They communicate via IP to servers. The facility to access precise electricity readings for the consumers every 30 minutes helps them monitor and manage their electricity usage. Giving users access to explicit daily consumption information has been proven to reduce power consumption 3 to 11 percent [179]. The layout of a smart meter with detailed consumption data is illustrated in Figure 3.15

Figure 3.15: Smart Meter
Source: Adapted from VDE [191]

Impact on Smart Grid

A smart meter supports the smart grid as it provides frequent information about who uses how much, where they use it and when they use it. Without this amount of data, it's hard for the electricity system including the transmission and distribution networks to be smart about self-optimizing and self-healing. However, smart metering technology isn't sufficient for the smart grid. The system lacks predictability and controllability. Other features that serve energy management need to be obtained. Using real-time information from enclosed sensors and automatic controls to predict, observe, and respond to system errors, a smart grid can automatically avoid or mitigate power outages, power quality problems, and service breakouts.

A "self healing" transmission or distribution network doesn't exist. If there is a failure of an overhead power line, there is an unavoidable loss of power. It is envisioned that meters with smart grid features will likely have a control system that examines its performance using independent controllers. Such controllers learn successful strategies to regulate the conduct of the grid in the view of an ever changing environment such as equipment failures. Power Outages and power quality problems cost US businesses about $100 billion each year [155, p. 2]. It is declared that establishing more stable power rendered by smart grid technologies will reduce downtime and prevent such enormous losses. Such smart grid technologies that should be included to the meters are also referred to as "Energy Managers" as they give customers control over electricity costs and create financial inducements for energy savings [172, p. 3-4].

3.3.4.2 New Measurement Policies Due to Increasing Self Supply

Due to the increasing decentralized electricity production and tendency to energy self supply, competent electricity measurement facilities have to be applied. An electricity policy for measuring self supplied energy is the power export metering.

Description

The power export metering is a construct which is relevant to those electricity customers who are installing private electricity generators. These are users who own any little renewable energy facilities such as wind, solar power or home fuel cells. When a consumer is producing more electric power than he actually needs for his own use at home, the excess energy is exported back to the power grid. This will result in the decreased consumption of electric power by the user. The consumer's registered energy usage is decreased by the amount the energy exported by him to the grid. There is a concept known as net metering, in which the owner gets the retail credit for at least a portion of the energy that is produced by him. In recent times, the upload sources typically arise in renewable sources, gas or steam turbines, which are often found in co-generation systems. Moreover, owners of electricity generator sources can receive bill crediting for selling surplus electricity back to the grid during high-demand hours [159].

Renewable energy sources are usually fluctuating and consequently customers may not be using electricity as it is being produced. Net metering solves this problem as it allows them to get total value for the power they generate without installing pricey battery storage equipment. It provides a simple, cheap, and easily-administered mechanism for promoting the use of small-scale wind energy and solar power systems, which provide local, national, and global benefits to the environment and the economy [183, p. 5].

Impact on Smart Grid

Net metering and power export metering influence the implementation of the smart grid and have a strong positive effect. The real-time, two-way communications available in an advanced smart meter will enable consumers to be remunerated for their efforts to save energy and to sell energy back to the grid through net-metering. By enabling decentralized generation resources advanced smart meters with energy management features will spark a revolution in the energy industry by allowing small players like individual homes and small businesses to sell power to their neighbors or back to the grid. Thus, the application of those technologies will serve the goal of making the smart grid reality.

3.4 Conclusion

The trend of an increasing number of decentralized power producers, which are subject of several volatile conditions, make it necessary to bundle small power generators to big and controllable virtual power plants. Moreover, the movement towards more self supply has two main reasons. While small electricity producers are driven by the financial gain of electricity production, others establish microgrids to maintain safety of power supply. These ideas of creating a smart grid out of the traditional grid will only work if the concept of smart metering is applied. Upgrades of the grid structure at this scale however cannot be done overnight. Retrofitting homes with PV panels and with small-scale wind turbines will be a challenge. The grid won't be only stabilized by these local electricity producers through their feed into the grid via a GTI, but will also make efficient use of existing grid capacity due to the reactive power compensation provided by these. However, the monumental task to lay new HVDC cables and to retrofit the existing grid infrastructure with PMUs will take years to accomplish.

While large scale electricity storage solutions were not economical in the past, they will play a major role in the future energy grid. Innovative technologies, such as advanced chemical batteries or flywheels will mature in the future and will offer new opportunities for the storage market. The remaining question is which solutions will fulfill the requirements in a rapidly changing infrastructure environment. Promising signs are shown by flywheels at the moment which will probably dominate the storage market in the future.

As the grid evolves, use of power quality monitors is increasing due to power reliability issues and power outages which cost businesses billions of dollars each year in lost revenue, process improvements, and unusuable, incomplete product. Because of the growing tendency of self supplied energy and renewable energy sources, net metering and power export metering will gain more significance in the future. Smart meters alone aren't sufficient to the implementation of the smart grid, electricity measuring devices with energy-management capabilities have to be obtained. However, it is only with incremental steps that a smarter grid can take shape and ultimately lead to the visionary smart grid.

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Chapter 4

4 Technologies in Electric Mobility and their Influence on the Energy Grid

Maximilian Cappel, Salma El Sayyad, Lena Hoeck, Diana Schneider, Daniel Strohmayr

The motive of applying technology ameliorations in E-Mobility development is two-fold with regard to the grid: Firstly, constructing smarter, more advanced electric vehicles capable of running on as little energy as possible, taken from the grid when it's least expensive. Meanwhile, industry is working on reducing comparative disadvantages of electric vehicles relative to combustion engine vehicles. Secondly, on a more holistic, integrative note, to explore the potential of E-Mobility to play a crucial role in the optimization of a 'smarter' energy grid: E-Mobility has the capacity to sustain grid efficiency, economize energy, diminish cost and amplify reliability and transparency.

The production and consumption of electric vehicles is only slowly rising because the energy storage systems which power electric cars are far from being optimized and hence are considered to be the weak link in the electric vehicle technology. Thus, researches and developments in E-mobility contribute to build more energy efficient and less expensive energy storage systems. The E-mobility infrastructure will however certainly experience a technologic and economic evolution from 2010 to 2015. As the supply of upcoming electric vehicles is increasing the expansion of the charging stations network will also be realized.

Changes in the domain of accumulation systems are expected by adding efficient energy storage technologies and broadening the concept of Grid2Vehicle with the introduction of Vehicle2Grid and therefore using electric vehicles' potential to become a storage for the intelligent grid of the near future. Several Systems and technologies such as regenerative braking and smart metering would also develop which would endorse the load balancing and load relieving effect on the gird. In this respect, all trends appear to share the same path: The supply, energy efficiency, reach extension and grid-interaction of electric vehicles is predicted to increase.

4.1 Introduction

In 2009, the German government adopted the "Nationaler Entwicklungsplan Elektromobilität", primarily providing support to Research and Development towards e-mobility. Other countries such as China and the USA are providing massive state subsidies encouraging people to purchase an Electric Vehicle (EV). This report aims to provide an overview of these main components and the development within the e-mobility discussion, proposing an evaluation of emerging trends until 2015.

4.2 Status Quo

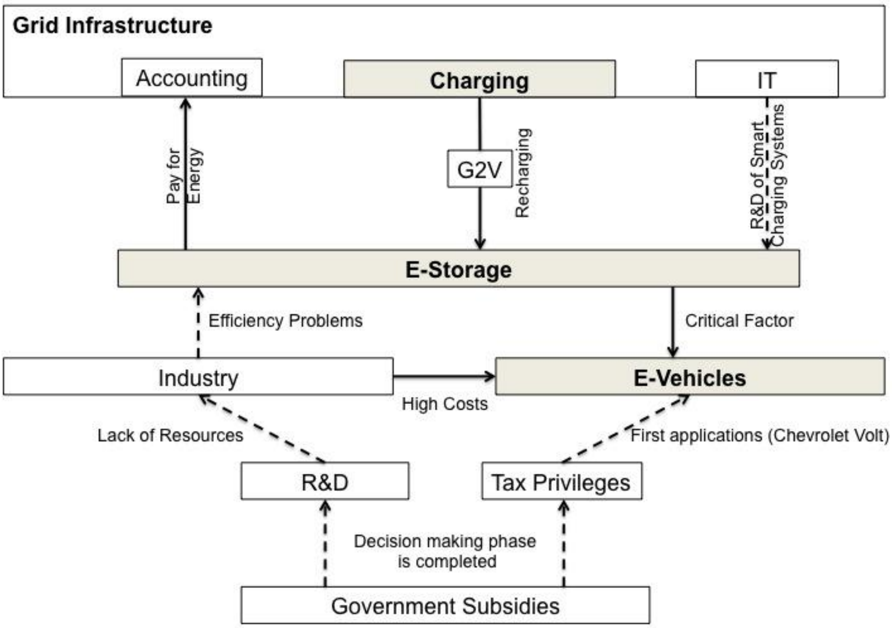


Figure 4.1: Status Quo: Grid Infrastructure and E-Mobility
Source: own illustration

Due to its impact on the acceptance and adoption of e-mobility, governmental support is a major influence-factor on the e-mobility industry. However, in most countries governments have just started with those activities yet and actually a forecast of its impact is very difficult to make. Therefore, up to today, there is a lack of resources on the side of the car manufacturers. Through tax privileges there are first applications of electric vehicles on the market. Still, high costs are a limitation of the spread of the new technologies. High costs are mainly attributed to efficiency problems of the energy storage. This is a major problem because the storage system, namely the battery is a critical factor for the electric vehicles getting ready for the mass market. As far as the energy storage system is concerned, it is highly connected to the electric grid infrastructure. There are three unilateral links between the battery and the grid. First the customer charges the battery (Grid2Vehicle) and subsequently pays for the electricity. Secondly there are ongoing research efforts concerning IT, which is needed to better control the charging mechanism in order to efficiently make use of the difference in load of the grid. The last link is the payment process of a customer, using the energy from the grid. Those coherencies are visualized in figure 4.1, which provides a structural understanding of the status-quo.

4.2.1 Political Decisions Influencing E-Mobility

The advance of E-Mobility causes major new system integration in the field of mobility. The past has shown that similar system integrations such as the current individual mobility could only be implemented because of governmental subsidies [243, p. 10].

There are different alternatives for the government to advocate E-Mobility. Two unequal, however both widely used forms, are on the one hand supporting the industry by giving benefits in the fields of Research and Technology and on the other hand giving tax privileges to the customers when buying a vehicle. Figure 4.2 gives a broad overview of commonly used funding instruments in the field of E-Mobility technologies. It compares the activities of Germany with the activities of other countries.

Governments are supporting E-Mobility activities, so they can be seen as market drivers. Public development programs can contribute to the market positioning of new technologies. Creating an incentive for politically desired demand, behavior is playing an important role. The scrapping premiums and the support of photovoltaic are two prominent German examples of the recent history [202, p. 20].

Many countries are facing the challenge of E-Mobility at the moment. In this highly competitive market the governmental strategies differ from one another and they are influencing the progress of E-Mobility in different ways. Countries such as China, France and the USA support the purchase of an electric-car with a state grant up to 9000€ differing by each country [243, p. 7-10]. The USA gives every buyer of the new Chevrolet Volt a tax privilege of 7500 US-Dollar and thereby sets up the requirements for a success story of the Volt [243, p. 7]. Those strategies help to increase the sales figures of electric vehicles and will lead to a growing rate of electric vehicles on the streets. Compared to those countries Germany looks very skeptical at direct buying incentives and decided to provide

500 million € for Research and Development related activities [202, p. 18]. A further purpose of Germany's development plan for E-Mobility is preparing the market launch of electric vehicles. The measures of the "Konjunkturpaket 2" shall act as catalysts, which will have to be adjusted to the technological process [207]. Figure 4.3 provides an overview of the different countries activities.

State Subsidy	Example	Adoption in Germany	Adoption in other countries
Subsidies	1. Research and Development 2. Preparation for Market Launch: Pilot Regions 3. Purchase Subsidies	+ + -	+ + +
Capital Appropriation	• Cheap loans • No risk of accountability • Flexible term • Special capital funding	+	+
Tax Privileges	1. Tax advantages according to carbon emission 2. Sales tax exemption	- -	+ +
User Privileges	• Free Parking Slots in cities • Special driving lines for EV	-	+
Public Sector Purchasing	Fleet procurement by public companies	-	+

Figure 4.2: Different forms of State Subsidies in the Field of Electrical Propulsion Methods

Source: adapted from Arnold et al. [202, p. 24]

Kontinent/Country	Activity
USA	• 2 billion US-Dollar for battery- technology • 25 billion US-Dollar loans for fuel saving vehicle production plants • 150 billion US-Dollar for green energy-technology • 400 million US-Dollar for infrastructure and pilot-projects
Europe	• 1 billion € for "Green Car" initiative • 4 billion € loans for green cars • 730 million € for energy-technologies • 65 million € for energy in transport
France	• "Pacte Automobile": 400 million € • Further investments of 2.5 billion € in the next 10 years
Germany	• "Konjunkturpaket 2": 500 million €
China	• 1 billion € for efficient propulsion technology • 2 billion for 13 pilot-regions with more than 10000 vehicles
Japan	• 200 million US-Dollar for the development of cheap traction batteries

Figure 4.3: Activity Comparison of different Countries
Source: adapted from Fraunhofer Institution fuer Arbeitswirtschaft und Organisation [274, p. 35]

4.2.2 Description and Market Relevance of E-Mobility Applications

Motivated by increasingly stringent government regulations, energy security concerns, rapidly diminishing fossil fuel reserves, higher oil prices and an enhanced public awareness and demand for sustainability, the mobility industry has shifted from internal combustion engines (ICE) towards electric propulsion solutions, observable with electric vehicle (EV) concepts in virtually all car manufacturers' product portfolio.

Though electric engines have a far higher energy efficiency (60-80% tank-to-wheel efficiency [270]) than conventional ICEs (15-20%) [216], their market relevance is still modest, spanning hybrid vehicles (HV), plug-in hybrid electric vehicles (PHEV) and battery electric vehicles (BEV).

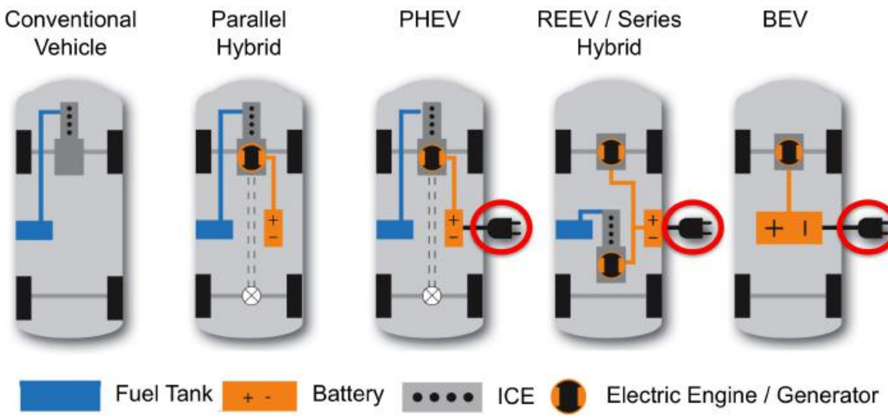


Figure 4.4: Different propulsion methods of E-Mobility vehicles
Source: adapted from Spath et al. [266, p. 6]

4.2.2.1 E-Mobility Technology in Four Applications

This report distinguishes four types of vehicles comprising E-Mobility, representing four stages of electrification between conventional ICE-driven vehicles and all-electric BEVs.

Within the hybrid vehicle (HV) category, firstly there are conventional hybrids, in which both the ICE and the electric motor are connected to the mechanical transmission as shown in figure 4.4 - they are able to simultaneously transmit power to the wheels [240, p. 10f]. The main purpose of the electric engine is to support the ICE [266, p. 6]. All-electric drive, if possible, is limited to a short distance because the electric engine and battery are rather small [266, p. 6]. One example is the Honda Civic Hybrid. A different kind is the power-split or series-parallel hybrids (not in the illustration). Depending on the driving situation, the ICE powers the wheels and/or the electric engine and battery [204], for instance the Toyota Prius, introduced in 1997, which is probably the most popular HV to date.

The battery of HVs is normally recharged through recuperation [266, p. 6]. Since there is no mechanism to plug the car to the grid, conventional HVs are not directly important to the smart grid, instead they act as technology driver, e.g. bringing down unit battery cost through mass production (see 4.3.5).

The next type are grid-connected PHEVs, with batteries that can be charged through the regular grid [245, p. 20], combining characteristics of HVs and EVs alike. They have a higher all-electric range (from 15 km to 65 km [229, p. 2]) than HVs, but are also more expensive. On the other hand they allow a high total range and attractive driving performance because of their simultaneously equipped conventional ICE (c.f. figure 4.4)[245, p. 20]. Examples for PHEVs are the Fisker Karma or the BYD f3dm.

The next step towards full electrification are Range Extended Electric Vehicles (REEVs) [229, p. 2], in which the electric engine is the only power source for the wheels - the ICE has no direct connection to the wheels (see figure 4.4), it only powers the electric motor and recharges the battery when depleted [266, p. 7]. One example is the Chevrolet Volt, which will be available in November 2010 in the U.S.

The last class of EVs is the all-electric Battery Electric Vehicle (BEV), which are often very light in order to offer an appropriate range, but therefore lack comfort and driving performance. The only energy sources are the grid (c.f. figure 4.4) and brake power recuperation [266, p. 7].

4.2.2.2 Evaluation of E-Mobility Applications and their Limitations

The first limitation of current EVs is their lacking standardized framework. The mpg-ratings as performance classification tool don't suffice: PHEVs and BEVs reveal significant variance in fuel efficiency under different driving conditions. As opposed to ICE-vehicles where all electric accessories and mechanical linkages draw power from a single source, PHEV intermittently draws electricity from the battery, resulting in fuel displacement and difficulty of predicting total fuel range.[246]

In addition, the slow switch from a decennia-old ICE-mindset inhibits consumer's demand. Though an EV-product portfolio is being produced by 20+ OEMs on a small, local scale, consumer's acceptance and EV-supply are not yet aligned [246], due to the widely spread perception of e-technology as "glorified golf carts" [259]: low-performance light EVs that don't require driver's license.

Thirdly, EV's setbacks in comparison with ICE including lower driving range and vehicle performance and higher curb weight constitute two main hurdles in EV's attempt to capture the market leading position of ICE [224, p.40-41]. The former is limited by the lower energy density of batteries in comparison with conventional fuel [239] while the latter could only be remedied by a dense network of public charging stations or overnight plugging into the electric grid at home. Due to the lower power density of automotive batteries in combination with limited implementable dimensions [224, p.42], top speed of EVs is on average 40-100kmh lower than corresponding ICE solutions. Furthermore, full recharge with an electric range of 50-100 km takes three to eight hours through the grid [239], compared to an ICE refueling process at a gas station of a few minutes.

4.2.2.3 Product Range and Current Niche Status

BEVs are an increasingly frequent, yet still a niche alternative to the widely spread ICE technology, a coexistence that will continue for the near to medium term [269]. Grid-independent HEVs have a market share of one percent of new car sales in Europe and two percent in the US [230], while BEVs have an even more limited market penetration of 0,004% within the global vehicle fleet of approximately 800 million vehicles [203][224, p.35].

The majority of EV-concepts currently on the road in Europe are HVs (ex: Toyota Prius), BEV versions of existing ICE-vehicles (ex: smart ED, e-mini) and small-scale produced light EVs (Mitsubishi G-Wiz, Th!nk City). In addition, a range of less known brands such as Aixam Mega, Micro-Vett, Heuliez offer EVs. Also most OEMs show intensified R&D effort towards BEV, which can be observed in concepts, test fleet cars and announced series-production within the next two years - a full list of which can be consulted in the appendix ([224, p.166]).

Parallel to their market entrance in the city/ light car category, EVs are distributed as sports cars (ex: Tesla, Fisker), trucks for city parcel couriers (ex: modec for UPS[212]) and zero-emission two-wheelers in Asian metropolitan areas, benefiting from the local ban of conventional ICE two-wheelers to reduce air pollution [237].

4.2.3 Energy Storage and Efficiency Systems in Electric Vehicles

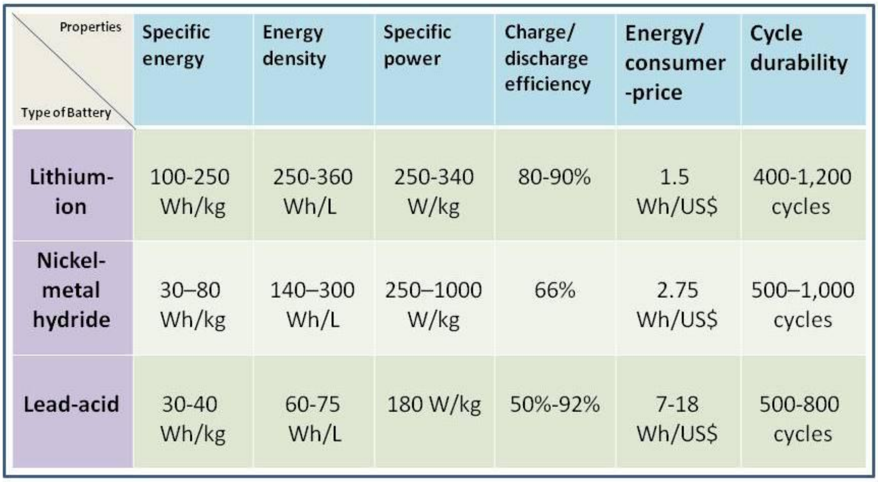
The main difference between ICE vehicles and EVs lies in their respective energy storage systems: EV's electric motor replaces ICE's gasoline engine and gets its power from a controller which in turn retrieves it from a series of rechargeable batteries. EV batteries are charged with 120-volt or 240-volt depending on the e-motor's power.

The three main types of batteries used in EVs are lithium-ion (Li-ion), nickel-metal hydride (NiMH) and lead-acid (PbAc) batteries.

Figure 4.5 indicates than Li-ion batteries have the highest electrical power and the highest charge/discharge efficiency of all EV battery types. Li-ion batteries even feature the highest number of charging cycles and therefore last the longest. With 1,200 charging cycles Li-ion batteries would sustain a life expectancy of eight to ten years, factors favoring Li-ion's battery of choice in EVs.

Although the electricity needed for an EV costs significantly less per mile than comparable ICE-vehicles, one must add the cost of battery and its replacement. An EV battery replacement costs up to $30,000 and a battery life will last about 20,000 miles. [208, p. 1]

Their cost is only one of seven setbacks of EV-batteries, also included are: weight (minimum 1000 pounds), large volume of a minimum of 50 batteries, limited battery capacity, limited electric range (50-100km), length of charging time (4-10h, needed to avoid reducing total number of charge cycles before loss of efficiency) and relative short life cycle (1000 charge cycles).



Type of Battery \ Properties	Specific energy	Energy density	Specific power	Charge/ discharge efficiency	Energy/ consumer -price	Cycle durability
Lithium-ion	100-250 Wh/kg	250-360 Wh/L	250-340 W/kg	80-90%	1.5 Wh/US$	400-1,200 cycles
Nickel-metal hydride	30–80 Wh/kg	140–300 Wh/L	250–1000 W/kg	66%	2.75 Wh/US$	500–1,000 cycles
Lead-acid	30-40 Wh/kg	60-75 Wh/L	180 W/kg	50%-92%	7-18 Wh/US$	500-800 cycles

Figure 4.5: Battery types in electric vehicles and their properties
Source: adapted from Dinger et al. [214, p. 4-8]

The problems with battery technology have been an incentive for scientific effort concerning fuel cells, which are smaller, lighter and instantly rechargeable [238, p. 1].

4.2.4 Existing E-Mobility Infrastructures

Today's charging infrastructure market readiness and the interface standardization are the key pillars of EVs success and vice versa, both needing to be increased for optimal EV/ Grid integration.

Among PEV plugs there are two coexisting standards: SAE J1772, initiated by the Society of Automotive Engineers (SAE) as standard in the US, a five-pin plug with three different charging speeds [209, p.2]. As of May 2010, SAE announced a new standard J2836/1, providing a potential two-way communication between vehicle and utility grid[231].

Concurrently, the International Electrotechnical Commission (IEC) has implemented a second standard for connectors tailored to the European market: IEC 62196, a seven-pin plug, supported by automakers including Daimler, BMW, VW, Renault-Nissan, PSA, Fiat, Volvo, Ford, Mitsubishi and Toyota, incompatible with the American standard. [205]

As far as the charging facilities are concerned, there are four possible options which are illustrated in figure 4.6:

The first one is charging at home with a private garage or parking space.

	At home	Infrastructure facilities	At work	Public areas
Type of location	Own garage or parking space	Customer parking e.g. at shopping center	Parking space on the companies site	Public paring spaces
Private/ Public	Private	Private	Private	Public (City/Commune)
Electricity supply	Home connection Separate meter	Connection infrastructure partner Separate meter	Company Connection Separate meter	To be made accessible Or existing connection ports

Figure 4.6: Charging Facilities
Source: adapted from Smart E-Mobility GmbH [263, p. 9]

The second possibility is car charging at infrastructure facilities provided by institutions or companies on their property. The third possible solutions is charging the car with provided facilities on the company's site. The last option is charging the car at public parking spaces for example on the street.

With most car owners habit of night-time charging at home for convenience [220, p. 8], this first charging option currently has the largest market share. This implies a low demand for public charging grid infrastructure at night and a high demand in peak times when on the road and in need of ad-hoc energy.

4.3 Trends

In Section 2 there was a short review of the current status of E-Mobility as well as an introduction to the most important technologies and an overview of today's charging facilities. However, in Section 3 there will be an analysis of how these and further factors will develop in the next five years. Where will be gains in importance and how will this influence the smart grid?

4.3.1 Increasing Massmarket Feasibility of Electric Vehicles in Metropolitan Areas

Electric vehicles are expected to show up especially in metropolitan areas where the short reach is not a major problem as opposed to areas in the countryside where people have to travel longer distances without charging the vehicle on the way.

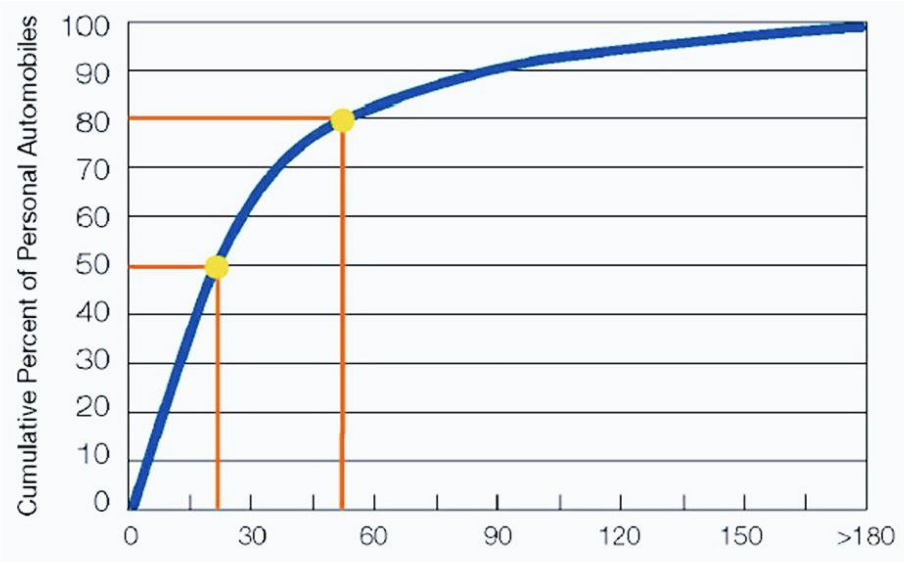


Figure 4.7: Travel Distance
Source: WWF [228]

Description

Urban and suburban areas are assumed to be the most feasible upcoming target markets for EVs due to limited daily driving needs of less than 80 kilometers, easily within range of a full charging cycle of current automotive battery capacity. For instance, 95% of daily car trips in London are less than 75 kilometers, 84% less than 20 kilometers [224, p.61], similarly figure 4.7 shows average daily travel distance per vehicle in the US in 2008.

In response to this, the increasing R&D effort of most major OEMs towards EV that could be observed over the last few years will increase at a predicted compound annual growth rate (CAGR) of 106% between 2010 and 2015, resulting in sales of more than 3.24 million vehicles. More than one quarter (27%) of upcoming worldwide sales during that period will be in China, closely followed by the US with 26%[273, exec.summary]. Concurrently, the market acceptance of EVs is predicted to increase: according to a survey by the Consumer Electronics Association (CEA), 40% of American adults report a likelihood of following future news reports and the willingness to test drive EVs [250].

Economic feasibility of EV is predicted to increase due to a substantial decrease of battery production cost following ongoing technological improvement and economies of scale in light of the increasing market penetration of electric vehicles. Current cost could be divided by ten, allowing for an estimated 150-200€/kWh

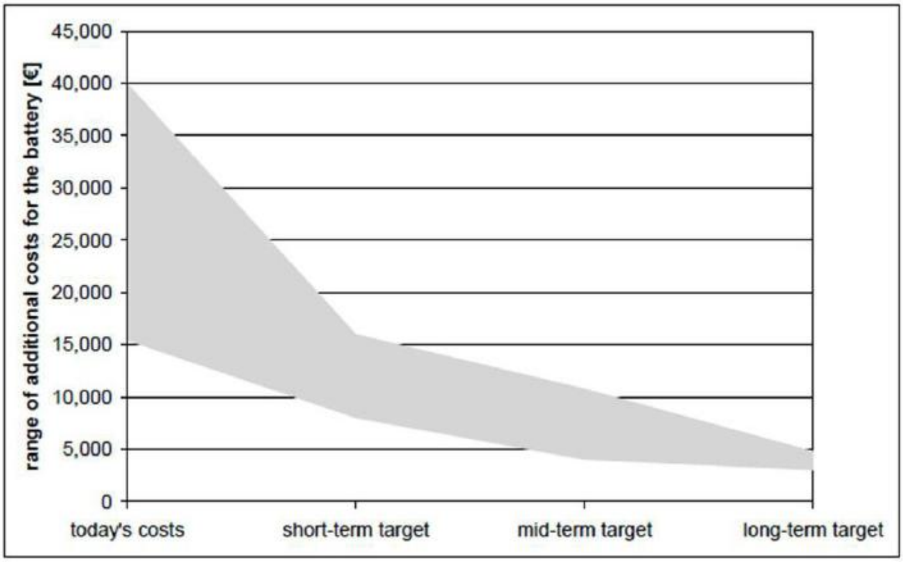


Figure 4.8: Expected Price Difference between ICE and EV
Source: Zimmer, W. [224]

within the next 20 years, which can be seen in figure 4.8 [232][230][241]. While today's battery costs constitute a price addition of 15000-40000€ compared to conventional ICE vehicles, this discrepancy is anticipated to diminish with technology development and lower availability of fossil fuel sources, resulting in a decreasing 10000€ mid-term and 5000€ long-term price premium of EVs versus ICE-solutions [224, p.40].

Impact on Smart Grid

The increasing capacity of the market to produce viable EV-solutions for metropolitan areas and correspondent increasing market demand enable realistic predictable market outlet assessments that justify further development of EV-solutions.

In addition, the predicted significant decrease of price difference between ICE and EV solutions will presumably incite more EV sales and fortify EV's relative market share, which in turn ensures the necessary cash flow for OEMs to strengthen their R&D efforts towards optimizing this technology and its applications.

4.3.2 Corporate Fleet Vehicles as Precursors for Electric Vehicle Integration into the Smart Grid

Corporate Fleet Vehicles can serve as precursors and role models for the wide adoption of electric vehicles and their integration into the electric grid in the future.

Description

Pilot projects replacing ICE with battery-electric solutions have been tested and implemented in fleets operating within short-distance and short-cycled daily driving patterns, such as parcel couriers and urban delivery vehicles [237]. FedEx' march 2010 declaration [249] to further expand its alternative-energy fleet to include BEVs is only one example in a series of increasing BEV-use in this sector, including UPS' June 2010 announcement of operating 200 new Hybrid Electric Vehicles (HEV) [248] and Verizon's June 2010 statement of acquiring 576 new Chevrolet HEVs [251], hence this trend will presumably gain in magnitude in the near future [213**?** , p.21].

Impact on Smart Grid

Increasing commercial fleet applications of EVs will facilitate an easy integration into the smart grid due to frequent start-stop operations and possible nightly charging at the depot [203]. In addition to the predictability of their charging and operating times and guaranteed minimal amount of vehicles (mostly 100+), this could enable a centralized company-wide smart metering system, perhaps integrated into already existing mileage metering devices in these use-adapted vehicles. The significant energy cost savings extrapolated to an entire fleet are likely to act as incentive to convince more companies in this sector to follow suit.

4.3.3 Increasing Need for Charge Control through Smart Metering to Balance Changing Electricity Load in Grid

Given the expected rise in EV adoption, there is going to be a challenging additional grid load for the electric grid. To handle the additional load, smart metering is a necessary concept for the future.

Description

The predicted increase of PHEV and EV sales in the near future will be accompanied by an increase in the power plants' required load. A full understanding of the vehicle's charge cycle effect on the grid is necessary to facilitate a frictionless emergence of a global vehicle fleet. Depending on the time and location of connecting these vehicles, they can cause local or regional constraints on the grid [225, p. 1]. Problems will mainly occur induced by the increase of energy demand caused by EVs: local distribution grids will be affected, some lines or substations could become overloaded sooner than expected [225, p. ix].

A research study of the U.S. government predicts that EVs could replace 73% of its domestic light vehicles without requiring any additional capacity under current conditions, apart from optimal flow management of available electricity [257]. Hence there is rising need for smart-meters -currently in their early development stage- that know the price of electricity and the user's driving habits and trigger charging of the EV accordingly [225, p. 4].

Precursor OEMs have started implementing this idea and are predicted to increase Research and Development (R&D) effort in that direction. The Ford Escape Hybrid technology for instance comprises a Vehicle System Controller device to manage charging [219]. Moreover, Mitsubishi implemented a wireless charging program in their Concept PX MiEV, thus signaling their interest to follow up the idea of smart charging in their series vehicles, allowing the owner to remotely start charging the battery[244].

The technology of charge control will allow real time control of the charging/discharging cycle, in all likelihood postponing EV charging during peak demand, initiating energy storage during times of excess capacity such as maximum wind and solar production [217]: all measures of Grid 2 Vehicle (G2V) optimization. In addition, this technology will later allow buying back energy from an EV's battery for load leveling or grid stabilization during peak demand [217], termed Vehicle to Grid (V2G, see 4.3.4).

Impact on Smart Grid

The first positive impact of EV's smart metering on the grid is an optimization of battery charging during off- peak hours when there is excess energy and electricity costs are at their lowest [260, p. 207-208]. Secondly, coordinated charging induces a reduction of power losses and maximizes the main grid load factor, hence reducing the load difference between peak and off peak hours [211, p. 371]. Lastly it is mentionable that smart charging will allow an easier integration of intermittent renewable resources to the grid [258].

Besides those regulatory effects of the smart grid, charge control is the first step towards Vehicle to Grid (V2G), because the technology is fully developed [272, p. 9-10] the only thing lacking is a successful implementation, for which further research and development will be helpful in the future.[253, p. 6]. Figure 4.9 shows the relationship between smart charging and V2G.

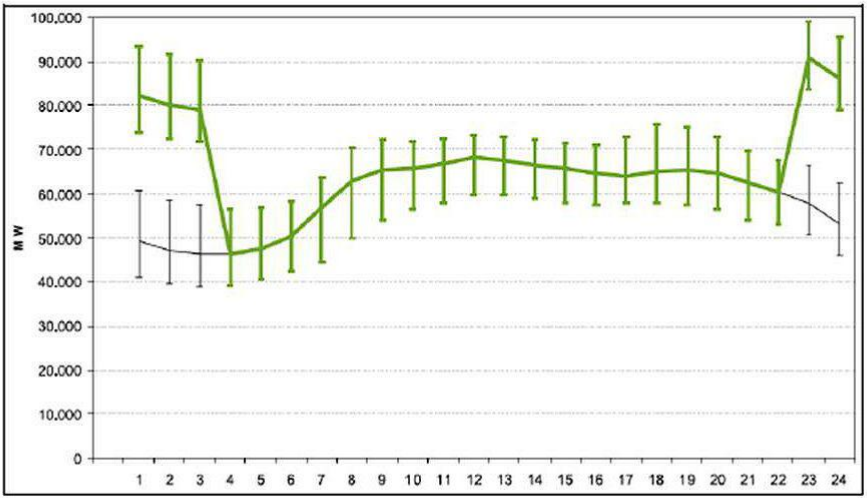


Figure 4.9: Load Management Estimatio
Source: WWF [228]

4.3.4 Research & Development Overcoming Obstacles Hindering Bidirectional Vehicle-to-Grid

After the first step of balancing the energy load curve by charging the vehicles in low-demand hours, there is an even more efficient way to integrate Plug-In vehicles into the grid. This principle and an ongoing trend concerning this principle will be explained in the next paragraphs.

Description

Bidirectional Vehicle-to-Grid (V2G) means that the battery of the car is used as a temporary energy storage for the smart grid and the energy stored can also be supplied back to the grid when necessary as one can see in figure 4.10 [255, p. 12]. So far there are no noteworthy pilot projects working on a larger scale, but more and more researchers are working on the topic. In Germany there are several research initiatives ongoing, like “MeRegio Mobil” [261, p. 3], “Harz.EE-mobility” [254], “future fleet” [223] or “eE-Tour Allgäu” [271]. But all of them are in early project stages and are about to tackle the V2G issue with field tests in later phases. The underlying technology is available, but not implemented yet. “The period from 2010 to 2015 is seen as the testing and demonstration phase (market infancy).” [275, p. 7] Before the V2G concept will be feasible in real life environment on a large scale, there are a number of issues that have to be addressed first. These are also the main research trends of public and private R&D now and even more in the future:

Storage obstacles

From a technical point of view, one main problem is the low capacity of current battery technology. A lot of R&D is going on in this respect (c.f. section 4.3.5). Even more important is the cycling expectancy of the batteries since frequent charging and discharging, which V2G naturally involves, has interdependencies with the remaining battery capacity [245, p. 25]. Today after around ten years an average battery has a residual capacity of 80 %, when not involved in V2G [214, p. 6]. If the car now was used as a temporary storage, this value would decrease. So far, the estimated value loss of the charging and discharging cycles is about 0.10 € per kWh [227]. There are possible solutions the researchers are currently working on. But there is a conflict of interests between the car manufacturers and customers who are keen to have a high reach and on the other side utilities which are mainly interested in an increased cycling expectancy [245, p. 25]. Some scientists argue that about 1000 charging cycles per year need to be realized first, in order to make V2G possible [218, p. 4]. A different possible solution to the problem maybe are new business models like battery leasing. The battery-owning firms would try to maximize the total lifetime value of the battery [252, p. 22]. Research initiatives are going on concerning a second life of batteries as fixed energy storage for the grid or even for commercial companies and private parties to store energy (e.g. from PV) or as a home energy backup system [252, p. 4]. Nevertheless some people say that about 200 € can be earned per car per year by providing the car as a temporary storage [227].

Control obstacles

There are also other technical matters which have to be addressed: the Plug-In vehicle's power electronics unit has to be able to work bidirectional and the whole system will require very sophisticated software and hardware in the vehicles [275, p. 7]. Beyond the basic technology, which is available, a sophisticated control structure has to be developed - there is a strong need for smart technolgies in the homes as well as in the cars [233, p. 54] and also wireless communication between provider and end-user (c.f. figure 4.10). There is no real consensus on the control of the V2G system yet. Direct control through the utility would involve a signal from the utility to the car or to a group of cars to start charging or discharging; in the indirect system the car would react intelligently to price changes and sell and buy the energy in the most economical way and therefore get the most out of the arbitrage [262, p. 3], but research on these topics will increase even more and as additional trend, standards concerning parking and charging infrastructure will have to be set [275, p. 49]. There has to be an adequate infrastructure including parking with the possibility to charge (apart from home also in the workplace, see figure 4.10, c.f. section 4.3.6) and metering and billing in place. The integration has to be seamless since the consumer behavior plays a decisive role for the success of the concepts: The procedure of plugging and unplugging to the grid has to be really without hassle otherwise the customers are not likely to do so every time they park their car. The system has to provide enough availability of storage when there is excess energy production as well as enough stored energy when there is exceed energy demand. This conflicts with the freedom of the car drivers to use their car whenever they want. Questions like this have to be answered: How does the system make sure that there is enough energy left for the next ride if one has to drive unexpectedly? [203, p. 44]

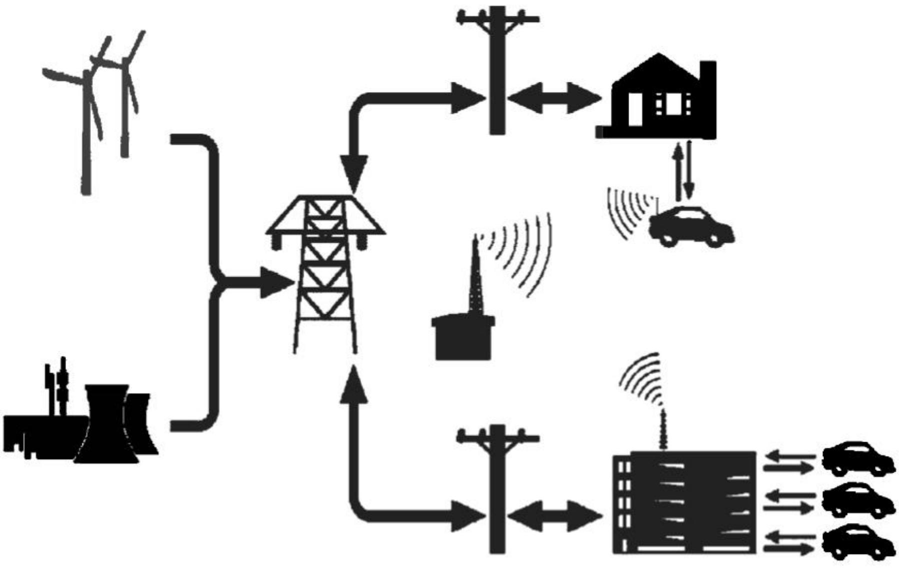


Figure 4.10: V2G Concept
Source: adapted from Kempton, W./Dhanju, A. [234, p. 1]

Impact on Smart Grid

As soon as R&D has overcome the mentioned obstacles and as the technology and infrastructure is in place and a certain mass of EVs are available for V2G, there will be several positive impacts on the smart grid: Mainly there is the possible role as time-critical spinning and regulation reserve [224, p. 144]. For Germany there are estimations that already around 2.5 million Plug-In vehicles (which equate roughly five per cent of the German car base installed), could provide the whole energy necessary to cover the whole operating reserve of the country [227] [1]. In the U.S. already about three per cent of the car fleet would be enough [236, p. 11]. One million electric vehicles could provide three GW of regulation reserve which equals about half of the installed capacity of pumped-storage power plants in Germany today. In this case the utilities would not have to rely on expensive combustion turbine plants to secure the coverage of the peak load [235, p. 18]. This would presumably reduce the energy prices for all customers.

If a larger number of cars would engage in V2G they could be even more efficiently used as a virtual power plant (see 3.3.1.1). However this will take a while since within five years V2G deployment will probably be limited to large vehicle fleets and some early adopters in the private sector [275, p. 55]. The usability of the V2G system though, is very dependent on the overall time Plug-In vehicles are actually plugged in and available for V2G. In Germany the availability is calculated to be around 89 %, which is quite high [226, p. 7].
Later V2G could as well serve as storage of renewable energy generation which is shown in figure 4.10 by the windmills [236, p. 11]. Since e.g. the PV energy production's peak does not coincide with the peak of demand there is a lot of storage buffer needed for this exceed supply. Hypothetically 26% of the U.S. car fleet would have to be under V2G contract [2] if the solar power supply was increased to 20 % of the production [236, p. 6]. Similar calculations are made about wind energy, although it is less predictable [234, p. 4]. V2G therefore is expected to be one of the key technologies to allow an extension of the use of fluctuating renewable energies [275, p. 6].

4.3.5 Increasing Energy Efficiency and Reach Extension of Electric Vehicles

Computing the well-to-wheel energy efficiency of any vehicle commences with reckoning the energy substance of the foundation fuel because it derives from the ground. The energy content of this fuel would be tracked as it gets rehabilitated to its final fuel product e.g. electricity, subtracting the energy needed to transport the fuel to the vehicle. Finally, the fuel efficiency of the vehicle itself would be added to complete the equation.

Description

Lithium is the lightest metal and has the highest electric potential of all metals. That isn't the only motive for the excessive usage of lithium-ions in cars though: Figure 4.11 shows that a lithium-ion–based car has extremely high well-to-wheel energy efficiency.

[1] 595 TWh total consumption in Germany; thereof 7 % photovoltaics / 365 days = ca. 100 MWh / day / 43 kWh (typical e-car battery) = ca. 2.4 Mio electric vehicles
[2] availability assumed at 50 %

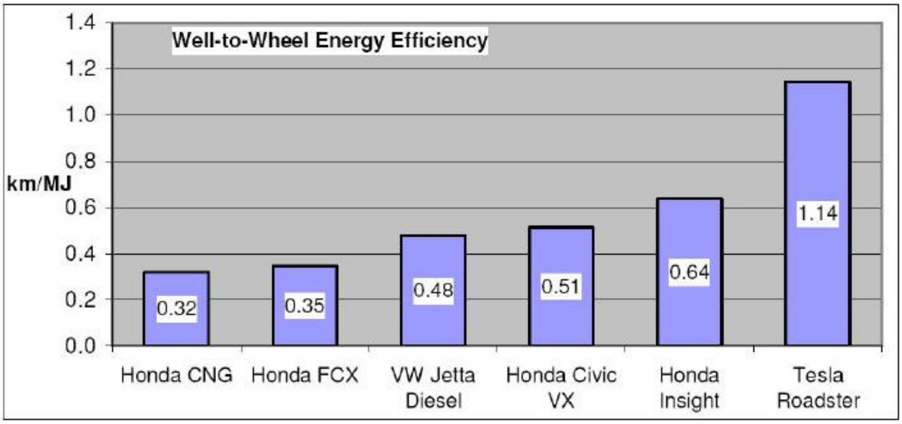


Figure 4.11: Well-to-wheel energy efficiency of high-efficiency cars
Source: Eberhard, M./Tarpenning, M. [215, p. 3-7]

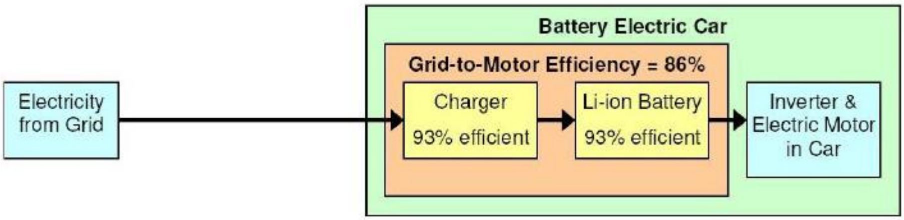


Figure 4.12: The energy efficiency of the electric vehicle battery
Source: Eberhard, M./Tarpenning, M. [215, p. 4-8]

According to figure 4.11, the Tesla Roadster reaches an energy efficiency of 1.4 km/MJ which is almost twice as much as the Honda Insight. This is mainly due to the chosen type of battery: Honda Insight's batteries are NiMh, whereas Tesla Roadster runs on Lithium-ion batteries.

The next figure illustrates the connection between the electric vehicle, the grid and its efficiency.

Figure 4.12 clarifies that with electric propulsion, it is difficult to beat lithium-ion battery's efficiency of 86% (93% x 93% = 86%). Even taking into account fuel-cell vehicle's high efficiency for compression and electrolysis, it needs three times more electricity from the grid than a lithium battery vehicle to drive the same distance.

With constant electric current, Lithium-ion comprehends higher efficiency than nickel-metal hydride (NiMH) and nickel-cadium (NiCd). When the duty

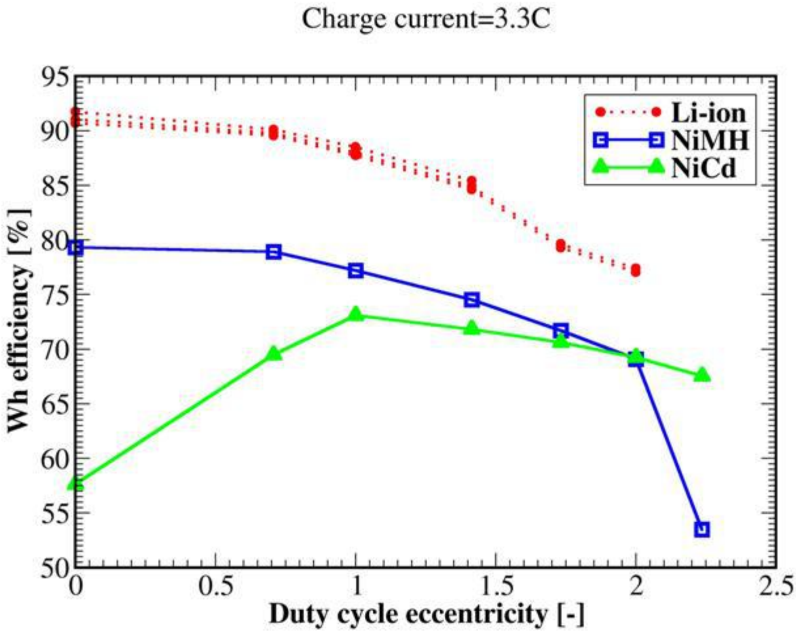


Figure 4.13: The duty cycle eccentricity and efficiency of different batteries
Source: Valoen, L. O./Shoesmith, M. I. [268, p. 6-8]

cycle eccentricity increases the energy efficiency decreases for all three types, but NiMH drops off faster than NiCd and Lithium-ion, as indicated in figure 4.13.

Figure 4.13 shows how the duty cycle eccentricity contributes to the range of energy efficiency in a vehicle's battery. As the duty cycle eccentricity of the electric current increases, the energy efficiency decreases for all three tested battery systems. With constant current discharge the efficiency of a Lithium-ion battery is considerably higher than comparable NiMH and NiCd batteries. The performed measurements using three cell series packs for NiCd and NiMH dispensed the same efficiencies as those performed for single cell tests.

Impact on Smart Grid

With the increase of the duty cycle eccentricity the heat production increases as well and offsets the gain in energy efficiency. However, this is not inopportune for the grid as it is of more essence for a battery charged using limited energy source such as stored energy from regenerative braking than for a battery charged from

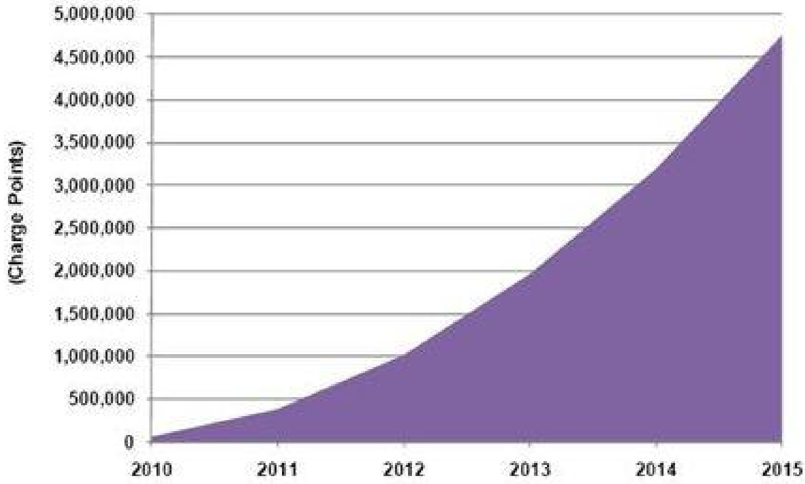


Figure 4.14: Installed EV Charging Equipment, World Market 2010-2015
Source: Gartner, J./Wheelock, C. [221, p. 3]

affluent power from the grid. Thus, the efficiency of a battery while charging is almost only conditioned by the energy efficiency of the grid-to-motor which is 86%.[268, p. 5-9]

4.3.6 Expanding Network of Charging Stations

The expanding network of charging stations is seen as one of the most critical factor for the potential success of electric vehicles. Within the next five years multiple solutions of charging facilities will be on the market and so far it is not clear whether there will one dominant solution.

Description

The two grid-relevant key aspects concerning charging stations are the charging methods on one hand (e.g. battery swapping or fast charging [222, p. 14]) and the increasing efforts of charging standardization on the other hand.

Firstly, as shown in Figure 4.14, the worldwide overall number of installed charging equipment will increase by 2015.

Fast-charging focuses on charging stations in the streets, with the first Coulomb's Charge Point installed in Detroit, Michigan on September second, 2010. The initiative will install 5000 charging stations in the US, providing authentication, a billing system, a future smart grid integration and efficient load management with future V2G capabilities[264]. However, fast charging stations are not capable of store energy. Moreover, there are no or only limited V2G Business Models within the next five years and thus fast charging stations cannot make use of their full potential and are expected to have no impact on improving the load balancing of the grid.

Battery Swapping has been initiated by “Better Place”[206], offering a system of battery-switch stations allowing drivers to exchange a discharged battery for a charged one. Swapping stations allow using the stocked batteries as storage, even draining energy back into the grid. Battery swapping can thus make better use of renewable energies and encourage the integration of renewable energies in the grid. Another advantage is that it allows controlled charging and load management, since the charging can be shifted to off-peak-times where energy consumption and prices are low. However, there are some concerns about the future success of battery swapping being costly for the station operators and requiring high standardization of battery location and size [220, p.8]. Thus, it is not clear which charging facility will dominate in the future [265].

Urban areas have been acting as breeding ground to the e-mobility development, primarily because EVs can remedy city-typical symptoms including exhaust pollution, noise overload and lack of dense inner-city gas station infrastructure. For instance, 1/4 of all 8000 EVs currently on the road in the UK are registered in London[247]. Hence the predicted rise of EVs expected market share in metropolitan areas. Experts anticipate charging of PEVs to take place near a primary residence[242], which will result in an increasing need for more public parking slots with (night) charging possibilities, since only few people living in the cities have access to a garage (16% in San Francisco) [201].

Companies like Better Place [256] and CHAdeMO[210] including OEMs have been trying to establish global standards that will eventually accelerate the wide-spread adoption of EVs. This includes the standardization of charging infrastructure components such as electric plug connectors and communication protocols. Further areas of focus are battery attributes and roaming.

Recent years have seen the introduction of several pilot projects connecting OEMs with energy utilities, mainly focusing on urban areas and the installation of a charging infrastructure [224, p.54], an evolution that is predicted to intensify in the upcoming years, supported by co operations between OEMs and energy-distributing utilities such as BetterPlace [224, p.58].

Impact on Smart Grid

The increasing number of charging stations around the world within the next five years stresses the need for the development of a smart grid. If people only charged their cars at night at their homes, there would be no need for additional generation capacity. However, there is a risk of local power transformer breakdown in areas with higher density of electric vehicles, which is even higher during peak-times [200][242].

Using the concept of battery swapping stations would offer a better integration of renewable energies in the grid and allow energy storage. This promotes shifting EV-charging to non-peak times and would imply a capacity relief, necessitating load management through a smart grid.

Standardization is one of the prerequisites for a future smart grid. Therefore, major utilities and OEMs increasingly trying to establish standards for plugs and EV infrastructure that are necessary to build the up a foundation for a viable smart grid.

Further, the intensifying co operations of both industries are accelerating the understanding and optimal integration of e-mobility with the grid and contribute to the fast development of tools and systems to interconnect electric vehicles and the energy industry.

4.3.7 Proliferation of New Pricing Models Concerning E-Mobility by Utilities

Within the next five years, electric vehicles will still be facing one main hurdle: the very high initial costs. To accelerate the adoption of electric cars, car manufacturers as well as utilities and battery manufacturers, will have to consider establishing new attractive pricing models.

Description

The main factor inhibiting EVs full market penetration is their high initial cost, caused by expensive batteries that can make up to 50% of the total EVs. In addition to that they also have a shorter lifetime than the EV, hence battery replacement will be necessary. Another hurdle for EVs is that costs savings compared to an ICE only occur after a very long operation time. To solve this while accelerating adoption of EVs there is a trend towards establishing new pricing models: the first option is that customers purchase the car without the battery, cheaper than an ICE-vehicle. As far as the battery is concerned, there are several options such as leasing, renting or different tariffs depending on time, distance or energy consumption. Furthermore, there are various options concerning the battery leasing: customers could lease their battery from the car manufacturer, or from the energy utility company [263].

Impact on Smart Grid

New pricing models will enhance the energy usage predictability due to consumption based leasing contracts with utilities and increase financial feasibility for private users due to lower initial costs of the EV. Thus, new pricing models lead to a higher number of EVs in the long run [267]. Initiatives like Better Place focusing on battery charging while it is removed from the car, strongly favor the development towards such new business models. Trading batteries

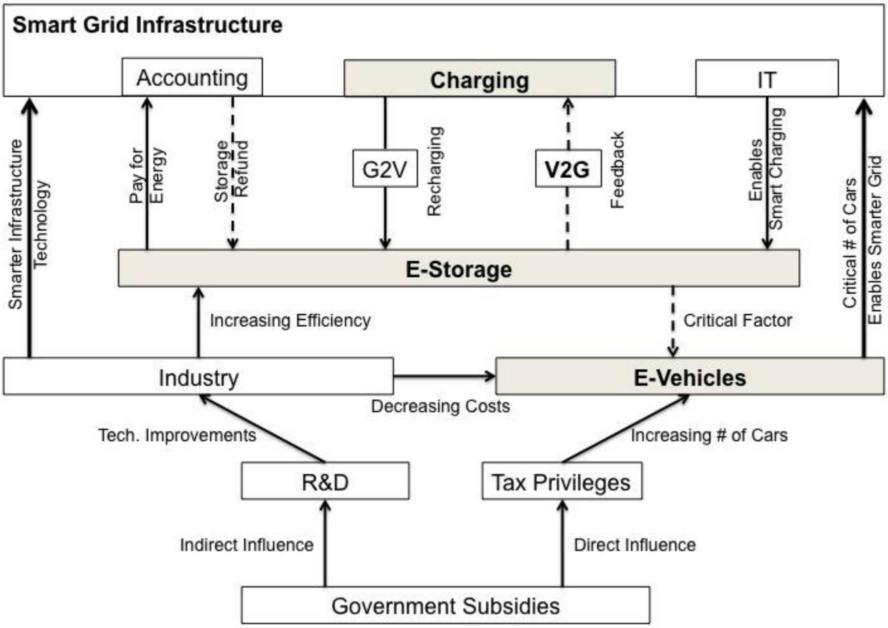


Figure 4.15: Trend Prospect: Smart Grid Infrastructure and E-Mobility
Source: own illustration

and cars separately is also an opportunity for new load balancing and storage systems such as the batteries' second life in the grid.

4.4 Conclusion

As previously described, several different trends are likely to occur within the next five years, rendering the grid infrastructure smarter in comparison to its current disposition.

The predicted changes and improvements among the market players within the E-Mobility/ grid interaction are shown by comparing the status quo diagram (c.f. figure 4.1) with the respective trend prognosis diagram (figure 4.15), highlighting relevant factors and relationships of the future -smarter- grid. Within the next five years governmental subsidies will have a direct impact on research and development in the field of e-mobility. This will help the industry to conduct technology improvements towards optimized EV-solutions, tailored to a more efficient grid infrastructure. Following their enhancing mass production, improving processes and increasing storage efficiency, the cost of EVs is likely to decrease. The intensified amelioration of the storage efficiency -currently a critical factor limiting EV's market penetration potential- in particular will make EV-systems a viable mobility solution. E-mobility's alignment to the grid infrastructure will help laying the groundwork towards a smarter, more energy-efficient grid. The current IT technology state of the art is sufficiently advanced to allow smart charging, a fact that is likely to empower the industry to develop efficient G2V solutions. Concurrently, the refinement of the mechanisms will enable customers to feed their stored or generated energy back to the grid, paving the way for V2G applications.

Tax privileges for customers buying an EV, yet another form of governmental support, will have a direct positive influence on sales number of e-vehicles in the near future, underlining their immediate importance in speeding up EV-sales, hence attaining a critical number of vehicles acting within and on the grid, a necessity towards quickly becoming a smarter grid.

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5

Chapter 5

Market Players and Market Trends in Europe

Tanja Kornberger, Maximilian Matschke, Sonja Stockert, Wesley Stuurman

In this section the status quo and the trends towards a smart grid are analyzed from a market perspective. The current status in the European national markets are compared and show a large disparity between the frontrunners and the non-adapters. As a possible threat to smart grid deployment, the high level of Mergers and Acquisitions (M&As) activity taking place is using up financial resources to the detriment of investments in smart grid technology. However, legislation, public awareness, EU research and support, as well as investments from outside the sector push smart grid deployment forwards. In the coming five years we can expect to see a growing role for renewable energy and distributed generation leading to an expanding role of ICT technology in the operation of the energy grid. To combat increasing complexity and instability, plans for a European SuperSmart Grid will become more tangible and will perhaps yield their first results. This should lead to the opening of a real-time European Energy market where supply and demand can be balanced. Again, public awareness and legislation will be major driving forces in these developments. Moreover, adaptation of smart metering can be quickened by pointing out the cost savings to consumers. However, possible privacy concerns could hamper adaptation.

5.1 Introduction

Europe's electricity networks have provided the vital links between electricity producers and consumers with great success for many decades [297]. They have been supportive of a business model in which the roles of supplier and consumer were both clearly defined. Increasingly, this model is becoming outdated and is being replaced with a business model where interaction is a key understanding and the traditional boundaries between the different market parties are becoming less distinct every day. The smart grid infrastructure that is being implemented and tested in more than seventy projects around the world, is the grid of the future [316]. On the pages below, the European energy market and its various elements are analyzed in their current form. Highlighted are the differences between the various national markets and the different approaches to smart grid deployment. Moreover, several external factors such as legislation, investment and public awareness are to be assessed in order to complete the picture of the present-day European energy market. Building on this, the trend section emphasizes the trends over the coming five years, where these trends come from and what they signify in the changing market place.

5.2 Status quo

In this part, the current European Energy market is descriped in combination with various external factors. The current situation is visualized in Figure 5.1. Market players are strictly divided into supply and demand side which, in a continues cycle influence each other. However the communication between market players is limited and there is a clear seperation of supply, demand and the different sectors within the energy market. The identity of all the market players are clear. In the first part, section 2.1, the current European markets and its players are examined while the second part, section 2.2, identifies three external forces influencing the market situation.

5.2.1 The Present-Day European Energy Market

The first section categorizes European countries into frontrunners, planners and non-adapters in view of smart grid development. Next, European markets and market players are examined. The last section covers cross-European cooperation related to a smart grid.

5.2.1.1 European Smart Grid Deployment: Frontrunners, Planners and Non-Adapters

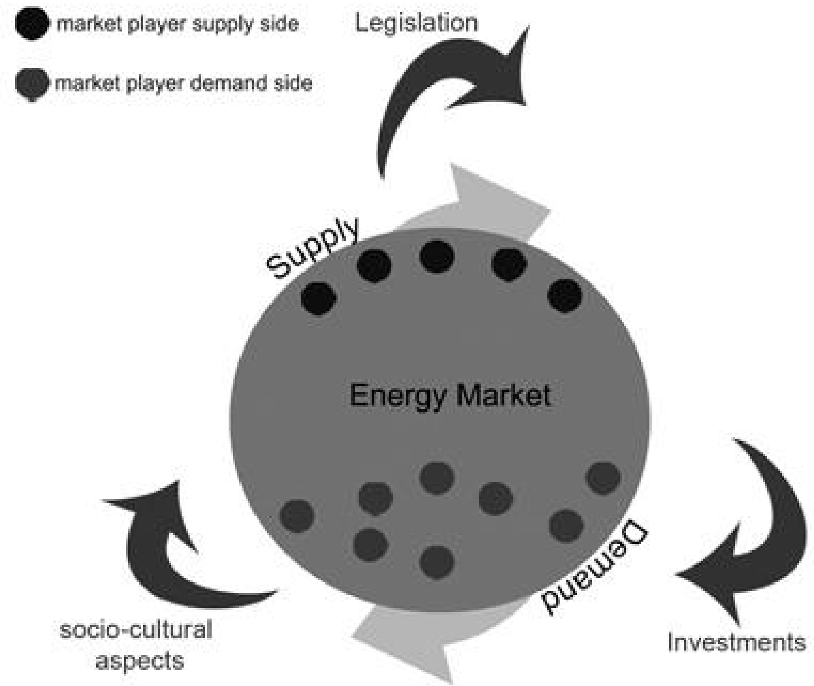


Figure 5.1: Illustration of the current energy market and its influences
Source: own creation

Group/ Description	Frontrunners	Planners	Non-Adapters
Smart Grid Investment	High	Medium	Low
Smart Metering	(Near) Complete Rollout	Pilot-Projects	No or limited deployment
Future Plans	Building upon Existing Infrastructure	Full Scale Introduction of Smart Metering and Smart Grid Technology	No Plans beyond the Minimum as set by EU Legislation

Table 5.1: Comparison of European Smart Grid investments
Source: own creation

Smart grid deployment within Europe has so far lacked a coherent plan. Rather, various local, national and European initiatives have invested in smart grid technology projects with different focuses and different expected outcomes. Moreover, the level of urgency is not equal among the various European States even though European legislation has been passed that commits EU member-states to rolling out smart meters to 80% of the households by 2020 [324]. The choices that have been made in investing in smart grid technology and smart metering differ from country to counry because of the variety of emphasis that is put on the importance of a smart grid rather than investing in other energy sectors such as renewables or nuclear energy. In Table 5.1 three different categories of countries and their most important properties are identified: frontrunners, planners and non-adapters.

Frontrunners are leading the deployment of a European smart grid. In some countries such as Italy, the roll out of smart meters was seen as a solution to the pressing problem of customer relation management. Some 85% of Italian homes are now outfitted with smart meters. This is the highest percentage in the world and although the meters were not very smart to begin with, future software rollouts with added capabilities depend on the infrastructure in place. A similar roll-out of smart meters has taken place in Sweden [325]. In countries with a high percentage of renewable energy production, the need for smart meters will become evident very soon to ensure a continued stability of the grid. The Planners therefore have invested considerable effort into pilot projects that precede a nation-wide deployment of smart technologies. An example of such a country is Germany which currently has six pilot projects underway. Non-Adapters have currently either made very little or no investments in smart grid technology. These countries are lagging behind because of a lack of investment and attention. An example is Portugal, which although very reliant on renewable energy, has not been active in smart grid investment. Smart meters are one of the first steps towards a smarter grid because they enable the provision of dynamic pricing, which reduces peak demand and lowers the need for building and running expensive peak power plants [302]. When smart meters are in place, is it possible for the grid as a whole to upgrade to a smarter existence.

5.2.1.2 Mergers and Acquisition: The European Energy Market Landscape

In the last few years, the energy sector has seen an increased amount of movement as many companies have concluded M&As with foreign or national competitors. A recent financial markets report estimates that the value of EU deals, just considering those operations concluded in 2006, increased by 56% in a year, and the number of bids increased by 25%, marking a higher-than-ever level [331]. The economic crisis has impacted the amount of M&As taking place, with limited activity in recent years. The ongoing liberalization of the European energy market has in first instance led to a disintegration of many energy companies by splitting the several divisions (retail, transmission, production etc.) into different companies or stand-alone units. The increased liberalization on the energy market then led to a crowded marketplace where the small players were quickly snapped up by larger corporations. This development has taken place unevenly with some markets (retail) being more competitive than others. Some countries have even actively intervened to create large energy companies that dominate the home market and are able to compete in the European market [331]. Thus, European companies have chosen to invest their additional liquidity in M&As, to the detriment of investments in generation, transmission, or even in exploration activities. The market dictates short-term returns and investing in smart grid technologies is a long-term process with uncertain returns for the companies.

5.2.1.3 Cross-Border Cooperation: European Grid Integration and Research

The investments made in European grid integration have been limited and experiences have not always been good. This was illustrated in November 2006 when the shutdown of one power line in Bremen led to blackouts throughout Europe. The power grids have been constructed from a national perspective, although the European markets have been interconnected for decades. However, there has been no need for strong interconnections in the past and the connections that are available are in most cases inadequate. This has led to congestion at most of the borders at a time when interlinks are becoming more crucial every day. 321. High-tech lines are part of a network plan recently unveiled by the European Network of Transmission System Operators for Electricity (ENTSO-E). The plan would lead to more than 42,000 kilometers of high-voltage lines built or replaced throughout Europe by 2020. The idea is that a new and more flexible grid will create more opportunities to balance supply and demand [314].

To deal with the various projects going on, the EU has set up a task force for smart grids who facilitate and support smart grid implementation by sharing knowledge and research. Its goal is to tackle the existing barriers to the roll out of smart meters and smart grids [329]. Moreover, the EU has invested into several smart grid projects such as the “Smart Cities” initiative that is meant to deploy smart grids in twenty cities by 2015. For smart grid technology to really work, scale is needed and that is why EU involvement is important in realizing an open marketplace where technology can be used to balance supply and demand and hence, the market.

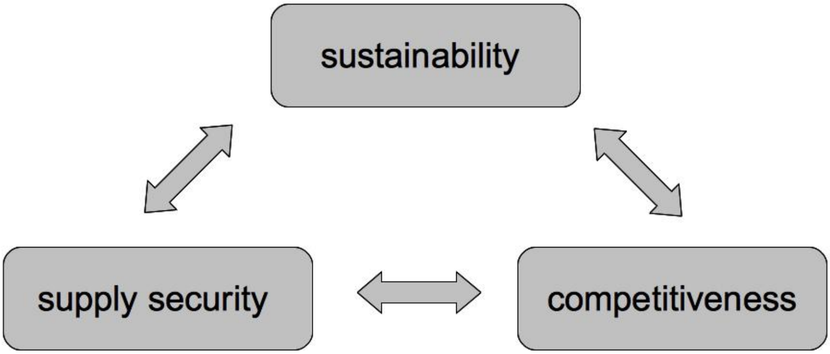


Figure 5.2: Three major objectives of a single European energy market
Source: adapted from [283, p. 3]

5.2.2 Factors Influencing the Market Structure and Players

This section takes a look at all the market factors that are not directly integrated into the market but still have a major influence on its structure and players.

5.2.2.1 The Regulatory Framework for a Single European Energy Market

Since 1993 there is a single European market, however this does not hold truth for the energy sector [306]. Nonetheless there have been various efforts to create a single European energy market, which has three major objectives. As shown in Figure 5.2 the single market ought to be characterized by sustainability, supply security and competitiveness.

The first liberalization guidelines for electricity were created in 1996, according to those guidelines electricity is a good and falls under the principle of non-discrimination [306]. Further changes achieved by EU Electricity Directives are summarized in Table 5.2. The table lists all relevant aspects of the energy sectors while showing concrete changes achieved through EU Electricity Directives in 1996 and 2003. It can be seen for example that since the Electricity Directives of 2003 the unbundling of transmission and distribution have to be enforced by law.

	Most common Form pre-1996	1996 Directive	2003 Directive
Generation	Monopoly →	Authorization Tendering →	Authorization
Transmission / Distribution (T / D)	Monopoly →	Regulated TPA, Negotiated TPA, Single Buyer	Regulated TPA
Supply	Monopoly →	Accounting separation	Legal separation from transmission and distribution
Customers	No Choice →	Choice for Eligible Customers (=1/3)	All non-household (2004), All (2007)
Unbundling T / D	None →	Accounts	Legal
Cross-Border Trade	Monopoly →	Negotiated	Regulated
Regulation	Government Department →	Not specified	Regulatory Authority

Table 5.2: EU Electricity directives
Source: adapted from [312, p. 10].

In 2007 the EU brought up a "Climate and Energy Package", containing the so called 20-20-20 targets. In detail those targets focus on increasing the consumption of renewable energies to 20% and decreasing the use of primary energy sources also by 20% till 2020 . Further within the same timeframe there should be a 20% reduction of EU greenhouse gas emissions (GHG) according to 1990 levels. Those goals are directly addressed through the EU's energy efficiency action plan [289].

In June 2009 the European Council adopted the "3rd Internal Energy Market Package" and made a huge step towards the liberalization of the European energy market [298, p. 20ff]. It aims to strengthen consumer rights by i.a. providing all relevant consumption data to the consumer. Further the implementation of smart meters becomes mandatory. By 2020 80% of the population is supposed to be provided with smart meters, as mentioned in 2.1.1 [311].

Within this package the creation of the Agency for the Cooperation of Energy Regulators (ACER) is enacted. ACER will start its work in 2011 aiming to ensure the coordination of rules on network access across borders [292, p. 9f]. The most important factor included in the package is the unbundling of vertically integrated incumbents [322, p. 17]. As the primary unbundling option, the 3rd Internal Energy Market Package forsees ownerships unbundling [311], which means that an entity is not allowed to control generation or supply, and transmission at the same time [317, p. 86]. From June 2009 on the EU member states have 18 months to transform the directives into national law [311].

Though not fully implemented a single European energy market would create both incentives and opportunities for the deployment of a smart grid. With the compulsory implementation of smart metering, legislation as an external factor is already paving the way for a smart grid infrastructure.

5.2.2.2 Awareness on Environmental Issues and the Smart Grid

The topic of climate change and its influence on our environment gained significant relevance in recent years. Where politics failed to provide necessary steps towards a greener future the public awareness rose towards issues related to the impacts of climate change, alternative energy use and green technologies. According to the "Eurobarometer", a regular survey conducted by the European Commission, European citizen see climate change as the second most urging problem the world is facing today, two-thirds rated it to be a very serious problem [290, p. 20]. On the other side less than one third thought that the EU has undertaken sufficient efforts in order to fight climate change [290, p. 20]. In 2006 almost half of the European citizens mentioned that they tried to reduce their energy consumption [288]. Measurements in 2009 showed that this figure has risen to 63 % [290, p. 73].
Though already in 2006 Europe's citizens showed a positive attitude towards the use of renewable energies, reflected in an increased readiness to use those [288, p. 28], when asked in 2009 which actions they have already undertaken to fight climate change, only 6% mentioned the use of renewable energies [290, p. 73]. However, almost half of the Europeans are willing to pay more for alternative energies (49%). Figure 5.3 shows in detail how much more Europeans are willing to pay for energies producing less GHG emissions.

This already is the necessary foundation for a high acceptance of new technologies necessary for a smart grid. Further, governments are already offering incentives for citizens enganging in the usage of renewable energy sources (RES) [287]. Additionally in 2003 the EU started a program on educating people towards a more rational energy use called "Intelligent Energy - Europe" [291].

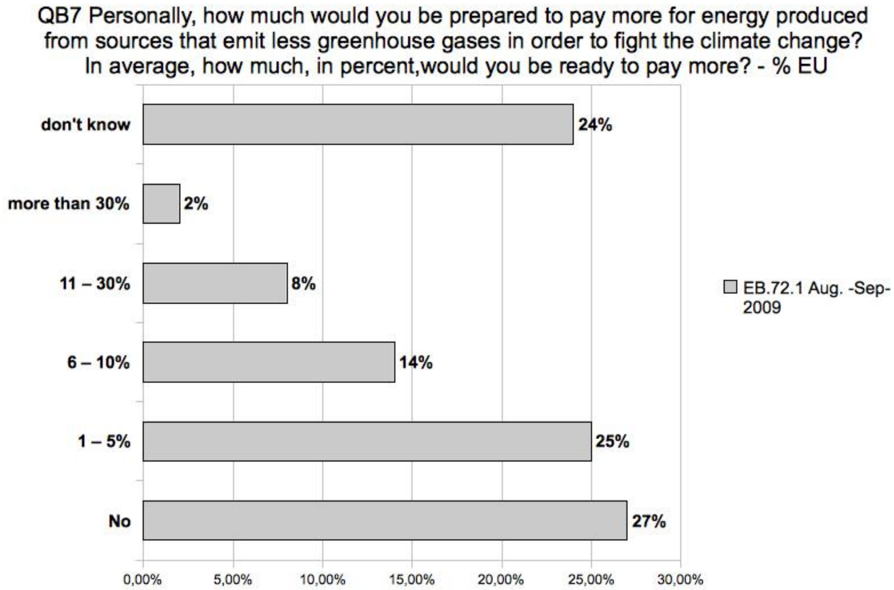


Figure 5.3: Willingness to pay more for environmental friendly energy sources
Source: adapted from [290, p. 86]

Country	Smart Grid Investments 2010
Spain	$807 m
Germany	$397 m
UK	$ 290 m
France	$ 265 m

Table 5.3: The four highest European Smart Grid investments.
Source: adapted from [336]

5.2.2.3 Public and Private Investments in the Smart Grid

Though the necessary hardware for implementing a smart grid is quite expensive andinvesting in smart grid nowadays is not without risks, there still is a reasonable number of public and private investments. In 2010 four of the top ten countries investing in smart grids are from Europe, including Spain ($807 m), Germany ($397 m), UK ($290 m) and France ($265 m), which can also be seen in Table 5.3. A study of pikesearch estimates the total volume of global smart grid spending from 2008 to 2015 to amount to $200 bn [326]. The European Technology Platform even forecasts European-wide investments to rise up to €390 bn [279]. German electric utilities alone plan on spending €15 to 25 bn until 2020 in the development of smart grids [307, p. 72]. Reasons for investing in smart grids vary as much as the estimations as to which amount investments may further rise. Beside the mentioned public spending, also industrial players like Cisco [315] or Google [313] invest large amounts in the smart grid. A lot of those investments are in start-ups and research concerning the smart grid. GE even created a smart grid challenge, offering $200 m for the best ideas concerning smart grids, renewable energies and green buildings [285].

5.3 Trends

The above described factors and the adaption of available technologies lead to profound changes on the European energy markets. Figure 5.4 describes the future energy market in 2010. ICT serves as a connector, enabling information flows among all market players. Secondly, the strict divide between demand and supply side disappears and customers tend to become prosumes meaning they serve as supplier and consumer.

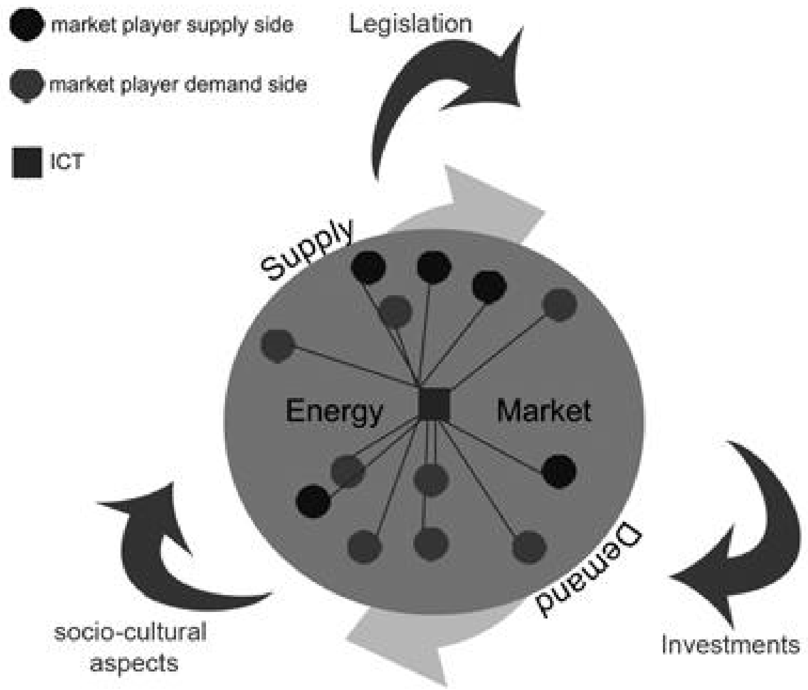


Figure 5.4: Framework for the market trends
Source: own creation

5.3.1 Structural Market Changes on Supply Side

The following chapter examines the structural market changes from a supply side perspective. As the merger of ICT and energy sector leads to changing roles of traditional market players [304, p. 144ff], the impact of each actor along the supply value chain is analyzed. The last section concentrates on the development of new markets at the intersection of ICT and energy and describes important future market players.

5.3.1.1 Emerging Decentralized Production Shifts Market Power

Green movement, mature technologies, EU targets and governmental subsidies lead to increasing use of RES. Aggregating power of DG units endanger the market share of traditional utilities.

Description

In the short and long run, the renewable energy segment has high market growth predictions. As the EU Heads of State and Government target a 20% share of renewable energy of the overall consumption in 2020 [300], renewable energy production will expand. Consequently RES are an interesting market for new entrants, attracted through high potential growth rates, governmental subsidies [305] [334], high potential innovations in growing markets and increasing environmental awareness among the public. Through the prognosed ending of fossil fuels and the public discussion of the carbon energy phase-out, the trend goes towards broadening the energy production base.

Renewable energy production takes place decentralized in small and medium sized plants. The comparatively small size of the plants leads to decreased investment risks which lower the barrier of entries for new suppliers. Additionally, small-scale decentralized power plants gain higher market chances through ICT. Decentralized plants can bundle their market power through being connected and centrally operated due to communication technologies [280, p. 11]. The so-called Virtual Power Plants aggregate small-scale plants of different power sources and can cope with high fluctuating RES. The plants can either be third party or end consumer owned and centrally operated [293, p. 112ff].

Large traditional utilities face high investments in renewable energy generations, driven by the green movement and forced by legislation in terms of the EU 2020 targets including a 20% reduction of greenhouse gas emissions [300]. Through the trend towards energy market fragmentation and structural changes from fossil fuel and carbon plants to decentralized renewable energy plants, the market share of traditional utilities decreases. Their existing business model needs to be adapted. A concept for utilities can be the controlling and operation of Virtual Power Plants which aggregate decentralized third party or end consumer owned plants.

Impact on Smart Grid

EU 2020 targets and governmental subsidies will boost DG of RES. Increasing share of DG and RES underlines the necessity of a smart grid infrastructure and thus supports the smart grid establishment. Traditional utilities can play an important part when adapting their traditional business model. They can integrate small-scale decentralized RES into Virtual Power Plants which further supports the Smart Grid development.

5.3.1.2 Distribution Network Operators' Changing Role Enabling Bi-directional Information and Energy Flow

The increasing share of DG challenges the existing power network. DNOs have to become more involved in controlling and managing power flows [333], formerly done by TSOs.

Description

To overcome the limits of DG and RES, new investments in the distribution network are necessary in order to allow bi-directional energy flows [284, p. 380]. DNOs face a changing role from an energy distributor towards an energy control and management entity. Active distribution networks link power sources with consumer's enabling real-time communication and information flows. Through smart metering infrastructure, smart sensors, two-way communication devices and networked connection between feeders, active distribution networks integrate market players effectively [286]. Bi-directional information flows connect endpoints with the control center allowing real-time pricing and energy control [296]. The concept of DNOs' increasingly important role leads to intelligent nodes which are spread throughout the system allowing decentralized decision making [286]. Advantages of decentralized generation and control are increasing capacity as supply and demand are within a distribution network [309] and more efficient usage of the infrastructure through access of a higher penetration of decentralized energy providers [280, p. 11].

Impact on Smart Grid

Through an increasing share of decentralized energy production the DNOs have to adapt their role. Load balancing and grid control which was formerly mainly done by the TSOs, become increasingly important for DNOs. The changing role enables smart power routing and increasing efficiency through bi-directional energy and information flows. Moreover the changing distribution network allows a higher percentage of RES.

5.3.1.3 Starting Initiatives towards the Development of a European SuperSmart Grid

A Super Grid is defined as "a wide area transmission network that makes it possible to trade high volumes of electricity across great distances" [321,p. 86] whereas a European SuperSmart Grid (SSG) is "a hypothetical system which would unify Super Grid and Smart Grid capabilities and technologies into a comprehensive network. Envisaged to connect Europe with northern Africa, the Middle East [and] Turkey (...)" [321, p. 86].

Description

As most European high-voltage grids are reaching their maximum life time, which is about 30-50 years, an upgrade and maintenance will be necessary [282]. As mentioned in 2.2.1. the EU is pushing towards an increasingly connected

European network. One emerging trend out of those conditions might be starting initiatives for a European SSG. Figure 5.5 illustrates existing and planned trans-boundary HVDC interconnections in west Europe.

Impact on Smart Grid

A European SSG supports DG of RES and builds the foundation for a single European market. A survey concerning the stakeholder perceptions of a SSG from 2009 asked i.a. for the necessary next steps towards a SSG. As can be seen in Figure 5.6 the common EU energy policy and a long-term climate policy were mentioned to be most important.

5.3.1.4 Increasing Competition among Retailers

An high innovation potential through ICT enabled services boosts new market entrants which increases competition.

Description

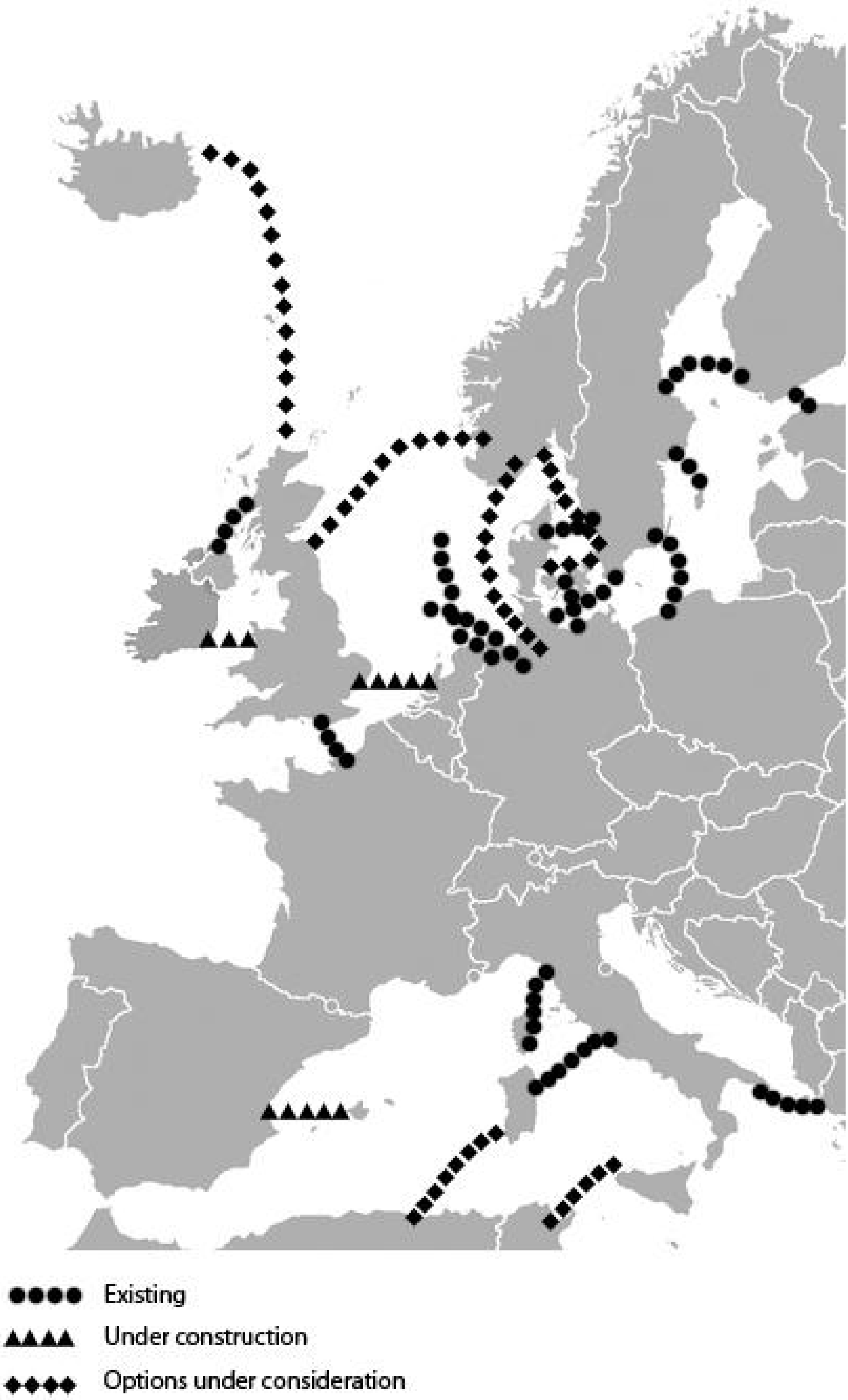
The use of new technologies offers high diversification potential of value-added services. Instead of enforcing the market position high technological opportunities lead to the entry of new innovators which increases the competition among retailers [294, p. 378]. This development leads to a customer-centric market [319].

Impact on Smart Grid

Increased competition and diversification efforts lead to a growing number of value-added services. The development of customization increases the attractiveness of smart grids for consumers. Rising attractiveness for customers supports the development towards an active customer role which is essential for effective smart grids.

5.3.1.5 Increasing Growth Potential and Investments at Intersection of Energy and ICT

ICT plays a key role in the future of the energy sector. New evolving markets at the intersection of Energy and ICT have a high growth potential and thus attract new market entrants.


Existing
Under construction
Options under consideration

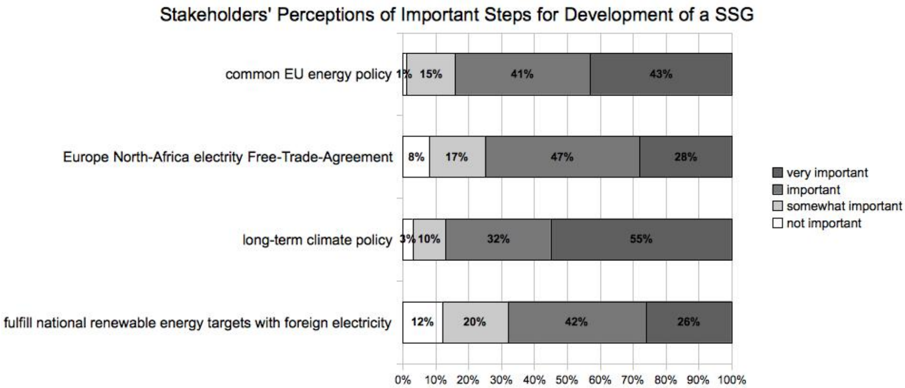


Figure 5.6: Stakeholders' perceptions of important steps for development of a SSG

Source: adapted from [281]

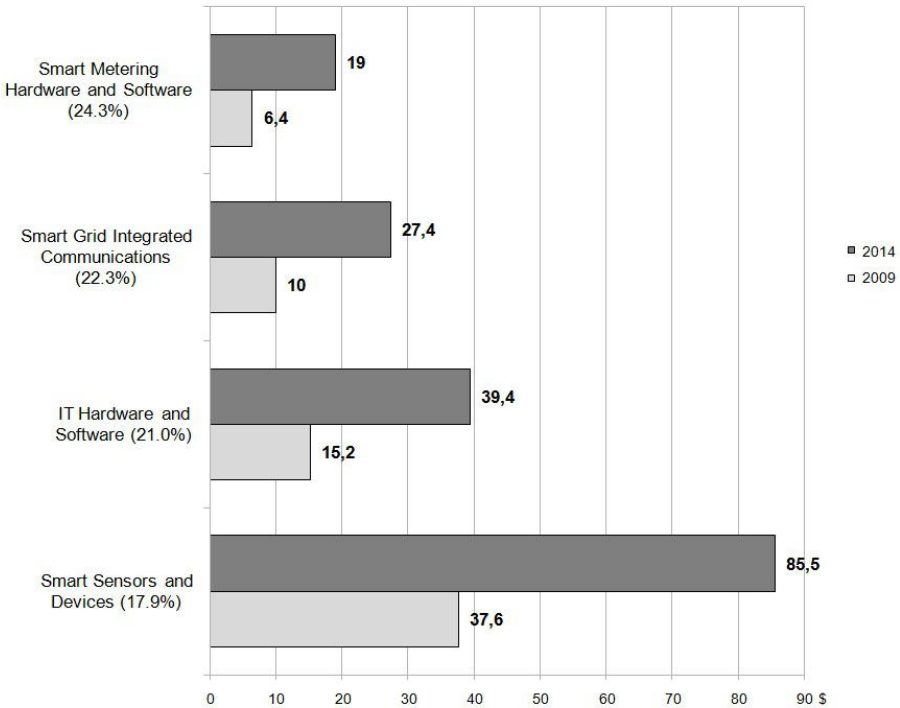


Figure 5.7: Projected global Smart Grid market for 2009 and 2014 (by technology)

Source: adapted from:[295]

Description

Three domains are evolving in which ICT architectures build an overlay on top of the existing electricity energy industry. ICT enables new market services, grid quality services and green efficiency services. Market growth predictions for Smart Grid related ICT products and services are 19.9% p.a. [295]. Figure 5.7 shows the smart grid market divided by technology, with the segment of smart sensors and devices having the highest market volume. Smart metering hardware and software will account for only 11% of the market share by 2014. Additionally, complementary services for smart grids are rising. The smart grid cyber security market is predicted to have a share of 15% of the total smart grid capital investments between 2010 and 2015 [318].

Impact on Smart Grid

ICT related products and services enable the development towards a smart grid. ICT originated companies are stepping into the evolving market at the intersection of Energy and ICT. Microsoft, Oracle and Google as well as many new ventures are entering the market, both groups are attracted by high growth rates. The companies profiting most from the smart grid development are small and medium sized companies specialized in energy and ICT [326]. Further, investments in new markets at the intersection of energy and ICT foster the development of products and services which strive for efficiency and increase the scope of the smart grid while accelerating consumer acceptance.

5.3.2 Consumer Driven Changes in Energy Demand

As described above, suppliers are keen to develop and implement a smart grid infrastructure. Nevertheless a market does not only consist out of supply but also out of demand. The customers are predominantly the production industry and the households. As long as they do not have any intention to adapt the new technologies the system of supply and demand will not be adopted. Therefore incentives have to be found and implemented to strengthen the demand for a smart grid among energy consumers. The part of the smart grid infrastructure that is visible to the consumers is the smart meter. Incentives to install a smart meter can be driven by economical, personal, social or legal factors, whereas there are also obstacles that hinder the development. [276]

5.3.2.1 Considerable Cost Savings Increased through Smart Metering

The first and predominant incentive to participate in the smart grid for a consumer is the potential for cost savings.

Description

80% of the commercial consumers state that financial aspects are the most relevant reason to participate [303]. The instrument to monitor energy costs is the electric meter. With the latest version of smart meters two-way communication is possible and thus customization of tariffs can be put into place. [332] The awareness of the cost of energy is rising. 85% of the consumers are interested in learning about electricity management programs [308, p. 21], whereas only 28% of the people have heard about programs with which they can optimize their energy consumption. [276]

Impact on Smart Grid

The energy consumption over one day varies strongly. Figure 5.8 shows this variance.

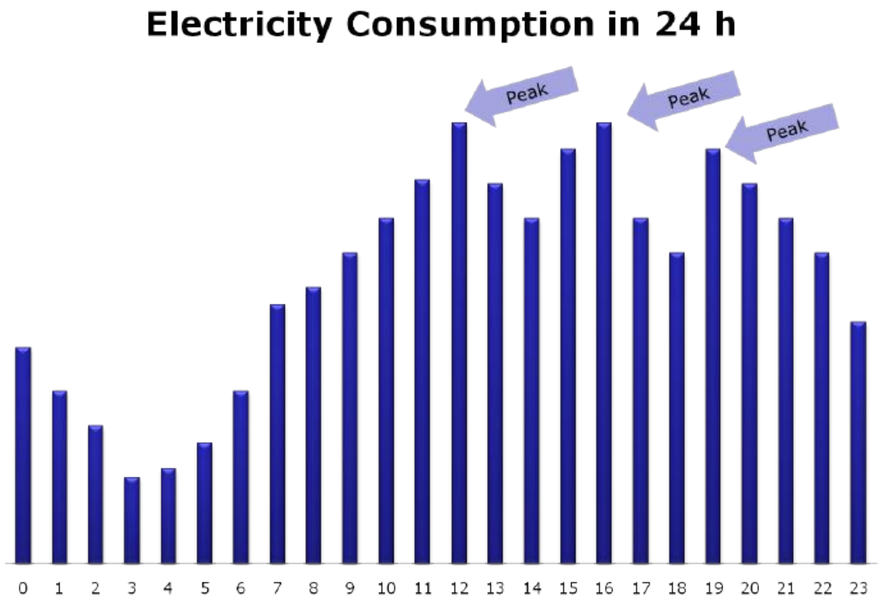


Figure 5.8: Electricity consumption
Source: adapted from B.A.U.M. Consult

Following the logic of supply and demand the price for energy at the peak times is much higher than when demand is low. A smart meter is capable of turning certain devices on and off according to time or market price. For example the dryer or the fridge can run at night, when the energy is cheap.

Consequently large costs can be saved by intelligent interactions. This trend can be further enforced by energy suppliers implementing fines for over-proportional peak time usage or even radically cutting of the energy supply when reaching a top mark. [320][277][327] Consumers are increasingly willing to engage in the trend as they realize the benefits of smart metering. Thus a large step towards a smart grid will be accomplished.

5.3.2.2 Increasing Consumer's Awareness Caused by Increasing Convenience

Another important factor for the adaption of smart metering for customers is the convenience that it creates.

Description

As single devices are implemented in a smart meter these devices can be addressed individually. Further customers will get data access through the internet or cell phone. Customers will thus be able to access their home or company devices from off-sight. This allows them to remotely control their air conditioning, alarm system or simply check if the stove is turned off [320][332].

Impact on Smart Grid

Further, the customers's involement in their energy habits can be increased. Using a computer the energy consumption can be viewed via statistics and graphics. By that people will recognize which devices are how energy intensive. As a next step inefficient devices such as old refrigerators will be replaced and the grid will be disburdened [327].

5.3.2.3 Increasing Social Awareness and Request for Renewable Energy

One of the most important factors besides costs is the environmental aspect.

Description

60% of consumers feel socially pressured to participate in environmentally friendly trends such as saving energy [308, p. 22]. Behavioral attitudes are caused by education or arise through social pressure. Customers who receive peer-to-peer comparisons cut their energy consumption by 2% on average [308, p. 24]. A study by the Massachusetts Institute of Technology (MIT) and the New York University (NYU) even found out that the energy consumption can be reduced by 5 to 20 percent. [278]

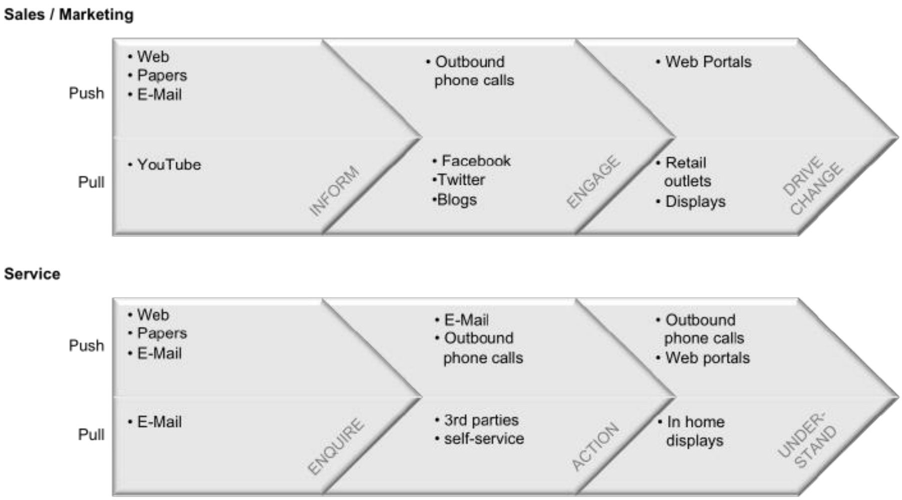


Figure 5.9: Push and pull strategy
Source: adapted from [308, p.25]

Impact on Smart Grid

However the social awareness has to be aroused [308, p. 24]. To settle environmental resourcefulness focused on energy consumption more promote actions have to be taken. Accenture developed a concept for involving the consumer. This concept consists of a push and pull strategy. The awareness has to be pushed by the suppliers, whereas the subscription to smart metering and thus flexible pricing should be pulled by the consumer. Figure 5.9 illustrates this coherence [308, p. 24]. The awareness for environmental change regarding the energy consumption is rising strongly and will be for the next years. Especially the energy suppliers will be creating new demand by sensitizing consumers. The consumer's demand and the general necessity for renewable energy sources have a large impact on the grid because of the high fluctuation renewable energy causes.

5.3.2.4 Increasing Openness of the Electricity Market Enforced by European Legislation

As the government is also interested in implementing a smart grid, laws and acts will strongly change the demand for consumers regarding energy consumption.

Description

In Germany new built and reconstructed buildings have to install a smart meter since January 2010 [328]. Whereas in Sweden already in June 2008 98% of all households had a smart meter [323]. Besides regulating the installation of smart meters, the legislator also forces the energy suppliers to offer consumers tariffs that have variable prices according to the time of the day and the linked energy peaks. In Germany this act will be in place by December 2010 [303]. The government has an additional possibility to influence the demand for energy. By increasing the tax on electricity, consumers will even more focus on costs. Further, and even more important, the legislator can cause public attention when increasing the tax on electricity and thus provoke interest in the smart metering and smart grid topic. This process has proven to be effective on other topics as well, such as the tax on petrol [330].

Impact on Smart Grid

As seen, the national governments and the European Union have certain levers with which they can push the demand side to the usage of smart electricity systems in the next years and thus will achieve to implement a smart grid.

5.3.2.5 Demand Side Trends Hindering the Implementation of a Smart Grid

As seen above there are very strong trends pulling towards a smart grid by persuading consumers to install and use a smart meter. However there are still some barriers that have to be taken and some challenges that have to be resolved.

Description

One obstacle is data security. As personalized information about the energy use of consumers is transmitted to, stored and used by the supplier, data leaks can occur. Consequently the data privacy has to be ensured by the suppliers, which causes costs and efforts. Further leaks can create large damages for the customer and supplier. Suppliers are fined heavily if data gets lost or stolen. [276] For consumers there is also a large risk. Data intruders can easily observe your personal habits and can recognize when you are at home and when not, which can cause serious danger [328]. Besides the data security that strongly concerns consumers, other obstacles have to be clarified. Customers are also worried that their freedom of action will be compromised. For instance the consumers are worried that they will have to pay a fine or even worse that their electricity supply is being cut off if they use too much energy at peak times. [276]

Impact on Smart Grid

It is on the energy suppliers and partly on the government to ensure this freedom and security to the consumer. By resolving these issues the counter trends can be disbanded. The driving elements for electricity demand are clearly recognizable, but still not widespread among consumers.

All factors lead to the awareness of possibilities the electricity system can provide. In the next years these possibilities will definitely strengthen and thus provide a straight path to a smart grid infrastructure.

5.3.3 Opening of the Market towards an International Real Time Market

Due to an increasing electricity variance caused by RES the grid operators and energy suppliers have to adjust the electricity load in the grid. For that an exchange place is needed where long term, and more important short term adjustments can be made.

Description

In Europe there are ten power exchanges that only cover one to three countries each. At these exchanges spot and derivatives markets are operated. [310] At the spot market electricity can be traded one day ahead or on intra-day basis. Thus a fluctuation, such as overproduction or underproduction can be averaged out. Electricity can be traded until 75 minutes before the actual delivery. This market operates all night and day without exceptions. [335][299] Secondly there is the derivatives market in which for example futures can be traded. This option is not relevant for the short term fluctuation as it occurs in a smart grid, though. The trend towards centralized markets has strengthened. Only a few years ago, before the financial crisis the major part was traded over the counter (OTC) or bilateral between suppliers. This has changed towards the trading in organized markets. The advantages are the centralized clearance and thus the reduction of counter party risk [301, p. 47]. Further the trend towards cross border trading can be followed. Volatile trading venues, which include the major part of European Exchanges tend to follow this trend [301, p. 47]. The cooperation between the German EEX and the French Powernext highlight this trend [310].

Impact on Smart Grid

Putting all the above mentioned drivers, such as increased fluctuation due to renewable energies, a recently established electricity exchange, centralizing markets, cross border exchanges and European Legislation together an explicit trend towards a gathering at exchange markets is becoming visible. Currently, there is still a time lag between trade and delivery, but this will change over the next years as the driving factors mentioned above continue to impact the energy market. Cross-border, real-time trade is a crucial part of the smart grid infrastructure because it enables a prompt reaction on the local and national fluctuation of energy input into the grid.

5.4 Conclusion

Building upon the knowledge available today, the trends towards a smarter grid are increasingly becoming visible. The infrastructure is in some cases already in place and many plans exist for the further rollout of smart grid technology in the coming years. When looking at the various influences on smart grid deployment, it becomes clear that most indicators are pointing towards the implementation of a smart grid rather than moving away from it. Legislation, public awareness, EU research and support, as well as investments from outside the sector push smart grid deployment forwards. The trends that have been identified need the current developments to increase their impact on the European energy market.. In turn, the trends create opportunity for a full-fledged transformation of the European energy market towards a more open network. On this network, energy can be traded at any instance and supply and demand can react to each other. The legislation that is opening up the market and the lowering of the threshold for market entrance are important. It allows for the spreading of the energy supply and allows smart grid technology to play an important role in the communication between the various market players. The next years can prove to be crucial for the uptake of the smart grid on a wide scale and the further utilization of existing smart grid technology. The trends pointed out in the report above, certainly point towards a more widespread and intensive uptake of smart grid technology.

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Part II

Scenarios and Business Ideas

Chapter 6

6 Telecommunications Service Provider Perspective

Felix Baaken, Kilian Moser, Victor Petcu, Hanna Schneider

Telecommunication provider might play a highly important role when it comes to the Smart Grid of the future. In this report three distinct scenarios are developed where telecommunication providers could evolve in different ways because of political, technical, environmental or social developments until the year 2025. The first scenario describes the picture of a future in which electricity and smart grid markets diverge, where a multitude of communication standards are in place and cause difficulties. Furthermore, the lack of security in user's electricity data makes the effective use of the smart grid immensely difficult. In the second scenario, a largely oligopolistic structure of the telecommunication and energy market is established. An abundance of standards and increased security by physical detachment of important energy nodes distinguish this scenario. The third scenario drafts a future in which the energy and the communication provider markets converge. Here, a high degree of standardization enables end users to participate in the market. Additionally, security concerns have been resolved through progress in encryption technologies.

Based on the third scenario, the Energy Brain was conceptualized. The Energy Brain is a combined energy communication infrastructure, which collects usage and metering data, calculates real-time prices and forwards this data to utility companies, the energy stock markets as well as to end consumers. Thus it makes real-time pricing, demand response and load-balancing efficient and feasible.

Concerning the business model of the Energy Brain telecommunication service providers realize profits by providing forecasting, data analytics and smart grid data services to a variety of different companies and customers. In essence, the Energy Brain represents the most vital part of the future electricity grid: making it smart.

6.1 Introduction

In today's society, the telecommunication provider's main market is that of providing data and communication services to companies, to industry, and to the consumer. While most large telecommunication companies used to be part of the postal service as a governmental organization, others have newer business models. Both form what is known as today's telecommunication company, which provides reliable services throughout. Their responsibilities are founded on the basis of maintaining network up-time and ensuring that the quality of service is not compromised under excessive usage or external factors. Their extensive network of communication lines extends over cities and continents with undersea cables and satellite up-links, which poses the challenge of ensuring very tight security on all communication channeled. Not only is security of primary concern, but it is necessary for the telecommunication to have the customer's trust in their data. While providing this service, telecommunication companies also have to ensure that despite their complex structure and different communication channels, a standardized means of interconnection exist between them, other telecommunication companies and consumers.

With necessary advances in electricity grid infrastructure, monitoring and automation, today's communication company faces an ever-increasing role in providing the necessary technological expertise to deal with and to process data from a vast number of locations and sources. New participants in the telecommunication field will challenge the existing telecommunication company's core competencies and new markets may emerge where telecommunication companies will be able to provide consumers with real-time information on electricity demand, electricity supply and most importantly the market price for electricity.

Firstly, both certain and uncertain drivers deemed important to shape the future of telecommunication service providers will be analyzed and discussed. Secondly, three distinct scenarios describing a future state in the year 2025 will be presented, each with their own focus on particular drivers discussed in the first section. Lastly, a service idea will be introduced that will be a viable option for a particular scenario and boasts both a revolutionary and promising business model for the telecommunication service providers from 2025 onwards.

6.2 Driver Analysis

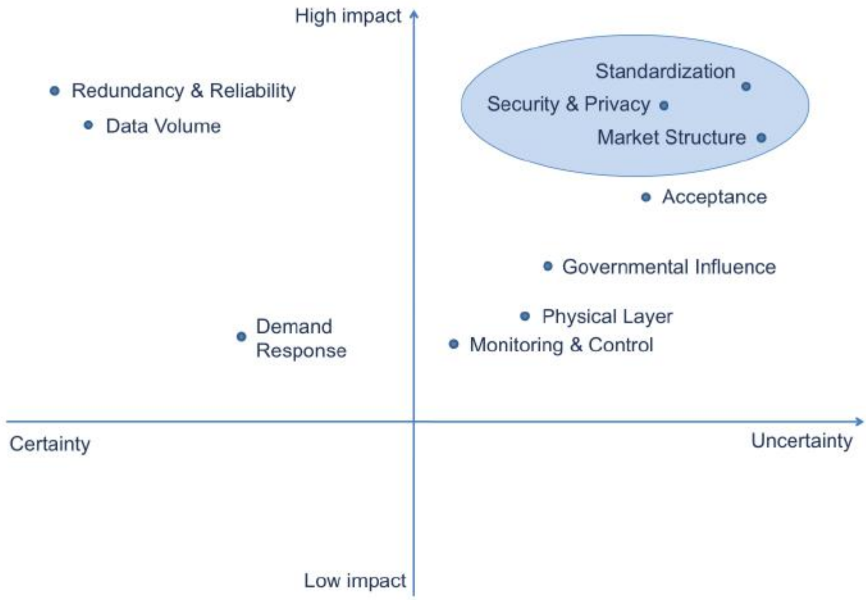

Figure 6.1: Ten drivers and their impact and certainty on future developments Source: own illustration.

In this section, an overview of drivers that will impact the direction of developments in the telecommunication industry will be given.

A driver is an important factor shaping the industry's environment in the future, also called variables. There are two types of drivers that will be analyzed: certain drivers and uncertain drivers. The former will focus on the likelihood connected with them, that they will develop in a specific, clearly definable direction and how they will be present in all of the scenarios. However, the latter drivers are more important as they bring with them a variety of possible outcomes. Of these uncertain drivers, there are three key drivers, which are vital to the scenarios proposed, as they characterize the three scenarios best by having the most impact on their formation. Additionally, key drivers do not influence one another. The other uncertain drivers are also shaping the scenarios, but influence the future a little less. Every uncertain driver can develop in different ways, e.g. consumer acceptance of the smart grid can rise over time, or, if incidents occur, it may also decline. Additionally, the importance of factors in different scenarios may vary.

Figure 6.1 shows the relationship between the certainty of drivers on the horizontal axis and their impact on the vertical axis. On the left side of the graph, three certain drivers have been identified, with demand response being the least important, then increasing in importance, data volume and redundancy and reliability. The right side of the graph shows seven uncertain drivers. These seven uncertain drivers shape the distinct scenarios of the future, with monitoring and control having the least impact and then, ascending in importance, the physical layer of the communication network, the role of the government and the customer acceptance of the new technology. Security and privacy implications, the possible market structure, and most importantly the standardization for interoperability are key drivers, as they will have the most impact on the development of the telecommunication companies.

6.2.1 Certain Drivers

Certain drivers will be present in all of the future scenarios as they exhibit a clear direction today and their impact is crucial to the telecommunication sector.

6.2.1.1 Demand Response

Electricity providers depend on data streams from customers to adjust their production output.

Description

Having the ability to dynamically adjust one's electricity usage in accordance to the electricity price is what demand response is for. These intelligent devices have, in addition to their normal power connector, a data link to an information system [363], which provides them with the real-time data on the electricity price. Furthermore, load balancing can be greatly refined by triggering behavioral change in electricity usage .

Development

Chapter one and two of the Basic Report (see 1 and 2) outline the advances in more intelligent electricity use in both households and in the industry. Beginning with smart meters, which provide accurate real-time usage data, devices will be able to use this information to change their operating procedure.

This intelligent usage will lead to increasing communication between various components [351], be it household items or industrial processes, and between larger and more distant network nodes, where one region can hold information about another [364, p. 421][361, pp. 82-83][344, pp. 14-17]. Not only will this cause additional network traffic, but it will substantially increase the data volume that needs to be transmitted and processed, as explained in 6.2.1.2.

Additionally, smaller or virtual power plants will be able to react efficiently upon price changes.

6.2.1.2 Data Volume

Computerized systems in the electricity sector create increasing amounts of data from sensor equipment which needs to be processed.

Description

While the question of excessive data volume was not posed in the past, today's evolving smart grid is challenging that notion. With the increased usage of smart meters in homes, in businesses and in the industry and an increase of sensors on the electricity network, a growing amount of data from these devices has to be transferred over the telecommunication network. Data is vital to utility companies as they utilize it to regulate and manage power supply and demand by analyzing the generated usage data. This shift into more data-intensive grid operations is a characteristic of the smart grid and will continue to play an important role.1

Development

The increase of data volume on the communication network is due to a number of factors [338]. Rising population numbers in addition to an increase of easy access to electronic devices, which require high power quality, necessitate an expansion of required measurement sensors in the electricity network. These sensors provide measurement data on electricity quality to the producers, which in turn regulate the power supply [348, p. 59].

To keep the data streams manageable and to be able to handle the influx at all, the communication infrastructure will have to be improved by updating bandwidth levels, transmission protocols and by increasing storage facilities to warehouse the data before and after it is processed [341].

6.2.1.3 Redundancy and Reliability

Having a communication and an electricity network that is both reliable and redundant is critical to its successful implementation.

Description

A heavily utilized communication network needs to be heavily redundant and reliable [352, pp. 40 - 41], [367, pp. ES-1 - ES-2]. The physical connections need to be designed redundantly; damaged parts of the network are not to affect the greater functionality. Additionally, the protocols have to be optimized for bandwidth efficiency and trustworthiness ensuring that a compromised area of the network does not adversely affect the function of the entire network [370, p. 5].

Development

A manually managed communication infrastructure is not feasible and as such it is developing towards a more redundant and self-healing state [371]. When unpredictable disturbances occur, alternative communication routes are implemented immediately and traffic is diverted to ensure seamless operation [356].

As the electricity grid still needs to function without the communication infrastructure, these technologies are being built around the grid in an add-on manner to ensure that the grid reliability is maintained whether or not the communication infrastructure is functional. Additionally, smart devices have fallback systems in place, which enable their continuing operation under a communication break down.

6.2.2 Uncertain Drivers

Uncertain and certain drivers mark partings and have different developments for the future evolution of the telecommunication market. These drivers account for the different developments towards the scenarios examined subsequently in a later chapter.

6.2.2.1 Monitoring and Control

Today, electricity grids are controlled by SCADA-like systems. However, those systems do not allow real-time control and monitoring activities (see 1.2.2.2), which are essential for the future development of the smart grid. Future technologies could enable reliable, low-latency, high-speed communication over wide areas and control the grid in real-time.

Description

For monitoring and control purposes, data provided by smart meters as well as various grid technologies like distributed sensor networks and phasor measurement units can be employed [343, p. 20][362, p. 1]. In this respect, the degree of automation versus manual input becomes critical both in aspects of security as well as controllability of large energy communication networks. Developments in two different directions are possible to achieve this effectively.

Developments

There will either be high priorities towards human interaction because of security issues or a lack of acceptance of computer controlled energy supply. Gathered data would then converge at few human controlled monitoring and control centers. These central nodes will control the future energy grid comprising more detailed information about the grid status. Of course, such systems have other disadvantages and vulnerabilities compared to distributed networks [346, pp. 1-2].

Another option of monitoring and control is based on self-controlled systems. The development and improvement of concepts like swarm intelligence allow highly sophisticated fast responding networks which control the grid by acting within preset tolerances [369][365]. Additionally, those networks would be self-healing which provides a higher reliability to the communication grid.

6.2.2.2 Physical Layer

Like every telecommunication network, smart grid infrastructures have to be based on a physical layer. Telecommunication providers own various technologies and networks which can also be used to enable communication in the future energy grid.

Description

Selecting the most capable, profitable and secure communication technologies is an important aspect in establishing a smart grid. Therefore the existing infrastructure may need to be updated and new technologies may have to be installed in order to reliably provide a higher bandwidth and lower latency. Only in few cases may existing infrastructure be sufficient for future development, which allows for two different possible developments in the physical layer.

Developments

A clear definition of layers and interface standards is required to increase the efficiency and interoperability of the technologies utilized. This development originates from the idea of leveraging all existent infrastructures and combining them to an interconnected communication grid.

On the other hand, a concentration on few communication technologies simplify network architectures and lower the standardization requirements. Thus it is plausible that a single standard (e.g. DSL) is to be used for fixed-line communication and the remaining, more remote areas will be connected via mobile technologies (e.g. WiMAX).

6.2.2.3 Governmental Influence

In Germany, the EWG regulates the installation of smart meters for newly constructed or totally renovated buildings. Estimating that residential buildings have to be renovated every 50 years, this implicates that it will still last a long time until every household is equipped with a smart meter. Additionally, it remains uncertain whether existing laws will still be enforced or if new regulations will be passed in the future [342].

Description

Governments have various opportunities to push or impede the technological development of smart grid infrastructures in various directions. Common means and methods to promote technological change include stimuli, regulations of markets and infrastructures or subsidies [337**?**] for newly applied or especially sustainable technologies. For governments, there are two ways of behaviour when it comes to influencing consumers and the market.

Developments

Given today's political discussion and laws, one can assume that governments will further support the establishment of a smart grid. The future of governmental influence can have the following characteristics: Governments could offer subsidies to incentivize customers to buy smart meters, enforce the installation of communication technologies via regulatory efforts or offer telecommunication providers other financial and non-financial stimuli for investing in the smart grid [337**?**].

Contradicting this development, the liberalization of the energy markets in Europe could in theory impede the establishment of one integrated energy communication network. Gathering and utilizing energy related data becomes more complex with the number of parties (utility providers, energy traders, sensor network providers and communication technology providers) rising. Already today, the former monopolistic market in Germany has ten different market participants [338, p. 9], a development which could continue.

6.2.2.4 Acceptance

The issue of acceptance includes the consumers' attitude towards privacy, willingness to occupy themselves with and spend money on high technology as well as their awareness of energy consumption.

Description

As of today, the lack of acceptance of smart meters has an impeding impact on the smart grid as there are not many incentives for smart meter installations

today. Mainly the utilities benefit from the gathered data. Demand response systems are a vision, but not yet fully developed, nor is higher acceptance ensured. Additionally, end consumers increasingly raise concerns about privacy and security. The adoption of advanced technologies present another barrier. Therefore, the belief in the opportunities arising with smart metering and energy awareness is crucial for the acceptance of smart grid infrastructure.
The acceptance of integrated services and single providers of both energy and telecommunication solutions might be required for the future success of telecommunication service providers in the energy markets. Taking technological advances into account, there is either a quick adoption possibility or a long adoption period that will determine the acceptance.

Developments

If the general interest in smart meters stays on today's level, it will most probably take a long time to install smart meters in every household. The aim of the European Commission is that 80% of all households have integrated smart meters in 2020. Taking into account that existing buildings have to be totally renovated after about 50 years, it could be challenging to reach that goal. Low acceptance because of privacy concerns and the lack of added services will postpone installations and end consumers try to reveal as less information about their energy consumption as possible [354].

The general technology adoption live cycle suggests another more promising development for smart meter technology; projecting a gradual increase over the next 15 years [359].

Eventually, the acceptance of smart meters will rise more sharply, because new business models or technologies offer completely new incentives for remarkable parts of the society to trust in or benefit of smart grid infrastructures.

6.2.2.5 Security and Privacy

The possibility of remote controlling devices or even parts of the electricity control system, to communicate consumption and generation data and forecasts and thus balance the load also creates new vulnerabilities and threats that are unavoidable by the very nature of the interlinked systems.

Description

The future smart grid, especially communication channels and communication technologies, need to be secured efficiently against data loss, data falsification and data corruption, whether on purpose or not, to avoid security and privacy concerns [358, p. 18]. High security standards of energy grid communication has to be guaranteed for vital parts of our society (i.e. hospitals, transportation infrastructure, emergency services, etc.). Thus security and privacy are an important driver in establishing grid communication but it remains uncertain which concepts will be implemented. Three different directions of development are plausible for the future application of security and privacy.

Developments

If the future smart grid will rely on Internet-based technologies (e.g. DSL), it needs to be protected by encryption, authentication, authorization, firewalls and demilitarized zones (see 2.3.4). It can be expected that huge effort will be put into the development of specialized security protocols which provide these services [340].

Another plausible development suggests that communication providers will rely on communication technologies which are physically detached from the Internet. Possible examples include for instance long wave technology. In this case the sheer network architecture provides the necessary security. However, technologies like encryption can still play a supporting role.

If neither the first security concept of deploying sophisticated encryption and authentication mechanisms nor the second security concept of relying on physical detached networks is put to use and old SCADA systems continue to be used without remarkable improvements, security issues will become a main concern in the future smart grid infrastructures [357, p. 1][368]. If only patch solutions without minimum security standards are put in place to keep the systems up and running, the reliability and effectiveness of the grid is no longer guaranteed.

6.2.2.6 Market Structure

The future market structure of both the telecommunication as well as the electricity markets determines the possibilities of telecommunication companies to be successful, the competitive state of the industry and the chances to form alliances.

Description

The number of players in both markets affects the chances of new start-ups and existing companies to be successful in the establishment of a smart grid. Furthermore, the degree of separation or convergence of these markets can promote or impede the development of smart grid infrastructures. From this, two extremes and one middleground are possible as three different developments.

Developments

One plausible development suggests a convergence of both markets. Companies will form alliances across industries in order to provide wholesale services.

Standardized systems will allow services to be built on common APIs which could help the service sector to boom.

On the other hand, the market structure as of 2010 could stay the same. In this case, both markets and their participants will be separated and work independently, possibly buying and offering one another's services and forming medium-term partnerships. Because of governmental regulations, the main players in the energy markets could even be split up in smaller companies.

In a third possibility the market consists of a mixture of smaller and bigger companies and only few communication providers try to form alliances with electricity providers in order to provide specialized services.

6.2.2.7 Standardization

Whenever different specialized devices should be able to communicate and exchange data - probably using different mediums - it is necessary to agree on common standards. The higher the distinction between technologies that should interoperate, the more important standards and a clear structure in layers become.

Description

Standardization bodies, for instance the Centre for the Protection of National Infrastructure (CPNI), the International Society of Automation (ISA) or the European Commission have developed security standards for electricity systems during the last decade [366][355]. All these recommendations and guidelines have various differences. But up to now none of these standards have achieved international acceptance and implementation. As standardization is a critical topic, only two different developments are feasible.

Developments

As the different approaches of establishing a security standard do not diverge remarkably, it is likely that different utilities, standardization bodies and governments could agree on one standard. Thus, a high degree of interoperability and interchangeability of technologies can be achieved in the future.

However, if providers deploy proprietary and all-embracing layer protocols in order to develop a unique selling proposition or break-through technology, it is likely that standards cannot be established in the energy communication grid within the nearer future. If further attempts to establish a clear layer structure fail, patch solutions are developed in order to keep a system with a multitude of communication technologies up and running.

6.3 Scenarios

The following section will deal with three possible scenarios which are derived form the certain and uncertain drivers and their developments. Certain aspects, such as security and privacy, standardization in the communication standards as well as the market structure will play an important role in the formation of the three different scenarios.

6.3.1 Dystopia

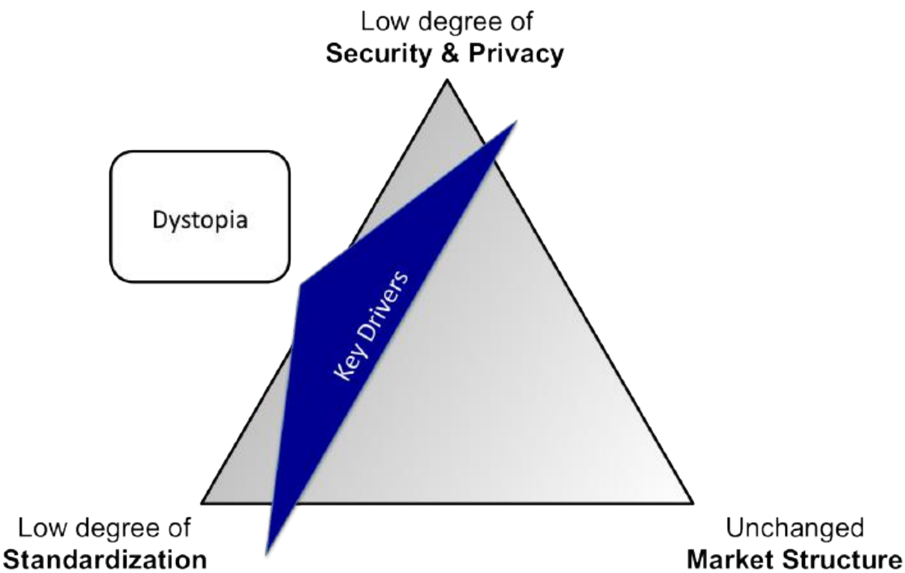

Figure 6.2: Dystopia - Key Drivers
Source: own illustration.

In the scenario 'Dystopia' the governmental, technological and social circumstances have impeded the establishment of a smart grid infrastructure. The three key drivers are shown in figure 6.2: the lack of sophisticated security and privacy measures, the low degree of standardization and the diverse market structure. While some networks relied on existing infrastructure, e.g. the Internet for communication, security was only an afterthought when electricity grids were first built. This lack of security is also linked to the lack of standardization. By 2025 interoperability is still not possible due to a divergence of standards. The liberalization of the energy markets by the European government has hindered the establishment of one integrated energy communication network during the last ten years. Gathering and utilizing energy-related data is complicated because various utility providers, energy traders and communication technology providers are involved and use different technologies.

6.3.1.1 Description of Scenario

Governments have failed to promote smart meters effectively by regulations and incentives during the last decade. Various communication technology start-ups wanted to be successful in the smart grid market but the expected break-through of the smart grid is still missing. Monopolies are split because of governmental regulations and the different companies do not form alliances.

Technical implications

Attempts to establish a layer model similar to the OSI reference model failed because providers relied on different communication technologies (DSL, GPRS, long wave, power line, WLAN) and proprietary overall-layer protocols, which are not interoperable, in order to have a unique selling proposition. Thus the exchange of data between different regional energy communication grids is barely possible and very costly. Communication technology providers control their networks independently and use different control systems and data formats. Energy consumption and prices are merged at the energy market in Leipzig but the entity of gathered data can not be used efficiently because data formats of different communication technology providers are not consistent.

Moreover, because of the lack of standardization there is no minimum security standard guaranteed - security and privacy measures differ significantly from system to system. Many networks are not physically detached, but interconnected to existing communication networks, which makes them vulnerable to external attacks. Instead of an integrated security design measures are mostly a reaction to incidents of the past. In case of a network breakdown the public back-up system consists of energy storage systems to ensure energy supply in hospitals and emergency services until the communication is built up across alternative channels. This can be a time-consuming procedure because the grid is not self-healing. The various intelligent devices on the market react diverse to the loss of connection to the communication grid.

Stakeholder implications

Because personal data was abused in some cases, customers are very distrustful. In addition, smart devices are expensive and do not offer real benefit for the customer. Other customers use smart devices to manipulate the documentation of their energy consumption. The development of manipulation software for smart meters is faster than the establishment of new security mechanisms. Furthermore, the customers do not believe in or care about energy that could have been saved with smart meters. They want to use energy whenever they see fit and not when the price is cheap. The advanced technology of smart meters is a barrier for many customers and digital systems seem vulnerable to them. The question of how much energy can really be saved with smart meters is still controversial because there are only few devices in private households, which are completely flexible in their time of energy consumption.

There are many competitors on the market of energy grid communication. Providers try to gain market share with their own technology and protocols instead of forming alliances or using a common ground standard. Moreover, security incidents are a big danger for telecommunication technology providers because of huge financial and business consequences.

6.3.1.2 Weak Signals and Signposts

The scenario 'Dystopia' can become true if no remarkable changes and achievements are made within the next years. In Germany smart meters are slow on the uptake due to the fear of the "transparent household" [354]. The current law enforces that a smart meter is installed in every new or totally renovated building [342] but it could take another 50 years until all existing buildings are renovated. The liberalization of the energy markets of the European government could prevent the establishment of one integrated energy communication network in future. Field tests of smart meters until 2010 have used different technologies, thus it is unclear if interoperability of systems will be possible [354][350]. In 2010 there are already different approaches to establish a security standard, but an international agreement is still missing [366].

6.3.2 Divided Oligopolistic Markets

Other driver development combinations make up a second scenario, in which the key players of different markets are operating separately. Alliances are not formed; the customer only chooses the energy provider, which itself buys services from telecommunications service providers. Thus, the market structure is a continuation of the structure of 2010.

As can be seen in figure 6.3, the most important drivers apart from the market structure are security and privacy, as the communication networks are secured by the network architecture, and the low degree of standardization.

6.3.2.1 Description of Scenario

The utility companies are ensuring the security in this scenario by a physical detachment of the transmission grid from the Internet infrastructure up to the lowest level. This means, that all major distribution nodes, power plants and substations are connected via fiber optical cables to each other and to

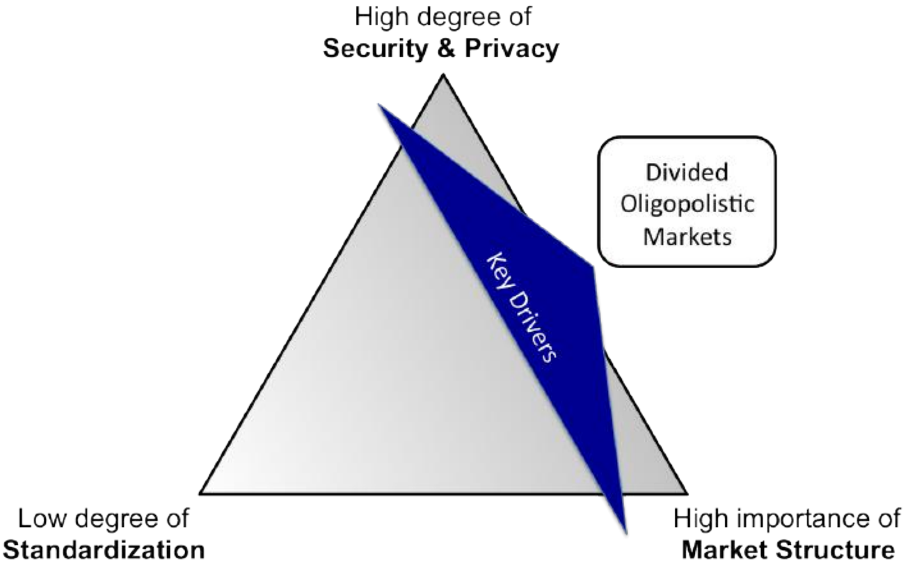

Figure 6.3: Divided Oligopolistic Markets - Key Drivers
Source: own illustration.

the centralized control systems, which are still owned by the utility companies. Fiber is very secure in terms of intrusion, as it is not easy to intercept signals.

Communication via fiber infrastructure is either operated by the bigger utility companies themselves or by a service bought from telecommunication companies who have the competencies and know-how in that area.

With a lot of players in the diverse markets and energy and telecommunication markets still being separate, the privacy in this scenario is on a very high standard. Meter data is collected monthly or bi-weekly via 4G and short message service (SMS), the pricing signals are being distributed by long wave signals such as very long frequency (VLF) transmitters. That way, manipulation can be performed on an individual customer basis by tampering with the meter reading.

The utility company structure from 15 years ago is still largely intact. The energy markets are oligopolistic, providing the consumers with a semi-free market controlled by a few big players. Smaller utilities do exist, but they have virtually no control over the prices. Governmental control was starting to free the markets at the beginning of the century, but failed in disrupting the market.

Free markets do exist in the provider markets for telecommunication as well as sensor and metering services, giving utility companies the choice of a buy-or-make decision for most of their smart grid information exchange. However, as there is only a low degree of standardization, business partnerships for the most part locked in once the network is build up. A shift of service providers is very unusual for a utility to perform, as a lot of patchwork has to be done to overcome the problem of many proprietary standards.

Technical implications

Utility companies extended and enhanced their communication network with the help of specialized telecommunication companies. Utilities were able to build up their own in-house providers and save costs. Communication via fiber optics does not take place on the consumer level as it would not make sense to attach every household to a separate fiber optical network. All other sensors, nodes, power plants and substations are monitored and controlled by the separate energy communication grid.

Numerous standards have been established in the energy communication sector. Virtually every major player in this sector has developed their own proprietary set of standards to survive in the free market and offer a valid unique selling proposition. Standardization initiatives could not keep up with the rapid development of smart metering and the growing requirements for control and load balancing by the utilities.

Stakeholder implications

These many standards result in an inefficiency of the market, as business partners only can establish a long-term relationship, as well as inefficiencies in communication. Different standards always have to have a decoding mechanism in place, resulting in huge efficiency degradation or even data loss.

The results for the telecommunication industry stakeholders are mixed. The telecommunication companies have been entering the energy market since the smart grid started with smart meters being obligatory in every household. They work closely together with the utilities, especially smaller ones, to collect meter data and to roll out the energy communication grid. Physical detachment of this communication grid from the Internet ensures security on the one hand, but it led to a variety of proprietary standards. Consequences are a difficult market entrance for smaller Internet service providers as well as a lot of patchwork that has to be done in order to overcome the standard differences.

6.3.2.2 Weak Signals and Signposts

As smart meters are already mandatory in 2010, privacy concerns of customers and security concerns by the utilities are the key signals for this scenario [339]. This could probably lead to a lower acceptance of Internet-attached monitoring and control systems. The utilities would erect a centralized control system, leading to high investments in network architecture and connection of all major distribution nodes.

Standardization initiatives could fail, as research conducted could not keep up with the rapidly increasing requirements of the smart grid infrastructure or there are simply too many initiatives [338, p. 19][349]. Today, initiatives have been launched late and many companies could have developed their own standards by then. Agreeing on a single standard could only have been achieved by a high government involvement.

6.3.3 Utopia

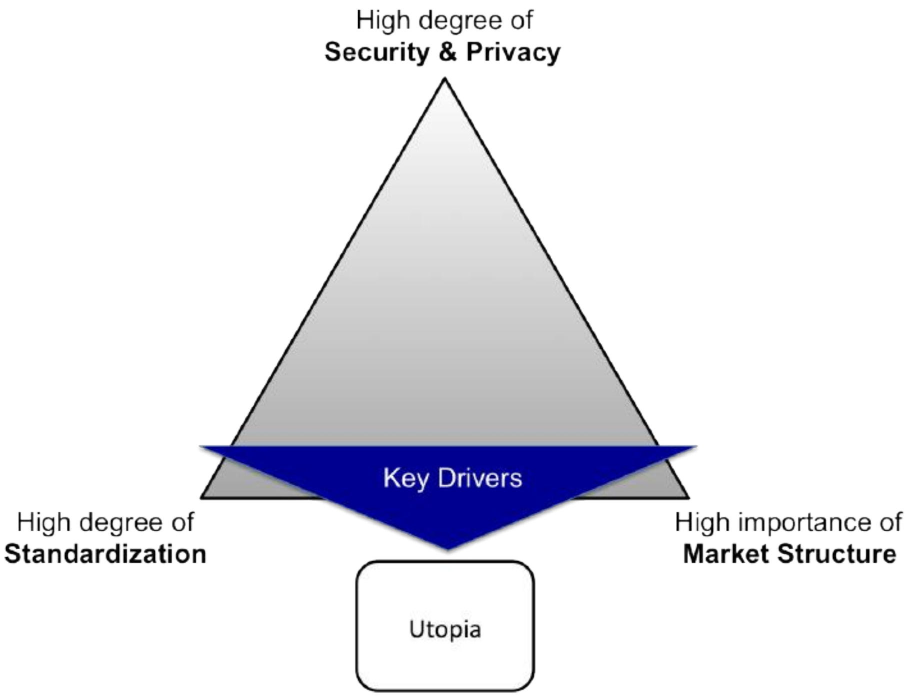

Figure 6.4: Utopia - Key Drivers
Source: own illustration.

The 'Utopia' scenario is founded on the basis that the telecommunication and energy industries will converge and large-scale standardization has occurred. A high degree of security and privacy motivated customers to actively participate in the market (see figure 6.4).

6.3.3.1 Description of Scenario

Privacy is a main concern in 2025 and companies have developed systems, software and protocols that allow the safe exchange of relevant information such as electricity network load data, current prices and customer behavioral patterns. These network technologies, which ensure security, prescind the detailed personal level and do not raise security and privacy concerns. For this reason the networks are able to be highly interconnected and to exchange data, thus fulfilling the purpose of various past initiatives. Here, funding was only given to companies implementing security measures in their systems which resulted in the network technologies being built with embedded security protocols and software tools, such as VPN, firewalls and user authentication, to protect both network integrity and privacy.

Today, the telecommunication, information technology and electricity market have converged to a single, unified market structure. As formerly separated market players have been working together with a common goal, alliances across markets have strengthened their service offerings. Companies have merged to become integrated wholesale providers offering both telecommunication services and electricity provision. As the integrated wholesale providers formed, new markets evolved in parallel, where network sensors need to be installed and data needs to be collected and processed.

The service sectors experienced a strong boost over the last decade, as those highly interconnected markets made room for new business models that aimed at helping end consumers as well as companies to find their way within a highly complex system. Consumers became prosumers over time, where they not only consume electricity, but also generate and trade it. They are connected to a data network, which enables them to change their electricity consumption based on price signals from the electricity exchange.

The above mentioned highly interconnected markets have become possible because of a very high degree of standardization. These few standards guarantee that all systems can work together and that the sharing of information between companies, consumers and telecommunication and electricity providers is effortless. While becoming ever more complex over the last decade, the communication systems in 2025 have been designed with clear structures of layers and interfaces to accommodate for the rise in market players and for added complexity. Because of the clear structure of the layers in addition to the highly standardized communication between them, the technologies and software within the layers can be updated and exchanged in a fast and flexible way. This highly structured layout and standardized communication enables new companies to offer solutions that are specialized to one single layer.

While formerly private electricity consumers neglected the acceptance of smart devices because of lacking use cases, privacy concerns and high costs, the acceptance has gradually increased over the last decade. Thus in 2025, private electricity consumers are used to be part of a large smart data network that helps to integrate renewable energy sources and allows consumers to save energy in daily life.

Governments have promoted a single integrated market for telecommunication and energy. This was to enable different market participants to provide network services and to maintain efficiency and transparency simultaneously. Even though governmental initiatives differ between countries, the influence had been strong on the grid side. In 2025, both the electricity grid and the network operators are highly regulated, while the market on the other hand has continually become more deregulated, thus effectively allowing cross-market collaboration.

Technical implications

As the complex systems of telecommunication and energy are highly standardized and layered, the physical layer benefits from common interfaces. Consequently, a multitude of communication technologies are used in 2025 to achieve a high efficiency within every technological corner, examples include long wave for large unilateral communication and fiber for fast and reliable bidirectional communication. Due to the market structure, a large number of companies, which propagate their technological solutions are active in each layer .

Monitoring and control activities have become more and more important over the last decade. The complex networks established until 2025 require autonomous control systems. A logical step to achieve this, has been the establishment of swarm intelligence like automated control systems that operate within set parameters. With this highly automated network monitoring data and reports are distributed to the various stakeholders in an intelligent way.

Data volumes have increased significantly over the last decade. The highly interlinked systems of 2025 create massive data streams that have to be handled and as such, telecommunication service providers have used their experiences and partnered with utility companies to solve this issue. By expanding network infrastructure and optimizing transmission systems, the increase in data volume can be contained and does not affect the performance of the communication network and the electricity grid.

Redundancy and reliability have been identified as the key towards changing customer acceptance of smart data networks to solve the challenge of integrating renewable energy sources.

Over the last decade companies realized that profitable business cases could only emerge if customers could rely on the services offered. In 2025, electricity is even more important than in 2010 because of the increase in usage of electronic devices. Consequently, reliability is even more critical.

As electricity grids need to function without the 'smart' components that adjust and optimize the grid, redundancy has become critical. These 'smart' components however ensure a high efficiency of the electricity grid, which would otherwise not be possible. Therefore the smart data networks simply operate as an add-on and do not interfere with the underlying redundancy built into the electricity network.

Furthermore, Demand Response (DR) systems are the backbone of the electricity grid. By employing load-level information, the utilities are able to adjust to fluctuating use instantly and they do not need to be trapped in a time window where they can only react to predictions. The highly interconnected smart data network relies on DR to operate the grid in an effective and stable way.

Stakeholder implications

The various stakeholders of the telecommunication and energy market have been affected by the changes over the last decade in a number of ways and assume slightly different positions by 2025. The impact on telecommunication service providers is twofold. Some companies have managed to promote their expertise in networking have either partnered with utility companies and formed alliances in order to jointly establish smart data networks, or have evolved to become an integrated wholesale provider offering telecommunication and energy solutions. The other companies, which missed the chance, consequently experience sales declines. Their niche shrunk, and in 2025 these companies lack the required skills to satisfy all customer demands which leaves them with two possibilities: either failure and eventually bankruptcy or the specialization in certain niche markets to promote specialized solutions.

Utility companies experience similar shifts in business models as telecommunication service providers. They either become integrated wholesale providers or specialize on specific tasks, such as electricity generation or transmission grid operation, within the value chain.

End consumers evolved from consumers to prosumers. The decentralized power generation at home has increased over the last decade, thus the number of prosumers has reached a significant level in 2025. Trading their own energy has almost become a habit and a lot of private households are familiar with those techniques in 2025.

Consumers rely on services by various companies that help them to manage their life in the highly complex systems of telecommunications and energy. These services, most transparent to users, are the backbone of the prosumers' ability to partake in the energy generation and energy market.

6.3.3.2 Weak Signals and Signposts

Weak signals in 2010 already allude to this scenario. The Deutsche Telekom is investing in smart grid technology to ensure its role in the future as both a telecommunications provider as well as an energy provider [345]. Not only are telecommunication providers investing in the future of smart electricity usage, but also producers of household appliances aswell [347, p. 144]. Miele, a german appliance manufacturer, announced their partnership with RWE Effizienz GmbH at the IFA 2010 consumers electronics show to illustrate that their smart grid ready washing machine and tumble drier can be programmed to start automatically when electricity is cheapest [360][363] .

Further initiatves by the National Institute of Science and Technology in the United States have invested substantial time and effort since 2007 to coordinate the creation of standards for information management, to achieving interoperability of smart grid devices and to coordinate the development of protocols [361]. Home automation standards are starting to become more accepted throughout the industry with BACNet and KNX standard of building automation. The latter has 215 members, including industry leaders such as ABB Switzerland, Bosch, Siemens, Honeywell, and Cisco in 30 countries which are not continent specific [353] leading innovation and standardization.

6.4 Service Idea: The Energy Brain

The service idea for 2025 is a communication infrastructure developed and maintained by few big telecommunication companies connecting all stakeholders of the energy grid. The solution approach will be derived from the industry needs present in 2025. Subsequent chapter will outline the unique value proposition as well as the main beneficiaries in detail and provide a schematic overview of key revenue and cost drivers. Concluding, other market entrance possibilities provide a way to enlarge the use of the service idea introduced.

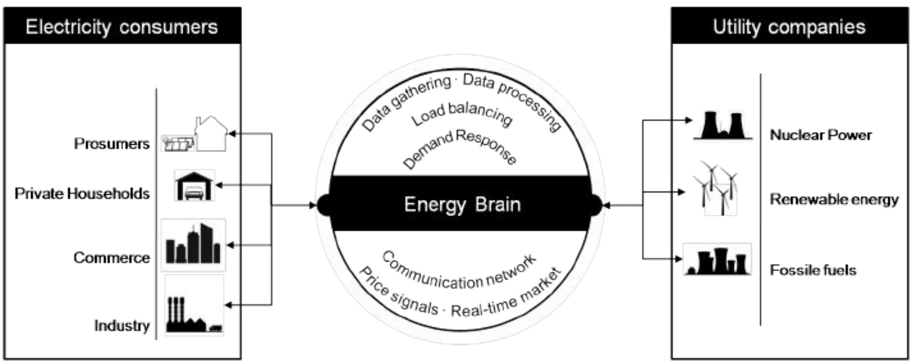

Figure 6.5: The Energy Brain
Source: own illustration.

6.4.1 Industry Needs in 2025

In 2025, a smart grid was established by utility companies and telecommunication service providers. Grid communication and data measurement is already possible to some extent because smart meters are in place in private households, prosumers, industry and commerce. In 2025, telecommunication companies already collect and process the meter and sensoring data on behalf of various utility companies. But although utility companies try to make load-balancing as efficient as possible, they only share the data with few other stakeholders. Thus, no comprehensive industry-wide view exists. While the grid of 2025 is highly interconnected, it is still bares potential for efficiency improvements and consumers have difficulties managing the fluctuating prices. The trading activities are not yet completely automated and real-time market responses are not possible on a full scale. Con- and prosumers' systems may receive the current energy price of their individual energy providers, but the price is defined only on a local (i.e. city) scale.

6.4.2 Solution Approach

To solve these problems and achieve a higher influence in the energy market, telecommunication service providers can leverage their existing data pools to create a unified basis for real-time trading, demand response and load balancing, the Energy Brain (see figure 6.5). Active data exchange over a well defined, open interface standard leads to an industry-wide picture of the current and expected grid load on an aggregated level.

6.4.3 Unique Selling Proposition

The telecommunication providers have the expertise and know-how in real-time data transfer and analysis. As can be seen in figure 6.6, they are in possession of highly distributed regional databases of metering data as they are the companies already collecting data from the consumers and utility companies. This happens on an individual basis as a service provider for utility companies, but so far this data is not shared. Therefore telecommunication providers are the only possible providers of the energy management database called the Energy Brain. Competitors will have to overcome a high entrance barrier as they have to acquire the relevant information (i.e. usage, consumption and measurement data) first.

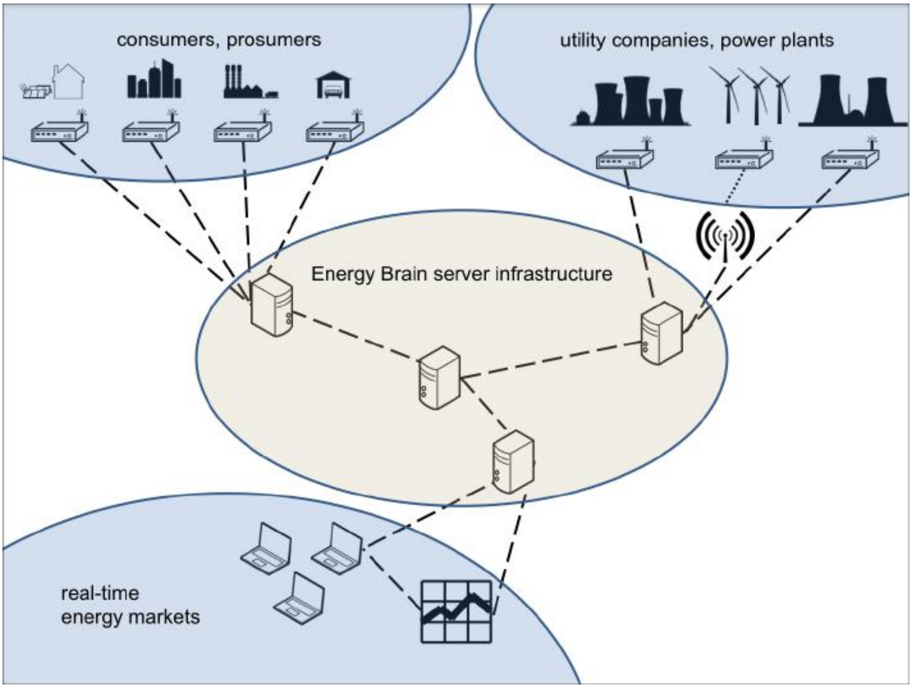

Figure 6.6: The Energy Brain: Network infrastructure
Source: own illustration.

6.4.4 Beneficiaries

Utility companies can rely on this service to balance their grid load and thus can postpone grid extensions which would otherwise by needed for an efficient peak load management. As can be seen in figure 6.7, utilities can then change the load pattern of their power plants and transmission grids accordingly. Households, prosumers and industrial consumers upload their usage patterns and load forecasts to the central system the Energy Brain, maintained by few large telecommunication providers (on the right side of figure 6.7), The Energy Brain aggregates the load data of each single utility company and forwards relevant information like forecasts and the real-time price to the utilities, which then take appropriate action to balance the load of the grid. Real-time data is crucial to achieve this task, as the grid relies heavily on renewable energies and virtual power plants to balance the load and to ensure a constantly high energy quality. Energy storage solutions like molten salt and water pumping facilities can now operate on a larger, on-demand scale and prepare for peaks with high-resolution need projections.

Additionally, the whole available data is fed into trading systems to create those real-time prices. Utility companies upload the data for the sake of the added value of the easy access to real-time data for load balancing as well as pay a fee for the real-time access to the European energy market. Their market interactions are managed by the Energy Brain as well, although the flow of finances is still managed by the market participants themselves (see figure 6.7). The utilities pay for the market turnover. Thus, the higher the turnover through the communication channels, the higher the share for the telecommunication companies.

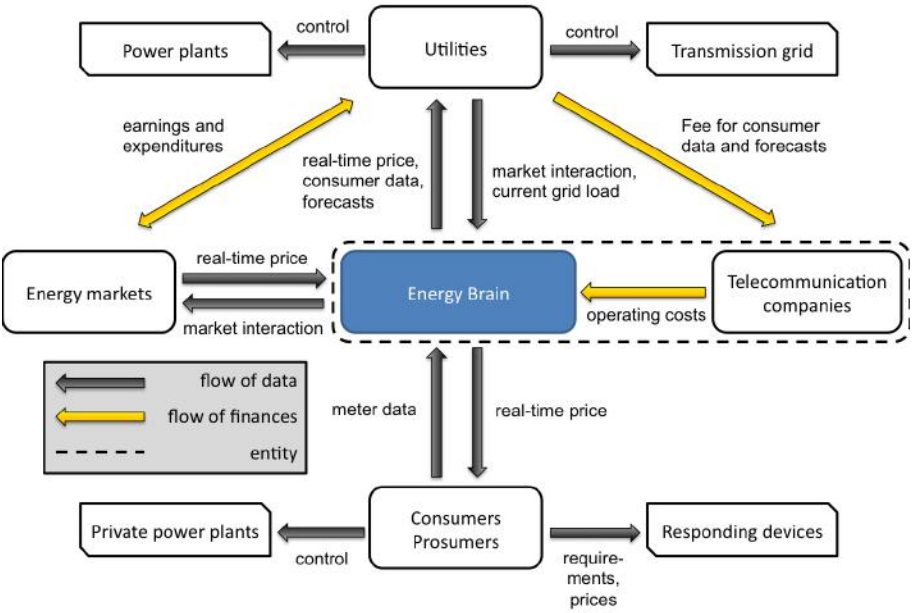

Figure 6.7: The Energy Brain: Flow of information and finances
Source: own illustration.

Operators of interconnected private power plants (virtual power plants) tap into the data to respond efficiently to price changes. Thus, they can operate on-demand power plants like block heating stations when it is economically practical. Also, combined energy generating and storage facilities like photovoltaics connected to a household-scale battery system provide a higher incentive for investors in renewable energies because they can react quicker to price changes.

Price curves are transfered electronically to all consumers and their energy management devices in order to influence their consumption behavior. This data serves as input for home automation servers and is forwarded to responding devices to increase the efficiency in households. Heating systems profit from the cheap prices at night as they are able to store heat. Electric vehicles can respond to price valleys. Household appliances that are not needed at a specific time, e.g. dishwashers and freezers, can run when the load is not at a peak.

Industrial consumers profit from specialized demand response systems according to their individual needs. All energy-intensive industries, especially the heavy industry (e.g. steel mills), can benefit from work shifting and work more efficiently at night or in the morning. Other examples for high efficiency gains are cooling houses and waste-water treatment facilities (see 2).

Producers of home and office appliance and personal power plants can tap in the open architecture of the smart meters already rolled out by the telecommunication companies to optimize on an individual scale. Consumers are buying energy-efficient domestic appliances. The value added by automated demand response programs will further incentivice the purchase of communicating smart appliances.

6.4.5 Revenue and Cost Drivers

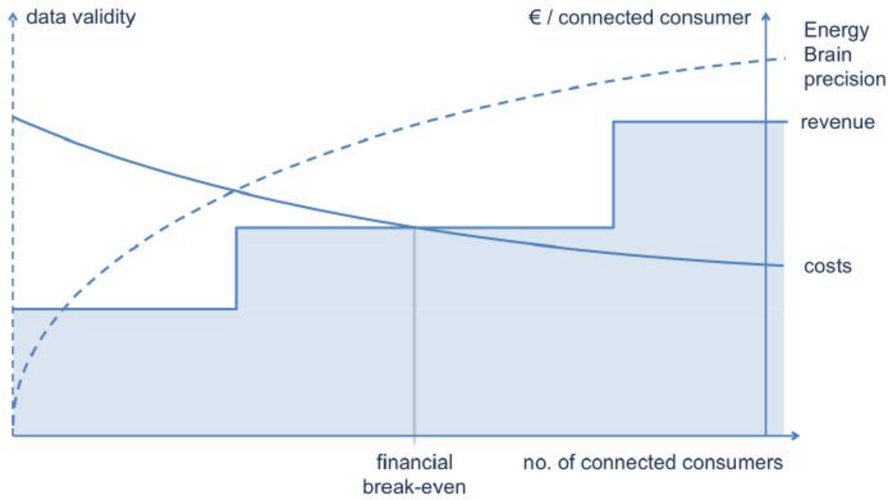

Figure 6.8: The Energy Brain: Financial break-even
Source: own illustration.

In figure 6.8, one can see the financial break-even of the Energy Brain for the telecommunication companies. At first, there are almost only fixed costs like the server infrastructure, with only little variable costs per customer involved, e.g. network and server scaling. With every additional customer, the forecast quality improves. At some point, the telecommunication companies are able to increase the fees for forecasts to accomodate for higher data validity and thus eventually reach the break-even point. Other costs involved will be for the standardization initiatives as well as the negotiation involved when dealing with the few biggest players on the market. Additionally, associated security measures and reliability through redundancy will be necessary to ensure viable and trusted access to the data. 4G technologies such as WiMax provide a backup solution in case of a failure of primary, wired communication channels as they are developed on a nation-wide level in 2025. Server and storage facilities will be provided by specialized information technology service providers, as cloud computing has gained acceptance and is seen as the rational solution to server load balancing and effective IT infrastructure.

6.4.6 Other Market Entrance Possibilities

Smaller communication companies already collecting meter data can enter the market using and paying for the infrastructure of the Energy Brain, i.e. servers and communication channels, provided by the bigger players. That way, they can tap into the resources being deployed by the other telecommunication companies. This business model will look similar to the discount cellular resellers in 2010 which also rely on existing infrastructure. As such, the energy market stays open and accessible to smaller players.

With a comprehensive data source of the whole energy available, future service and service mashups building on the existing standards and infrastructure are imaginable. New pricing models like energy ’flatrates’, which offer a fixed energy price independently of the current real-time market price for a price premium, as well as prepaid energy for short-term flat rentals can be implemented without much further investment.

Additionally, the existing market could be expanded to gas and water real-time pricing as well, giving incentives for water efficiency in dry areas or longer periods of drought.

6.5 Conclusion

Of the three described scenarios, the last one, picturing a highly standardized world with few market players, holds the most potential for companies of the telecommunication sector. Although a lot of work and effort is needed to achieve such a high degree of standardization, it is not impossible. A lot of signals already point to the development of telecommunication companies playing a vital role in tomorrow’s smart grid. Some of the bigger companies have created departments for research and development of technologies in the energy sector. Additionally, not many utilities have their competences developed according to the requirements of an interconnected energy communication grid. Partnerships between the telecommunication and the energy sector are inevitable.

In this scenario, a service idea like the Energy Brain, for which an alliance of big telecommunication providers interconnect their data streams in order to leverage real-time forecasts on a national level, is the perfect solution for effective grid load balancing and peak management especially considering an increase of renewable energies. Demand response systems are a welcome incentive for end consumers in order to overcome privacy issues and bring them to upload their data. Even more exact forecasts and load curves are the result.

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Chapter 7

Information Technology Service Provider Perspective

Martin Kiechle, Tanja Kornberger, Jan Stanzel, Sonja Stockert

Information technology has seen great success in many industries and daily life over the past decades. Its abilities to monitor, control and automate have boosted businesses and introduced a new form of convenience. As the energy industry is confronted with drastic change due to the need for sustainable energy concepts, this is the chance to integrate innovative IT solutions to build the future energy grid - highly efficient and reliable. In this chapter, driving forces for the business opportunities of an IT service provider are being discussed. The application of business intelligence, the relevance of privacy issues and the standardization of ICT in the grid have been identified as key drivers which provide the largest potential due to their uncertainty. Derived from the identified drivers, three distinct scenarios have been created. The scenario of the Customer Integrated Smart Grid was selected for its innovative potential for business activities to be the environment for a new product idea. Based on the need for stability in the grid due to the massive expansion of RES, the LastMile concept has been developed to minimize the energy flow from the lowest levels of the distribution network to upper layers. With the SCI:LastMile software solution, operators of the distribution network will enable producers and consumers to actively participate in providing and demanding green energy in a future highly reliable grid.

7.1 Introduction

Most experts involved in the topic say that the development of a Smart Grid is not only inevitable but already underway. However, it is still quite unclear what exactly a Smart Grid is - views on this differ greatly between all concerned parties. As such, it is very uncertain in what form this Smart Grid may come into existence. Various developments are possible, and some of those seem more likely than others based on today's situation. However, for an Information Technology Service Provider one finding is the most important one: No matter which direction the development will take, IT solutions are necessary in each and every one of them. In the following first section the drivers which influence this development will be presented. Next, three distinct possible future scenarios are envisioned: The Smart Grid Islands, the Industrial Smart Grid and the Customer Integrated Smart Grid. Based on the last, most innovative scenario a product idea has been developed - SCI:LastMile. The aim of this idea is to ensure grid stability by enhancing local consumption of nearby generated energy, hence decreasing the need to transfer energy over long distances, which is problematic from the view point of a distribution network operator. The details of this concept are explained in the last section.

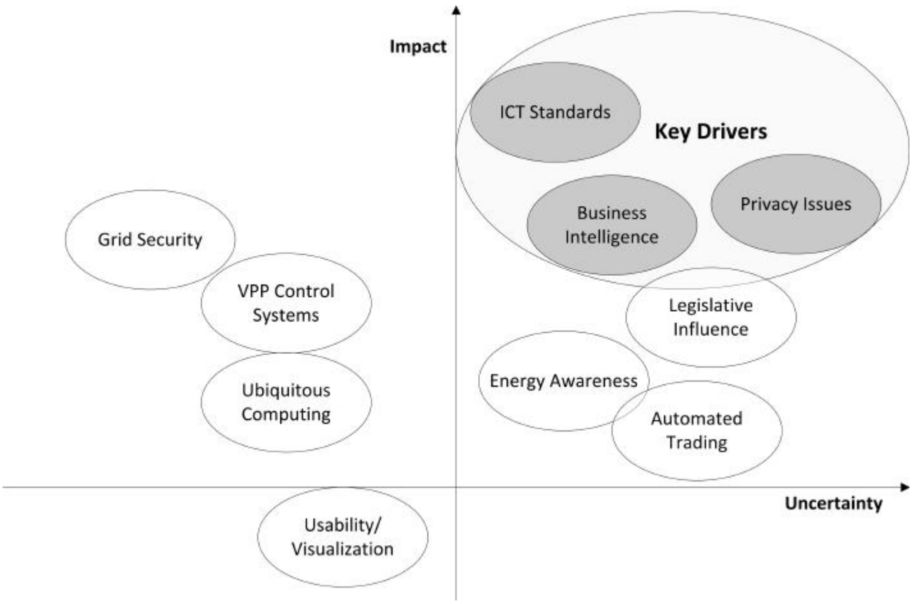

Figure 7.1: Drivers rated by uncertainty and impact on Smart Grid infrastructure
Source: own illustration

7.2 Driver Analysis

Several driving forces influence possible future Smart Grid scenarios. In the following those with the biggest impact on the Smart Grid are described, separated into certain drivers which go into a specific direction with a high probability, and uncertain drivers that could take several distinct paths - depending on how the involved parties act in the coming years. They are visualized accordingly in figure 7.1 . In both parts the drivers are ordered from lowest to highest impact.

7.2.1 Certain Drivers

Certain drivers in the IT sector of the Smart Grid regarding future scenarios can already be extrapolated from the current situation. Some of them are direct consequences of current developments, while some are simply a necessity without which the Smart Grid cannot work. In the following the four most important certain drivers from the perspective of an IT Service Provider will be presented - those being usability and visualization, virtual power plants control systems, grid IT security and reliability and ubiquitous computing.

7.2.1.1 Usability and Visualization

In the end, even mostly autonomous and automated systems have to be controlled and monitored by humans, therefore usability and visualization play an important role [381].

Description

While it is certainly possible to train experts on complicated systems, this also means that it is a costly and time-consuming affair. Typically, the term hygiene factor is used: Human-Machine Interfaces do not necessarily need to be extremely intuitive or simple to use - especially in the industry sector - but if they are overly complicated, it will hinder their adoption and possibly add security risks when humans can no longer react sufficiently fast in cases of emergencies.

Development

Thus, usability will be an important issue to be taken care of in the design of new IT systems. More important, efficient visualization of the vast amounts of data collected in the Smart Grids will be key parameters in the operation of systems like VPPs.

7.2.1.2 Virtual Power Plants Control Systems

By bundling several power sources into a virtual entity, fluctuations of energy production caused by RES can be minimized. However, intelligent IT systems are needed to handle this complexity [393].

Description

VPPs are already beginning to see use, for example in Germany by one of the largest energy providers, the Stadtwerke München [396]. In other countries like the UK or the Netherlands they are on the rise as well.

Development

In order to control these systems software has to be developed. Through high market growth rates the competition among IT systems is intense. Most likely, neither one will become the sole dominant solution, leaving room for several players in the market. Due to the very high importance of a stable energy supply, there will be a high demand for security in these systems. Even slight failures may lead to unforeseen consequences and hence discourage potential consumers from buying solutions from affected IT vendors.

7.2.1.3 Grid IT Security and Reliability

The development of the Smart Grid must not make the energy grid less reliable if it is to be accepted by the consumers. Hence, this has to be a focus of all involved parties. Due to the increasing interconnectivity - especially with the Internet - security is an equally important requirement, otherwise the reliability of the grid could be affected [388].

Description

Attacks on the infrastructure of the energy grid are already widespread, ranging from attacks on smart meters to large-scale virus attacks. However, also more mundane aspects like tree-cutting have to be meticulously taken care of as the black-outs in Northern America in the past years have made clear [379]. In case of failures, the grid must be able to fail gracefully to at least a basic mode of operation - otherwise making all the control infrastructure work again would be very difficult, as it requires electrical power itself.

Development

The US Department of Energy has already decided not to fund any future projects which do not take security into consideration and fallback solutions for the Smart Grid have to be developed.

Thus, expertise in these areas will be highly sought after. IT vendors who already have accumulated knowledge will profit. Still, these costs will also have to be paid for - meaning that the IT systems built for the Smart Grid have to take these expenses into account.

7.2.1.4 Ubiquitous Computing

Ubiquitous Computing means that computers are involved in more and more aspects of everybody's life, as well as that computing devices themselves are more pervasive than ever [387].

Description

Today, almost all devices in typical households are powered by computers - be it the coffee machine, the dish washer or the telephone. Moreover, also industry equipment is usually outfitted with some sort of control system. This directly relates to the topic at hand: computers already in place may either be used directly to control them in a way that suits the requirements of the Smart Grid, or at least alleviate the introduction of more advanced control systems which may be used that way.

Development

One of the most visible signs of further development towards ubiquitous computing is the current trend in mobile phones. These are getting more capable with each version, going so far that some phones are being designated as being smart. Accompanying these devices are often numerous applications which may be installed at the user's request, offering specialized information depending on the current context at hand or location the user is at. Also, due to the natural demographic change IT affinity is on the rise, as more and more users become accustomed to using computers in their daily life.

As pertaining to the IT industry, there is an ever-increasing market for computing devices growing with the invention of new services. Also, users can be expected to grasp at least the basic concepts of such technology, enabling more advanced ideas to be implemented. Another important aspect is that the Internet is becoming much more important also for the energy grid, as it is a pervasive and robust network which can be used for all sorts of services regarding the energy grid infrastructure.

7.2.2 Uncertain Drivers

The following section covers driving forces that are influenced by various aspects and therefore presently remain uncertain. As highlighted in grey in figure 7.1, the following three drivers have been identified as those with the highest impact on the development of the IT industry, namely: application of business intelligence, relevance of privacy issues and standardization of ICT in the grid.

7.2.2.1 Automated Trading of Energy

Different from conventional energy sources, most types of RES such as photovoltaics or wind turbines have very volatile generation characteristics. Dynamically reacting to fluctuating demand and supply requires automated trading systems based on extensive metering infrastructure.

Description

As area-wide smart electricity meter deployment is starting to be carried out in many European countries, the infrastructure for usage and generation data acquisition on all levels of the energy grid might be available in a foreseeable future [395**?** **?**]. Automated energy trading between consumers and utility companies and between utility companies at the EEX requires new IT solutions which analyze the immense amount of data collected by smart meters. Real-time trading enables new possibilities for utility companies but also poses a challenge to the planning reliability. The potential for new demands on IT solutions will be determined by the extent of pricing flexibility of utilities. More dynamic energy trading will add a new dimension to opportunities of IT service providers, for example in the area of automation. Based on this, two different developments are possible.

Developments

In the case that utilities will conduct real-time trading of energy with customers, IT systems will be required to manage the complex and highly dynamic processes of selling and purchasing. Providing consumers with online pricing information for electricity depending on the actual generation from renewable resources will stimulate the demand for extensive software solutions that analyze the current energy supply in the grid as well as the demand. Exchanging this information with devices in the customers' premises and visualizing it in a user-friendly manner will enable further opportunities for IT service providers.

Concerns regarding Smart Grid security and privacy have already been raised and are being discussed publicly. The reason for this is that energy consumption monitoring in combination with data mining technologies could be used to determine the types of appliances being used and at what time [375, p. 13ff]. Additionally, real-time pricing and automated trading might be seen as a too complex and to a certain extent as an intransparent process. In the case that pricing flexibility of utility companies is low and the data acquisition and analysis of consumption information raises end-consumer concerns, static pricing policies as presently in use day and night time tariffs might persist in the future. Such case would limit the use of IT systems to contract management solutions and static load forecasting.

7.2.2.2 Public Awareness of Grid-Related Issues

As awareness concerning the environment highly influences consumer behavior, public awareness on grid-related issues is a driver for the Smart Grid with a high impact.

Description

Public awareness on grid-related issues refers to the degree of usage and acceptance of new technologies such as smart meters amongst the public and sophistication concerning environmental issues related to the deployment of a Smart Grid such as the implementation of RES and new technologies in the energy sector in general. People might tend to sophisticate themselves more on energy related subjects as resource scarcity becomes a highly discussed topic in the public. Alternatively, people might also show ignorance towards this subject and act passively. As both, high interest or absolute ignorance towards grid-related issues, might have a major impact on the IT sector, those alternatives will be further addressed.

Developments

High interest in energy topics might lead to an increased number of prosumers. Therefore IT support services for private homes might become a possible market. A generally broad acceptance and high interest might especially boost the market for mobile applications. Sophistication on technological issues might lead to a broader acceptance of IT based services, as people will be more familiar with them.

Alternatively people might develop a 'plug-and-play mentality' which would imply that they do not care about the technological background and simply want their devices to work. People who by now are uninformed about environmental issues and energy related topics, will still lack knowledge and most of all motivation to learn more about it. This would not lead to more energy efficient consumption behavior and would significantly decrease the possibility of creating revenue for IT providers in the segment of private homes. Only a small percentage of the population would feel the need to educate themselves about issues concerning subjects as the environment, RES and energy supply, further reducing innovation potential for IT based solutions and services.

7.2.2.3 Legislative Influence

Legal influence sets the framework in which a Smart Grid could be developed and hence it is of great importance for the future Smart Grid infrastructure.

Description

Legal trends and the future adoption of laws will generally influence the success of a Smart Grid, as it might enable crucial governmental incentives and the whole framework for the deployment of a highly interconnected Smart Grid. This includes inter alia laws concerning the compulsory implementation of smart meters or the enhancement of the unbundling process. As the crucial legal steps for a Smart Grid might or might not occur, it is necessary to look at two possible developments.

Developments

The EU has already undertaken several steps to create a single European energy market, further in 2009 the "3rd Internal Energy Market Package" has been adopted which made smart meter implementation mandatory. In this sense legislation might further enhance a Smart Grid. One of the most important aspects is the unbundling process, as described in chapter 5, 2.2.1. An effective unbundling mechanism may create the possibility for several IT companies to offer new solutions and services, as it will become steadily harder for participants within the energy market to operate without sufficient IT support. Besides, the whole European population might be provided with a smart meter which poses an opportunity for IT companies. Moreover, legislation might enable Europe-wide more governmental subsidies for the implementation of RES. This will create a high innovation potential for IT services like offering specialized mobile applications or business intelligence solutions for the industry sector. Further controlling and monitoring software will be needed for instance for load management.

Another likely development is that the lack of consensus as to how specific laws in the EU within the energy sector should look like, may make legislation rather an obstacle than an endorsement for a Smart Grid. Already at the 15th Conference of the Parties in December 2009 politicians proved incapable of creating a legal framework for environmental and energy related issues [376]. Efforts to reduce for example CO2 emissions have constantly failed, also the target of the EU to reduce CO2 emissions by 20% till 2020 refers to 1990 levels, making the reduction utterly insignificant [377]. As the Kyoto Protocol commitment period will run out in 2012, Annex I countries[1] are no longer legally bound to any conditions concerning CO2 emissions [383] and the like which could lead to a decreased RES usage. This in turn will reduce the

[1]Industrial countries that are committed to emission reduction under the Kyoto Protocol

innovation potential for IT services. Also the need for monitoring software will be rather scarce. However, in this case IT providers would have to offer isolated applications for particular customers.

7.2.2.4 Application of Business Intelligence

Automated reporting and the analysis of vast amounts of information from data warehouses is an important application of IT. While business intelligence systems have been commonly used in the energy sector just as in other industries, changes in the energy grid might also have an influence on the IT market in the future.

Description

As data mining and intelligent search algorithms are constantly improving, the amount of information that can be gathered from many different resources increases further and further. While this data can be relevant for business processes, business intelligence software is an important tool to support decision-makers. Currently many companies maintain data warehouses to collect huge amounts of information relevant to their business. With the development of the future energy grid and in particular with its expansion of measuring and control units like smart meters, data acquisition of energy usage and generation will challenge existing IT infrastructure for business intelligence to a great extent. The unbundling process of the energy sector that has started over the past years might require utility companies to improve their efficiency even further [385]. Therefore the use of business intelligence tools might become an important factor for both network operators as well as energy providers. Load balancing and demand response systems play an important role and offer optimization possibilities which will require respective IT systems.

Developments

One possible development of the above mentioned aspects is that the future Smart Grid feeds massive amounts of information into the data warehouses of network operators and utility companies. Energy generation and consumption but also data on other important factors such as consumer mobility or details on weather conditions might be relevant. The real-time capabilities of the meters produce data streams that require new IT solutions to process and store them but also to analyze them in depth and draw meaningful conclusions that support grid optimization or load balancing, conduct demand response functionalities or assist strategic decision-making. Database technologies and efficient intelligent algorithms will be of particularly high importance for coping with such challenges.

Opposing this development, another case might be that data mining will be scarce due to aspects like security or privacy concerns. It might also be possible that large-scale data storage and processing will be unfeasible especially for smaller utilities. Finally, data warehouses also require tremendous amounts of energy and in the end energy consumption and costs caused by the efforts for business intelligence could have a greater impact than improvements achieved through business intelligence.

7.2.2.5 Relevance of Privacy Issues

As the end-consumer will be of core importance in making the implementation of a Smart Grid fully successful, addressing privacy issues or motivating the consumer to actively engage in the sharing of private data, is essential.

Description

IT systems for optimization of functions in the Smart Grid or subsections of the Smart Grid require extensive data acquisition. This is only possible if people are willing to share sensible data. The relevance of privacy issues therefore refers to the readiness of the public to use devices that will analyze their consumption data. The storage of sensible consumer data in huge databases brings along a lot of consequences. With this data it might be possible to thoroughly analyze one's daily routine and hence figure out what a person is doing at a given time. Further, as ICT can always be subject to hacking attacks spreading viruses and the like, this data also might get lost or stolen. On the other side, through the before mentioned data storage there would be the possibility to increase energy efficiency and optimize a lot of processes for the end-consumer. In the future privacy issues might play a more or less important role for the consumer, however in both cases this would have a major influence on the market potential of IT services. From the IT perspective issues concerning privacy would have the greatest impact, if they are particularly high or low. This is why those two possible developments will be further explained.

Developments

Consumers might have high concerns regarding the intransparency of the data usage and the misuse of their data. This would require high transparency of data usage as well as constraints about data acquisition. Even if security would be guaranteed, consumers with high privacy concerns would generally rather refuse to share their data and further also reject new devices such as smart meters. For IT services this would mean that solutions have to be based on anonymous data. On a more general level, with high privacy concerns amongst the public the deployment of a Smart Grid infrastructure will become very difficult. Only isolated solutions would be possible. Installation of ICT in combination with the grid would then only function for the industry sector or with solutions that keep the anonymity of the end-consumer.

In contrast to this, people could also develop a high confidence in ICT being able to keep their data secure and a willingness to benefit from positive aspects of data analysis. Sophistication concerning technology and electricity related subjects might increase the acceptance for data acquisition because of benefits for the grid. In this case there would not only be a high participation in social networks, but also generally high acceptance of exposing private data. This would enable a large market for business intelligence and also increase the innovation potential for IT based services. With consumers having low concerns about their private data there would be no objections to the installation of devices such as smart meters and the combination of ICT with the electricity grid.

7.2.2.6 Standardization of ICT in the Grid

As communication technologies evolve and almost every place on the globe can theoretically be reached through at least one communication channel, the areas of information and communication technology are highly dependent on each other.

Description

While IT is vital for communication technologies on different levels such as network management or decoding and encoding, the availability and the type of communication infrastructure also defines the impact range of IT systems in general. Where IT is used to monitor, control or manage certain processes, the reach of sensors and actors connected to the IT systems is defined by the connectivity of the communication layer. As in many applications it is not possible to connect different components of an IT system with one physical medium, standardization of interfaces between different mediums significantly influences the reach of such systems.

The standardization of communication protocols determines the interoperability of communication over a cross-media channel. For instance accessing the Internet on a mobile device is only possible if data packages sent over the wireless network can also be transmitted over a wired network to connect the device with a data center.

Standardization of data models plays an important role for the interaction between different IT systems. It is only possible to share information between independent software applications if the exchanged data package types are commonly defined.

Dependent on the degree of standardization, there are two different possible developments.

Developments

Regarding the above aspects, one possible development in the future is that the trend of standardization in network technologies, such as the IEC efforts [389?], continues to develop and will also be applied to the information and communication technology components in the Smart Grid. Promoting highly standardized ICT infrastructure that uses common interfaces creates the possibility to develop standard solutions that can be deployed to different parts of the grid in separate geographic locations. A highly interconnected data network together with clearly defined open data models makes it possible to operate IT systems across different platforms and include all layers of the Smart Grid into an IT controlled optimization process. At the same time more efforts for security protection are necessary.

As extensive standardization is a difficult and often longsome process, it is also possible that the efforts for the Smart Grid in this area only develop to a much lesser extent within a foreseeable future. For example, the emergence of different Smart Grid model regions in Germany that are developed by different parties are born out of the same initiative but have a potential to lead to coexisting independent solutions which can later on not work together. In such cases, IT solutions would have to focus on customized solutions for a limited area of impact. Automation and grid optimization could only be carried out in a regional scope and comparatively little interaction with grids of different standards. Due to a larger variety of different systems, the IT efforts for security protection might be of smaller importance.

7.3 Scenarios

Out of the many thinkable developments which may result from the peculiarity of above factors, the below three scenarios were selected for being the most innovative and at the same time quite different and realistic possible futures. Most importantly they all distinguish themselves by the state of the key drivers that were identified above - namely the application of business intelligence, relevance of privacy issues and the standardization of ICT in the grid.

7.3.1 Smart Grid Islands

The Smart Grid Islands scenario envisions a world where mainly companies have influenced the development of the Smart Grid. As they were not pressured by governments, they have failed to cooperate sufficiently and now each operate their own, mostly incompatible IT systems. Past efforts to unify and automate the grid were not taken seriously, partly because of egoistic economic interests and partly because too many parties were involved, making decisions even harder.

7.3.1.1 Scenario Description

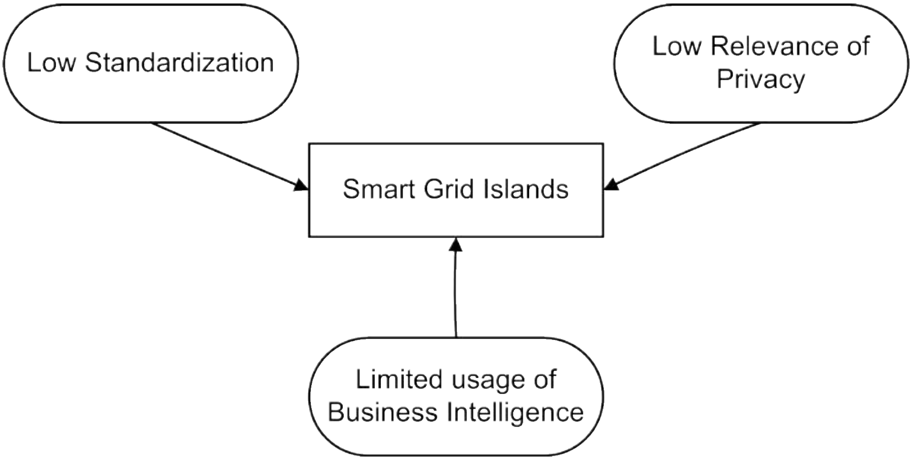

Figure 7.2: Key Drivers for the Smart Grid Islands Scenario
Source: own illustration

As can be seen in Figure 7.2, the amount of standardization among the grid operators is relatively low. Due to the limited scope of information flows caused by incompatible systems, the benefits from business intelligence efforts are quite limited. In this scenario privacy aspects are not very important and people are quite willing to share data, even if incentives in return are low.

Smart Grid Infrastructure

While there is a certain amount of activity in the grid which could be termed smart, it is limited in its scope. Seeing that grid operators employ different control systems, automated information exchange - essential for a Smart Grid - is impossible. This means that RES can only be used inefficiently, and large power sources still dominate the infrastructure. Several IT vendors try to offer solutions to the different market players. While smart meters are deployed in parts of the grid, their information potential is hardly used. Fixed delivery contracts dominate over energy trading, which is still quite inflexible because of the little automation possibilities. Although further advancements have been made in RES technologies, their usage remains unattractive because of their unpredictability and the competition of large-scale centralized generation. No load balancing is being done in private homes and mostly static pricing schemes are prevalent.

Consumer Behavior and Awareness

Social networks are used with little regard to privacy which enables companies to use personal data more easily. Governments fail to impose strict rules on neither privacy issues nor the industry to optimize the energy grid. The average consumer has no interest in the problems of the grid or how energy is being generated - for most people it is much more important that electrical outlets simply work than environmental issues. This also means that the adoption rate of DERs is very low. Economies of scale are hard to achieve for IT vendors because of many differing standards in the separate market segments - building systems which function in all of the systems is too unattractive in terms of costs. Instead, it is easier to specialize on one of the various solutions in use.

7.3.1.2 Weak Signals and Signposts

Solving critical horizontal issues - meaning interoperability and standardization among others - is already being seen as one of the biggest potential problems for the German model regions [380]. Also, different countries approach the creation of the Smart Grid differently - for example implementations used in smart meter deployments differ greatly from country to country. The frequent theft of personal data within companies makes the importance of privacy evident. The lack of information about the current load in the grid further instills the mindset of a 'plug-and-play mentality', for there is currently no way for a user to react to different loads in the grid, nor any incentive to do so.

7.3.2 Industrial Smart Grid

In the Industrial Smart Grid Scenario privacy concerns are very high the public refuses new devices such as smart meters but the industry has taken the necessary actions to implement a Smart Grid for their sector.

7.3.2.1 Scenario Description

In the Industrial Smart Grid Scenario there is a high degree of standardization of data models and communication protocols. The public is very concerned about privacy issues and does therefore reject the idea of a Smart Grid. Business intelligence does still offer some opportunities for IT companies, however the end-consumer is not involved in this. A visualization of the before mentioned driving forces can be seen in Figure 7.3.

Smart Grid Infrastructure

ICT and the energy sector are converged. However, private households are not connected to the Smart Grid. The grid itself is highly reliable and interoperable due to high standardization. Through several legal steps the industry mostly

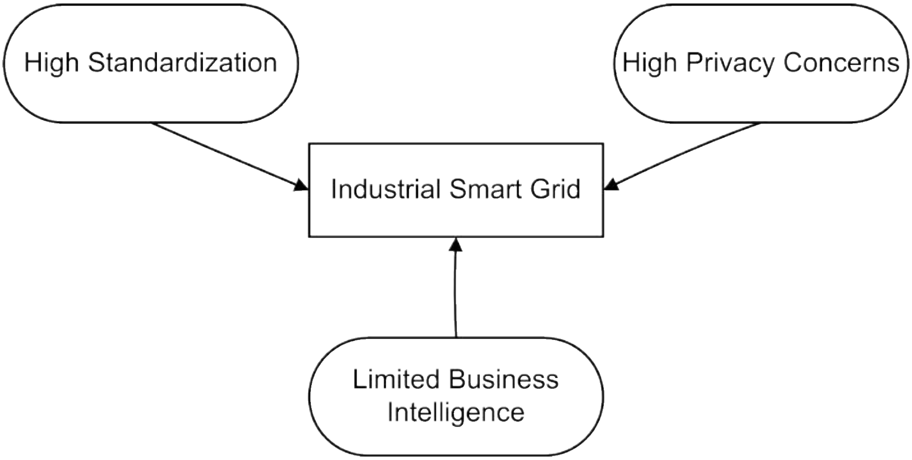

Figure 7.3: Key drivers for the Industrial Smart Grid Scenario
Source: own illustration

consumes green energy. Metering of consumption and generation data only takes place up to the last transformer and is not measured in each household separately. There is only restricted innovation potential for IT-services, still basic solutions for more grid stability are needed.

Technology

Despite the low innovation potential, IT services are still highly needed within the business sector. IT companies can offer general IT solutions or specialize in particular problems and offer niche-solutions. The market for business intelligence is very limited, as data from private households is barely available and people absolutely refuse to share any kind of data. There is also no market for IT services for the end-consumer as there is basically no demand.

Environmental Awareness

The consumer is aware of the topic of a Smart Grid and also technologically sophisticated, but does not trust new technologies and hence rejects the idea of a Smart Grid for his own household. But as people are increasingly aware of the dangers the usage of fossil fuels poses for the environment they demand energy providers to generate power from RES or change to energy providers who already offer this respectively.

Consumer Behavior

In general there will be little changes for the private consumer, as the Smart Grid will only exist for the business sector.

End-consumers will reject the idea of data disclosure through devices such as smart meters. Nonetheless, high environmental awareness leads to a high demand for green energy. Also as people refuse to engage in the usage of new devices, they try to change their own consumption behavior towards more energy efficiency.

7.3.2.2 Weak Signals

Reactions after the failure of the 15th Conference of the Parties to create a new legally binding framework to cope with environmental issues, show that people are losing their trust in politics [398].

Further, research shows that parts of the German population already reject the idea of a smart meter, which might lead to a generally low acceptance of new grid related devices [384]. Moreover, concerns about privacy issues will arise. Research shows that a general concern about privacy issues alone might be enough for a general rejection of technological devices such a smart meters. [372].

On the other side there is a lot of interest, investments and research from the business sector concerning a Smart Grid. Companies from different sectors are keen on investing into the development and deployment of a Smart Grid and related technologies [373**?** **?**].

7.3.3 Customer Integrated Smart Grid

In the Customer Integrated Scenario the Smart Grid is applied from generation to consumption. All involved parties cooperate and are connected through bi-directional information flows. The grid operates very efficiently and a high share of energy is generated from RES.

7.3.3.1 Scenario Description

The Customer Integrated Scenario is based on the following state of the three key drivers: high standardization implies interoperable communication protocols and data formats. Low privacy concerns among the society stand for the willingness to disclose personal data when benefits in return are high. The last driver is efficiently used business intelligence in terms of extracting information from data for strategic and operative decision making. The key drivers and their impact are illustrated in Figure 7.4.

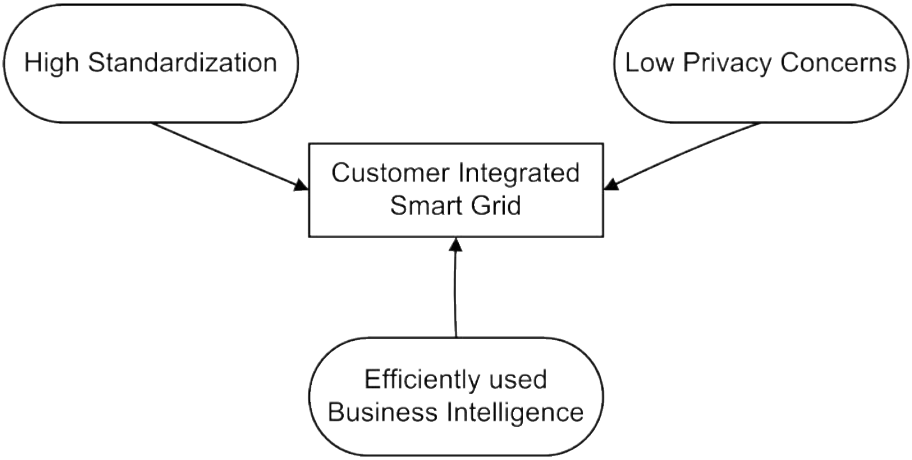

Figure 7.4: Key drivers for the Customer Integrated Smart Grid Scenario
Source: own illustration

Smart Grid Infrastructure

In this scenario the unbundling process is fully applied, with a strict divide between energy producers and network operators. Thus, the Smart Grid infrastructure consists of large-scale energy providers, transmission system operators (TSO), distribution network operators (DNO) and various small-scale energy producers and consumers. Seen from a European perspective, the grid is highly connected and due to ICT standards very interoperable. Energy can be traded on a European real-time market although network losses over long distances occur. Through high standardization and IT systems, trading takes place highly automated on a European energy market. Moreover, smart meters are fully applied throughout Europe and through low relevance of privacy energy providers and network operators have access to energy consumption and generation data of households. Information flows bi-directionally from generation to consumption including the last mile. The share of decentralized RES is very high within the overall energy production. The massive integration of RES has led to a very unstable grid which has influences on all industry sectors as well as the common living standard in Central Europe. Therefore grid stability is an important goal which needs to be pursued in order to better integrate and even expand RES. Network operators hold feed-in contracts and do the billing with small-scale privately owned power plants. Furthermore, IT services have a high innovation potential which is amongst others enabled through low relevance of privacy if resulting benefits are high. An important aspect is the Smart Grid cyber security as IT security threats pose a big danger on the highly interconnected grid.

Technology

In private households as well as businesses ubiquitous computing is reality. The penetration of smartphones among all demographics is high and the number of automated appliances in private households increases steadily. A large number of IT services and applications enables remote control of appliances like heating or coffee machines. Usability and visualization is necessary to gain broad acceptance. The technological dependency is high among all age groups. In industry, business intelligence is efficiently used for predictions, strategic and operative decision-making with a high availability of IT services for data analytics and data mining.

Environmental Awareness

Public awareness of environmental issues is very high. The society is aware of the limited availability of fossil fuels and its impact on climate change. Through high commitment and public initiatives nuclear energy production has been phased-out in Germany. Furthermore, through social networks and other Internet services the gap between environmental awareness and personal consumption is bridged. Society begins to directly link the individual consumption with environmental impacts. The above described developments are also responsible for a high number of privately owned small-scale renewable energy plants.

Consumer Behavior

The average consumer can be characterized as having a high technological affinity and a high sophistication through simplified access to information. Consumers have continuous access to the Internet for personal activities and actively participate in social networks. They are interested in their personal energy usage patterns which are accessible through smart meters, personal web accounts and mobile applications. They share their usage patterns with friends through social networks and blogs which leads to competition and creates non-financial incentives to reduce the personal consumption. Moreover, consumers are willing to adapt their consumption patterns through sale appeals. Financial incentives and personal interests also lead to further investments in energy related systems like automated home appliances, highly insulated buildings or energy storage systems.

7.3.3.2 Weak Signals and Signposts

Smart Grid Infrastructure

The EU Commission is strongly pushing towards a highly connected and interoperable European Grid. The European Network of Transmission System Operators for Electricity (ENTSO-E) in close cooperation with the European

Commission and other stakeholders set up the European Electricity Grid Initiative (EEGI) Roadmap 2010-18 and Implementation Plan 2010-12. The Roadmap includes functional projects like the "Joint task force on IT system protocols and standards" [382]. Also the German legislation enacted a law in 2009 (Energieleitungsausbaugesetz EnLAG, §1) for upgrades of high voltage transmission lines to guarantee European grid interoperability and to allow cross-European energy trading.

Smart meters will be fully deployed in the future, as already several European countries like Sweden and Italy have a high penetration [391] and laws like the 3rd Internal Energy Market Package by the European Council [385] or the German Energiewirtschaftsgesetz (EnWG), paragraph §21b start to force the built-in of smart meters. The liberalization of the European energy market which started in 1998 will further continue and the share of RES will highly increase. EU targets like the "Climate and Energy Package" which claims 20% RES of the overall consumption in 2020 [377] and even higher targets by Federal States will boost the development towards a high share of RES.

Technology

Smart home appliances and cooperating objects have been a large research field in the last decade. These technologies are now ready for the market and in the near future products will be in use not only by innovators but also early adopters. The development will go towards ubiquitous computing. Considering the smartphone adoption in Europe, the increase in subscribers was enormous from 2009 to 2010. The average rate in the EU5 (U.K., France, Germany, Spain, Italy) accounted for 32%, with 34% in Germany and even 70% in the UK [378]. The market will switch from the early majority customers to the late majority and will include all demographics.

Environmental Awareness

The ongoing public nuclear energy discussion in Germany shows concerns and commitment on environmental issues. Moreover, a sales trend goes towards energy efficient appliances. Sales figures of BSH in this segment in Europe tripled in 2009 compared to the previous year [374]. However, there is still a gap between the awareness of climate change and personal energy consumption. In the upcoming years the consumer will further receive suggestions on how to change the energy consumption in order to make it more efficient. Therefore the end-consumer will be enabled to actively bridge the gap between environmental awareness and personal consumption. Social networks [386] and the sharing of energy usage patterns can play an assisting role in this development.

7.3.3.3 Consumer Behavior

Beside the overall increase of time spent on social network sites, the demographics of the average social network users are changing. In 2010, the average Facebook user in the U.S. is 38.4 years old [390], on a social network site which started as a college network. Moreover, the technological affinity, the access to information and thus sophistication among all age groups will further increase which will provide the foundation for an active consumer integrated in the Smart Grid.

7.4 Product Idea: SCI:LastMile

The product idea described in this chapter is derived from the Customer Integrated Smart Grid Scenario - a very innovative and probable scenario explained in section 3.3. SCI:LastMile (Stability through Customer Integration) is a software solution which enhances distribution network stability for DNOs. The product idea is perfectly suited for a medium to large-sized company with expertise and knowledge of both - the ICT and the energy sector. The logo is illustrated in Figure 7.5. Section 4.1 explains the need for a solution like SCI:LastMile and the overall idea. In section 4.2 the underlying business model is further described.

Figure 7.5: Logo of SCI:LastMile
Source: own illustration

7.4.1 Description of the Product Idea

SCI:LastMile offers a concept for bottom-up network stability in distribution networks.

7.4.1.1 Important Role of DNOs in the Smart Grid

A large number of decentralized RES challenge the distribution networks. Traditionally the network stability was mainly coordinated by TSOs as the energy feed-in was done in the transmission lines. The voltage minimum was originally at the point of consumption in the distribution lines. Voltage differences appear if supply and demand within a subnetwork are not balanced. Through decentralized feed-in voltage fluctuation happens in both directions within a distribution network: voltage can drop or rise in case of sudden overdemand or excessive feed-in. Network stability is harder to guarantee as voltage fluctuation doubles. This phenomenon is illustrated in Figure 7.6. Moreover, through

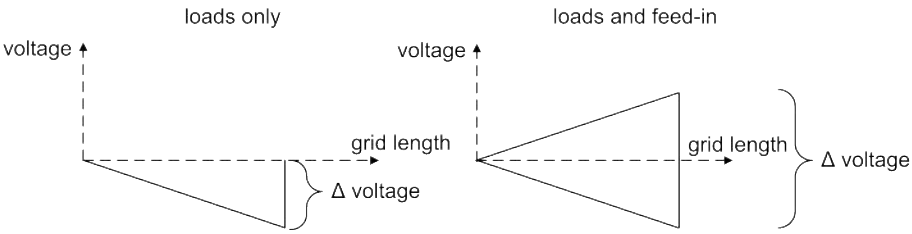

Figure 7.6: Voltage fluctuation in distribution networks with loads only (left side) and load as well as feed-in (right side)
Source: adapted from [397]

decentralized feed-in the load flow becomes reversed. In case of decentralized feed-in, the voltage maximum appears at the end of the line which is the point of decentralized supply.

In Smart Grids with a high share of RES, DNOs need to coordinate voltage quality and network stability influenced by the fluctuating feed-in. Network stability can be achieved either through upgrades of transformers in order to transport overcapacities in the medium voltage lines more easily or through switching off renewable energy plants during supply peaks. Both alternatives are very costly. A third sustainable solution is described in the product idea below.

7.4.1.2 LastMile Concept

As load balancing and network management becomes increasingly important SCI:LastMile is a solution for DNOs which enhances distributed network stability and avoids large-scale network upgrades. Each distribution network is subdivided into small clusters, herein further referred to as LastMiles which include all end-consumers and small-scale producers in a certain geographical area. The topology of the energy network as well as the integration of the SCI:LastMile solution are illustrated in Figure 7.7. SCI:LastMile offers a full solution for DNOs and provides customization to adopt the software to DNO ERP systems. The software allows real-time analysis of energy generation and consumption within a LastMile. Moreover, it enables short-term prediction of energy generation through the access to weather forecast data. The software gives the DNOs the ability to enhance close-to-source consumption. Households and appliances in the LastMile get real-time and forecasted information of the availability of locally produced energy. Moreover SCI:LastMile offers paid web services for third parties like smart meter vendors. Thus, the LastMile data can be integrated and visualized in other devices or mobile applications which has value-added effects on end-consumers and prosumers which are described in 4.2.5. Through the usage of locally produced energy, DNOs avoid large investments in the grid and are able to guarantee network stability in parallel to further expansion of RES.

Furthermore, the software tool enables automated billing of feed-in and (self-) consumption and thus simplifies the requirements posed by the German Ausgleichsmechanismusverordnung on the network operators. The Ausgleichsmechanismusverordnung took effect on January 1, 2010 and directs that no longer the energy provider but the network operators need to hold the contract with small-scale renewable energy providers and thus pay the feed-in compensation and need to sell the energy on the market.

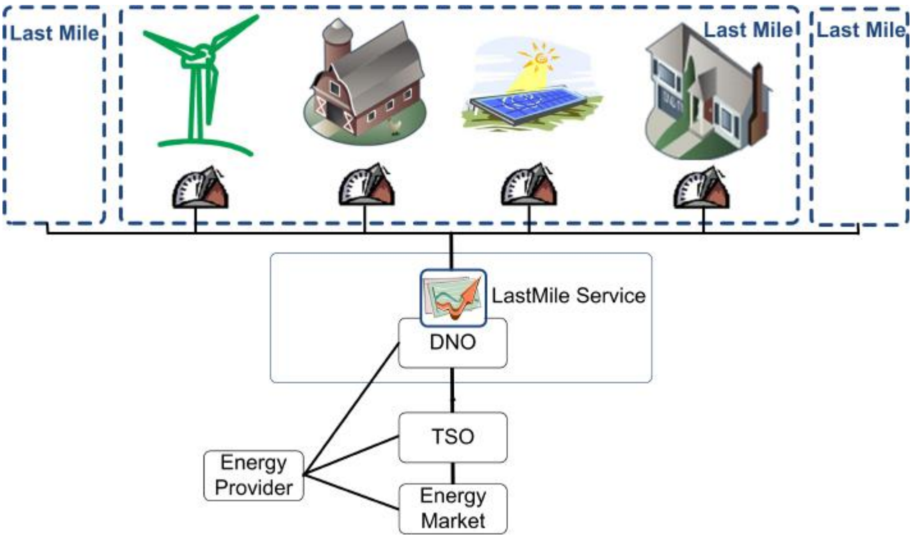

Figure 7.7: SCI:LastMile Solution
Source: own illustration

7.4.1.3 Stakeholders of the Distribution Network Stability

The stakeholders of the distribution network stability are DNOs, end-consumers, large-scale centrally run energy providers and small-scale renewable energy providers. Each stakeholder has diverging interests. The energy and cash flows between the stakeholders are illustrated in Figure 7.8.

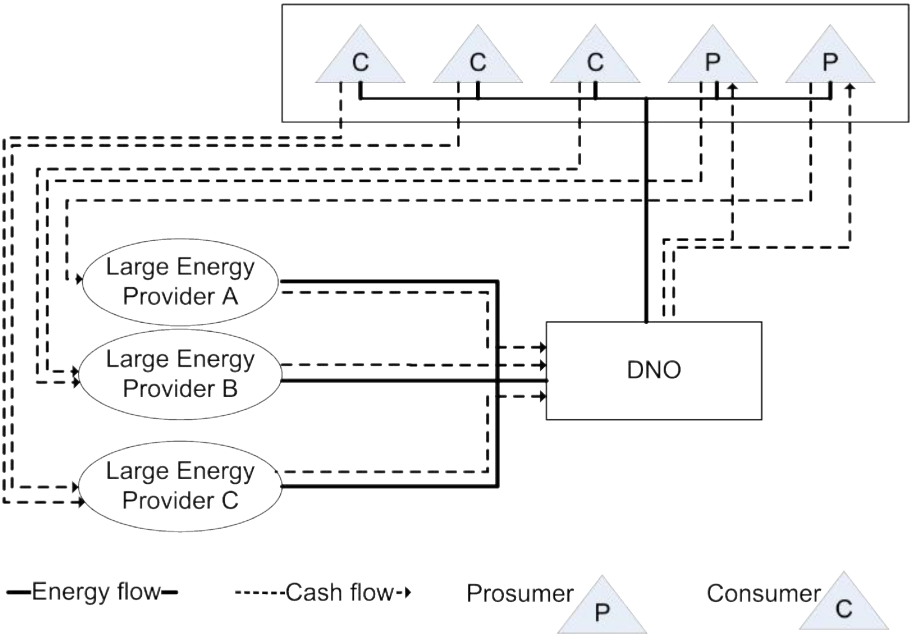

Figure 7.8: Stakeholders of the distribution network stability
Source: own illustration

DNOs serve as a connector between large-scale providers, small-scale providers and end-consumers. They get paid by large-scale energy providers for the delivery of energy to the end-customers and in return offer grid access and network stability. The fee for grid access and energy transportation is regulated by the Federal Network Agency. The objective for large-scale energy providers is to sell energy with a high margin to a large number of customers. High competition influences the price. End-consumers' objectives are cheap energy prices, a high grid reliability, less effort and continuous supply. For some end-consumer segments additional objectives like low environmental impact, usage of green energy and low personal consumption are important. Small-scale producers are prosumers, which means they are end-consumers and producers simultaneously. Their objectives are profitability of the investments, self-supply and a reasonable price for the overcapacity. With the LastMile concept an additional virtual stakeholder is created. The aim of the LastMile is to enhance the consumption of locally generated energy when it is available. Through the adaption of their consumption, consumers get cheap prices, prosumers can sell their overcapacity and DNOs achieve network stability.

7.4.1.4 Principle: Network Stability through the Active Participation of Consumers

In order to be able to implement the concept of close-to-source consumption, it is not sufficient to provide end-consumers only with real-time and forecast information generated by the LastMile solution and link it with consumers' environmental commitment. Additional financial incentives are needed.

For the end-consumer in a LastMile the energy price at a specific point of time depends on three quantities, namely the demand of each individual consumer within a LastMile, the availability of locally generated energy and the need for centrally produced energy.

Therefore four different extreme cases can occur within a LastMile which are illustrated in Table 7.1.

No.	Consumption in a LastMile	Local Energy Availability	Need for centrally produced Energy	Price for consumers within LastMile
1	High Consumption	High Availability	Low Need	Medium Price
2	High Consumption	Low Availability	High Need	High Price
3	Low Consumption	Low Availability	Low Need	Medium Price
4	Low Consumption	High Availability	Low Need	Low Price

Table 7.1: Overview of energy supply and demand and price effects within a LastMile

From the DNO point of view regarding the grid stability, case 2 and 4 are critical. In case 2 with high consumption and a low availability of locally generated energy a voltage drop can occur. This can be forecasted with the SCI:LastMile software through access to weather data and can be overcome through the supply with large-scale centrally produced energy. In case 4 with low consumption and high availability of local energy a voltage rise is likely to happen. Again, the forecasting service of the SCI:LastMile software can predict the high availability of local energy. In this case, consumers get financial incentives in order to use the locally available energy. Automated appliances like smart fridges, washing machines, heating of highly insulated buildings, energy storage and plug-in EV are connected through smart meters to the SCI:LastMile software and are started automatically in case 4. The relatively high price in case 2 originates from network losses due to long-distance energy transport and the grid access fee for large-scale energy providers. The cheap price in case 4 can be achieved through governmental compensations for self-consumption and close-to-source-consumption which are integrated in paragraph §33 of the

German EEG law since 2009.

7.4.2 Business Model of SCI:LastMile

The following section describes the underlying business model of the SCI:LastMile solution. The unique selling proposition, customer segments and cost and revenue streams as well as the value proposition is further analyzed.

7.4.2.1 Unique Selling Proposition

SCI:LastMile is offered by a medium-sized ICT company with experience in the energy sector. The long-term relationship with players in the energy sector has resulted in a well-known reputation and a trustful brand image. As the potential market for the SCI:LastMile solution has a limited size, already existing relationships to DNOs through former business connections are highly important. The company has high market knowledge and expertise in the energy sector which reflects the suitability of the software. It is easily customizable and capable of being integrated into existing DNO systems. Moreover, SCI:LastMile offers a web service interface for third parties like device manufacturers and application providers. The company has already built-up several partnerships with smart meter vendors and service providers. Through these partnerships consumers and prosumers of a LastMile get access to value-added services and products.

Know-how in the energy sector and already existing connections to potential customers pose high barriers of entry for competitors, especially in a market of limited size with well-known customers.

7.4.2.2 Customer Segments

Regarding the current unbundling process which will be finished in the near future and the focus of our product - namely DNOs - one can easily conclude that the market size is more or less fixed. In Germany there currently are about 900 DNOs [392]. In most other European countries the figure is significantly less, usually ranging between ten and twenty in e.g. the UK, the Netherlands or Belgium [394].

7.4.2.3 Revenue Model

Providing a complex and highly specialized solution for critical infrastructure components, SCI:LastMile requires all available data on generation and consumption of energy in a distribution network. As this data can be very sensitive for the customer, the product cannot be provided as a service but has to run within the customer's premises. Therefore the revenue model consists of the following three parts:

Core Software License

As the basic functionalities of the product are built upon the highly standardized communication infrastructure assumed for the scenario, a common software core can be developed and charged through a license model. Customers of different size and complexity in network infrastructure can be provided either with a pure software solution or bundled with deployment of server infrastructure. The hardware part might be outsourced or done by a partner.

Service and Customization

As the core functionality of the product only provides a standardized solution, integration into existing IT infrastructure and optimization for the energy grid of the customer will be offered as an additional service. Interoperability of SCI:LastMile with other business intelligence or ERP solutions can be provided and charged separately. To ensure maximum convenience and security for the energy grid, a long-term support cooperation is intended.

Web Service for Visualization Components

The acquired data of decentralized energy generation and consumption in the LastMiles is vital for the load management but also needs to be processed and presented to the end-consumer or prosumer. In order to provide consumers with a tool to maximize self-consumption within the LastMile, data needs to be transferred back. The product will therefore include a secure web service that uses standardized data models to provide visualization devices with necessary information:

- Smart meters
  In the scenario a high penetration of metering devices that monitor and communicate energy generation and consumption within the LastMiles is assumed. Smart meter manufacturers are enabled to offer consumers advanced meters that make use of the SCI:LastMile web service and display generation and consumption information or make suggestions on how to optimize self-consumption within the LastMile.

- Mobile Applications
  The ubiquitous availability of mobile computing devices which can always connect to the web service through the Internet makes it possible to offer end-consumers full coverage of their LastMile information wherever they are located.

- Websites
  A web platform that makes use of the web service can provide consumers and operators with all information necessary.

A web service for standard and advanced visualization components will generate additional revenue and promote further investments in the Last-Mile concept by third parties.

7.4.2.4 Cost Structure

The underlying Customer Integrated Scenario assumes that metering devices will have been deployed on all levels of the infrastructure. Monitoring data acquisition is already being done by the network operators or their respective subcontractors. SCI:LastMile will be provided by a medium-sized company and will be offered as a pure software solution which runs in the data center of the network operator. As such, all necessary hardware will need to be provided by the customer and the product will have the following cost structure:

As a software product, the predominant part of the cost of SCI:LastMile is the cost for human resource. During the product creation phase, labor cost consists of the payment for labor that will be spent on product requirement engineering, systems architecture and design, code implementation and testing. Simultaneously with the development of the software, cost for trademark registration and copyrights for the application will occur. During the product deployment phase, labor which needs to be spent on customization according to customer requirements and the following on-site implementation and testing will need to be considered. There is also need for customer care and support after the software is successfully installed. Maintenance costs play an important role for software products and cover bug fixing, change request handling, configuration management and regression testing.

As human resource accounts for the greatest part in the cost structure of the development and maintenance of SCI:LastMile, also additional expenses that are connected to human resource such as infrastructure and equipment need to be considered. The business model involves a close cooperation with the customer. Hence, the cost for on-site support engineers who adjust and expand the core product is dependent on the number of clients while the efforts for the software core are fixed.

7.4.2.5 Value Proposition

SCI:LastMile particularly helps DNOs as its customers to overcome the challenge of an increasing number of decentralized renewable energy generation and hence guaranteeing network stability.

Besides this main value proposition there will be other value-added side effects. As DNOs need the involvement of the end-consumer for the service of SCI:LastMile to work, there will be incentives for the end-consumer in the form of a lower energy price. Those lower energy prices for close-to-source consumption can further function as incentives for investments in more RES, so that more consumers will be able to maintain self-supply. Not only price incentives, but also the will to actively protect the environment will enhance a great number of private investments in RES. This also might create incentives for investments in temporally flexible automatable systems with high energy consumption like heating, energy storage systems or highly insulated buildings.

When being part of the SCI:LastMile, the consumer has the chance to be provided with detailed real-time data concerning the energy consumption, energy source, energy efficiency and the paid energy price at any given time. This might lead to an increased awareness of the own energy consumption. The consumer will further receive suggestions how to change the energy consumption in order to make it more efficient. Hence the consumption behavior will be influenced towards more energy efficiency. Within a single LastMile, there might further be an evolvement of social dynamics, with different end-consumers supporting each other and creating a strong sense of belonging to a group with the common goal of protecting the environment. With this omnipresence of the energy topic related issues will become more salient for the consumer and will be integrated into the daily life routine. Moreover it can serve as a common subject to address between neighbors, as the SCI:LastMile works within geographically close located households. In a reciprocal manner consumers within each LastMile will grow together and steadily motivate each other to act more environmentally friendly.

7.5 Conclusion

The analysis of the IT service provider perspective on Smart Grid infrastrucu-tures has revelead three key drivers as having the highest impact and being of high uncertainity on this topic. These key drivers are application of business intelligence, relevance of privacy issues and standardization of ICT in the grid. Derived from different possible states of the key drivers three distinct but equally plausible scenarios are envisioned. However the future may look like, a lot of effort has to be made and interesting business ideas will arise in each scenario. Due to the convergence of ICT and the energy sector, IT will be of utmost importance. Many of the Smart Grid components still have to be further developed, standardized or in many cases even invented. Nevertheless, there is much progress and thus the next years will determine a lot in terms of what will become possible and who will be able to extract the most benefits. The Customer Integrated Smart Grid scenario shows a very innovative and probable picture of the future with the need for services like the SCI:LastMile to support the stability of the grid. Technologies like this will contribute to the creation of a Smart Grid.

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Chapter 8

8 Utility Perspective

Veranika Andreyeva, Salma El Sayyad, Lena Hoeck, Christoph Neyer

This report describes three possible scenarios concerning the utilities' status in 2025 and the respective drivers that could lead to that development. It also describes a product idea, which solves some issues and challenges the utilities will face. From the utilities' perspective, political decisions, energy storage systems and real-time management, will mostly determine the future development of the grid. These key drivers will be used to develop three possible scenarios. In addition, other certain and uncertain driving forces are defined.

The first scenario, the Technological Solution, considers a very technology oriented society and governments that highly support R&D to push energy technologies and to strengthen the economies. The Renewable Energy Law is adapted in almost each European country and decentralized energy storage systems are available due to a wide adoption of e-vehicles. The European Solution describes an European Union that grew together to one force and tries to be autarkic of energy supply. Smart metering allows real-time demand response and real-time trading on the European Energy Exchange. Moreover, the transnational super smart grid enables the utilities to store energy in countries where pumped hydro storage systems are available. In the Green Solution, the society has an environmental friendly spirit that comes along with a high proportion of renewable energy sources in order to be independent from nuclear power. However arising new problems such as higher energy prices and high volatility in power generation make the need of a smart grid solution certain.

Furthermore, a product idea that solves the problem which arised in the

Green Solution is presented. The SmartMicroGrid is a system that makes constant power feed-in of volatile PV power plants possible. It is a product that can be offered from the utilities to reduce volatility and to make renewable energies a suitable substitute of nuclear power plants.

8.1 Introduction

A few decades ago, utilities didn't have to care much about the possible threats to their core businesses, power generation and distribution. Even though, the utility industry has always been very dependent on political decisions, it has never failed to form a relatively untouchable and stable system with a strong and effective electric grid.

However, there are recent developments that will involve significant changes in the utility industry showing that the same grid is not able to respond to today's needs. The rising proportion of renewable energies exhibits a big challenge to the utilities as it lowers the power quality and comes along with a highly volatile and difficult-to-predict power feed-in. As this development is also accompanied by increasing energy prices, because cheaper gas turbines and nuclear power plants shall be phased out in the future, utilities have to defend their position on the market. It is expected that there will be new competitors in and beyond industry boundaries forming additional challenges. The increasing self-supply by today's called "prosumers", consumers and producers at the same time will be another hazard in the future.

This report brings out the serious challenges that the utility industry will be facing until 2025 and beyond. Firstly, certain and uncertain drivers for the future will be identified. Subsequently, possible outcomes of these drivers and their impacts are illustrated by drawing three different scenarios of the future also indicating signposts hinting at the development for each one. Lastly, for the most promising scenario, this report introduces an innovative product idea that will match the opportunities and threats of that scenario and thus providing an insight in strategic reaction options of the utility industry.

8.2 Driver Analysis

Drivers are defined as driving forces which form the future. As illustrated in Figure 8.1, they are divided into certain and uncertain drivers and are characterized by high or low impact on utilities. Concerning the future smart grid, there are various important drivers. However, utilities are most concerned about possible political decisions, further energy storage systems and real-time management. Due to their high impact, those three drivers are considered to be the key drivers for the utility industry. To give a complete overview about the possible developments of the smart grid, other certain and uncertain drivers relevant for the topic are included and analyzed with regard to their influence on the utility industry and the smart grid.

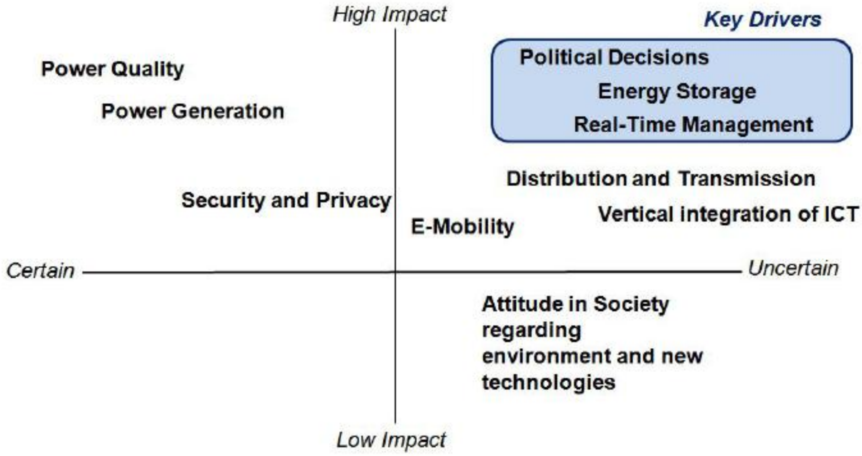

Figure 8.1: Illustration of Drivers
Source: own illustration

8.2.1 Certain Drivers

From the utility perpective, the three certain drivers that will have a high impact on the industry are power quality, security and privacy concerns and a mix of centralized and decentralized power generation.

8.2.1.1 Power Quality

Utilities are expected to maintain high power quality to protect customers from economic losses and to provide uninterrupted power on a continuous basis. Improved power quality is considered to become an integral part of the smart grid.

Description

Good power quality means a sinusoidal AC source that provides a stable voltage at a constant frequency within narrow limits. Due to the lack of efficient storage methods, utilities have to keep a vigilant eye on demand and to be prepared to bring reserve facilities into action at a moment's notice in order to prevent power interruption [420, p. 4-6]. The certainty of the driver power quality is strengthened by the increased volatility in the production of renewable energy.

Development

To hold power quality steady especially by the raised number of renewable energy generation systems, utilities continuously increase the complexity of

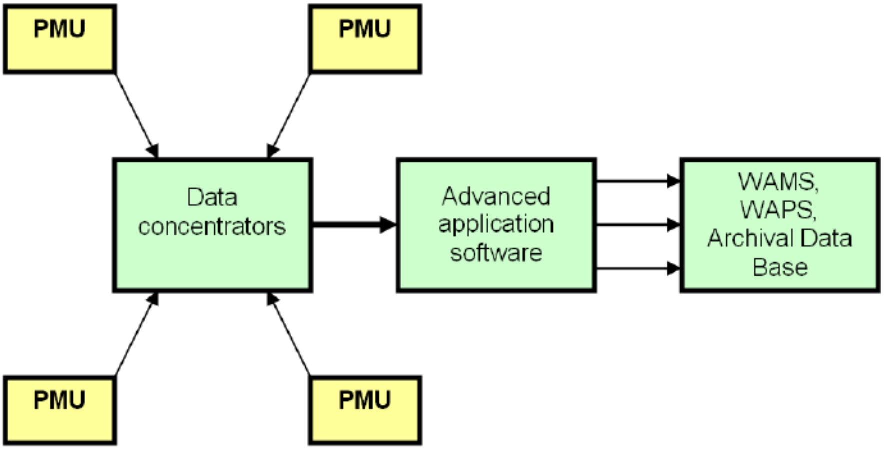

Figure 8.2: Applications of PMU in a Power System
Source: adapted from H. Bentarzi [402]

operation, control and protection of electric power systems. This includes the widespread installation of Phasor Measurements Units (PMU), which measure the system's state in real-time and detect its dynamics in order to improve the system's operations [416, p. 1-4]. As shown in Figure 8.2, the data gathered from PMUs, with the help of advanced application software will be sent to Wide Area Measurement and Protection Systems (WAMPS), that provide a reliable high-speed transfer of all measurements and indicators to a control center for evaluation and decision. All these technologies will be refined for the future smart grid [402, p. 93f] [421, p. 4-5].

8.2.1.2 Security and Privacy

In order to provide the safeguard of personal information, utilities need to follow strict privacy and information security practices, decreasing privacy risks and concerns, created by new smart grid technologies.

Description

Privacy is one of the most fundamental human rights. Smart grids however, can damage it due to new data collection, communication, and information sharing capabilities related to energy usage [407] [413, p. 5-39]. Besides effective integration of ICT in the smart grid, utilities have to eliminate privacy risks of consumers. Therefore, security and privacy being a part of all developments concerning smart grid belong to the certain drivers.

Development

Due to the lack of security standards and increasing privacy issues, utilities will be highly focused on finding solutions across the smart grid. The main developments will include establishing security standards, the search for new ways to exploit meter data minimizing invasion of consumers' privacy and the development of reliable technologies. Already existing security and protection systems such as SCADA, EMS, WAN will be upgraded, interconnected and completed with new security solutions [413, p. 39-42].

8.2.1.3 Power Generation

The current mix of power generation resources in almost all nations depends heavily on fossil fuels and other pollution-producing supplies.

Description

Electricity generation is the process and system of producing electricity from other sorts of energy. For electric utilities, it is the first litigate in the delivery of electricity to consumers. Other processes such as electricity transmission, distribution, and electrical power storage and recovery using pumped storage methods are usually executed by the electric power industry. Electricity is in most cases generated at an electric power station by generators, primarily operated by heat engines fueled by nuclear fission or chemical combustion but also by other appliances such as the kinetic energy of moving water and wind. There are several other technologies that can be and are used to generate and produce electrical power such as solar photovoltaics and geothermal power.

According to figure 8.3, Germany's electricity generation from renewables is about 14%. Power generation will develop in one direction, which is in increasing the electricity production from renewables.

Development

More decentralized generation such as solar photovoltaics, virtual power plants as well as new generation technologies like Desertec will be mounted in order to sustain various reliable energy generation systems to cover the need and demand of the growing society. Since most renewables are however dependent upon either the sun shining or the wind blowing, researchers will develop new technologies that can store energy during peak times, resulting more reliability and sustainability of renewables and thus, reducing oil dependence and minimizing environmental threats such as greenhouse gas emissions. New efficiency systems and technologies will hence be developed to ensure energy reliability and of course low cost due to the mass market [412].

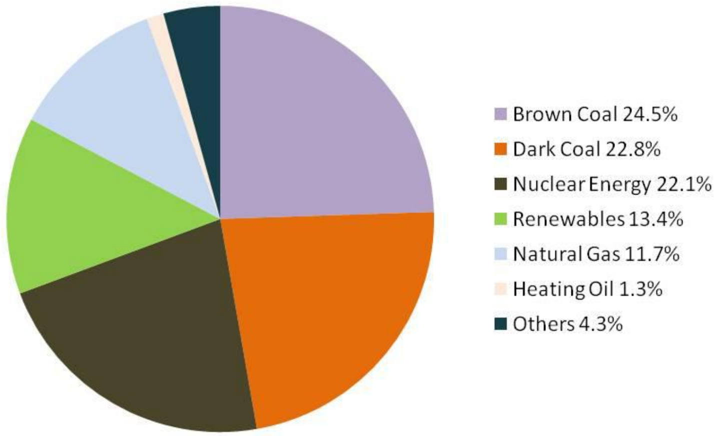

Figure 8.3: Gross Electricity Generation in Germany, 2007
Source: adapted from H. Frey and E. Obe [419]

8.2.2 Uncertain Drivers

Identified by several possible developments, uncertain drivers count to decisive factors, which highly influence the future smart grid. They cover a field from attitude in the society to future distribution and transmission systems and advanced technologies. As key drivers political decisions, energy storage systems and real-time management are defined.

8.2.2.1 Attitude in the Society Regarding Environment and New Technologies

The society's attitude towards adopting new technologies and engaging in pro-environmental actions scales the intensity and frequency of change and modernism within the society itself.

Description

How the society reacts to innovations and the development of advanced technologies has an impact on the implication of those new systems and their further development, especially if the innovation requires behavior changes in the society. Another influential society attitude is the environmental awareness and the respective environmental behavior as both define to which degree a society would actually adopt eco-friendly policies or regulations. There are two possible developments concerning the society's attitude towards the environment and new technologies.

Developments

The first possible development of a society's attitude would be a society with high environmental awareness as well as high acceptance and adoption of new advanced technologies. A society with those traits would be able to adjust itself to new systems and to follow eco-friendly laws. In that case, the society becomes more flexible to dealing with alteration, both technologically and environmentally.

The second possible development would be a society with low environmental awareness and also with the tendency to act reluctant when it comes to the acceptance and adoption of new technologies or systems. In most cases the main reason is the lack of knowledge. If people are not aware of the problems and consequences of their behavior they will never be able to change it.

8.2.2.2 E-Mobility

It is widely agreed that the capacity and charging time of EV battery will determine the utilities' and accordingly the grid's ability to power EVs.

Description

EV research seeks an improvement and efficiency of EV technology and its infrastructure so EVs could be adopted in the future. Existing power plants are aging, population growth is exponential and an ever-growing reliance on electronics has become a habit in almost all societies. Base load will increase but not to a dramatic level. There are three possible developments, the EV adoption could be low, middle or high.

Developments

There is a valid concern about the electric grid's ability to absorb EVs into its already-stressed system. Nation's utilities may be hard-pressed to absorb more demand by supporting EVs. With a low adoption of EVs however, a comprehensive load management scheme will be necessary yet without exceeding current peak capacity.

As more EVs are adopted, for instance in case of middle adoption, the demand for electricity will be growing and additional generation capacity will be required to meet that demand. However, a larger number mainly effects the load curve of the grid over the course of the day.

Vehicle-to-Grid (V2G) has been hyped as one of the most promising opportunities of the EV revolution. The idea is that utilities will be able to use the distributed storage provided by EV batteries as back-up capacity to help meet unusual demand peaks. For example, power could be drawn down from car batteries and sold back to the grid to power a home for the afternoon and then be recharged at night. This is a possible development in the case of high adoption of EVs [408].

Whether a high, middle or low adoption of EVs will be undergone in the future, certainly has a high impact on the utilities and the grid capacity.

8.2.2.3 Distribution and Transmission

Transmission and distribution represent the foundation that supports activity in all areas of the energy sector. Used in efficient, reliable and secure way these systems enable to get benefits of renewable energy and smart grid technologies in the future.

Description

High voltage electric transmission transfers electrical energy from generating power plants to substations located near population centers. This draws, on the one hand, distinctions to electricity distribution which provides only local wiring between high voltage substations and customers and on the other hand, points to interconnenction of both systems [417].

Different forces like increases in electricity demand, decentralized generation of renewable energy have created the need for increased transmission capacity, the use of Phasor Measurement Units (PMUs), Wide Area Monitoring Systems and transmission automation [416, p. 1-4]. As shown in Figure 8.4, in contrast to the current mostly uni-directional power distribution there is a tendency for a bi-directional way which will strictly connect prosumers with suppliers, creating strong communication channels between them. Bi-directional distribution will allow flexible pricing and feed-in tariffs and will create innovative services and products for the future smart grid. Two possible developments can be identified.

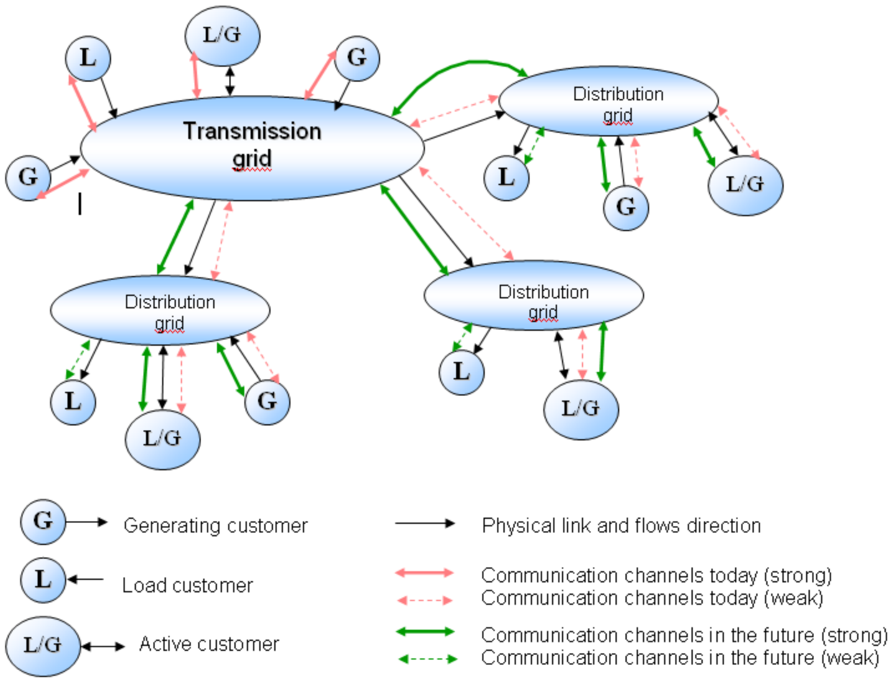

Figure 8.4: Distribution Grids Scheme
Source: adapted from European Commission [400]

Developments

Driven by renewable energy focus the existing systems have to be retrofitted to add new capacity and greater monitoring capabilities. Whether these aims will be achieved, connecting whole Europe with transmission lines or being spread only on national level is uncertain. Therefore, the following developments are possible.

The first of them is that transmission and distribution will remain on the national level. Due to already tolerable conditions and security of the German transmission network essential modifications will be made in minimization of the energy degradation and providing of sufficient energy supply. To support the approach of a smart grid the decentralized generated energy will either be able to be fed directly into the grid or the concept of Virtual Power Plants will come into play.

In the second development transmission technology will be highly advanced and will enable cross-border distribution and transmission. New transmission lines will be built all over Europe in order to relieve power shortages and to feed competitive electricity markets. Technological advancements such as High Voltage Direct Current (HVDC) and high-temperature superconductors will be increasingly utilized for specialized transmission applications [424].

8.2.2.4 Vertical Integration of Information and Communication Technologies

Nowadays, many utilities maintain their information and communication technology (ICT) infrastructure without external support. However, the extension of ICT used along the value chain would make more sense for to the merge of ICT and energy industry.

Description

ICT is required to link everything from high-voltage transmission systems and utility control centers to consumers individual appliances [400, p. 18-26]. However, while making the grid smarter, it can also make it more vulnerable to cyber attacks [407]. Therefore, the smart grid represents the melding of traditional industrial grid utilities with communications equipment and services firms, enabling new ways of collaboration and dynamics in price due to vertical integration of technologies. Apart from that, it is still not foreseeable in which volumes ICT will be used along the electricity value chain and therefore an uncertain driver with three possible developments.

Developments

ICT will either high, middle or low be vertically integrated in the next years.

The first development is characterized by a high vertical integration of ICT. Almost all devices will be able to communicate along the value chain. ICT will enable the automation of electricity consumption, including wide usage of smart meters and information to real time electricity prices. Due to high extension, innovative ICT departments will grow in the energy utility companies, combining professionals with competencies in different markets, which will lead to higher incentives for innovations and extension of utility portfolio.

In the second development middle vertical integration of ICT is expected. Hence, ICT providers will act as intermediary between energy utility providers. In this development ICT could be mostly focused either on smart metering or internet of energy and will be only partly covered by utilities.

In the third development vertical integration of ICT will be low, that could be caused by several reasons such as the lack of awareness and even trust of the consuming public, lack of a common vision and/or standards, insufficient investments in ICT and radical innovations, which will put ICT in the background. Therefore ICT will of less importance for utility companies and will not covered by them.

8.2.2.5 Energy Storage Systems

The energy storage system driver is one of the three key drivers from which the utility scenarios for 2025 are derived.

Description

Energy storage is effectuated by gadgets or physical media that save energy to carry out useful operation at a later time such as powering various kinds of electric or mechanic devices depending on the kind of energy which was stored. In case of electric power, energy storage technologies determine electric utility application requirements and therefore have to be suitable as well as compatible with the multiple applications in various individual installations. Thus, they have a high impact on the future of utilities. There are two possible developments, either mainly decentralized or mainly centralized storage systems.

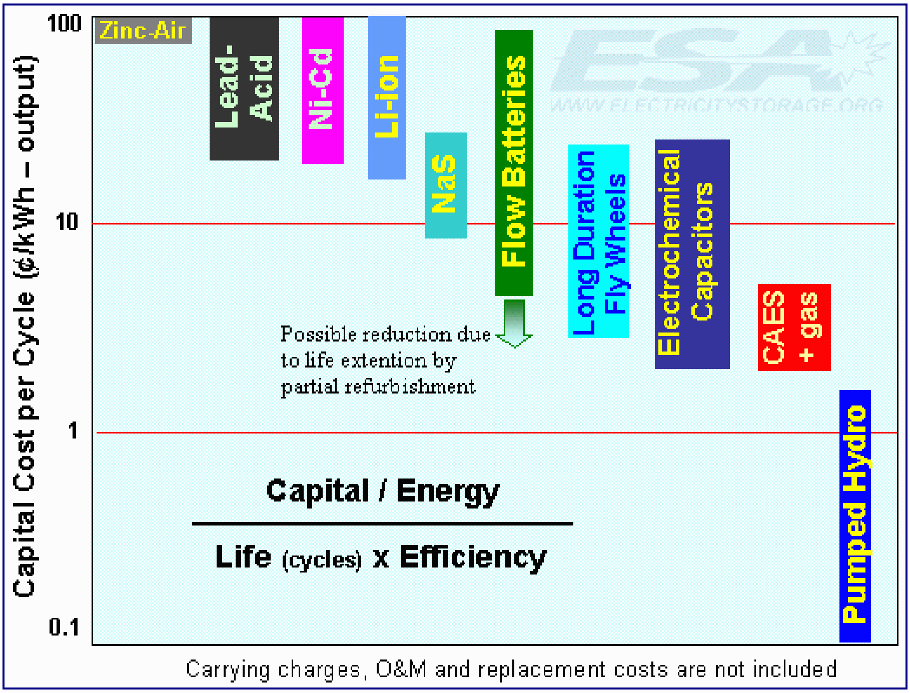

Figure 8.5: Capital Cost per Cycle of Different Energy Storage Systems
Source: Electricity Storage Association [399]

Developments

The first possible development would be the mount of more decentralized energy storage technologies. In that respect, the most influential storage technology would be the battery. Lithium-ion batteries could be replaced with a new class of metal-air batteries which has about ten times the energy density of lithium-ion batteries. In addition, planar liquid sodium beta batteries would be able to facilitate power from renewable resources like wind and solar. In other words, those all liquid metal grid-scale batteries would be able to level electrical power storage for the grid [415].

The second possible development would be the growth of more centralized energy storage systems such as hydro-storage or compressed air energy storage. However, hydro-storage will put on more substance as it offers a more stable and efficient way of storing energy, water is pumped from the lower reservoir to the upper reservoir during off peak hours. The technology of centralized mass battery systems also including vehicle-to-grid implementation, will also undergo further developments, resulting a good alternative to store the energy of the grid.

Figure 8.5 shows the capital cost per cycle of various energy storage systems. Via Per-cycle cost it is possible to evaluate the cost of storing energy in a recurrent charge/discharge application. In this respect, the figure illustrates that pumped hydro has the lowest capital cost per cycle and how the technology of flow batteries will develop in order to achieve a higher energy storage efficiency. The high energy efficiency of liquid metal batteries and pumped hydro is thus the reason why both systems will show significance in the future.

8.2.2.6 Real-Time Management

Real-time management plays a pivotal role in the pricing for the final customer and energy quality. One of its main functions from a utility's perspective is to solve a problem of energy consumption at times of peak demand.

Description

In their current form, demand response management systems (DR) can be characterized as incentive-based and time-based. Incentive-based signifies that the systems provide immediate means for utilities to reduce load by shutting down customer equipment and time-based adds real-time price data to DR [414, p. 141f]. Both aspects are strictly interconnected with the usage of smart meters and communication technologies, which enables active participance of energy consumers. Nevertheless, due to the lack of modern ICT, these systems cannot provide real-time management, needed for the future smart grid. According to the unstable influencing framework, investments made in ICT and future legislation on smart metering on one hand, and high impact on other hand, real-time management is classified in the group of key drivers.

Developments

Today's research efforts are being made to create advanced technologies, which will be able to provide two-way communication between consumers and utilities via the internet, delivering signals for incentive-/ and time-based DR. Moreover according to §21b of the Energy Industry Act it is mandatory to install smart meters in the houses built since 2010. Depending on future political decisions concerning investments in R&D and general acceptance of smart meters, two different developments are possible.

Within the first development a wide usage of smart meters and advanced technologies is expected. Real-time management systems will be broadly used to exchange information between utility and consumer. It will be possible due to reliable privacy and security issues, high awareness in society and mandatory installation of smart meters. The information from smart devices will be provided to other entities and controlled centrally by utilities.

Within the second development, there will be almost no smart metering and real-time management will be of less importance. Due to insufficient privacy and security issues smart metering will not be accepted by the majority of population, which might even force the politics to make changes in Energy Industry Act. Real-time management will remain on the level of utility securing the integrity and stability of the grid status and consequently avoiding black-outs.

8.2.2.7 Political Decisions

Nowadays, energy legislation focuses on infrastructure, energy security and environmental problems, becoming more determining for a future smart grid.

Description

Political regulations are needed to empower consumers to make choices to manage the energy usage and save money, which is already provided in §21b of Energy Industry Act by the widespread of smart meters. Moreover, governments can empower advanced technologies to decrease carbon emissions and encourage to the production of more renewable energy as in EEG by feed-in tariffs. Ultimately, political decisions are needed to reward utilities for supporting efficiency and conservation. Due to the fact that political decisions have a very high impact on a smart grid and the industry environment of the utility industry, this is considered to be a key driver with two possible developments.

Developments

Because of today's energy-hungry world and high carbon emissions, governments will foster renewable energies and energy efficiency. Which of these aspects will be taken and on which level, national or international, is impossible to predict at present times. Therefore, there are several possible developments.

Concerning the first possible development, green governments will push the development of advanced technologies with a main focus on the decrease of carbon-dioxide emissions and reduction of German dependence on foreign oil. Therefore huge investments will be made in developing low carbon technologies with a post-fossil fuel and post-nuclear energy vision. It will promote wide generation of renewable energy and innovations in the e-vehicle sector. Especially hydrogen fuel-cell storage technologies and storage technologies for portable, stationary and transport usage will be developed and a decentralised bottom-up hydrogen infrastructure will be established.

The second development could be characterized by a high progress in information and communication technologies (ICT) that will be caused by the widespread of smart meters and increased development of IT-based security and privacy systems. The liberal parties will mostly focus on basic research, technology demonstration and open market creation. Governments will enforce regulations to enable each country the participation in the projects such as maximizing energy efficiency, development of advanced ICT systems and an interconnection of European power grids by the creation of a European transmission networks (ETN). The main goal of the liberal government in this case is to push the economy to its limits.

8.3 Scenarios

The following section will deal with three possible scenarios which are derived from the certain and uncertain drivers and their possible developments. Political decisions, new energy storage systems and real-time technologies are key drivers that determine the characteristics of the following scenarios. Technological developments will play an important role in the Technological Solution, while political influences are very present in both, the European and Green Solution.

8.3.1 The Technological Solution

In this solution technology is the core of all economic and social matters as well as the main focus of business executive parties and governments. Figure 8.6 illustrates the key driver developments to this solution. Energy storage systems are mainly decentralized. Batteries have become not only highly advanced, storing a remarkable big amount of energy but also cost less since they have reached having a mass market.

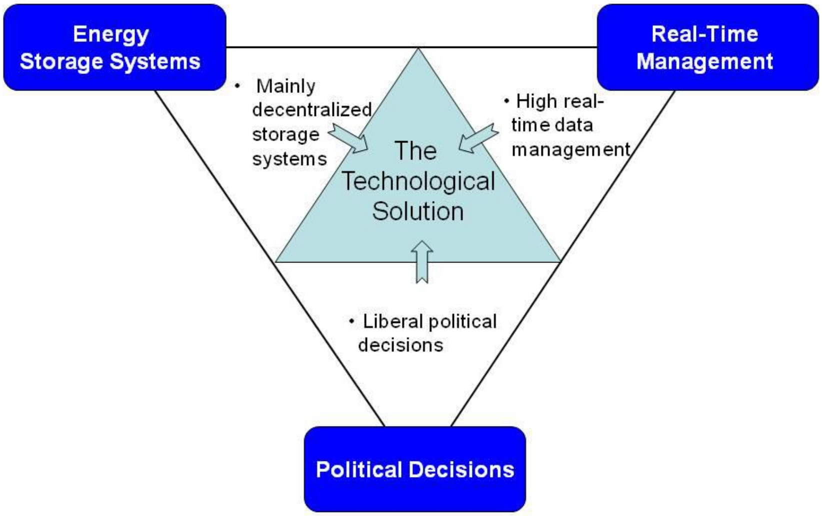

Figure 8.6: Key Drivers and Developments of the Technological Solution
Source: own illustration

As for the grid load management, real-time market and automated demand response has become reality as all households, industries and utilities are being connected with an advanced smart metering system. Regarding the political decisions, the Renewable Energy Law was enacted and embedding a smart meter in each household was announced to be mandatory as the government invested a lot in developing new technologies and thus awaits them to be adopted and exploited by the whole society.

8.3.1.1 Description of Technological Solution

In this solution where smart meters are legally binding, the society in 2025 is aware of the monitoring as well as billing purposes. Politics and media are working on influence people's attitude towards privacy and security and ultimately succeed.

Technologies

The society is convinced that in order to become highly developed and energy efficient it has to accept and adopt new technologies. Consumers see it as a chance that has to be taken and thus a two-way communication between the meter and the central system in utilities is enabled. As a result, an economical way of measuring smart metering information is provided, allowing price setting utilities to introduce different prices for consumption based on the time of day and the season.

Power grid systems still have varying degrees of communication within control systems for their high value assets, such as in generating plants, transmission lines, substations and major energy users. Due to the smart metering and bi-directional transmission, the utilities meet the demand and succeed to varying degrees such as brownout, rolling blackout and uncontrolled blackout. Generators and loads interact in an automated technique in real time, coordinating demand to even out spikes. Eliminating the fraction of demand that occurs in these spikes eliminates the cost of adding reserve generators and users are therefore in the position to cut their energy bills by adjusting low priority devices to use energy only when it is cheapest.

Infrastructure

There is an adequate charging infrastructure. Electric vehicles are highly adopted within the society because governments promote the technological development and its application to the highest level possible. In this solution batteries are highly advanced and have low costs, therefore electric cars cost less which is the main reason for their mass market.

Also due to the media which is influenced by the politics, the society is aware that electric vehicles offer solutions to critical energy problems. Indeed, there's a shortage on high priced fossil fuels and the transportation sector is one of the largest sources of the greenhouse gases whose accumulation in the atmosphere drives global climate change.

Consumers

Since the total amount of power demand by the users has a very wide probability distribution, the utilities in this solution encompass spare generating plants in standby mode to counter the rapidly changing power usage. Hence, the supply and demand of electricity in EU is via real-time market and the integrated automated demand response balanced.

8.3.1.2 Weak Signals and Signposts of Technological Solution

Concerning installing a smart meter in each household, some countries have already begun with embedding the smart metering system for all users and others have set that as a target in the next few years.

In Italy between 2000 and 2005 Enel deployed smart meters to its entire customer base while in 2007, the Dutch government declared that all eight million households of the country should own a smart meter by 2013 [426]. Therefore, setting the smart meter as a mandatory gadget is very possible.

Developing battery technologies will also continue intensively, especially concerning liquid sodium batteries. Several European countries are investing immensely in R&D concerning this kind of batteries and other efficient energy storage devices in general. The new batteries will sustain a high capacity which will make them competent and usable for utilities. In 2010, the Swiss-Swedish corporation ABB started system projects that should supply the power electronics and system integrations for sodium-sulfur batteries [423]. Hence, having low priced batteries that are sciential of storing a great amount of energy is very possible in the future.

8.3.2 The European Solution

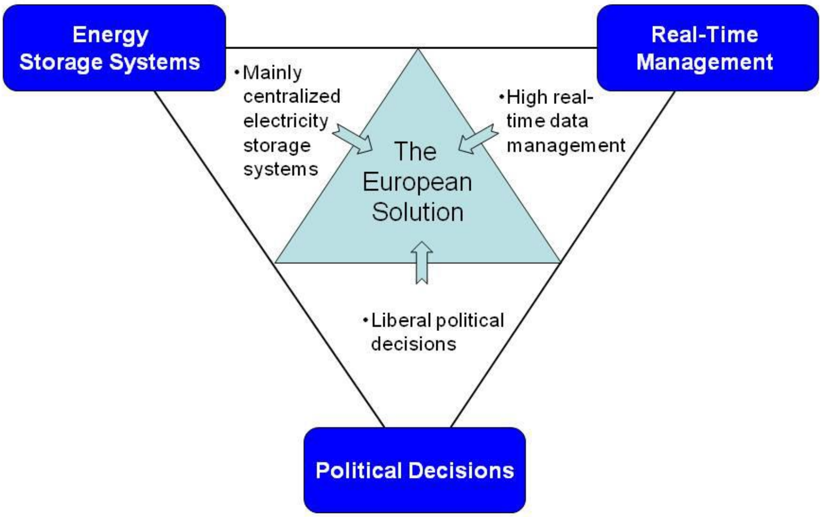

Figure 8.7: Key Drivers and Developments of the European Solution
Source: own illustration

Europe grew together to one force and has made efforts to be autarkic of energy supply. Smart metering allowed real-time demand response and real-time trading on the European Energy Exchange (EEX). Furthermore, the transnational super smart grid enabled the utilities to store energy in countries where pumped hydro storage systems were available. Figure 8.7 shows the three key drivers and their particular developments for the European Solution. The liberal politics of each country support the growing together of the European Union (EU) and the idea of mainly centralized electricity storage systems. Furthermore, real-time data management makes the European super smart grid work more accurately.

8.3.2.1 Description of European Solution

The EU has become more and more one "nation" instead of one union and one force. The different heads of the states realized that there were more advantages than drawbacks working closer together and building a strong united EU in a globalized world. The world now consists of three superpowers: the United States, the European Union and China. It became more important for the EU to speak with one voice to have a stronger influence on the world politics. Another political intention why the EU grew closer together was to become autarkic of energy supply.

Infrastructure

To accomplish this goal, the EU largely invested in mining own resources, constructing renewable power plants and electricity storages where they made most sense. The electricity storage systems are mainly centralized because countries like Norway offer great opportunities to build pumped hydro storage systems due to their cliffy landscape. Other pumped hydro storage systems have been built on several mountains in France, Italy, Austria and Eastern Europe. These centralized storages made the need of HVDC lines to transmit the electricity from the European land to the European islands self-evident.

The distribution of the electricity is still organized by the different utilities. The last mile of the distribution grid has been adapted so that electricity feed-in of decentralized power producers doesn't cause problems. The utilities and the EU strongly invested in a better transnational transmission grid to make electricity storage and electricity import from other countries possible.

Technologies

Furthermore, the EU and the utilities invested billions in a super smart grid that enabled a transnational transmission. Electricity can be bought from where ever it is cheap and in times of oversupply it can be stored in storage systems that are free. It is smart, which means that it collects information in real-time from the consumers about the current load and compares it to the current supply. In peak times it is able to decide in real-time whether to use stored electricity from pumped hydro storage facilities, to buy cheap imported electricity at the European real-time market in Leipzig or to produce it on its own with gas turbines. The automated demand response makes smart metering necessary. It is regulated by European law that each household must have smart meters, which are provided by the different utilities in each single country of the EU. This enables the utilities to trade on the EEX in real-time. The decisions, which the super smart grid makes, mainly depend on its cost effectiveness. It makes for example some times more economical sense to sell electricity to a neighbor state instead of storing it.

There has also been a big change in the ICT market. Different data are collected, compared and are used to make decision such as whether to buy electricity on the EEX or to produce it on one's own. Another decision could be whether to store electricity or to sell it on the EEX. The smart grid cannot only decide but also execute the decision on its own. The utilities gather all information given from each single smart meter to generate a real-time load curve. This load curve is also taken into consideration from the super smart grid. Therefore, new innovative concepts of national and transnational information and communication systems have been installed.

Due to the low environmental awareness in the EU, e-mobility only plays a minor role in the EU. Since the percentage of electric vehicles is low, decentralized electricity storage systems are not considered as useful electricity sources for peak times.

8.3.2.2 Weak Signals and Signposts of the European Solution

There are several weak signals and signposts that are visible already today. People who are newly building or renovating a house have to install by law a smart meter since the beginning of 2010 [401]. In Scandinavia and the Netherlands the government is about to obligate smart meters for each electricity consumer [401]. Therefore, the assumption in the European Solution that a smart meter will be obligatory by law in 2025 is very likely to happen.

The Lisbon treaty is another signpost of how the EU is growing closer and closer together to one single force. The member countries also work together in questions of the justice and police investigations. And furthermore, "it harnesses Europe's economic, humanitarian, political and diplomatic strengths to promote European interests and values worldwide, while respecting the particular interests of the Member States in Foreign Affairs" [410]. Hence, the assumption of an operative European political force in 2025 is a likely scenario.

In the beginning of 2009, Russia stopped the delivery of gas to the Ukraine due to unpaid debts from the Ukraine to Russia. Since 80 % of the Russian gas for Western Europe is pumped via the Ukraine, which is about 25 % of the overall gas consumption, the EU became aware of the threat they face if they further rely on gas from Russia [409]. This made the EU think about a higher diversified gas supply and invested in the Nabucco pipeline, which bypasses Russia and assures the gas supply for all Europeans [422].

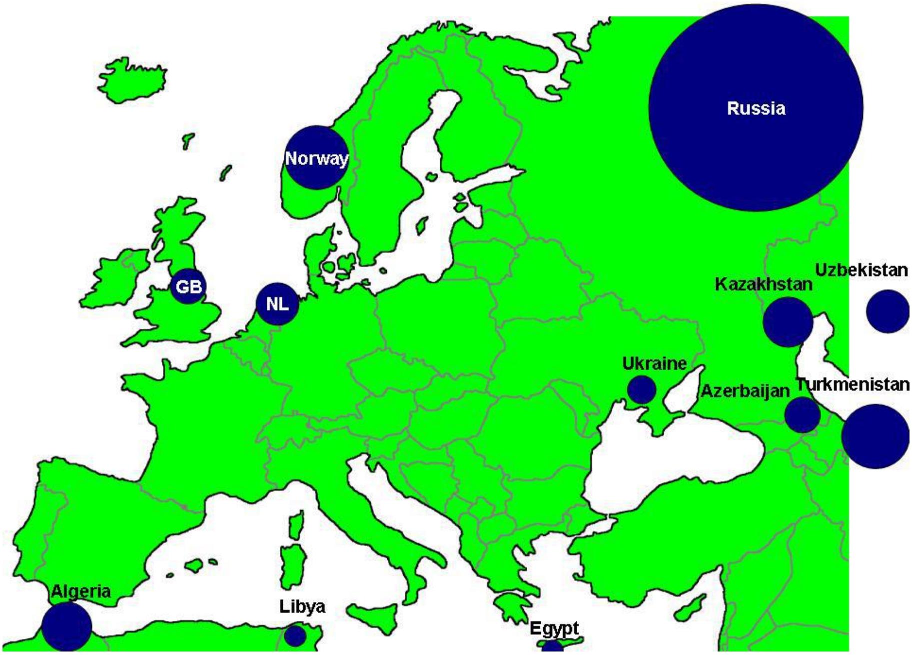

Figure 8.8: European Natural Gas Reserves in 2010
Source: adapted from Spliethoff [427, p. III.32]

The European states coherently decided and invested to assure the common future interest in save energy supply. This exemplifies how Europe already today works together to assure the future energy supply. Figure 8.8 shows the distribution of gas reserves in Europe and the Middle East in 2010. They are distributed over Europe, while Russia, Turkmenistan and Norway keep the most gas reserves. Figure 8.9 shows the distribution of gas reserves of the same geographical area in 2025. The difference to Figure 8.8 is the fact that the gas reserves in Europe shrinked rapidly while Russia still keeps a very high percentage of the overall gas reserves. Great Britain for example even runs out of gas. This shows the need of a diversified energy supply and the advantage of an autarkic EU that produces renewable energies and manages it with a European super smart grid.

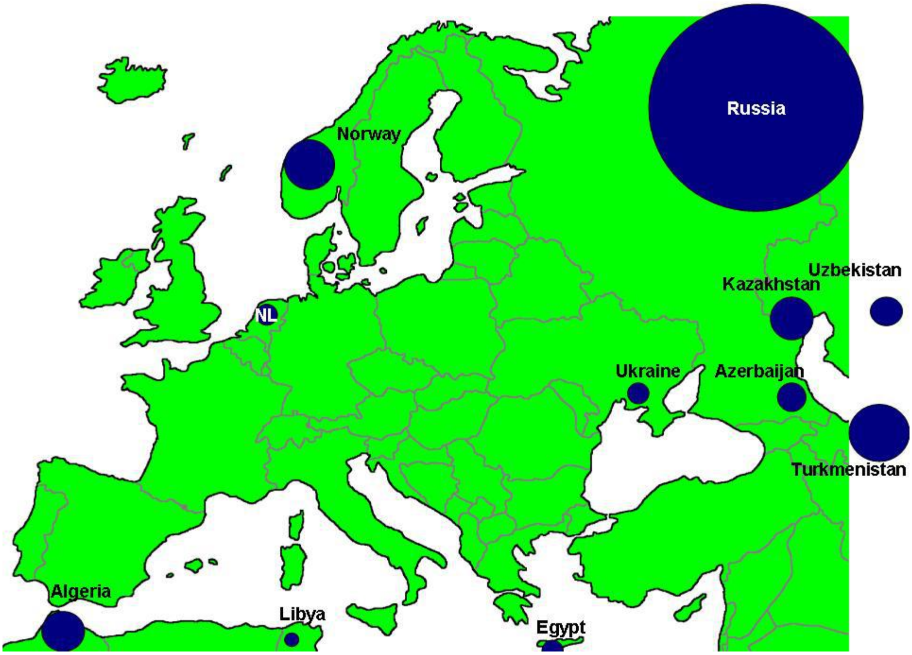

Figure 8.9: European Natural Gas Reserves in 2025
Source: adapted from Spliethoff [427, p. III.33]

8.3.3 The Green Solution

The Green Solution is defined by the possible developments of the three key drivers as illustrated in Figure 8.10. The first one to mention is the political decisions. The political landscape is driven by a high percentage of green parties within the single parliaments in Europe and therefore political decision will be strongly influenced by the green values and perspectives. Outcomes of the rising influence of green people governing in Europe are more green projects such as for example carbon dioxide limits or a fixed and increased proportion of renewable sources of energy providing Europe's electricity.

The second main factor influencing the Green Solution is the development of new centralized storage capabilities allowing mass storage of electricity in the grid. However, also small and middle-scale storage devices play a minor role in the Green Solution.

The third possible driver development is the absence of real time management. Smart metering is not present in this solution. Especially politics are very concerned about privacy and security issues and therefore monitoring and controlling the private households is largely rejected by the society.

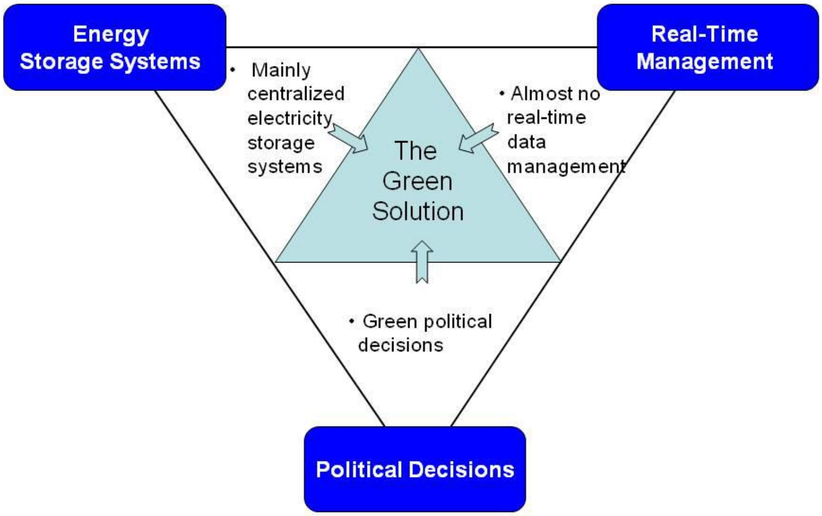

Figure 8.10: Key Drivers and Developments of the Green Solution
Source: own illustration

8.3.3.1 Description of Green Solution

In many parliaments a rising proportion of eco-friendly and environmentally engaged politicians and parties can be observed. There has been an ongoing development towards a “greener” world within whole Europe. Renewable sources of energy, especially solar power are highly supported by all the governments in Europe and the goal is to become independent of nuclear power.

However, renewable sources are not able to substitute nuclear power completely because of their high volatility and there still is a centralized part of energy production such as the big coal and nuclear power plants in order to secure a stable and reliable energy deployment. This is especially necessary when it comes to the base load electricity which needs a constant and stable power generation such as it is produced by nuclear power plants.

Technologies

The high percentage of volatile power feed-in from the renewables poses a challenge to the power quality in the grid. Utilities and politics have to deal with this problem since they are risking the power quality. Possible solutions that are discussed in this context are the increase of Phasor Measurement Units (PMUs) and systems to reduce the volatility of renewable resources.

Moreover, as green energies are on the rise, there is a high need for intelligent storage possibilities that can eventually store energy, reduce volatility and ensure the electric power in the grid at all times. Thus, there are a lot of new technologies such as storage systems in the pipeline. Batteries with different capacity levels for small and large amounts of energy as well as hydrogen storage facilities are employed.

In addition to the small and middle-scaled solar power plants, new projects such as Desertec are in place allowing electricity generation from solar power on a very large scale with a big extension in areas with a high solar radiation such as the desert of the African Continent.

E-vehicles are widely adopted within whole Europe. Internal combustion engine cars are on their way to be replaced by electric, plug-in hybrid as well as hydrogen vehicles. On the one hand, e-vehicle's acceptance and spread is largely promoted by green politics and one the other hand new storage technologies and other technological improvements implemented in electric cars make electric cars more attractive.

Electric vehicles experience a large increase in number due to two reasons: Firstly, costs have decreased dramatically due to a higher production number of electric cars and thus achieving economies of scale in the production. Secondly, because of new technologies enabling assimilable performance of electric cars compared to internal combustion engine cars. As far as hydrogen vehicles are concerned, they also offer a promising alternative solution to internal combustion engine cars.

Furthermore, large HVDC-lines have been built to allow and ensure power transmission from the big offshore wind parks that have been constructed within the scope of new green projects supporting renewable energy sources.

Lastly, virtual power plants are built to reduce the volatility of the installed renewable power plants. They allow combining for example wind and solar power also from different locations and reducing therefore the volatility of all installed generation plants.

Infrastructure

Overall, transmission and distribution is bi-directional. Almost every household has become a producer and consumer at the same time thus abandoning the idea of a household only consuming energy. In this context, self-supply also has achieved an important role. A large part of the European households has installed photovoltaics on the roof aiming primarily at self-supplying the own energy consumption but also feeding in the excess energy.

For energy providers the absence of smart metering is a challenge as they have to deal with non-intelligent distribution and transmission on the one hand and a more sophisticated energy mix with a high volatility and a threat to power quality on the other hand. Facing both factors at the same time, utilities risk having capacity problems in the grid. This also means an issue for politics, as they have to guarantee the electric power supply.

As real time management and smart metering are rejected by the society because of privacy reasons, there is no development of a smart self-sustaining grid that is based on communication technologies and data flow between producers and consumers and vice versa.

Both, utilities and politics recognize the problem of renewable sources and create financial incentives for constant, non-volatile electricity feed-in. In that sense, a real alternative to the smart grid and load and time management can be achieved and electricity can be sustained in an efficient way.

To transport the energy from large-scale projects of clean power generation such as Desertec in Africa, hydrogen storage possibilities are used. This allows carrying the energy in tanks without power that is volatilized and therefore prevents losses.

Consumers

One major problem that is associated with the decentralized power generation from renewable energies are the increased energy prices for private households and therefore increased rental prices due to the higher ancillary expenses.

As far as private households are concerned, incentives for non-volatile feed-in of the amount of power generated by renewable resources are established in order to achieve stable power supply on the one hand and a high power quality on the other hand.

8.3.3.2 Weak Signals and Signposts of Green Solution

There are several weak signals and signposts that are indicators for the Green Solution to become true in 2025. One signpost is that the German Federal Government recently declared in its "Energiefahrplan 2050" and the "Neun-Punkte-Programm" that in 2030 the proportion of energy generated by renewable resources shall be 50% [405]. If Germany for example follows that autarkic and decentralized approach in the future, that would mean that energy prices will increase dramatically from production prices of 6,5 Cent per kwH to 23,5 Cent per kwH in Germany [403, p. 92].

In addition to that, during the last years, green parties have already gained a significant, stable and powerful share in their respective governments [425, p. 9]. If green parties continue to maintain that large share of even enlarge it, the green solution could become reality.

There is also a lot of research going on in the field of storing the energy from renewable resources [428, p. 7] and some deployments of large-scale batteries to store the volatile power from renewable sources [406]. If large storage facilities will be developed and established as it is predicted and storing of renewable sources will be feasible, the Green Solution is very likely to happen. Further, due to the new installed self-supply incentives for the customer of the Energie Einspeisungs Gesetz in 2009, experts consider energy storage to a profitable solution in the future [418, p. 38].

Studies conducted in 2010 also have shown that large parts of the population reject smart meters due to their lack of security and privacy on the one hand and the absence of a real benefit for the customer on the other hand. [411]. If this will be an important development observed in the future, it might be another indicator for smart metering not to become true and it is therefore highly probable that other balancing facilities mentioned in this solution have to be developed.

8.4 Product Idea: SmartMicroGrid

The following section describes the product idea SmartMicroGrid, which is a system that makes constant power feed-in of volatile PV power plants possible. The SmartMicroGrid is a product that can be offered from the utilities to reduce volatility and to make renewable energies a suitable substitute for nuclear power plants. Besides describing the idea and how it solves the problems arising in the Green Solution, this chapter also describes the customer segments, revenue model and value proposition of the product.

8.4.1 Description of the SmartMicroGrid

Two main challenges of the Green Solution are to substitute nuclear power by renewable energies and to handle the problem of volatile energy feed-in by decentralized small energy producers. The idea is to implement a management and storage system that avoids volatile feed-in at the production stage. It flattens the volatile power production of the solar cells (see Figure 8.11 (7)) and feeds-in constant power into the grid (see Figure 8.11 (6)). Since the power is constant and fed-in continuously, it is usable for base load power. Therefore, flattened photovoltaic power can substitute other base load power plants such as nuclear power plants or coal power plants. Utilities provide this system for the photovoltaic power producers.

As described in Figure 8.11 the system consists of three components: the solar cells (1), a management system (MS) (2) and a storage device (3). The power curve of a photovoltaic power plant (9) has one big peak over the day and is at zero stage during the night. For constant feed-in, the management system has to store the energy that is higher than the constant power level in a battery during peak times. When the photovoltaic power production sinks under the constant level the MS restores the energy from the storage device

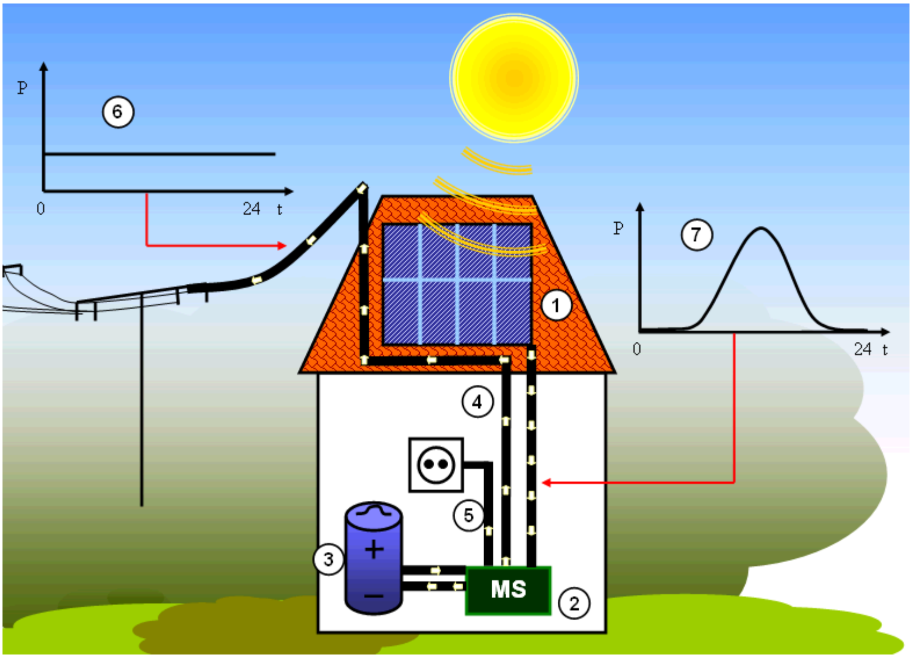

Figure 8.11: The SmartMicroGrid
Source: own illustration

and feeds it into the grid (4). The result is a constant energy feed-in without any volatility. Furthermore, the MS makes self supply possible. Power can be drawn directly (5) from the MS. This results in a lower but still constant power feed-in. An alternating current converter in the MS is in charge for a high power quality to make self supply sustainable.

This system uses the advantages of a closed intelligence, which does not need any centralized control or feedback systems. This also means that no smart meters are needed. Each system on its own is able to reduce the volatility, which reduces the overall volatility as well. The concept of constant power feed-in is a viable alternative to the smart grid concept.

Since the batteries do not have high restrictions concerning size, weight and safety like batteries in e-vehicles, they are relatively cheap in comparison to those. Moreover, the MS charges the batteries only up to a certain stage to extend the lifetime of the batteries [418].

8.4.2 Matching of the Product Idea with the Green Solution

According to the Green Solution (see 8.3.3), the utilities are facing two main challenges in 2025. On the one hand they have to handle the problem of an increasing number of volatile and decentralized energy producers, and on the other hand they have to find a way to substitute nuclear power plants. These are not only challenges for the utilities but also political goals of the green parties in Europe. The governments are under big political pressure to accomplish these objectives. Therefore, it is also of political interest to implement the SmartMicroGrid. Moreover, the SmartMicroGrid addresses another concern of the society. The society denies all violation of privacy and does not support smart metering. The SmartMicroGrid offers a solution that makes renewable energies competitive to conventional energies and nuclear power plants unnecessary, while protecting the privacy.

8.4.3 Unique Selling Proposition of the SmartMicroGrid

In 2025, the self-supply of electricity is high and electricity prices will have increased due to a higher proportion of renewable energies in the energy mix. The SmartMicroGrid provides an answer to many of the customer's concerns. Moreover, it offers a unique service by giving the customer the security of having a constant cash flow by feeding in the same amount of power at all times. The system therefore reduces the volatility, stores the energy and manages the feed-in at the same time. Utilities are well suited to offer the SmartMicroGrid Solution as they have the necessary know-how to provide such a system and can manage perfectly the constant feed-in of energy for several reasons.

Firstly, utilities have large knowledge in energy storing facilities and secondly they have the financial capacities to make large investments in innovative and viable products and services.

Additionally, patents for the system could help to offer a protected system. The advantage in technology and time allows the utilities to be far ahead of the competition also in terms of costs.

8.4.4 Customer Segments of the SmartMicroGrid

There are two target customer groups for the SmartMicroGrid as it is illustrated in the upper right corner of Figure 8.12. The first one is decentralized photovoltaic energy producers. On the one hand, this means private households, on the other hand it also includes institutions, industries and other larger buildings with a larger solar power generation. Another potential target group is large photovoltaic power stations. However, since the ownership of those large plants is more complex (they are often owned by a consortium), the focus in the first phase will be the more decentralized and smaller power producers. Moreover, some big solar plants are also owned by the utilities themselves.

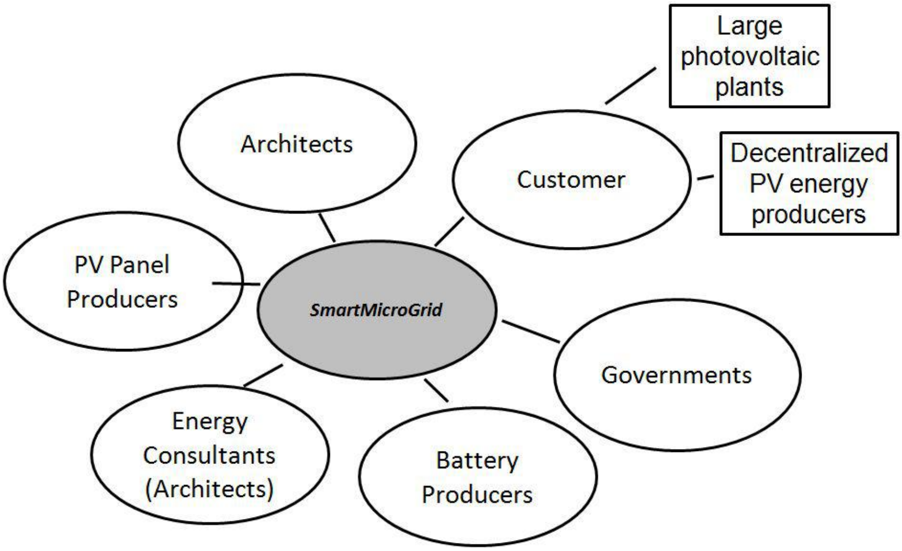

Figure 8.12: Stakeholders of the SmartMicroGrid
Source: own illustration

Thus, the main and the most important target group are decentralized PV energy producers consisting of private households and industries. Those share the same needs and some similar characteristics that allow the utility to offer one system fitting for all customers. Yet, there are some differences for example the capacity and size and therefore the costs of the storage device that will vary a lot depending on the amount of generated electricity.

8.4.5 Revenue Model of the SmartMicroGrid

Figure 8.13 provides an overview of the costs and revenues of the SmartMicroGrid. On the revenue side, four main sources of income can be distinguished.

Firstly, the system including the battery and the management system is leased or sold to the customer what generates income for the utility. Leasing rates consist of a fixed price per month over a certain time. After that time, the battery is replaced by the utility. The second option is to sell the battery at a partially subsidized price by still getting money monthly. However, the management system will be sold to the customer in each option. The constant revenue for the utility is the part of the customer's additional earnings due to the higher feed-in tariff. The higher feed-in tariff is based on the non-volatile power feed-in. The last part of the revenue consists of after sales and other fees in order to maintain the system that has been sold to the customer before.

Costs	Earnings
Storage device, hardware	Revenue from leasing (monthly or yearly)
Programming	Revenue from selling
Implementation and maintenance	Quota of customer savings
Other (marketing and more)	After sales, maintenance

Figure 8.13: Overall Profit Model
Source: own illustration

Moreover, there are further factors playing an important role however not being illustrated in Figure 8.13. On the one hand, there are possible savings for utilities by substituting the base load produced by gas turbines by renewable energies. On the other hand, utilities also have the advantage not having to invest in developing the smart grid and its communication and smart metering concepts.

8.4.6 Cost Structure of the SmartMicroGrid

The overall costs of the SmartMicroGrid, also illustrated in Figure 8.13, consist of four main cost pools. The first one is the costs of the hardware including the purchase costs of the storage device e.g. the battery. The actual extent of these costs depends on the choice of the battery capacity and performance. Another big cost pool is the programming of the Management System included in the SmartMicroGrid. There have to be ongoing investments in programming the system, however, the main costs will be at the starting point of the business as later on the system will be rather standardized for the different sizes of the Photovoltaic Power Plants. Further costs will arise by the implementation and maintenance of the system that is to say utilities need additional labor to handle the support of the SmartMicroGrid. In addition to that, there is a last big cost pool consisting of other factors such as marketing. Marketing will be necessary to gain customer awareness for the product which in turn will be crucial for the adoption of the system.

8.4.7 Value Propositions from the SmartMicroGrid

Beside the utilities, which have a big interest in implementing the SmartMicroGrid, also the customers have advantages when they implement the system. The SmartMicroGrid addresses many customer concerns and needs, which are very important for a green society.

Firstly, the Green Solution describes that non-volatile renewable power feed-in is incentivized by the governments. Therefore, people with PV power production that use our system get higher incentives for each kWh they inject into the grid. Another value proposition for the customers is the fact that the utilities take over the installation and maintenance. Since the batteries are owned by the utilities, the service is for free, as long as it concerns the batteries. Thirdly, the left-wing society is highly concerned about privacy and they deny any solution that makes the use of smart metering necessary. Therefore, a system that doesn't collect private data is highly welcomed. The SmartMicroGrid avoids smart metering and is a closed system that doesn't send out any information.

Moreover, the SmartMicroGrid makes self-supply possible. The consumer can draw power up to a certain amount from the MS. They can autonomously decide which proportion they want to draw and how much power they want to feed-into the grid. This makes the consumer independent of the electricity price to a certain extent. Due to the Renewable Energy Law (EEG) the customers even get higher incentives if they consume their own power [404]. Since the energy costs rose due to higher renewable energy production [403, p. 92] self supply became even more attractive.

8.4.8 Possible Cooperations for Utilities to Market the SmartMicroGrid

The utilities don't just market the SmartMicroGrid on their own. There are several players in the market (Figure 8.12) that have closer contact to the consumers. They can recommend the product while implementing their own. PV-panel producers and installers are the perfect link to the target group. They serve exactly the target group the utilities want to convince, too. They can sell the SmartMicroGrid in addition to their own product and get an incentive for their efforts. Moreover, energy consultants such as architects are another important link to the customers. They can recommend the system and persuade them of the benefits of an intelligent storage and feed-in system. The battery producers are very important partners in the supply chain. A close cooperation with them is necessary to stay informed about the latest findings in technology. Furthermore, the biggest leverage to reduce costs is battery costs. Economies of scale in battery supply reduce the overall costs of the system. An important stakeholder of this idea are the governments because they are under political pressure to replace nuclear power plants by renewable energies. Therefore, the utilities need to inform the government about the advantages of the SmartMicroGrid in comparison to a centralized smart grid in order to make them supporting the idea.

8.5 Conclusion

The possible developments of political decisions, energy storage systems and real-time management, which are uncertain key drivers of the utility industry, result in three different scenarios.

The Technological Solution describes a liberal environment with a high promotion of technological developments. The European countries want to strengthen their economies by pushing clean technologies. The European Solution describes a unified European Union that tries to be autarkic of energy supply. Synergies between European Countries arise due to the common use of energy storage systems and a transnational super smart grid. Finally, the Green Solution outlines a scenario with a society of high awareness of environmental topics. Nuclear power plants are denied and substituted by renewable power plants.

It is suggested that the most probable and most innovative of all three scenarios is the Green Solution and as a result the volatility of the rising proportion of renewable energies and the efforts to substitute the base load power will require smart solutions.

One answer to the problem is the SmartMicroGrid, which makes constant power feed-in of volatile PV power plants possible. The SmartMicroGrid is a product that can be offered from the utilities to reduce the volatility and to make renewable energies a suitable substitute of nuclear power plants. Another posibility to flatten the overall volatility courve would be virtual power plants that bundle different kinds of renewable power plants in different geographical regions, which takes advantage of the statistical balancing.

The opposite solution to the SmartMicroGrid that uses the advantages of a dezentralized optimization of the power flow of every household is a centralized intelligence that collects data from feedback systems to organize real-time decisions. The question is if such a smart grid with its amounts of information will ever be able to become reality. On the other hand, it is questionnable if the SmartMicroGrid will ever be able to reduce the volatility to an extent where no national or transnational smart grid is needed.

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Chapter 9

9 Automotive Perspective

Maximilian Cappel, Mariam El Sayyad, Johannes Lechner, Maximilian Matschke

Diverse forces are converging to enable the transition from combustion engine powered vehicles to electric vehicles. Because of the concerns about global warming, oil dependency and city pollution, automotive manufacturers and policymakers are increasing their efforts to make battery-powered vehicles a feasible alternative to conventional oil-fueled vehicles and finally adding the electric vehicle (EV) to the smart grid.

The aim of this report is to identify drivers, create scenarios based on them and to develop a product idea for e-mobility for the year 2025. In order to forecast the future and developments in the automotive market, a scenario planning methodology is executed. Based on a driver analysis, three scenarios are presented. The first scenario "No EVs on the road" reflects the failure of the transition to electric vehicles and its impact on the environment. Due to the high costs of the batteries, EVs are not able to dominate over cars with traditional internal combustion engine technology. The scenario "E-mobility in green cities" illustrates the significant acceptance and adoption of electric vehicles in the automotive market and society resulting in an improved ecological status. The EV market in this scenario is booming because of the technological innovations in the battery technology, leading to the reduction of battery prices and consequently the decreased costs of an EV. Finally the scenario "Stepwise adoption of EVs" is exactly the middle of the two aforementioned extreme scenarios and portrays an EV market which is gradually increasing. However, in the automotive industry, battery-powered vehicles are still the minority. This scenario is most likely to occur, thus the service idea, Energy & Drive is based on it. Energy & Drive (E&D) is a service provider in the automotive segment. On the one hand E&D offers an energy and lease contract for electric vehicle batteries and on the other hand serves as an energy supplier for EV-owners by providing them with energy for their cars and for utilities by furnishing a buffer storage solution to them. Due to the high costs of EV batteries, E&D depicts an innovative battery financing model which will make purchase prices for EVs significantly more attractive.

9.1 Introduction

The first electric vehicles have already been developed in the 19th century. In the 1990s the first modern EV- field tests took place. They were not carried through, though. Just recently modern concepts were launched and the first EVs were actually sold to end costumers. The following section of this report covers the perspective of automotive companies on the future development of electric vehicles and their role in a smart grid. At first the forces that influence the future development of society regarding technology, environment and electricity are looked at closely. These forces are split up into drivers with certain and uncertain developments. Three of these uncertain drives are key drivers, meaning their development is significant for the automotive perspective. Based on the key drivers, the second part of this section describes three scenarios that could be reality in the year 2025. The focus is on the life concerning mobility and cars. The last part of this section is a business idea resulting from the third scenario. This idea shows a solution for the lifetime management of batteries while providing an advantage for car owners and energy utilities.

9.2 Driver Analysis

The focus in analyzing the drivers is put on the description of the driver and the explanation of the possible developments. The drivers are split up into certain and uncertain drivers, whereas the key drivers, which are most important for the automotive perspective, are most emphasized.

9.2.1 Certain Drivers

There are some forces that cause a specific development. These forces that develop strictly in one direction are named certain drivers. The drivers concerning the automotive industry are “urbanization”, “demographic change”, “environmental awareness” and “privacy sensitivity”.

9.2.1.1 Urbanization and Demographic Change

The population undergoes a rapid change as people are getting older and the majority tends to move to urban areas. This change has a high influence on our society and also an impact on the German economy.

Description

Demographic change defines a change in the population, which may effect the working population in the future [436]. A long term prediction of demographics is possible because the relevant factors are life expectancy, birth and mortality

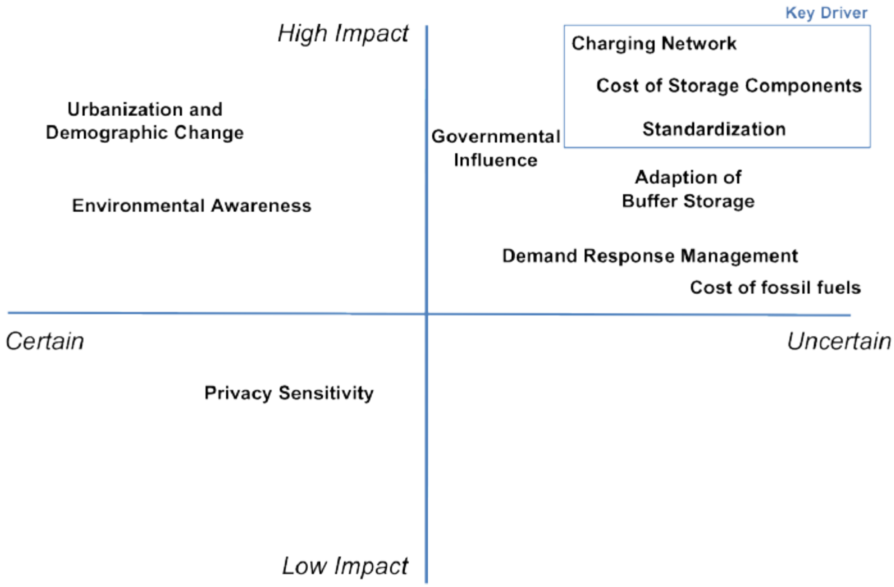

Figure 9.1: Driver Matrix
Source: own illustration

rate and they are known due to statistical investigation [443, p.232]. Several aspects of this driver will be of high relevance for the e-mobility industry.

Development

First off is the difference in demographic change between countries of the Organization for Economic Cooperation and Development (OECD) compared to emerging markets [431]. In contrast to the emerging countries the population of the OECD countries is decreasing. A comparison of the age distribution in Germany, which can be seen in figure 9.2, from 2010 compared to the prediction of 2025 clearly shows this issue [432]. Not only the low birth rate, but also the change of age distribution to an increasing share of people who are over 65 years old and the trend towards urbanization will be important aspects for the e-mobility industry when thinking about long term strategic decisions.

From today's perspective, the group of people older than 65 years old will increase by four percent up to 25 percent of the whole population by 2025 [431]. Also the urbanization progress is developing and by 2025 around 77 percent of the population is going to live in metropolitans [445, p.79]. Besides the trend of urbanization, the daily mobility of commuters will increase and influence the traffic volume on the road and the rail [448]. This certainty can lead to several negative effects for urban areas and its infrastructure in terms of traffic volume and carbon emissions.

The demographic changes and the increasing rate of people living in cities bring big challenges for the E-Mobility industry along. Car manufactures have to think about new solutions for city vehicles and proper transport opportunities for elderly people.

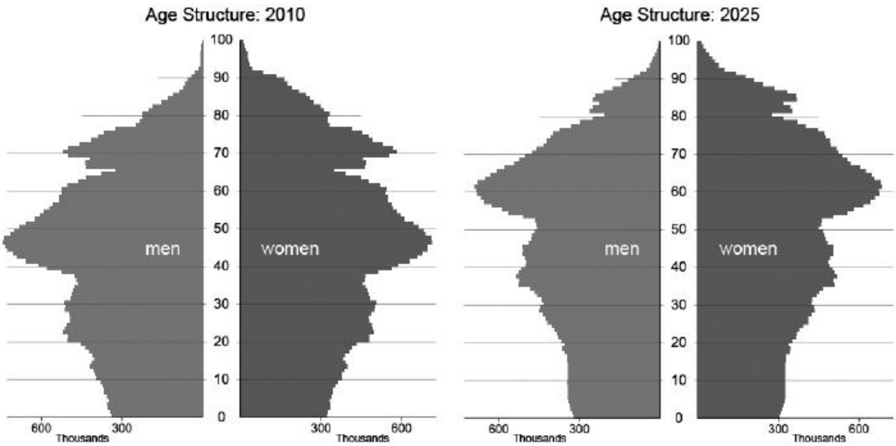

Figure 9.2: Comparison of the Age Structure of the German Population on 2010 and 2025.
Source: adapted from Statistisches Bundesamt [433]

9.2.1.2 Environmental Awareness

The awareness for environmental issues is continuously rising and thus is a certain driver.

Description

Living in a healthy environment is increasingly important for western citizens. As the awareness for global warming, greenhouse effect and carbon emissions rises, people become willing to take action and participate in the green movement. Already 60% of the citizens feel socially pressured to participate in environmentally friendly trends [438, p. 22]. This percentage will strongly increase within the next 15 years.

Development

The movie "An Inconvenient Truth", which was written and presented by the former US Vice President Al Gore in 2006 was a large step to increase the consciousness for environmental issues. This movie showed the risks of climate change that is caused by pollution. Automobiles cause a non-neglectable share of this pollution. This film did not solemnly start a green movement but was an indicator for it.

Besides this movie other education programs have emerged. There are education and awareness programs and trainings in schools, in the labor world and in local communities to sharpen the knowledge about our environment and the danger of pollution [449].

The legislation started to introduce regulations regarding the pollution of cars. For example the "Umweltplakette" in German cities. Starting in October 2010 no car with a red batch, meaning high fine dust pollution are allowed in inner cities [446]. The EU decided that in 2015 the average fleet emission should drop to 120 g/km and to 95 g/km in 2020 [444]. In the United States carmakers are required to offer at least one purely electrically powered vehicle.

As well as these and other regulations as the increased demand caused by citizens drive the automotive industry to develop and produce environmentally friendly and especially electric vehicles.

9.2.1.3 Privacy Sensitivity

People are starting to realize that their privacy is at risk when it comes to the smart grid and electric vehicles.

Description

Independent upon whether battery swapping or fast charging will become the accepted way of supplying an electric vehicle with new energy, it is unlikely that a wide-spread network of charging or swapping stations will be in place within the next years. For a customer wanting to travel larger distances (i.e. when it is not possible to recharge back at home) this will mean, that the customer has to provide an exact plan of where he wants to go, in order to find and book suitable energy supply stations along the way. Furthermore, if the battery serves as a buffer storage for the smart grid, some integration models will require the customer to specify the range he wants to be able to drive during the next day. Through this, a very accurate movement profile of the vehicle (and therefore the customer) could be created and abused, when privacy issues are not taken serious (see 1.3.3.1).

Development

As recent developments regarding the introduction of Google Street View in Germany have shown, customers will insist that their privacy concerns are addressed. Car manufacturers, utilities and infrastructure providers will work together, to ensure transparency concerning the collected data.

9.2.2 Uncertain Drivers

Besides the above listed certain drivers, there are also drivers of which the development is not predictable. One subject might have various developments that are relevant for the evolvement of the car industry. These uncertain drivers are described and explained below. They are ordered by an increasing relevance. The drivers with the highest relevance are the key drivers. They are “standardization”, “cost of storage components” and “charging network”.

9.2.2.1 Adoption of Buffer Storages

A big part of the smart grid idea revolves around the integration of buffer storage. Through buffer storage, it’s possible to flatten the load curve and to make better use of the volatile renewable energies.

Description

Buffer storage solutions like batteries; redox flow systems and pump storages make it possible to retain currently superfluous energy for later use [434, p. 1012-1014]. Storage solutions offer a way to balance the load curve of the grid and therefore reduce the need for new power plants (which would only be necessary to keep up with the peak load). Another interesting field of application for buffer storage are self-supply concepts for residential sites: customers e.g. can save energy generated by their photovoltaic for later use at night [442, p. 38].

Developments

It is well possible, that no bigger need for buffer storage solutions will emerge at all. Nuclear power plants will complement renewable energy sources and natural gas powered turbines, which provide an easy to manage output power level. Load balancing in the smart grid will entirely be achieved through this output power regulation and by demand response management.

If electric vehicles succeed in the marketplace and their integration, as buffer storage proves feasible, adaption of buffer storage technologies should see a big boost. Owners of EVs could provide their battery as buffer storage in exchange for monetary benefits.

9.2.2.2 Demand Response Management

For an efficient usage of electric vehicles, systems for demand response management are gaining high significance.

Description

A demand response management system (DRM) is a new strain of system which has the ability to control, operate and monitor remote assets and in this case the energy storage of electric vehicles. The goal of energy efficiency regarding the charging of electric vehicles can only be served through the consumption data collection. The DRM describes a bi-directional data exchange between the electric vehicle driver and the electricity utility. It leads to the most efficient usage of electric vehicles and to the peak load management, which is the main factor for balancing energy.

Because of the uncertainty of this driver, there are two possible developments. It is either DRM is established in the grid or not.

Developments

The first possible development is that the demand response management is sustained. As there will be an increasing smart home adoption, which relies on the eventual implementation of the smart grid. This is normally dependent on the technological development status regarding information technology, communication and the electricity utilities. To achieve such energy efficiency and managing the demand and supply side, some developments and establishments need to be obtained. DRM can be sustained by including smart meters, which enable the bi-directional data exchange and time-based consumption. Moreover, smart metering offers advanced power measurement and management capabilities. Systems for pricing consultancy and recommendations regarding EV charging are being developed. Such pricing data can be utilized so that you are charged cheaper electricity rates at off-peak times, for instance at night. For managing the demand as efficiently as possible, real-time data collection is essential. Real-time information from enclosed sensors and automatic controls is being used to predict, observe, and respond to system errors. Via a DRM system intelligent Vehicle to Grid (V2G) and Grid to Vehicle (G2V) concepts will be established, leading to an extreme energy efficient charging process. The integration of DRM systems in EVs will spark a revolution in its market and energy efficiency due to the achieved high controllability [437].

The second possible development is the failure of the integration of a DRM. The managing demand will not succeed because of technological barriers and privacy concerns. Other reasons for the possibility of such a development are the social obstacles such as the failure of the acceptance of e-mobility on the wide range and adoption of the smart home.

9.2.2.3 Governmental Influence

The governmental activities are a main factor to lead the e-mobility industry towards market ability. All major new technology integrations in the past were dependent on governmental help.

Description

Governments all over the world have shown an involvement in the field of e-mobility. On the one hand countries such as Germany focus on subsidizing R&D project and hope that the industry will be able to grow with the help of those activities. On the other hand countries such as China, USA and France among other things try to advocate the industry by giving tax privileges to the customers. By that the governments hope to reach a critical mass, which is necessary to enable a free market in the future. (see 4.2.1) Because of the uncertainty of this driver, three different possible developments could occur.

Developments

In the best case the government will subsidize the industry in many possible ways. They will provide tax privileges to those who are buying an EV and also feed a lot of money into R&D, which disburdens the car manufacturing industry.

In another possible development governments of different countries decide on only one-way subsidies for the e-mobility industry. There will be some countries that are giving tax privileges to the customers, while other countries focus on giving tax privileges to the vendors. With this kind of support the government fosters the e-mobility in a way that a free market will be possible.

In the worst case the government decides on giving no subsidize to the e-mobility industry. This will lead to a very high possibility that EVs will not exist in the future.

This driver shows that the guiding decisions of the government will certainly influence e-mobility. Governmental decisions are very hard to predict, uncertain and dependent from many different factors, such as elections or cross-national agreements and therefore governmental influence has to be seen as an uncertain driver.

9.2.2.4 Cost of Fossil Fuels

The price of fossil fuels is crucial for the further development of electric vehicles.

Description

The price of oil, which is the primary factor in fossil fuel production, has been quite volatile. Many factors on the supply and the demand side influence the

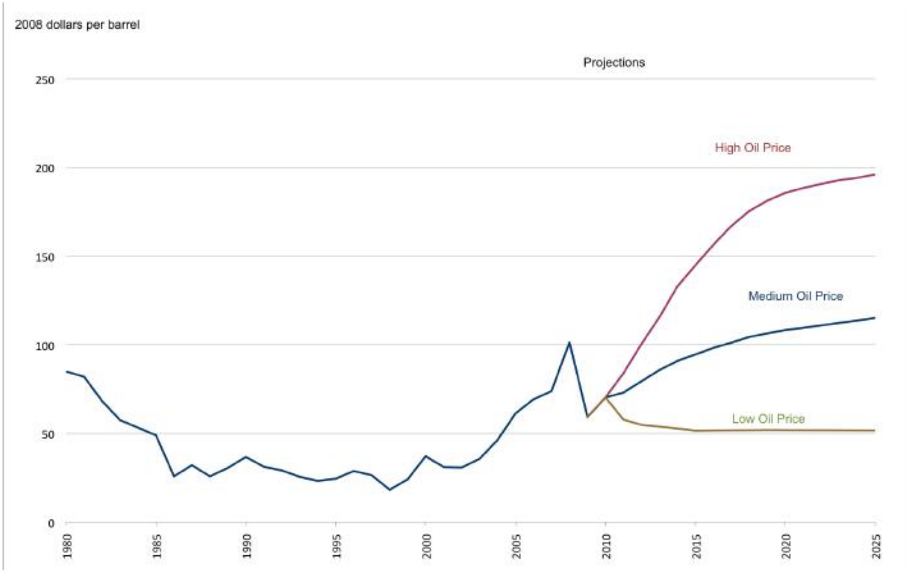

Figure 9.3: Oil Price until 2025 - Projections
Source: U.S. Energy Information Administration [450, p. 28]

price of oil. Further, oil is a heavily traded commodity and thus is also subject to speculations [450].

On the demand side, the major influencing factor is the consumption of the emerging markets, especially of China and India. This demand has rapidly increased over the last years. However, it is questionable if the demand is going to rise at the same rate. On the other hand a worldwide crisis can decrease the price of oil and thus give a drawback and keep the price at a lower level. The impact of the recent financial world crisis can be seen in figure 9.3.

On the supply side there are more, and especially more delicate factors. Forces that would rise the price of oil are trade barriers, such as tolls, export limits, artificial hold-backs or crisises and wars. Factors that lower the price are new accesses to sources of oil, such as the oil basin below the North Pole or a new technology that makes drilling and facilitation more efficient.

Figure 9.3 shows the development of oil prices in today's dollar from 1980 on until today and up to 2025 in three possible developments.

Developments

The first possibility is that oil prices stay low or even decrease. On the one hand the demand for fossil fuels does not increase as expected, but stays steady. On the other hand there is no shortage on the supply side. Technology has improved and an international completion without trade barriers has strengthened. In this case, the fossil fuel prices decrease slightly from a today's perspective. Consequently the incentive to find alternatives for combustion engines is low from a price perspective.

Another possibility is that the prices of oil rise at a constant rate to about $120 per barrel in 2025 from about $75 today. In this case, costs rise due to more difficult accessible wells, whereas the consumption is increasing steadily. This case, which is most likely, motivates today's society to develop a substitute to the conventional combustion engine, as the gas prices will continue to rise.

The third case is the high price case. The demand has increased in a higher than expected rate, whereas the oil producing countries, OPEC and non-OPEC countries install export limits, fiscal regimes or use oil as security. In this state EVs become highly attractive because the price of oil quadruples in real figures and it will be much more expensive to go by conventionally powered cars [450].

9.2.2.5 Charging Network

The main hurdle in the charging process of electric vehicles is the lack of charging station availability and most significantly the efficient and user-friendly accessibility.

Description

A charging network for the electric vehicle is an infrastructure system of public-accessible charging stations. In order to facilitate the charging process of EVs a network between charging stations and the owner of an EV needs to be efficiently installed and optimized. A communication network that has an IT basis is necessary for the charging process and overcoming the vehicles with internal combustion engines in the automotive industry [435, p. 31]. Due to the precariousness of this driver, the development of such an infrastructure has three possibilities.

The development could only be in the sense of charging stations. The second possible development is a very advanced and automated infrastructure, which includes data not only about the charging stations but also about usage analysis and management. The third development is that the dedicated network won't be based on high-tech and detailed data.

Developments

The first development concerning only charging describes the ability of the consumers to charge their vehicles at anytime and anywhere by the proposed network and communication. To achieve such a communication a navigation system and GPRS will have to be utilized. The data sent from the network is downloadable to GPS navigators and a mapping software. The network publishes the live availability of its charging stations online and permits consumers to book charging points in advance.

The second development is that the network sends detailed data regarding "charging management". The network will contain information objected for real-world usage by EV owners. The stations are all connected to the network which allows integrated limber billing, detailed consumption analysis and remote management. Existing filling stations such as Shell may also become or may incorporate charging points. They can be added onto other public infrastructure that has an electrical supply, for example phone booths and smart parking meters. Moreover, the charging network will include an user subscription plan and service grid management technology to aid electricity utility establishments to flatten electrical demand loads on the grid. Recharging a big battery pack presents an eminent load on the electrical grid, but this can be scheduled for off-peak load periods or reduced electricity costs. In order to book the recharging, either the charging station or the vehicle should of course be able to communicate with the smart grid [429, p. 17].

The third development is the rudimentary charging network, which is premised on not a highly-developed basis. It permits only data about the location of the charging stations. It is like the "yellow-pages" style presenting only address and telephone number. The network does not include any service regarding route-planning software such as a navigation system and GPRS. Moreover, it does not offer energy efficiency recommendations or data for "charging management".

9.2.2.6 Cost of Storage Components

The high cost of the electric vehicle, which is highly influenced by the energy storage system, is the main obstacle for the EV's approach of dominating the automotive industry and achieving acceptance in the society.

Description

Lithium-ion battery costs are wedged by a diversity of factors such as cell size and the quantity of materials, as well as battery patterns and the manufacturing process. Lithium price is estimated to account for 75% of the cost of a battery. The costs of a battery pack for EVs today is about $1,000 per kWh and for the whole battery pack $25,000 [447, p.11]. The 2009 EV battery cost structure to OEM includes a complete pack-level bill of materials, equipment depreciation, R&D, plant labor, scrap rates and overhead markup as being illustrated in figure 9.4. As the development of the energy storage system costs is uncertain there are two possible developments.

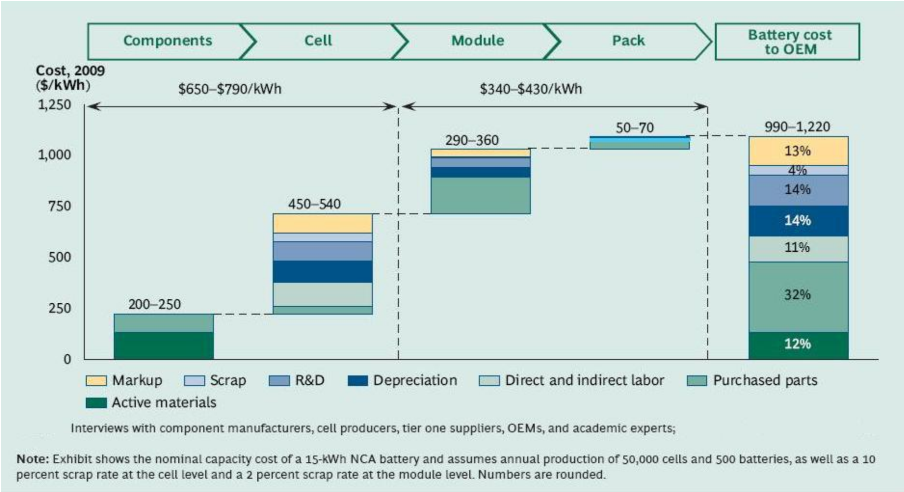

Figure 9.4: The 2009 cost structure for Li-Ion Batteries to OEM
Source: BCG [453, p. 11]

Developments

As some studies illustrate that the costs will remain high and even increase, other studies and research institutes suggest the decrease of the lithium-ion battery prices.

Demand in lithium minerals has increased significantly, driven by the growing importance and production of lithium-ion batteries as the future generation energy source. Lithium chemical substances demand is estimated to sustain continued 3-5% annual growth over the following fifteen years. On the potential request for electric vehicles' batteries, the annual demand in 2020 for lithium carbonate equivalent was thus 55,000 - 65,000 tones, and 135,000 - 145,000 tones in 2030 [429, p. 15]. The accelerating cost of Lithium is even confirmed by FMC, one of the world's largest lithium producer: "CHARLOTTE, N.C., September 7, 2010 – FMC Lithium announced today that effective October 1, 2010, or as contracts permit, it will increase global pricing for Lithium chloride products by 8 percent." With a relatively small number of Lithium producers, such as FMC or SQM, dominating a huge percentage of global production there is an effectual impact on the increasing lithium price [452].

The second possible development, however, is that the price of the batteries could also depreciate. The Boston Consulting Group analysis, as shown in figure 9.5, suggests that from 2009 till 2020, the price that Original Equipment Manufacturers (OEMs) pay for EV batteries will diminish approximately 60 to 65%. So a nominative capacity 15 kWh battery pack that currently costs $990

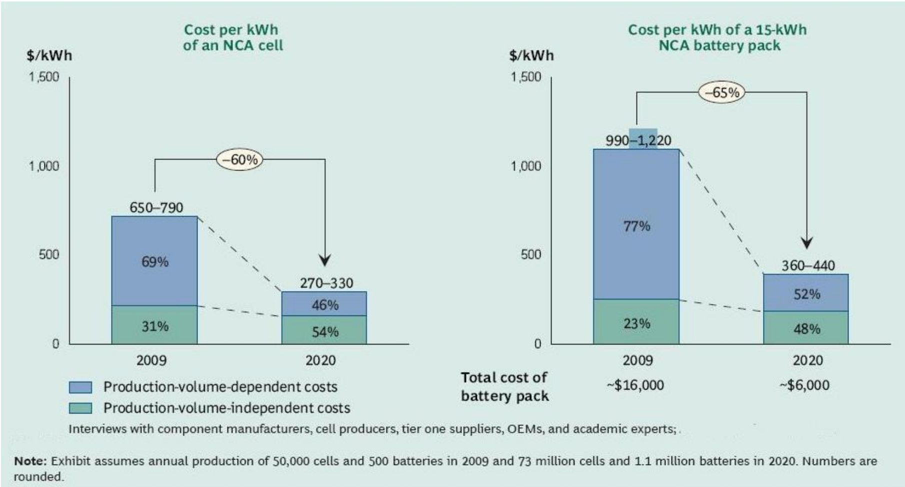

Figure 9.5: EV-Battery Price Decrease from 2009 till 2020
Source: BCG [453, p. 16]

to $1,120 per kWh will cost $360 to $440 per kWh in 2020 or roughly $6,000 for the battery pack [453, p. 11]. This cost depreciation is considered due to the technological development, industry experience, predicted mass production and an increasing automation, which will reduce the manufacturing costs. A major breakthrough in the battery science and chemical substances which leads to fundamentally higher power denseness without significantly increasing the cost of either battery materials or the manufacturing process needs to be obtained.

9.2.2.7 Standardization

The electric vehicle has not dominated over the internal combustion generated vehicles. One of the reasons is the lack of acceptance and reliability, which is usually established through standardization policies. The conformance to a released standard is a major selling argument, which launches a feeling of confidence.

Description

The approach for standardization in the electric vehicle industry and market is very significant. With no cooperative and conjunctive action being executed between various manufacturers, and with consequently no standardization and calibration of elements or materials in place, each component could only be utilized on that specific electric car for which it was specifically designed. This leads to a great disbursal of production and difficulties in service, and is a big burden for economical efficiency of the whole electric vehicle industry and the automobile sector. Therefore standard charging methods and battery swapping models need to be obtained. For example the assemblies and components in the battery, its shape and the plugs should have a standard and consistent scheme and application [435, p. 18]. Because of the uncertainty of this driver, there are three different possibilities to the standardization development. Its either a high, middle or low standardization.

Developments

The first possible development is the establishment of high standardization. This development describes the coordination of all utilities worldwide to preset models and assemblies. A lot of international initiatives are promoting the concept of standardization in terms of the electric vehicle market and its infrastructure around the world. According to Nissan's Chief Operating Officer in a conference statement: "We will compete when it comes to vehicle performance, but we should cooperate on areas such as infrastructure." Forming a mutual "language" for charging EVs across diverse brands would save development reimbursements for car manufacturers and ancillary industries. Moreover, this kind of high standardization will increase the likelihood that governments and private entities will invest in charging infrastructure, and make electric vehicles more attractive to drivers [430, p. 27].

The other possible development is a middle standardization. It is the implementation of some small independent standards: Each company has its own standards and system across the world, for example "Better Place" which is an international company, operating in different countries worldwide with its own standard models. The need for standardization in the automobile industry concerning one brand or car company is high. Within one brand a number of common necessary components will be standardized, to grant components and assemblies to be made in one plant and tacked together with the final product in another plant.

The third possible development is the concept of no standardization at all. Each national company has its own system, assemblies and communication system. Obviously, it is completely independent and complex in respect of such discrepancy.

9.3 Scenarios

The ten drivers, especially the key drivers, as described above shape three scenarios, as they could be reality in the year 2025. The three scenarios are the "no EVs on the road" scenario, the "e-mobility in green cities" scenario and finally the "stepwise adoption of EVs" scenario.

9.3.1 Scenario 1: No EVs on the Road

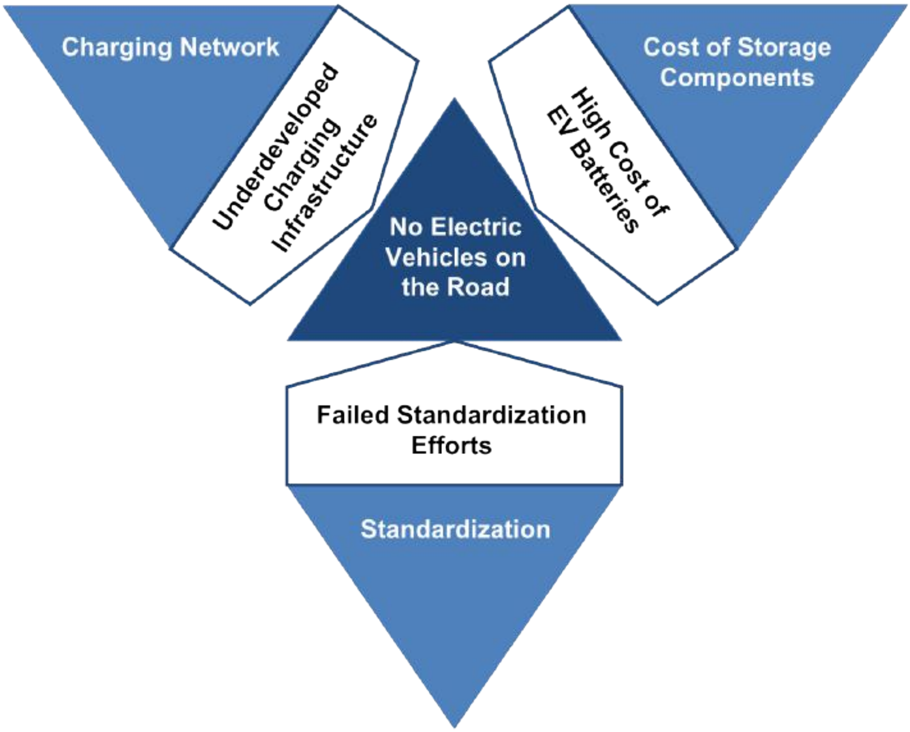

Figure 9.6: Key Drivers for Scenario 1
Source: own illustration

In this scenario, electric vehicles have failed to make an impact on the automotive market. Fossil fuel powered vehicles are as ubiquitous as ever and electric vehicles are nothing more but a niche phenomenon.

9.3.1.1 Scenario Description

This scenarios describes the worst possible outcome for the electric vehicle industry: Customers shy away from electric vehicles since fossil fuel powered are still more attractive.

Charging Network

One reason customers turn away from electric vehicles is that traveling longer distances is still a hassle. The utilities failed to establish a reliable and fully developed charging infrastructure. Customers are not willing to proactively plan their long distance travels to make sure they do not run out of power.

Cost of Storage Components

As depicted in figure 9.6, the cost of electricity storage components are on a very high level, since lithium based storage remains the only viable solution for portable energy supply. At the same time, the price of oil remains comparatively low, since more efficient combustion engines countered the increasing demand in oil. With the battery remaining the major cost factor, electric vehicles are still not competitively priced compared to fossil fuel powered vehicles.

Standardization

Additionally, the entire automotive industry could not agree on standards regarding battery design, charging interconnections, metering and billing, leading to even more customer resistance.

Restraints for a Stringent Development of Electric Vehicles

After huge investments in the last ten years, the automotive industry shifts away from research and development on electric vehicles again. Governments lost the faith in the future of the e-mobility and are starting to cut down on funds and incentives. The need for using the EV batteries as buffer storage within the smart grid was largely overestimated. Technical obstacles such as a high strain on the batteries, a complex IT infrastructure and the emergence of virtual power plants made the integration of cars in the smart grid more difficult than expected.

9.3.1.2 Weak Signals & Signposts

A combination of different factors leads to the “No EVs On the Road” scenario. First of all, if the development of more fuel-efficient combustion engines continues at its current pace, switching to an EV could become less of a pressing issue for customers. As of now, car manufactures already have working prototypes of vehicles consuming as little as one liter of diesel fuel per 100 kilometers [451]. Second, the projected rise in demand and therefore cost for lithium minerals could mean that cheap batteries are not feasible [452]. Third and last, current research in battery storage systems projects, that the storage capacity might not even double until 2030, meaning that long range travel without recharging will still not be possible [440].

9.3.2 Scenario 2: E-Mobility in Green Cities

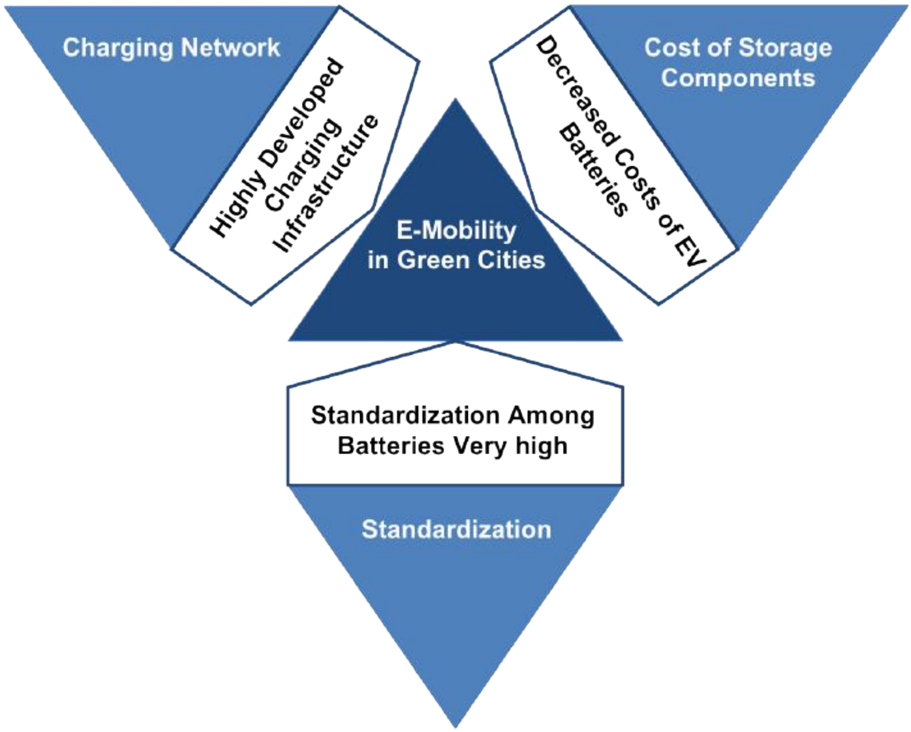

Figure 9.7: Key Drivers for Scenario 2
Source: own illustration

In this scenario EVs will have dominated the automotive market, which consequently has a huge ecological impact. By 2025, the broad acceptance of EVs cut down billion tons of greenhouse gases.

9.3.2.1 Scenario Description

Many citizens own an EV and most kinds of vehicles are now available as electric battery powered vehicles. Electric cars have a huge effect on the automotive industry. They are given advantages in city pollution, less dependence on oil, and an anticipated rise in gasoline prices. In this scenario the automation regarding the infrastructure as well as energy efficiency are sustained. The key drivers for such a development are illustrated in figure 9.7.

Charging Network

The battery-charging network is fully developed and includes charging stations, a grid management and an intelligent battery charging management. With the implementation of the electric charging network, an energy management software, route planning for charging points and their optimal usage have been introduced to the market. The software has a recommendation service that informs you about the station status regarding its availability and accessibility. Further general data, for instance the available charging options or the possible service of battery swapping is provided.

Cost of Storage Components

The EV market in this scenario is booming, which indicates the reduced price of the lithium-ion batteries and consequently the decreased costs of the EV. The Li-Ion battery technology is highly developed and efficient due to the technological boom.

Standardization

There are international standards in the electric vehicle industry, which leads to the high acceptance of EVs. The charging process, metering and billing methods are standardized worldwide.

Pushing Factors for the Wide Spread of EVs

The demand response management is fully developed. Implementing smart meters in the EVs will grant access to usage data for analysis purposes. Pricing information and recommendations are sent automatically to the consumer. Such a demand oriented communication leads to extreme energy efficiency and an improvement in the consumer's behavior. In this scenario, "e-mobility in green cities", vehicle-to-grid (V2G) is also established. It describes a system in which electric vehicles, intercommunicate with the power grid. Resulting from that, either rendering electricity into the grid or throttling charging rate is possible. Thus, the EV battery could be utilized as a buffer storage.

9.3.2.2 Weak Signals & Signposts

Nowadays, there are signs and indicators that apply to the development of the mentioned scenario of 2025. An indicator for instance is the continuous legislation regarding the reduction of carbon dioxide emissions. A series of international initiatives respecting the green house effect can be clearly noticed, for instance the Carbon Reduction Commitment (CRC) anf the United Nations Framework Convention on Climate Change [437].

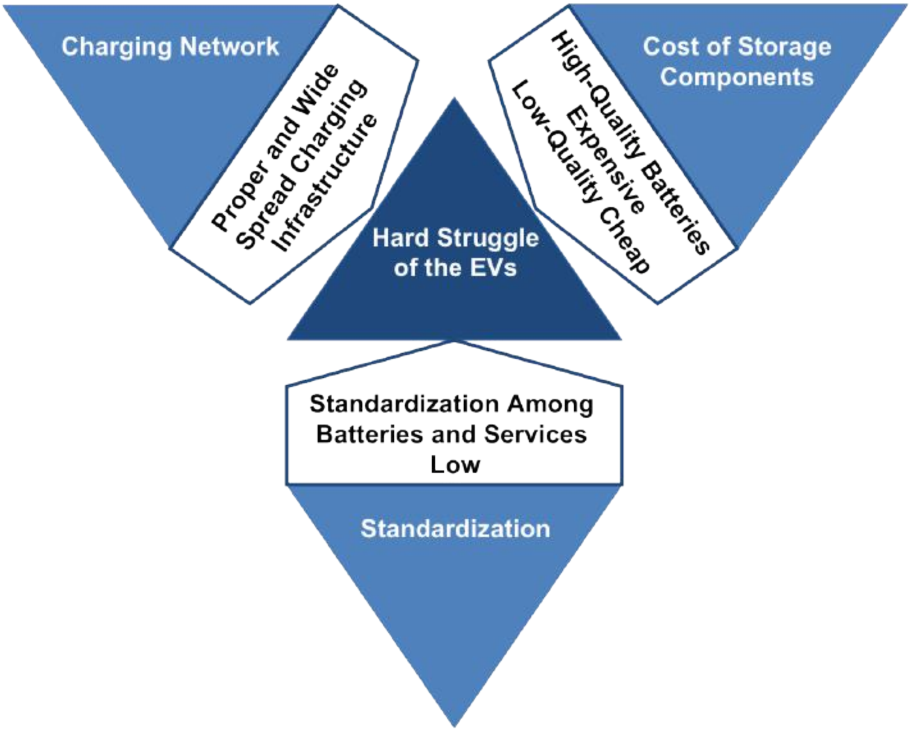

Figure 9.8: Key Drivers for Scenario 3
source: own illustration

Another observed fact that can reveal relative changes developing into this scenario are the new brands and types of electric vehicles entering the automotive market. There are now neighborhood electric vehicles, electric city cars and sporty EVs, for example the Tesla Roadster, the Nissan Leaf and the E-Mini. Several countries have even established grants and tax credits for the acquisition of new EVs. For instance the European Union renders tax incentives for EVs which comprise tax reductions [437**?** , p. 13].

9.3.3 Scenario 3: Stepwise Adoption of EVs

In the year 2025 some electric vehicles can be seen on the road. Only a weak minority of the cars in urban and suburban areas is powered by an electric power train.

9.3.3.1 Scenario Description

As described below, the key driver “charging network” has developed towards a proper and well organized charging infrastructure. The high quality batteries that are necessary for EVs still are very expensive as described in “costs of storage components”. The paragraph “standardization” explains the low standards among batteries and services. Further the development among the other drivers is described below.

Charging Network

A wide charging infrastructure has been build up over the last 15 years. The network of charging stations in cities is very tight. Regular charging stations can be found at the peoples’ homes and at offices. Quick charging stations are usually located at public parking lots such as at supermarkets or along the highway. The infrastructure was majorly financed by the government that supports the development of EVs in a special funding plan.

Cost of Storage Components

The main reason why EVs have not yet been adopted strongly is because of the price of the cars. The high price is still primarily caused by the huge costs of the batteries. The costs of a battery still plays a major role compared to the total car price. Consequently small cars such as an E-Mini are too expensive and middle- and upper-class cars with an electric engine are often not efficient enough because of their weight. Mainly corporate fleets and premium vehicles are equipped with an electric power train. Thus the EVs are still far too expensive for the average car for an average citizen.

Standardization

Standardization is quite an issue nowadays. Just a few years ago a European wide standard for plugs has been enforced. Before that it was necessary to take an adapter with you when crossing boarders. Just some years before this adapter was also needed within a country when you went to charging stations of different providers. On the contrary, there are no standards concerning the batteries themselves. If a car battery is broken, an exchange battery can only be bought at the carmakers dealerships. Neither are there standards for the charging nor for billing stations. By taking the closest, most convenient or cheapest charging station, you get many different bills at the end of each month. Charging station providers have introduced membership cards to bind their customers. Consequently you are bound to one operator or have dozens of different membership cards with you. Convenience here is not yet at its peak.

Further Influences

The cost of fossil fuels has not dramatically risen over the last decades. The car petrol thus is reasonably priced and in real Euros only increased by some percentage points. Compared to electric vehicles, cars with petrol or diesel engines are much cheaper to operate. So the incentive to change from a combustion engine to an electric engine is not sufficient form a financial perspective.

The government used to provide subsidies for EVs, such as tax cuts for carmakers and car owners. The carmakers' tax cuts were not forwarded to the car purchaser and the customers tax breaks do not compensate the high additional costs of the batteries. Nonetheless the state still provides incentives for private charging station operators to build up stations. The government also invests in the infrastructure such as induction charging.

Energy utilities installed large buffer storages to store energy for a short time. This has become necessary as a large increase in renewable energies plants has emerged. The batteries used in cars can be used as buffer storage. Some car fleet operators have a contract with a utility company. Private car owners usually do not participate, as this program is intransparent, the privacy concerns are not totally solved and finally the utility companies' tariffs are too complex.

Further the demand response software for cars is not standardized. This means that cars could only be used at certain stations as buffer storages and thus could only seldom feed energy into the grid. So it is not that attractive for the utilities to incentivize car owners to provide their car as buffer storage.

9.3.3.2 Weak Signals & Signposts

Signs that indicate this scenario are already noticeable. The trend towards urbanization has been visible all over the world and will keep on (see 9.2.1.1). The awareness for environmental issues is increasing steadily, but the sensibility for a healthy environment will not easily overcome the actual expenditures that are necessary to reach it (see 9.2.1.2). Governmental subsidies have been in place to push this movement. These subsidies however burden the public treasury. For example the subsidies for solar panels on private home, have been decreased dramatically just recently [439].

Demand response systems are being installed in private homes and are called smart meters. Still they are not spread widely and not used fully yet (see 5.2.1.1). The installation in other objects as in cars is not unlikely. Buffer storages are needed to store overproduction of the increased share of renewable energy power plants (see 9.2.2.1).

The cost of fossil fuels have risen and fallen, but locking back to the 1980s the price has been more or less constant in the long run (see 9.2.2.4). Battery charging stations can be seen in the areas where there are field tests of EVs. Getting competitors to cooperate in the field of components and standards is extremely difficult (see 9.2.2.7). Batteries still cost a tremendous amount nowadays. Batteries have been developed for decades, but still there were no large cost saving potentials worked out. Surely costs will decrease by economies of scale, but the components will not actually decrease in cost by much (see 9.2.2.6). So batteries will still be expensive in the future.

9.4 Service Idea: Energy & Drive

Energy and Drive is a new service provider in the field of automotive and utility services. On the one hand E&D offers a rental contract policy for electric vehicle batteries and on the other hand acts as an energy supplier by providing a buffer storage solution to its customers. In the following section the speacialties of the service will be described in detail and the reader will understand how E&D will make money with the service.

9.4.1 Service Description

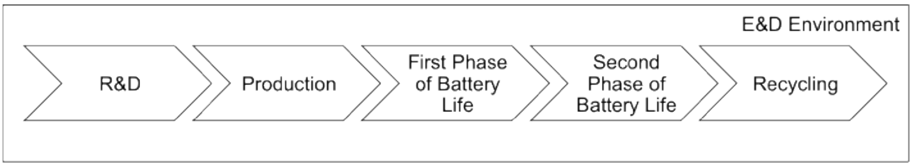

Figure 9.9: Whole Value Chain of Storage Systems
Source: own illustration

Many automotive companies are facing the problem that battery storage systems are the most expensive part of an electric vehicle. The development of the batteries is often outsourced by the car manufactures to suppliers because they are not having an adequate know-how to develop them in-house. Consequently batteries are very expensive considering their relatively short life cycle. As car manufactures did not find a solution for this problem the customers have to pay approximately 15,000 € for the EV's storage system. However not only the high costs of the battery are the only problem for the customers, as they also have to bear the risk of a possible battery failure. Besides car manufacturers seeing disadvantages in the short life cycle of the battery, also utility companies are confronted with the problem. EV-batteries are having a limited life of approximately ten years and therefore they are not able to use car batteries as a buffer storage for the grid and by that giving them a second life. Implementing as many buffer storage solutions as possible into their portfolio would help the utility companies to handle the unpredictable supply of renewable energies supremely. Whenever renewable energy is produced regardless whether there is a need for that energy or not in the grid, it can be stored in the buffer storage plants. Those plants could help to flatten the energy curve, which is very volatile due to the fluctuation of renewable energy supply.

Besides simply selling cars, E&D gives the car owner the chance to lease the battery and simultaneously providing the car's battery as buffer storage to utilities. The idea of the new service is to implement research, technology and production of the storage system into the company's value chain. Also the recycling of the battery will be integrated into the company's value chain. The whole value chain of the storage system can be seen in figure 9.9. Due to its value chain, E&D has the full control over the EV's storage system during its whole life cycle. This key advantage is the basis for splitting the batteries life cycle into three phases and creating different service solutions for every single phase.

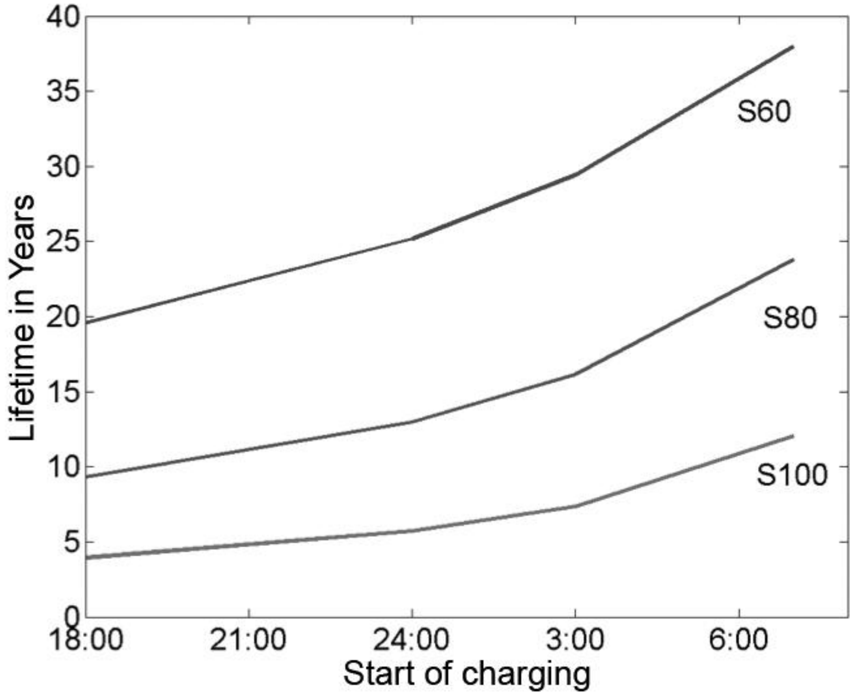

Figure 9.10: Battery Lifetime Depending on Charging Parameters
Source: A. Jossen [441]

The first phase is the storage systems life in the car. E&D installs the batteries into the cars in a way that they can easily be removed and exchanged. They also integrate a smart metering system in the car, which is controlling the recharging process and V2G exchange of the EV. By that E&D has the capability to limit the charging in a way that the battery is always only charged up to a certain level. The optimal level has to be evaluated by research and development and depends on the way of utilization. This is crucial for the battery's lifetime. By only charging up to the optimal level, the life cycle of the battery can be stretched from ten years to approximately 25 years. Figure 9.10 shows the different life times of the battery depending on how full they are charged. The axis "Start of charging" describes the starting time of the charging process during the day. Different starting times influence the lifetime of the battery differently. The value beside the three curve shapes describes in percent how full the battery is loaded. This advancement in charging enables a second life for the battery after spending ten years in the EV.

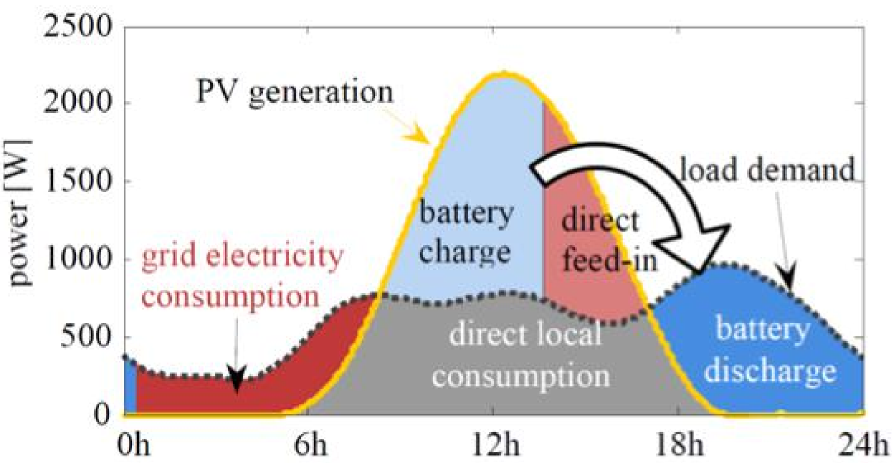

Figure 9.11: Battery Lifetime Depending on Charging Parameters
Source: A. Jossen [442]

During the first phase, E&D leases the batteries to their customers and also provides them an energy contract for the energy, which is necessary to run the EV. A cooperation with a utility company is very important to offer this kind of service. The reason for cooperating with an utility company is that E&D not only leases the battery to its customers for a very low price, more over they offer a contract package which includes also the handling of all energy fees that accrue with the EV. The customer has the advantage that he needs only one contract for the storage device and the energy consumption. Furthermore, the customer profits from the ability of E&D to use the cars' battery as a buffer storage for the energy grid. For the utility companies a big problem is that the energy curve is very volatile during the day. They need buffer storage plants to store energy when demand is low. If they do so they can easily feed back the energy into the grid when demand is high. Thereby the utility company is able to flatten the energy curve during the day, what can be clearly seen in figure 9.11. Because of this fact the utility companies can benefit from a cooperation with E&D, when using their buffer storage plants. E&D finally profits from this lateral cooperation: They are now able to provide their customers a cheaper energy contract than any other utility company and they give the utility companies an opportunity to store their overproduced energy. By that, E&D achieves a strong customer relationship to both, their vehicle-customers and their lateral partner.

In the second phase of its life cycle, the battery is no longer used in the car. The efficiency of the battery is still not good enough to operate in the vehicles. However now all EV batteries of the first life cycle can be connected together to some big buffer storage plant. Those buffer storage plants do not necessary need the same power of the battery as the EV needs. As they provided the battery in the EV as a buffer storage in the first life cycle to the utility partner, they now are going to store the energy of the grid in their buffer storage plants, when there is overproduction, e.g. because of unpredictable renewable energy supply. After storing this energy, E&D feeds the energy back into the grid and receives a margin for storing the energy of the utility company. Due to the battery's usage in the second phase, E&D is able to make profits with the battery over the full battery life cycle of approximately 25 years. Every single battery becomes profitable by having a positive net present value. Only because of the combination of both phases, E&D is able to lease the batteries for very low prices to its customers in the first phase.

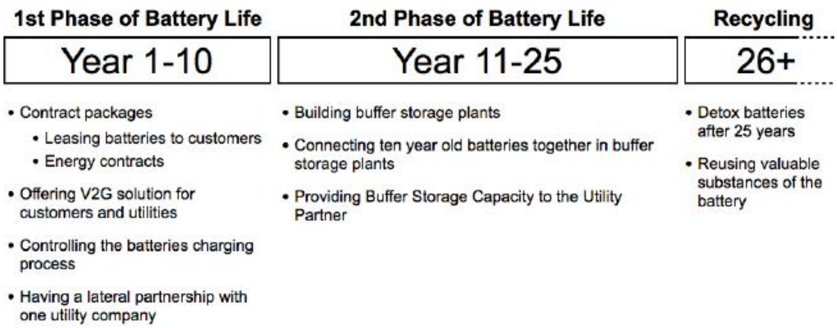

Figure 9.12: Key Activities of E&D in Different Phases of the Battery Lifecycle
Source: own illustration

After working around 25 years in the EV and the buffer storage plants the batteries lifetime is over and it has to be recycled. Recycling a battery is a complex process. However, there are some services on the market that are buying unusable batteries in order to win lithium and noble earth that are very valuable resources out of it. Because of selling the batteries to those companies, E&D is able to make money with the battery in the recycling phase.

Figure 9.12 summarizes the key activities of E&D in the different phases of the batteries life cycle and provides an overview of the different services that are offered and its customers.

9.4.2 Available Market Segments

In order to identify specific target customers, it is crucial to focus first on identifying several market segments and understanding their specific needs. As most of the people who are interested in buying an EV are living in urban areas, E&D mainly focuses on selling their EV and battery storage systems during the first life cycle in metropolitan areas. Also operating in the sense of an energy provider for the utility companies it is more valuable for the lateral partners to have many EV that can operate as buffer storages in cities than on the countryside. The reason for that is the high density of EVs in cities, which can be seen as virtual buffer system when combining them. In the second phase of the batteries life, E&D focuses on the market of utility companies. However they try to find one lateral partner to cooperate with in order to easily standardize their service solution and create a long-term customer relationship.

9.4.3 Customer Segment

In general E&D has two different types of customers: Private customers and business customers. Private customers are in this context considered as people who are making a contract on leasing the EV's storage system and the energy supply with E&D. Business customers are utility companies that are looking for a solution to store overproduction by renewable energy plants. Figure 9.13 gives an overview of the different types of customers and shows the characteristics of its private customers.

9.4.3.1 Private Customers

E&D's private customers are mostly living in urban areas, however they do not necessarily have to. The characteristic of E&D's private customers is that they are having an awareness against high car prices and bringing a high environmental friendliness with them. In the private customer segment two different types of customers have been identified. The first group are those kind of customers who want to switch from a combustion engine car to an EV. They are looking for the best offer in the industry. To target those customers it

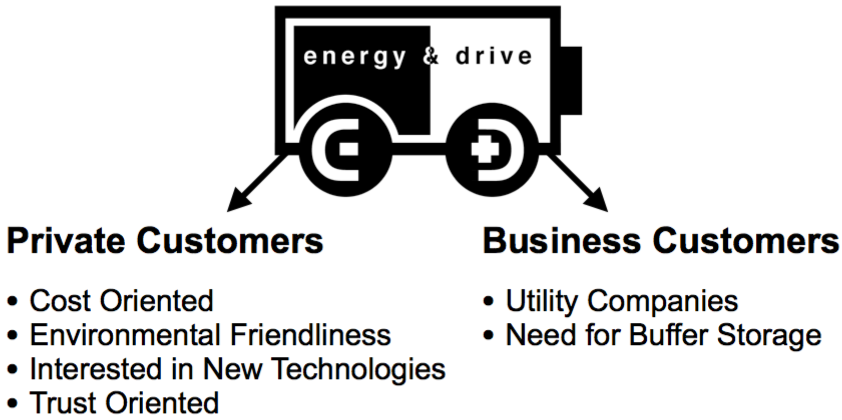

Figure 9.13: Different Customer Segments
Source: own illustration

is important to run a marketing strategy that focuses on the cost leadership advantage of E&D. The second sort of customers are those who are not only focusing on cheap battery storage systems, as they also want to reduce their energy bill by making an increasing use of the EV's V2G ability. For those customers who are using their EV as a buffer storage system frequently E&D has to offer a special energy contract which helps them to reduce their energy bill by the V2G exchange. These kind of customers are mostly very interested in new technologies and trying to save money whenever it is possible. By offering different kinds of contracts we want to target a wider range of customer and by that we try to strengthen our market position.

9.4.3.2 Business Customers

E&D's business customers are big or midsize utility companies that are focusing on the integration of renewable energies. Those utility companies are facing the problem that they are not having enough storage capacity when the supply of renewable energy, especially of wind and solar energy, is very high. To solve this problem they need buffer storage plants that are capable to store the overproduced energy and later on feed it back into the grid. Due to E&D's buffer storage plants the utility companies have another opportunity to store their renewable energy.

9.4.4 Positioning and Targeting

The specific segment that is targeted is especially people who are living in cities or those who are commuting from suburbs to the city. According to the very low battery and car prices we maintain a cost leader position and offer deals for the mass market. Therefore a broad mass of people is targeted and can benefit from these fact compared to the competitors that are only able to target the premium segment.

In the utility segment E&D is especially interesting for big utility companies, which are focusing on renewable energies. As E&D is looking for only one premium partner and there are different big utility players on the market, E&D is having a very good bargaining position. This bargaining power helps E&D to negotiate on the one hand very good tariffs for their car customers and on the other hand very good tariffs for storing the energy in buffer storage plants.

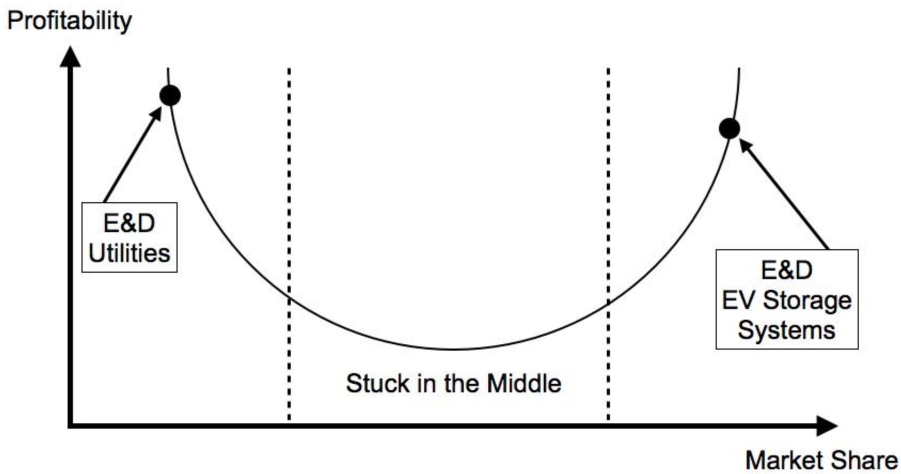

Figure 9.14: The Two Positions of E&D
Source: own illustration

The very special thing about E&D's two service segments is that they are able to be cost leader in the battery segment and a leader in the niche market in the buffer storage segment. Figure 9.14 illustrates these two positions of E&D in Michael Porters theory of cost leadership, niche market and being "stuck in the middle".

9.4.5 Unique Selling Proposition

A contract package that provides the leasing rate for the EV's storage system and also includes the energy fees for using the EV is unique on the market. Also unique is that the customer profits from the V2G ability that E&D is offering. The biggest advantage of E&D among its competitors is that they are the first company who controls the whole value chain of the storage system. Therefore E&D is the first company on the market who owns the battery during its whole life cycle. First this gives them the ability to control the recharging process via a smart metering system and by that extends the life cycle of the battery from ten to 25 years. Secondly E&D can offer a good price-value leasing contract for the storage systems because compared to their competitors they are able to depreciate the battery over a much longer period and they are having three different revenue streams, one in each phase. The last main competitive advantage of E&D is that the customers do not have to buy the storage systems by themselves and so they avoid the risk of a battery failure.

9.4.6 Cost Structure

Costs occur in different stages in the 1st and 2nd life. Firstly the costs for R&D have to be taken into account. Acquiring the necessary knowledge for the R&D process is pricy, though. Secondly there are the costs for producing the battery. Production plants have to be erected and machinery has to be installed. This is extremely expensive and further these are investments. Thirdly there are the actual costs of buying the components and then producing the batteries. The batteries' components cost quite a lot. As the production of batteries is complex and because of the required security measures the production process itself is also quite costly. Fourthly the maintenance of the batteries rise costs. To guarantee a long lifetime and thus a maximum use for E&D, the batteries installed in the cars need to be taken care of. Fifthly the consumer is being incentivized to participate in the car buffer program. This means the vehicle owner gets a cost cut on his vehicle-charging bill each time he plugs his car in. As the consumer not only leases the battery but also has an energy-charging contract linked to the lease, E&D has to pay for the electricity that is used to charge the car. For the transition from 1st to the 2nd life transaction costs occur. The battery has to be taken out of the car, their quality checked, transported and installed in the buffer plant. The buffer plant has to be developed and constructed beforehand. During the 2nd life phase the maintenance has to be kept in place to guarantee a long life. Lastly the costs of disposal occur. As described the batteries are toxic and need a special treatment, which is quite expensive. Nonetheless the waste components can be recycled and reused.

9.4.7 Revenue Model

Revenues can be generated in both life cycles and beyond. In the first life cycle, the main income is the energy & leasing contract-payment the car owner pays for his battery. This leasing rate is the largest variable.

The income generated by providing the energy contract to the customers is the second revenue stream.

In the second life the only income is generate by providing the buffer storage to the utility. The income in the second life is more stable, because the buffers can be managed more efficiently and more reliably. The time slots in which the cars are plugged in and are unplugged cannot be controlled by E&D, but in the second life, as the buffer storage is located centrally, this can be controlled. After recycling the battery the waste-components can be sold for reuse. This also generates revenue.

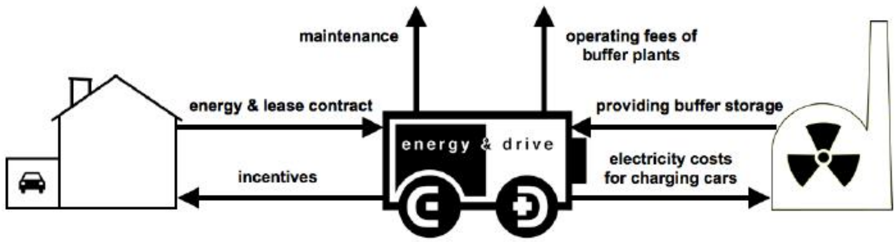

Figure 9.15: Cost and Revenue Stream (whole life cycle)
Source: own illustration

Figure 9.15 shows the revenue and cost streams that occur between E&D and the car owner and between E&D and the utility.

On the one hand the car owner pays a monthly settlement to E&D to cover the charging costs for the EV and the lease contract for the battery. Further the car owner gets a monetary incentive when he plugs his car into a charging station.

On the other hand the utilities pay E&D for providing the buffer storage, as well in the cars in the 1st life as in the buffer plants in the 2nd life. On the contrary E&D pays the utilities the price for charging the EVs of the car customers. Further costs for maintenance and operating the buffer plants occur.

Figure 9.16 illustrates the cash flows of the batteries' life cycle managed by E&D. Initially the production costs are the greatest block of costs. From then on the revenues accrue for ten years. Ending the 1st life, the battery needs to be placed in the buffer plant. These costs occur in-between the two lifetimes.

In the 2nd life, the income generated adds up over 15 years. After the second life the battery needs to be recycled. Costs occur, but the components can be reused for R&D or in the production. Overall the net present value of the battery is positive and thus a profitable investment.

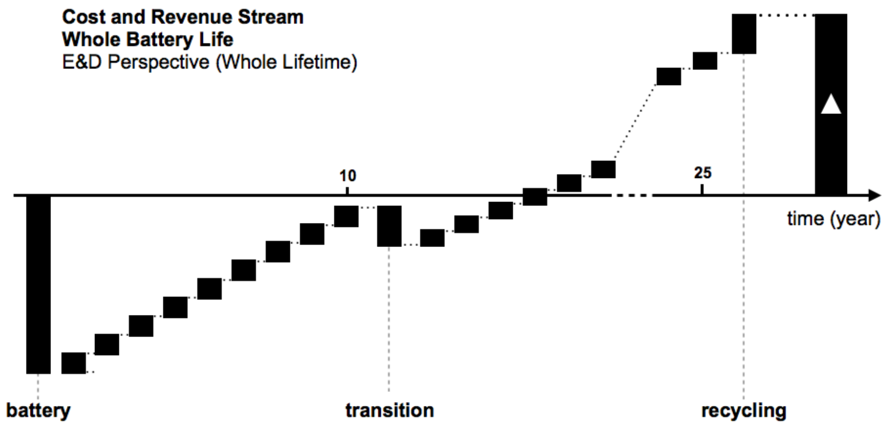

Figure 9.16: Cost and Revenue Stream (for the whole value chain)
Source: own illustration

9.5 Conclusion

Concluding, the first two scenarios „no EV vehicles on the road“ and “e-mobility in green cities“ are showing two totally contradictory scenarios for the year 2025. As the first scenario describes a world without the broad distribution of EVs in cities and on the road, the second scenario explains the opposite. In this scenario EVs will have dominated the automotive market and contribute to the green movement. The last and most realistic scenario describes a world, which stands in the middle of the first two described situations. The amount of EVs on the road is still increasing, however only a minor part of the vehicles are having an electric propulsion. Furthermore, the charging infrastructure is well developed and the industry is working to standardize the charging systems in whole Europe. The biggest issue of this scenario is the high costs of EV storage systems. Battery costs make up the biggest part of the EV costs. Realizing the problem of too expensive EV storage systems, Energy and Drive came up with a new service model, which operates with the batteries in three different phases over 25 years and owns the batteries over its whole life cycle. The first ten years the battery is in the EV and E&D generates revenues by providing package contracts that include the leasing rate for the battery and an energy contract of the EV to its customers. After ten years the battery is switched from the EV into the buffer storage plants. During this phase E&D gets money from a lateral partner of the utility sector because they are storing energy on their behalf and feeding it back into the grid when demand is high. The last revenue stream occurs when the battery cannot be used anymore and is sold to a service company that recycles it. The service idea of E&D shows that the e-mobility industry can have a crucial influence for creating an environmental friendly world and they will cooperate closely with the utility companies.

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10 Chapter 10
Private Home Perspective

Albert Feller, Pascal Nolle, Diana Schneider, Daniel Strohmayr, Wesley Stuurman

In this report the developments of the smart grid over the next fifteen years are analyzed from a private home perspective. Building upon signals and developments that are already visible today, the ten main drivers of change are identified, ranked and evaluated. Broadly speaking, the drivers can be clustered into three pillars: socio-cultural, political and technological. The three factors which will exert the most influence in either of their possible developments are legislation, technology usage and way of living. Henceforth, they are considered key drivers in the creation of three equally likely, mutually exclusive, future private home scenarios.

Upon evaluating the use of energy and technology, the personal habitat and external factors in the Smart Kommune 1, Robinson Crusoe and Mobile E-Society scenarios, the potential business climate of each was assessed. The Mobile E-Society scenario, which has the most potential for a future business solution, was selected for the development of Energy on the Go, a product idea that offers access to energy everywhere and at anytime. Through a personalized account and coherent billing system, the customers can consume energy through induction plates, smart parking plugs and temporary dwellings. This would be an ideal solution for the population of the Mobile E-Society consisting of modern nomads who require flexible, convenient and universal access to energy.

10.1 Introduction

The evolution to a smarter grid and the developments that take place in the energy sector are directly linked to the involvement of private households in the transitional process. Despite businesses being the largest energy consumer, private households can and will play a major role when it comes to the realization of the smart grid. On the one hand private parties will enable it (e.g. through decentralized production), on the other hand private parties are crucial for its adoption (e.g. through adjusted energy demand). Households are keen on lowering their electricity bill and are therefore interested in tools and devices which permit them to benefit from the smart grid. Energy consumption might be changed once information is available on how to manage it and the tools to do it. From a private home perspective it will be increasingly appealing to integrate intelligent devices and appliances into the household which interact among each other and with the smart grid. Out of this, countless new opportunities will arise for established businesses in the energy and other sectors, but also new players will claim a proportion of this future market.

In the first section, important drivers on the development of the private home in the future will be described, separated in certain and uncertain drivers. After that, three scenarios will be presented, which give an inspiring outlook on three very different, yet equally probable, developments of the smart grid and the private home in the future. In the last section, a business idea will be presented which can be the answer to many problems people will face concerning energy from a private home perspective in fifteen years time.

10.2 Driver Analysis

In the following section, the ten most important drivers for the future of the smart grid from the private home perspective will be described. Their developments will have a significant influence on the future environment for possible business ideas regarding private homes. Therefore they form the foundation for the three scenarios which are discussed in the next chapter. As shown in figure 10.1, these drivers are categorized into certain and uncertain drivers, according to their likeliness of occurring in the future and their impact. The key drivers, which have the highest impact on the private home perspective and which are most uncertain are highlighted in figure 10.1.

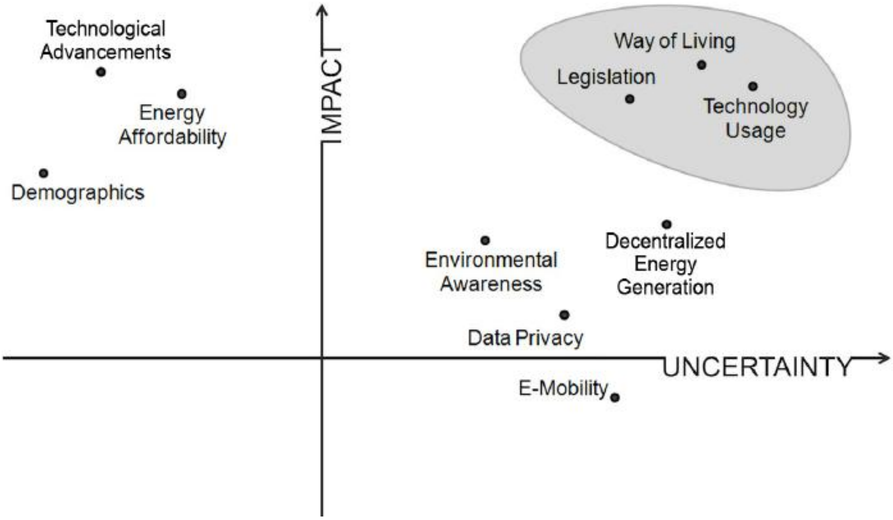

Figure 10.1: Comparative table of drivers
Source: own illustration

10.2.1 Certain Drivers

Concerning the private home perspective on the smart grid, several certain drivers have a considerable impact. Their development is quite foreseeable and a certain influence on private homes can be identified. The three most significant drivers, which are shown in table 10.1, are described in this section.

Driver	**Development**
Demographics	Aging society and shrinking population
Technological Advancements	Considerable advancements
Energy Affordability	High and volatile prices

Table 10.1: Overview of certain drivers and their developments.

10.2.1.1 Demographics

Demographics describe the structure and size of the population. They deliver valuable information for social, economic and political decisions. Signals which are already visible today help to recognize important structural changes that will take place in the future.

Description

The main demographic factors are the size and the age structure of a population, determined by birth and mortality rate, life expectancy and migration. The ratio between young and old people has a high impact on the economic situation within a country.

The demographic structure of the future has a significant influence on the smart grid from the private home perspective. The changing size and structure of the possible user base of a private home related service or product is considerably determined by the development of the population. Hence, the change in demographics is important for emerging market places as it determines possible future user bases for services and products which have a focus on the smart grid.

Development

In Germany, the population is getting older and smaller in size [497]. The fertility rate will stay at about 1.4 children per women, resulting in a decreasing number of young people [495, p. 11]. At the same time, the overall population is getting older as shown in figure 10.2. Even though life expectancy increases by about three to four years, the mortality rate will still increase because of the growing general age of the population. Since the birth rate will be lower than the mortality rate, the population is shrinking [496, pp. 12]. Naturally, this leads to a smaller potential customer base.

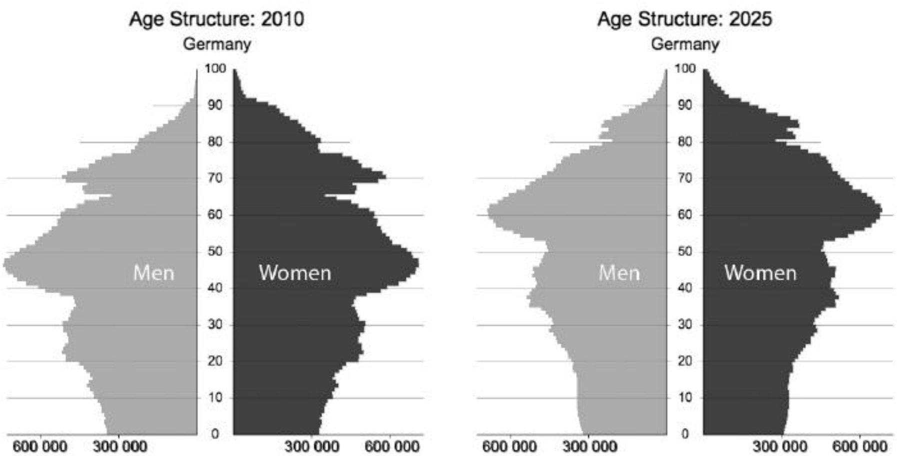

Figure 10.2: Age structure of the population in Germany in 2010 and 2025
Source: Statistisches Bundesamt [497]

Apart from that, the increasing overall age of the population influences the relation between young and old people. The population of working people will decrease and will be mainly characterized by older employees [496, p. 14-19] [495, p. 21-25]. The requirements for products will significantly change: older people have different needs for smart grid appliances, for example they will require smarter homes that support them with products for ambient assisted living [471]. They will demand comprehensible and easy to use solutions which are able to increase their daily convenience and wellbeing [498]. These products could for example use the infrastructure of the smart grid to communicate with service providers.

10.2.1.2 Technological Advancements

The advancement of technology is an important factor in the development of almost any sector. The amount of money that is spent on advancing smart grid technology and the technological progress that has been made in the past as a result of such investments will have a certain impact on the smart grid.

Description

In the basic report (see 5.2.2.3), public and private investments in the smart grid, it was made clear that European smart grid investment can reach 390 billion euros as soon as 2015. Many of these funds go into research and development and attempts to create a new generation of smart appliances that work with, and for the smart grid. These investments are a necessity to allow the smart grid to develop and become ever more efficient at managing the energy supply and demand. For the private homes, this would mean an increase of smart grid technology in the household and an increased connectivity to the smart grid.

Development

Technological advancements in the field of smart grid technology will take place and will be one of the drivers that advances the ability of the smart grid to make an impact. Interest will continue to rise among major industry players in telecommunication, information technology and energy business. Moreover, the continued government support and investment will give assurance to investors that the smart grid is a viable solution and will increase the amount of attention this sector will receive.

10.2.1.3 Energy Affordability

The price of electricity will have a remarkable influence on how the value of energy is perceived in the future. Depending on how affordable energy is for consumers, the situation for private households will change and the need for different products and services will arise.

Description

The price of energy depends on several factors. First of all, the production and exploration costs of energy have a high influence. This includes fossil fuels which are a main energy source today, but also material costs for future renewable energy generators and resources for necessary storage solutions such as batteries. Apart from that, legislative goals have a significant impact. High taxes can drive down energy usage and incentivize energy efficiency. Furthermore, the development and maintenance costs of renewable energy sources determine the affordability of energy. The energy affordability driver has a huge impact on private consumers, which are generally very price sensitive, leading to new business opportunities in the field of private households.

Development

The costs for energy will rise considerably. First of all, the resource costs for fossil fuels, which already play an important role today, and the costs for battery materials will rise [459, p. 9 - 12][475]. Since many resources are located in countries which are regarded as politically unstable, the prices will be volatile, leading to uncertain and higher energy prices [488, p. 5]. Moreover, the high development costs for new technologies needed for renewable energy sources and energy storage solutions will have to be paid off by the customers and will therefore contribute to higher energy prices [490].

The soaring and volatile energy prices will enable the need for a smart grid infrastructure including smart metering solutions to support real-time pricing and flexible demand response management.

10.2.2 Uncertain Drivers

In contrast to the certain drivers discussed so far, uncertain drivers have more than one possible future development. The seven uncertain drivers with the most significant impact on the private home perspective are described in the following section. The drivers are ranked on the basis of their impact. The three key drivers that have the highest impact on the private home perspective and which are most uncertain are shown in table 10.2.

Key driver	Development 1	Development 2	Development 3
Legislation	Locally, bottom up	Globally, top down	Failed political action
Technology Usage	Highly interactive usage	Active usage	Negligible usage
Way of Living	Community based	Mobile individual	Family units

Table 10.2: Overview of the key drivers and their developments.

10.2.2.1 Environmental Awareness

The public awareness for ecological and environmental issues has been increasing since the end of the 20th century, a development which is likely to continue in the future and will be important for the future of the smart grid.

Description

Environmental awareness is an understanding of the impact of human behavior and consumption on nature and wildlife. Those who are aware of environmental issues often try to avoid wasting resources and behave in a way less harmful to nature. Environmental awareness can be increased through education, by political action, or through individual initiative (e.g. recycling, consuming organic products). Apart from legislation, eco-awareness is a main reason why consumers might change their energy usage behavior and their investments towards a more sustainable lifestyle. The chances for adoption and development of a more efficient smart grid are dependent on environmental awareness: the degree to which the latter evolves and impacts behavioral patterns can be structured in three main possible developments.

Developments

The first possible development is triggered by increasing signs of ongoing climate change; an increasing number of natural catastrophes like floods, storms or droughts will occur [482]. More education on that matter as well as public discussion will increase the public awareness substantially. Environmental awareness leads to a realization of the impact of individual actions and consequently attempts to change personal habits [481]. People will tend to prefer goods and services that have a less negative impact on the environment. From the private home perspective, this includes building self-sustainable houses, driving low emission vehicles (e.g. electric cars) and using efficient and intelligent household appliances that are part of the smart grid. In addition to consumption patterns, environmental awareness impacts behavioral patterns on a daily basis. People will become more eco-efficient, for instance through using home appliances in times of low energy demand and high energy supply (e.g. because of renewable energies), therewith facilitating the expansion of the smart grid. On a larger scale, bottom-up initiatives will lead to greener politics and a top-down push for renewable energies and smart grid infrastructures.

The second possible development consists of people relatively aware of the consequences of their actions, yet unlikely to change their behavior unless given a financial benefit. Although there will be potential advantages for customers when they change their energy consumption to low demand times, the financial gain is too small to counterbalance the loss in convenience, therefore limiting the speed and scope of behavioral changes in private homes.

The third possible development involves the public's ignorance concerning environmental issues. People will mainly be concerned with convenience and established habits will not be changed because of environmental concerns. This means that although the technical prerequisites for the smart grid, like smart meters, might be in place, people will not be interested in using them out of an environmental-oriented motivation.

10.2.2.2 Data Privacy

One of the key issues that predates smart grid deployment, is a concern about data privacy. Compared to present-day electricity metering and billing, smart meters and smart grid solutions are far more intrusive in the data they require to function and the personal information that can be read from this data.

Description

Consumer consumption data is the key to establishing a viable smart grid that is able to manage the demand side as much as it is able to manage the supply side of the energy market. As breaches and the leakage of data on the internet by corporations, governments and public institutions take place on a daily basis, unease about data privacy is no minor concern [457**? ?**].

Privacy considerations can hamper the deployment of a smart grid by neutralizing any incentive in the form of savings or smarter energy management through a fear of loss of privacy or personal security and slowing down the uptake of new technologies. Current smart grid technology on the market has already been proven to be vulnerable to attacks that could have detrimental effects on the safety of the grid and could give the wrong parties access to energy consumption data [487]. This alleviates concerns on the awareness of other parties about consumer behavior within their own house [494]. Unclarity about which parties have access to consumer data, what this data looks like and what this information is used for are a roadblock that stands in the way of smart grid implementation [460]. Concerning data privacy, there are three paths that have been identified and that could lead to different developments.

Developments

The first possible development is that in the beginninng people will still be very concerned about their data and what it is used for. But out of this knowledge governments, public institutions and corporations will take the issue much more serious than before and make it a cornerstone of their policies. Data will only be stored anonymously and any breaches are acted upon immediately. This increases consumers' conficence in giving away data. Since the grounds for concerns about data confidentiality are becoming weaker, consumers will be quite willing to disclose their data to companies, which makes it easy e.g. for electricity comapanies to make use of that data.

A different possible outcome of the privacy discussion is that people are still concerned about their data but they will be willing to share it with parties they trust, as long as they receive an adequate compensation. Prerequesite for this behavior is that these parties provide a direct link between the data provided and an obvious benefit for the customer. The data will often still be owned by consumers who can make clear choices about the access to their data, managed by an easy and accessible method. In the case of the energy market this means that consumers will accept providing their data if they receive e.g. more efficient energy management and lower energy bills in return. On the consumer side there will be a strong desire to control the level of data openness to allow him or herself to profit, while restricting access to parties that are not directly involved in energy management.

The third possibility of consumer behavior concerning privacy is that due to a lack of corporate communication regarding data security, consumers will feel mistrust and concern with regards to usage of their data. They in general will be unsure as to which data is used, what it is used for and whether their personal information is safe in the hands of companies. The consequences of this development for energy firms and the energy market in general are very drastric. Since consumers will be less and less willing to commit to opt-in programs concerning their data, many innovative cutomized energy solutions will be a lot harder to implement and the cost involved in data management for electricity companies will increase substantially.

10.2.2.3 E-Mobility

A factor which may have an influence on the smart grid is the development of electric vehicles. In the following paragraphs the relevance of E-Mobility for the smart grid from a private home perspective will be described and different possible outcomes shall be illustrated.

Description

From a private home perspective, the aspect of E-Mobility will have different implications for the smart grid. The electric car is a significant additional energy consumer and asks for an intelligent way of charging. An according system has to be in place, to ensure a stable grid infrastructure and to avoid disruptions in the power supply without harming the needs of the customers.

For the consumer it would be most advantageous to charge the car(s) in low peak (and therefore low-price) times in order to avoid high energy bills. The batteries in the cars offer the potential to serve as a decentralized energy storage and absorb excess production which can be fed back in times of high demand and high energy prices (vehicle-to-grid, see 4.3.4). Therefore money can be earned by the private party by feeding back energy into the grid. On a grander scale this could help to smoothen the load curve. From a private perspective there is an indisputable need for charging locations at home but also in public spaces or at work for people who do not own a garage or fixed parking spot.

A main differentiator will be the number of electric cars being sold, which is mainly dependent on the relative costs and performance compared to vehicles with other propulsion methods. A linchpin will be the development of affordable and high-capacity battery technology. Moreover, the success of standardization efforts concerning charging, control and communication are critical. The development of the E-Mobility driver is not clear yet, three main possible developments have been identified.

Developments

In the first possible development, the research efforts of car manufacturers and suppliers will make it possible to quickly deliver a wide range of offerings of battery-electric and plug-in electric hybrid vehicles at affordable prices (see 4.3.1). This will be possible because the used battery technology will leap to a competitive range. Fuel prices will increase and emission regulation will tighten (see 4.3.5). The plans of the German federal government to have one million e-cars on the road in 2020 will work out and the spread will increase in the following years. [461, p. 18] Some studies see potential for share of 25 per cent or more Plug-In cars being sold after 2020 [483, p. 5]. The great number of people owning cars implies a high need for charging stations but these will publicly be only available in very limited numbers.

A quite different outcome is that the available battery technology will not be sufficient to provide a competitive user experience at reasonable costs, but alternative fuel sources such as the hydrogen fuel cell powered vehicles will prevail and replace fuel-driven cars after a transition phase [484]. This implies that the situation concerning the smart grid will remain unchanged from a private home perspective since there is no need for a decentralized charging infrastructure.

The third development involves the availability of relatively powerful battery technology but still only at a premium price [465][470]. Therefore electric cars will have a very small market share and will mainly be bought by affluent people who want to express their sustainable lifestyle. This development will be accompanied by new ways of viewing mobility. One will not have to own a car in order to be mobile, people will involve more and more in car-sharing and only use cars when they really need it [474]. In other cases, public means of transport will be used. So an impact on the grid and a need for charging at home will only be noticeable in a small percentage of the households.

10.2.2.4 Decentralized Energy Generation

The decentralization of energy generation has a significant impact on the smart grid of the future. Especially when assessing the smart grid from the private home perspective, it will make a huge difference whether private households act as passive consumers or as prosumers, who participate actively in the electricity market.

Description

The factor of decentralization regarding the future generation of electricity describes how broad generation sources are distributed over the landscape. In contrast to existing energy sources such as fossil fuels and nuclear power, future renewable energy sources (e.g. wind turbines, photovoltaic cells and geothermal generation), are often dependent on external conditions which are influenced by geographic location.

It is important to distinguish between large, industrial power plants and small-scale power generating entities. Since the difference between large existing power plants and large renewable energy generation sources has only a limited impact on the private homes, this driver focuses on the integration of households as energy sources into the electric grid. There are three possible developments of the future decentralization of energy sources.

Developments

First, a high decentralization of energy generation and a tight integration of private households into the smart grid is possible [503, p. 4]. Due to the success of legislative activities like the EEG and technological advancements in the field of small-scale energy sources, the shift from consumers to prosumers will happen for a significant part of the smart homes [458, p. 14]. Electricity supply is to a very large extent based on decentralized energy suppliers.

Secondly, another possible outcome is a certain grid apathy of private homes. Self-regulating and individualistic households produce their own energy and only refer to large power suppliers when their own demand exceeds their supply.

Apart from that, a third development is possible, where private households mostly function as consumers and play no role in energy generation. They are dependent on centralized large power plants and need the smart grid to have access to those energy sources.

10.2.2.5 Legislation

Political measures can include different incentive systems, provisions and also financing of research and development projects. In addition they vary in their geographic range which can be regional, national or international. Political decisions build an important basis and framework for the further development process of the smart grid.

Description

Political incentive systems can either support the development process or privilege specific technologies above others. One of the most famous incentive systems is the EEG which was enacted in Germany in the year 2000. The law is supporting the build up of renewable energies. As a consequence of the EEG, Germany became one of the worldwide leading countries with regard to installed wind power capacity [468, p. 2].

In the same way also provisions can enormously influence the future technological development. One example in Germany is a provision that makes it obligatory to install smart meters for all homes that are built after 2011 [469, p. 12].

A good example for political support of research efforts is the German E-Energy program. It provides an overall financing of approximately 140 million Euros until 2012 for research projects in the area of smart grids [455, p. 12].

Concerning the geographical impact, the above mentioned EEG is also an example of legislation that has been copied worldwide. First restricted to one country, today more than 40 countries have adopted similar regulations [467]. For the smart grid development, it will be especially important whether global standardization rules are in force [478] and to what extent politicians worldwide support smart grid concepts. An example for a regional political measure is the trend of cities and communities recapturing control about local distribution grids [463].

However, the enactment of legislation is based on the political preferences of the population which is reflected in election results. These are highly uncertain from today's point of view. Therefore the following section describes three different developments which are possible in the future and which will shape the development of the smart grid in very different ways.

Developments

First, it is possible that political action will be locally restricted and that smart grid actions are realized mainly by local authorities. Large international efforts will not work out efficiently and governments will not enforce further national and international regulations. Measures will be taken with a regional, bottom up approach giving funds and support to locally enacted projects. People will focus on their direct environment aspiring independence from the overall grid wherever it is possible.

Within a different possible development, global effort and local effort will be combined and work hand in hand successfully. Legislation will be able to handle most of the challenges connected with the smart grid development. They will provide plenty of funds e.g. for R&D projects and a globally organized standardization. This global way of thinking and the reliability of legislation in this area will give people trust and confidence in the system.

In a third development, political action will be taken neither regionally nor globally. As politicians do not believe in a smart grid for households, solutions in this area are rarely found. In many cases it will be not economical to use smart grid applications. There will be no standards and only few solutions for households are on the market. These will work mostly in small niche segments because a communication between different technologies will be restricted because of a missing standardization of products.

10.2.2.6 Technology Usage

The driver of technology usage is about how people are interacting with technology. In the past decade people have widely started to actively use technology. For example, today more than 70 percent of Germans own a computer [462]. However, understanding of technology is often missing. Only few people overlook the technique behind the devices and at the moment only a small part of the population actually shapes the technological process [491, p. 2-3].

Description

It can be seen as certain that technological progress will further advance in the future (see 10.2.1.2) it remains unclear which role the main part of the population will take. At the current state smart home technology is not yet widely spread. In Germany, only some households own smart meters and the most common current metering technology has been mostly unchanged for the last century [477, p. 3]. One vivid example of how this could change, is an innovative washing machine offered by the German company Miele [492]. This product can communicate with smart meters and start the washing process when it is wished by the customer and when electricity is cheapest [492]. Technological solutions could additionally aid in the area of electricity generation if households increasingly produce their own energy. However, it is unclear in which way households will adapt smart grid technology in their homes. For the market success of applications and devices it will be important whether people will actively participate in new technologies or not. Therefore three different developments are possible in the future.

Developments

The first development could be a massive technology involvement and interconnectivity of IT-systems in future households. A majority of people becomes part of an enthusiastic community which actively contributes to the development of applications for the smart grid itself. Industry players encourage this process and offer highly customer-focused smart grid devices and open source applications. These are often web-based and show flexibility concerning connectivity among each other.

In a different possible development, households will not become an active player within the smart grid development progress. However, smart grid technology will still find its way into households. People accept and appreciate it but without showing an interest for the technological background. Generally, people will not want to spend much time or get involved with smart grid technology. As a consequence, technical complexity behind devices will be invisible to the end-users and smart grid solutions will be characterized by an outstanding ease of use for the households.

A third possible outcome would be that customers will take a negative attitude towards technology. Most people will be afraid of the rapid progress and try to boycott smart grid technology in their households. The trust in the industry players will be very limited and people rely mostly on conservative players and solutions. Therefore, smart grid devices will look completely different. Solutions required within the grid will be hardware based with a main focus on complete controllability.

10.2.2.7 Way of Living

A person's chosen lifestyle is an expression of their values and norms, mostly acquired through socialization within their socio-cultural environment, education and experience. It is a way of structuring one's living environment and creating a framework of reference around daily activities, inter-personal relations with peers and consumption.

Description

The way of living is used to differentiate lifestyle modes and when defined as 'modus operandi', it constitutes a behavioral pattern that reflects developments and changes in societal values and allows an indication of the predominant zeitgeist. Therefore it lends itself as categorization tool for groups of populations and is used during the R&D process to develop solutions tailored to values, needs and expectations of distinguished user bases.

A society's dominant way of living spans a vast number of elements and will henceforth be analyzed from the three aspects most relevant to the private homes perspective: living arrangement, geographic flexibility and house owning behavior.

		age group					
		40-54		55-69		70-85	
		1996	2002	1996	2002	1996	2002
subjective assessment of family bond and emotional relationships	good/ very good	76	79	77	79	82	84
	medium	21	17	19	17	14	13
	bad/ very bad	3	4	4	3	4	3
frequentness of contact with children	daily	74	73	51	42	48	42
	weekly	20	20	37	48	40	46
	less than weekly	6	7	12	10	12	11
	never	1	1	1	1	1	0

Figure 10.3: Subjective assessment of family relations and contact frequency
Source: adapted from Klie [479, p.265]

Living arrangement options include singles, the nuclear family, cohabitation of 2-5 individuals with no family bond and community-based living solutions. German households will be mainly constituted of small units such as singles and couples, indicated by a steady decrease of households with more than 3 members over the last 50 years [495, p. 26]. In addition, the integration of the elderly generation within the community will be deepened. For instance 70% of citizens 70-85 years of age live in the same city as one of their children [479, p. 264], with an increasing emotional family bond despite declining contact frequentness, as shown in figure 10.3.

There are three degrees of geographic flexibility, namely stationary in one city with strong local attachment, regularly commuting between two main bases or gen-y nomads [501] moving to a new city or country every few months or years. Combining these cornerstones leads to three equally likely ways of living in future societies.

Developments

Firstly, the modern nomads will lead an international life, changing cities and countries every few months or years depending on study interests and job opportunities, mostly living as singles or young professional couples in a rented apartment or house and barely involved in the local community they temporarily consider 'basecamp'. Also referred to as 'gen Y' or 'Millennials'[499] , their low connection to one given stationary place along with their affinity to travel and relocate will redefine their notion of 'home' to a broader, flexible meaning closely linked to their current geographic position [486, p. 210]. In addition, they will find their way in new environments easily, having formed the habit of arriving, understanding and adapting to unknown surroundings quickly.

The second possible development of the way of living will consist of autonomous living units with a focus on the household-level. This will describe nuclear families or couples that remain stationary in one apartment or house they own and expect to stay there for the following decades. Strongly rooted in one place, this group will be less inclined towards inter-connectivity with the grid.

Thirdly, societies of the future will host community-based living and cohabitation models, including patchwork families, flat sharing and multi-generational household communities, characterized by a strong local interest, pro-active social behavior and neighbourhood-involvement. Inter-generational learning and mentoring from informed experts towards their surrounding citizens will be a key in maximizing social integration, commitment and integration within the community.

All three outcomes derive importance within this research context from their structuring function: the chosen socio-cultural setting lays the groundwork for how consumers interact with their surroundings. This in return determines how users view, approach, choose, select and use products and services, more specifically their definition of 'private homes' and the likely impact on the smart grid.

10.3 Scenarios

Scenarios illustrate different possible alternatives of the future. They envision a common understanding of the future environment which helps to prepare for possible future risks and reveals business opportunities. Focusing on private homes and consumers, three considerably different possible scenarios have been identified. These scenarios are based on the three key drivers as shown in figure 10.4. The scenarios are the product of the influences of the key drivers. Legislation, way of living and technology usage are all important in establishing the scenarios. However, they are also highly influenced by the other certain and uncertain drivers discussed before.

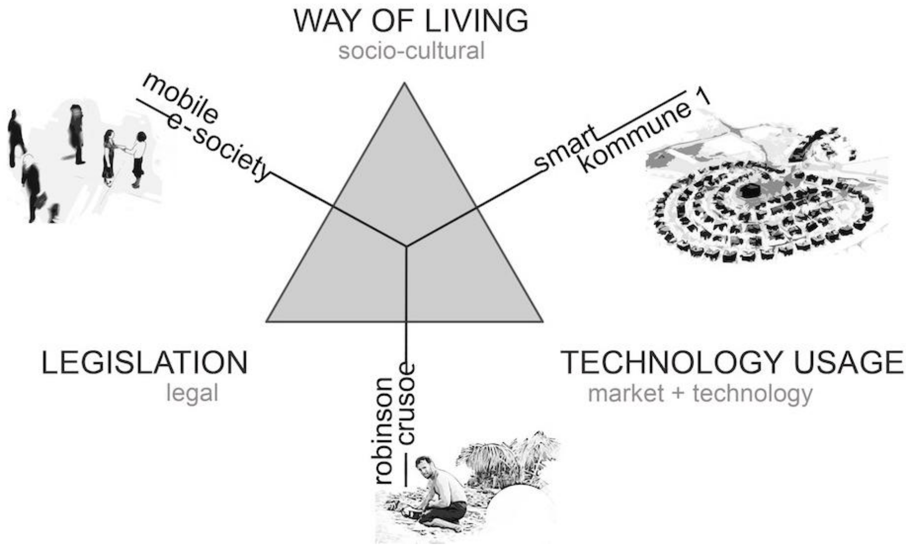

Figure 10.4: The scenarios and their key drivers
Source: own illustration

10.3.1 Smart Kommune 1

As shown in figure 10.5, the Smart Kommune 1 scenario is characterized by a community based way of living and by people who care mostly about what is happening in their direct environment. The adoption and understanding of technology is very advanced and the majority of people is actively involved in the usage of technology. Political legislation is mainly organized on a regional basis and actions are taken within a bottom up approach.

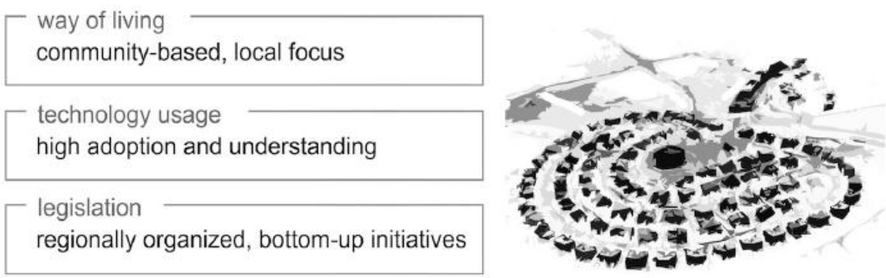

Figure 10.5: Key drivers influencing the Smart Kommune 1 scenario
Source: own illustration

10.3.1.1 Description

In the following section, the Smart Kommune 1 scenario is described by three main perspectives: the personal habitat of people, external factors influencing the scenario and the use of energy and technology.

Personal Habitat In this scenario, people have rediscovered the need for a sense of belonging. Rather then living an anonymous life in a megacity, they have started to put an emphasis on community. Organizing themselves and linking up with other interested people, small comunities have formed in former anonymous locations. Some of the people compare their current situation to a time when they were still living on the countryside. Accordingly, the growing number of old people and the wish of families to care for each other at home has contributed to a comeback of the extended family. As for many people it is normal to work from the computer and by using video conferencing tools to communicate, the boundaries between work and free time are blurred.

The people living in those communities consider their family as very important. Therefore they focus on an intact and vivid family life but also care a lot for the other households around them. A complete readiness to help each other is seen as a matter of fact for everyone in the community. The people within one community do not care a lot about their data, because everyone knows each other anyway. However, they are slightly sceptical towards an above-regional data collection and have less trust in giving away data to people they do not know.

External Factors Regarding the Kommune 1 scenario, several external factors have changed in the recent years. Generally the population has become older as a consequence of low birth rates. In addition the environmental discussion has become very important and everyone sees the importance of acting now to prevent a further global warming and to protect people from the consequences. However, there is not much international action observable, as countries have failed to find solutions everyone could agree on. As people were not willing to accept this they started local campaigns and were supported by regional authorities. Some cities have reached a 100% renewable energy supply already, especially by funding regional and decentralized energy production.

Use of Energy and Technology People in the Kommune 1 scenario generally have a very positive attitude towards technology. Consequently, most of them have a considerable knowledge and understanding of technological issues. In their leisure time they like to write their own applications for all kinds of mobile and non-mobile devices. Senior citizens, who are now living within their families, have through the intense contact with their families become active participants in this development. In addition, nearly every households owns at least shares in renewable energy production plants. Technology is used to carry through load management as well as to safe energy wherever possible. Especially within each community, energy regulation and balancing of supply and demand is done by the people as they can manage the underlying techniques. Because of the shrinking need for person to person communication in business life, which is mostly replaced by digital technologies, traveling is not such a big concern any more. For the traveling that is done, electric cars are used. Especially within the communities, people organize car sharing projects with E-cars. Families and households do not necessarily own private cars anymore, as they do usually work from home and do not need them all day.

10.3.1.2 Weak Signals

For the arrival of the described scenario several weak signal are visible already from today's point of view. First, there are already today tendencies that people wants to start a family again [500], a positive signal for the scenario, where big families and a vivid family life play an important role. In addition, the dramatic demographic changes as described in 10.2.1.1 have made politicians discuss about further family support [456]. This is a sign that legislation might also play further in the direction of the Kommune 1 scenario.

Moreover there are some weak signals to be identified which indicate an additional bottom up political action regarding future energy supply. On the one hand, the failure to find an international solution at the climate summit in Kopenhagen has shown that global agreements are difficult to achieve [485]. On the other hand, there are numerous examples for local action in the area of electricity supply. One of them is the community of Freiamt in the Black Forest which started to use wind power generation in 1997 and today produces more local energy than it consumes [493]. For the future importance of environmental issues one weak signal can be seen in the current strength of the green party in Germany [504]. This is a an indication for further political action concerning renewable energy production which is an important part of the scenario.

Additionaly, there are some signposts which should be observed in the future, as they would make the scenario more likely if they took place. First of all in this scenario people become active users of technology. Therefore if there people will start to become proficient in actively using technology, this would be a clear sign which would make the Kommune 1 scenario more likeley. Moreover, business technology will play a vital role for the Kommune 1 scenario. If there will be technologicaly important developments especially in the communication area, this would allow a further trend for the work from home. Lastly, the lifestyle in the scenario is very different from today. Therefore, if we will observe a change of people and families to live in a more community-based environment this would clearly enhance the probability of the Kommune 1 Scenario.

10.3.2 Robinson Crusoe

Figure 10.6 outlines the key drivers influencing the Robinson Crusoe scenario. Legislation having failed to generate comprehensible standards within a decentralized volatile energy market, this scenario describes autonomous family units with a low involvement in large-scale renewables or community-thinking, afraid of data privacy breaches and skeptical towards technologies they do not understand.

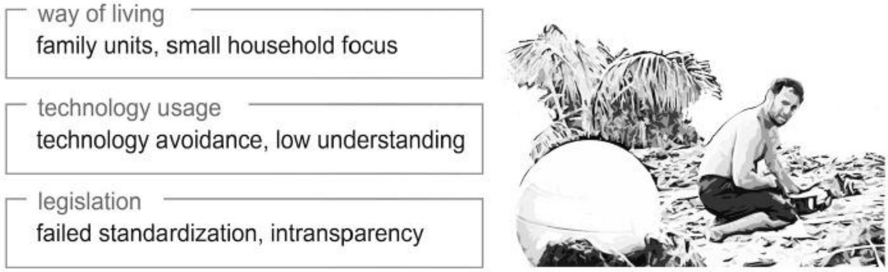

Figure 10.6: Key drivers influencing the Robinson Crusoe scenario
Source: own illustration

10.3.2.1 Description

The three main perspectives which are used to describe the Robinson Crusoe scenario in the following section, are the personal habitat of people, external factors influencing the scenario and the use of energy and technology.

Personal Habitat The 'Robinson Crusoe'-attitude describes the portion of society currently living in small units, nuclear families and couples, in a quaint row house they own on the outskirts of a medium-sized to large city. This includes families with high school-aged children and both parents in their early 40s working nine to five, but also an increasing amount of couples 50-60 years of age and older. The latter are coping with younger colleagues at the office trying to take their place, their children leaving the house, society evolving a lot quicker than it used to and retirement within sight. They can be seen washing their car on a Saturday on the driveway to their meticulously kept small garden.

Their natural habitat includes the city they live in, trips to the countryside to visit the family and the holiday-resorts where they spend their yearly vacation. Their main focus is regional or national at most and their interest in neighboring countries and international affairs is limited.

What defines the ’Robinson Crusoe’ of today is a focus on an intact household, the wish to lead a straightforward, solid, secure life in the safe, known environment they have created for themselves in years of building their home, fixing the broken lawn mower and renovating the attic. Routine and habit form their foundation of happiness and they rely on ’proven and tested’ solutions from the past, things they grew up with and what defines the status quo.

External Factors The failure of governmental actions to regulate the smart grid in a transparent, understandable legal framework over the last decades enhanced the mistrust of ’Robinson Crusoe’ in legislation and large institutions. This fortifies their desire to live in an autonomous environment where they do not depend on their neighbors PV to power their fridge, as well as their insistence on privacy, not wanting any information on data or energy consumption to leave the house.

With energy prices high as a result of the volatile supply, this part of the population is cautious on how they spend their hard-earned money, yet shun the high initial investments of remodeling their home into fully autonomous renewable energy prosumers. Therefore, their focus lies on ensuring a reliable, stable energy supply and low monthly bill by limiting their consumption.

Use of Energy and Technology Responding to energy scarcity and rising costs, the ’Robinson Crusoe’ population installed PVs on their roofs, when the technology seemed to have matured enough and have recently installed a small-scale ’wind-rotor for private homes’. These were additions to the rainwater storage tank in the garden and the ’powersave’-meter they got when building/restructuring the house in 1990. They have been using their old fireplace to heat the living room, following the soaring energy prices and rougher winters of the late 2000s. However, because of the volatility of renewable sources, the lack of an integrative, intelligent management and for fear of being momentarily left without energy, they still use fossil fuels to heat their house.

They have been hearing of smart grids for a while, convinced it was just another media hype for yuppies in the mid-2010’s and don’t like the idea of powering their next-door neighbors air-conditioning with their own expensive PVs. Member of the “late majority” in the technology adoption lifecycle, they buy new technologies or adopt new systems only when they’ve reached maturity and when enough neighbors, work colleagues, news reports have been talking about it to trigger interest in ’following suit’.

The ’Robinson Crusoe’ society is careful towards technology they do not understand and have a higher threshold to get acquainted with new technology applications, because they have not been ’up to date’ on the newest developments and feel like lagging behind. This mostly applies to the older members who are deadlocked in old habits and convictions that ’it worked then, why change now’.

In addition, their mostly skeptical attitude towards something new hitting the market is usually vindicated by early flaws or failures of radically new products, for instance the limitation of electric vehicles to parcel delivery vehicles in the mid-2010s validated their mistrust of EVs.

10.3.2.2 Weak Signals

The increasing speed of technology developments over the last decades [480, p.538] has been accompanied by an increasing lack of technology understanding, more and more pronounced with the digitalization of product use surfaces and interfaces. This has led to a portion of the population lagging behind, mostly the elderly or less technology-interested peer groups. Combined with the lack of understanding of the 'smart grid' and how different entities within the grid interact, there are large percentages of the population uninterested or uninformed about load balancing properties, technical specifications and infrastructural developments of the future smart grid.

Privacy concerns are being nourished by the media coverage of public data theft and privacy scandals focusing on the fragility of data security. For instance, a UK survey about online shopping showed that 66% of the respondents cited a concern for security issue [464]. Congruently, more than half the respondents to a survey about mobile-device security stated being concerned to very concerned about threats of unauthorized access to activity conducted on the mobile device, while more than two thirds of adults in a Financial Times worldwide online security poll express concern of cybercriminals and hackers accessing their information [476].

The adoption of decentralized energy generation in the private home environment has been on the rise with the increasing use of combined heat and power plants and photovoltaics, in Germany government-incentivized via the EEG. In 2008, Germany accounted for 33% of the European photovoltaic market [502, p.13]

In 2010, electric vehicles occupied a niche status with a one to two percent market share of new car sales in the United States and Europe, forecasting the predictably small market share of EV's in the following decade (see 4.2.2.3).

10.3.3 Mobile E-Society

The Mobile E-Society scenario describes a world where individualistically-minded, educated people base their decisions on personal growth, success, the desire to travel, connect, discover and the habit of immediate access to information (c.f. figure 10.7). Standardization efforts have been successful on a global scale, coinciding with the people's propensity to adopt technology early although they mostly have a passive, consuming attitude towards it. Those "modern nomads" are at the heart of a fast-paced world that is never stagnant.

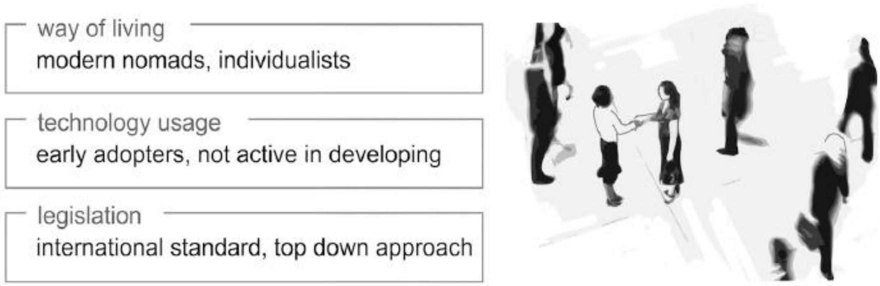

Figure 10.7: Key drivers influencing the Mobile E-Society scenario
Source: own illustration

10.3.3.1 Description

To outline the Mobile E-Society scenario, the personal habitat, external factors and use of energy and technology are described.

Personal Habitat The Mobile E-Society mostly consists of people whose main focus are career goals. A successful worklife is primordial, and when combined with their interest to challenge unknown territories, the personal habitat of the Mobile E-Society describes a modern nomadism of moving to a new place when the job requires it or promising opportunities arise. This involves a new definition of the term "home": the classical understanding of "home" as a fixed family living in a house in the suburbs being replaced by a flexible, short-term one. Members of the Mobile E-Society are citizens of the world.

Mobile E-People often live on their own or in small households with no interest in the surrounding community. They prefer renting ready-furnished apartments in cities or houses because they are easier to handle and can be left without complications when moving away again. Spending a lot of time at their job, traveling or meeting like-minded acquaintances, they are seldomly "at home", and it is not unsusual for Mobile E-Couples to keep seperated households. However furtive their current "home" is, those modern nomads wish to find a setting that is relaxing, functional and efficient from the moment they walk through the door.

Living in a world of globalized business, they adapt effortlessly, decide instantly, expect immediate connectivity and a world in which everything functions with effiency and clarity or can be solved quickly. They are used to traveling procedures and accept security and data checks and necessary data transfers, not concerned about data being used by governments and the industry as long as these processes are very transparent and they know what it is used for. In exchange they receive the convenience and freedom they thrive on.

External Factors Members of the Mobile E-Society aspire to get most out of their lives, rely on themselves and dislike the feeling of dependence on others. These career-minded nomads are less interested in "settling down" and family, explaining the low birth rates.

In this globalized world growing together, legislation is increasingly handled successfully on a European and even worldwide basis. Governments and industry have seen the advantages of binding standards early in de development process, avoiding conflicts over competing formats. This implies a high standardization in new technologies like e-mobility (plugs and charging systems are interoperable worldwide). In addition, standardized smart grid technology like smart meters with real-time measuring and communication capability have found their way into almost every home due to internationally binding legislation. These smart meters are not only able to transmit data to utilities but can also be accessed by third parties if they have the according permissions. For private users, the implimentation of standards concerning induction charging of small electric devices (e.g. cell phone, laptop, tablet) has proven to be very convenient.

Climate change meanwhile has reached mainstream awareness, inciting people to think about the consequences of their actions as far as consumption of resources is concerned. However, most of the time they stick to their old habits concerning energy consumption, unless they feel extensive financial pain or convenience disadvantage by it. As a result of soaring energy prices almost all institutions and businesses have limited the free availability of energy via plugs on their premises. Another unsatisfying fact for the Mobile E-People is that is still quite a hassle to change one's energy provider, not corresponding with their fast paced lifestyle.

Use of Energy and Technology The inhabitants of the Mobile E-World are highly dependent on technology: they need to stay connected to organize their stressful life and to communicate with people abroad. These people always own the latest gadgets as status symbols, but despite being up to date about sophisticated technological advances in the past, they do not want to get to involved in the development itself. They expect easy-to-use, functioning technologies, without investing the time and care to figure out how and why things work. Their main goal is to keep up with their fast-paced world, at any time, no matter where they are. Communication infrastructure and interconnectivity is important for their lifestyle.

The second prerequisite to the seamless functioning of the Mobile E-Society is power. Using communication devices (media devices, working tools) all day, causes them to run out of energy which disables the benefit derived from them. In these situations, they would be willing to pay a premium if a charging spot was available at that time and place in order to still be connected and to be able to resume working and living.

A similar attitude can be observed in the use of their "home" environment: when living "on the move", they do not want to worry about appliances functioning at home. Arriving home tired from a long day's work in a city they have recently arrived in, their main concern is to have everything running smoothly without too much effort from their side. Therefore they often outsource tasks which are time-consuming and give them no sense of achievement, instead inhibiting their convenience.

However, they know about the advantages which can be realized because of the smart grid and would like to benefit from it (e.g. by making use of the highly differentiated and volatile energy tariffs during the day to charge their car), but they will not accept a hassle in order to do so. A shift in behavior only takes place if there is a substantial financial incentive or convenience benefit in store for them.

The same applies to the decentralized energy generation: because they rarely stay in a place for longer than a few years, they usually do not engage in such activities. Only some people have their own, small wind or solar power generators, the vast majority of electricity is centrally produced in big power plants. Most of the Mobile E-citizens do not want to invest the necessary time and interest to take part in energy production.

A substantial part of the mobility of this society works with electricity, EVs being the dominant technology particularly in city environments. The ownership of electric vehicles is widespread and has become a status symbol for large swaths of the population. Ownership is therefore widespread, even though charging at times can be a hassle.

10.3.3.2 Weak Signals

Evidence for a development in the direction of the Mobile E-Society scenario can already be seen today. Single households make up the greatest percentage of households. In the future the number of single and double households will increase strongly[466]. This is related to the fact that the people are becoming more mobile concerning the job [472], especially the skilled workforce. They are accepting to relocate for their job not only within a region of a country but also between countries and continents. This can also be seen by the increasing number of expatriates today [473]. An additional factor to this development is the increasing number of women who decide to pursue their career over founding a family. This will lead to more non-classical household constitutions and even lower birth rates.

For the legal part, one can already observe today that legislation is in place, which obliges the installation of smart meters in some countries. Therefore it is likely that this will spread to other countries and a majority of buildings will be covered.

The technology usage in the future is quite similar to today, but is expected to intensify. People want to be connected and to communicate 24/7 today, spending hours on Facebook, Skype or on their cellular phone. This behavior will continue to expand with the advancement and dispersion of technology (e.g. video calls on cell phones) with currently 40% of cellphone users younger than 40 accessing the internet via mobile phone on a daily basis [454].

The future approach of the Mobile E-Socity concerning data security does not seem that far-fetched if one bears in mind the behavior of people today. People do not have issues sharing their data on Facebook or having data stored on personal cards (e.g. for DVD rentals or health insurance).

If the reduction of openly accessible public power outlets seems absurd, one has to keep in mind that already today employees are being fired for charging their cell phone or electric scooter at the workplace, considered guilty of electricity theft [489].

10.4 Service Idea: Energy on the Go

The following section is about the revolutionary service idea Energy on the Go. After a brief introduction of the general concept an analysis of the customer needs and possible use cases of the new service will be presented. After that the distinguishing features will be described as well as the activities and partners needed for the implementation. In the last section the focus will be directed on the different customer segments, the overall revenue model of the service as well as the cost structure that will occur.

Energy on the Go is a service provider that provides a solution for private and public energy use to an ever increasing mobile society. Energy on the Go provides a unified account system to a huge potential customer base in order to allow them access to energy everywhere, 24 hours a day, 7 days a week. Private parties or businesses (any plug owners) can sell energy from their plugs to our customers via one accounting system. Figure 10.8 shows the connection between the customers, smart plug owners and Energy on the Go. The service would connect the demand of consumers with the supply of the smart plug owners by allowing customers to access energy anywhere through their personal energy account. This can be at home, induction charging for small devices when travelling or chargers for e-cars. Smart plug owners would profit from the large customer base that Energy on the Go will offer and a secure way of handling the financial transactions between them, and the customers.

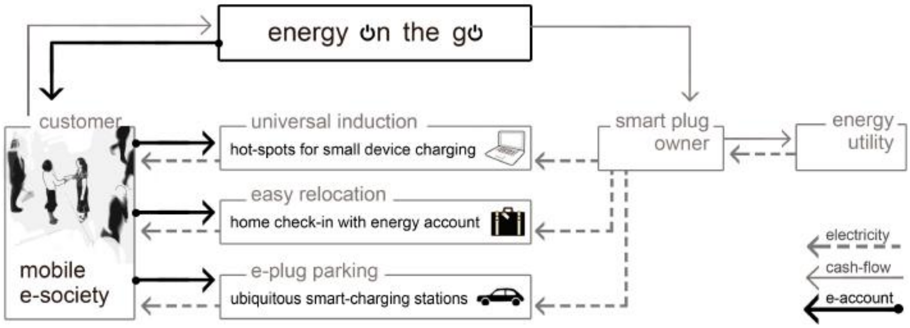

Figure 10.8: Business model of the service idea.
Source: own illustration

10.4.1 Product and Service

Energy on the Go responds to the three main energy-related requirements the Mobile E-Society customers have in their 'private home' environment. A unified energy account system as provided by Energy on the Go caters to these needs and spans a variety of possible use cases for both plug owners and mobile energy consumers.

10.4.1.1 Customer Needs

Firstly, the need for universal instant energy access, no matter where the user is. Due to heightened flexibility in the Mobile E-World, the fixed boundaries of 'private home' limited to one geographic place are replaced by the redefinition of the modern nomad's home: a fluid notion, applicable to any environment the user is temporarily located in. In any of these ephemeral surroundings the consumer expects to feel 'at home' with immediate connectivity and electricity supply, be that to charge a cellphone on a bistro-terrace in Lyon, keep their EV 'plugged in' during a boardroom day in Copenhagen or power the fridge of a 3-monthly leased apartment in Zurich from the instant they arrive.

Secondly, the target customer demands an easily understandable, transparent billing system that doesn't require in-depth knowledge in the fields of smart grid technology or IT, a consequence of their fast-paced lifestyle and ensuing short attention span for detailed information beyond their immediate area of interest or expertise.

Furthermore, the customers wish to reduce the complexity they automatically face due to their frequent city changes, language adjustments and intricate schedule. Not having innumerable accounts, interfaces and passwords for every single application they use is a necessity to remain in control.

10.4.1.2 Possible Use Cases

In the following section, three different use cases are described to demonstrate the diversity of potential applications for the Energy on the Go system.

Induction Charging of Small Devices

The first possible use case for Energy on the Go are small electricity hot spots to charge electronic devices in public areas. One area of application are waiting areas in high traffic hubs like airports, bus and train stations (see figure 10.9). Many travelers could use a publicly accessible energy plug to charge their electronic devices such as smart phones, laptops, cameras, music players or tablet computers. Other places where electricity hot spots can be used are cafés, restaurants and even flexible office spaces.

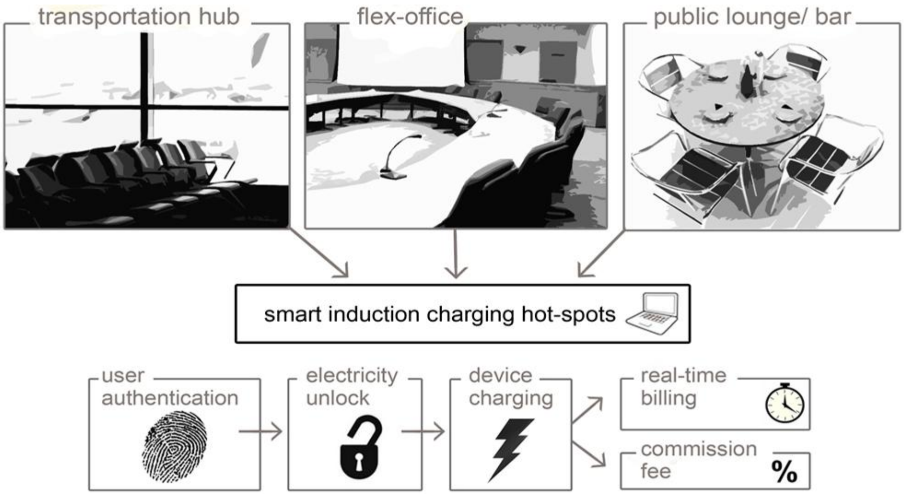

Figure 10.9: Induction Charging of Small Devices
Source: own illustration

The owners of such places can offer the energy they either obtain through their utilities or they produce decentrally themselves, at a premium price. The billing of the energy consumption of customers is handled through the Energy on the Go accounting system. To participate in the Energy on the Go system, plug owners are required to acquire special smart induction plates. These plates have an integrated Energy on the Go account identification and a built in metering system which measures the energy used by consumers. The metered data is sent to the Energy on the Go billing IT system via different possible communication mediums. Depending on the local conditions, either a cellular network, a Wi-Fi internet connection or the smart meter gateway of the building, which can be accessed through power line carrier (PLC), is used.

Customers of the Energy on the Go system can use any electricity hot spot to charge their devices via induction. They don't have to worry about the billing since the whole process is handled by their Energy on the Go account. Once they identify themselves at the smart induction plates using wireless smart cards or biometric data, they can charge their devices via induction (see figure 10.9)and have the convenience of instant access rather then the hassle of finding a connection.

The Energy on the Go system can be extended to public transport systems like trains and airplanes to offer passengers a premium service which allows access to energy during traveling.

Easy Relocation

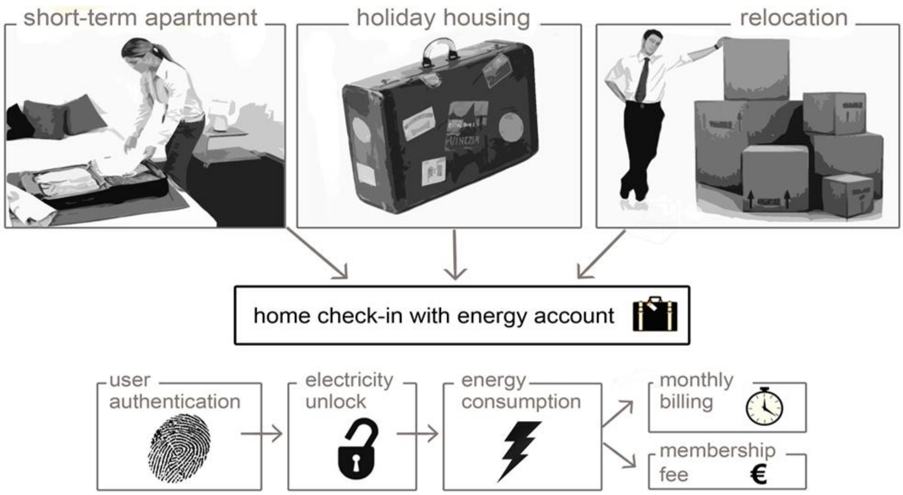

Figure 10.10: Universal Energy Account for alternating Places of Residence
Source: own illustration

Another possible area of application for the Energy on the Go system are short term apartments and holiday flats (see figure 10.10). Real estate companies can install a specially programmed smart meter which bills the consumed electricity of an apartment to the Energy on the Go account of the person who is using the apartment. The house owner has a long term contract with an electricity utility which provides the energy for all apartments. The owner gets back his energy expenses through the monthly Energy on the Go payment and does not have to worry about people excessively using energy since he does not have to offer a flat tariff anymore.

Customers of the Energy on the Go system can check in into these apartments by using their account and the identification means described above. Everything is then already configured and they do not have the hassle of setting up a new energy contract for the apartment. The identification and smart meter system automatically communicates with the Energy on the Go IT system (see figure 10.10). All the billing is then conveniently handled by the Energy on the Go account.

E-Mobility

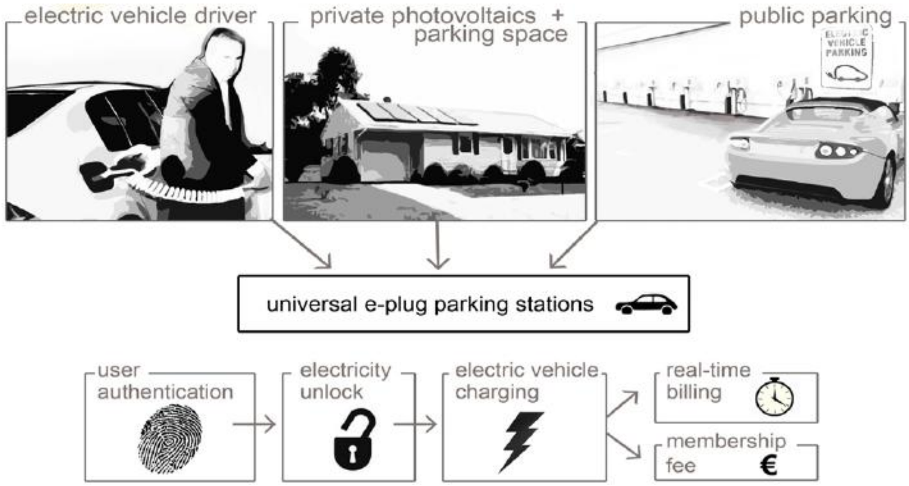

Figure 10.11: Electric Vehicle Charging
Source: own illustration

A third use case for the Energy on the Go system are e-mobility and parking places. Owners of commercial and private parking lots can offer the parking place and a power plug to recharge electric vehicles (see figure 10.11). They have to invest in smart charging plugs which measure the energy consumed during charging. Due to the high power consumption of vehicles, it is especially important for the e-mobility use case to rely on real-time prices for electricity. The smart plugs used by the Energy on the Go system receive the current price for energy from the plug owner's utility via power line carrier (PLC). This information is relayed through a smart meter, installation of which is mandatory by law. To simplify the preconditions for offering an e-parking place, the Energy on the Go billing system can also be used as a parking ticket.

Users of electric vehicles can use their Energy on the Go accounts to pay for charging power and optionally for parking tickets. The billing is automatically done at the end of the month. The car owner can control the maximum electricity amount which will be charged. It is also possible for the customer to predefine the parking period. The smart charging plug will then automatically try to charge the vehicle at times where energy prices are low. A vehicle-to-grid (V2G) mode is also possible, where the parking/energy bill can be further reduced by allowing the smart plug to feed energy back from the vehicle into the grid at high pricing times.

10.4.1.3 Unique Selling Propositions

The Energy on the Go business idea works best for a company that is already an established player in energy demand management for the private market. As service and convenience provider for private households, assets such as a known and trusted name, financial resources, experience in billing, usage of data management systems and market power are important factors in establishing Energy on the Go rapidly and successfully.

The main benefit for customers of the Energy on the Go service is convenience. No other company is able to provide their customers with access to energy everywhere and instantly. Since Energy on the Go deals for the customers with all smart plug owners and their utilities, just one unified virtual energy consumer identity is required to profit from convenient electricity billing. Instead of micromanaging their energy usage, customers rely on Energy on the Go. Without any extensive knowledge about smart grid technology, customers can comfortably use their energy account wherever they are and benefit from the smart grid.

10.4.1.4 Key Activities and Partners

The strength of the Energy on the Go concept will only be fully utilized once smart plugs are installed at enough locations where the customer base would require them. To reach this tipping point as quickly as possible, Energy on the Go would rely on partners. The partners would involve themselves in the production, installation, maintenance and operation of smart plugs. Moreover, the energy supply that is required to operate the plugs will have to be either provided by the smart plug operator or through a deal with a local utility. This would allow Energy on the Go to focus on providing the business solutions at the back end. This would include the distribution and maintenance of private energy accounts, marketing and advertising, utilizing existing communications infrastructure to profit from energy price volatility e.g. when charging E-cars, a customer account billing system and distributing the revenue to smart plug providers.

Energy on the Go's partners can be split up in two groups. First of all, there is the industry. The industry will have to provide, maintain and install smart plugs, induction plates, card readers and e-plugs. These partners can range from large companies such as Siemens, which can provide new technologies and solutions, to small local installation companies that service a city or neighborhood. Secondly, there are the operators. The operators are responsible for the placement of the plugs and their day to day operation. These partners can include both public institutions such as municipalities and libraries, and private entities such as households, small businesses and real estate owners. They would provide the site where access points is provided whether this be a public street, a private parking spot or a small café.

10.4.2 Market and Financials

The economic viability of the concept is described in the part below. First of all, the customer segements will be discussed. Secondly, both the revenue model and the cost side of the business is higlighted to provide a full picture of the business idea.

10.4.2.1 Customer Segments

The main target group of Energy on the Go are the population of the Mobile E-Society scenario. These people work hard and are therefore relatively affluent and able to pay premium prices for the services they use. With this comes a certain mentality, a time-is-money mindset. They normally do not want to be bothered with, in their eyes, unimportant issues and prefer a convenient life when not being at work.

They are driving electric vehicles, that have to be charged. In a mainly urban setting, private and public charging stations are mixed and cars are not always parked in the same location. As we know our customer group very well we will be able to provide our services at places especially important to them, for example at airports or other transportation hubs. When travelling, connectivity is a high priority. Running short on energy for their devices is not an option, therefore they are willing to pay premium prices to avoid such situations. Moving or migration is a recurring event in the lives of our customers. Setting up an energy provider contract all the time from scratch is a hassle, they would like to avoid.

10.4.2.2 Revenue Model

Energy on the Go will rely on two main sources of revenue to acquire income. Firstly, every owner of an energy account will have to pay a small monthly fee to remain a member. This is similar to credit card companies charging their customer a small amount per month or year to increase usage of the accounts and make people aware of their account. Secondly, every time the energy account is used to access a plug, Energy on the Go acquires a small percentage of the transaction that takes place. This percentage will be based on the margin between the actual cost of the energy used, and the price that the consumer will pay. This margin is also the plug owner's source of profit. Additional sources of revenue could include providing financing options for interested plug owners and the charging of a onetime fee to connect the plug owner to the Energy on the Go system.

10.4.2.3 Cost Structure

The costs which are associated with successfully implementing Energy on the Go on a large scale, fall mainly into two distinct categories. Firstly, substantial investments will have to be made in acquiring both energy account holders as well as plug owners and gain traction for Energy on the Go on a larger scale. Large, targeted marketing campaigns, outreach to enterprises, small businesses and consumers will require a generous marketing budget. Secondly, the core business runs on information and communications technology. Continued investments in the ICT infrastructure, billing systems and data management will take up a substantial part of the budget. Moreover, personnel, customer service and system security can also be expected to feature in the budget.

10.5 Conclusion

From a private home perspective, a substantial part of the smart grid concept and technology is invisible. However, this does not mean that the smart grid is an irrelevant concept for consumers. Smart meters and electric vehicles will develop further, environmental awareness and legislation will continue to have an impact and rising energy costs and lifestyle choices will force people to consider their options more carefully. Looking towards the future, we can distinguish these developments and evaluate their impact on the future of smart grids around the world. Throughout this chapter, developments that take place today have been analyzed to create multiple perspectives on the future. The three scenario's that have been developed are each distinctive in their outlook on the future and the interaction between private homes and the smart grid.

In the Smart Kommune 1 scenario, private homes will take on an active role in deploying and using smart grid technology. The contribution of local communities to the smart grid will lead to an increased role on the energy market for consumers. In the Robinson Crusoe scenario, external factors have forced private homes to adapt and adopt smart grid solutions in their homes. Lack of knowledge and wariness about solutions that are not understood will lead to a lack of active participation, even though the technology will be there. Lastly, in the Mobile E-Society scenario a rise in mobility and longing for convenience will lead to a more top-down approach in the development and implementation of smart grids. Based on this, the Energy on the Go product idea offers access to energy everywhere and at anytime. It allows participation both on the supply and demand side, without creating complicated structures or requiring structural investments from consumers. For a society that is constantly on the move and that values convenience, it is a business idea with huge potential.

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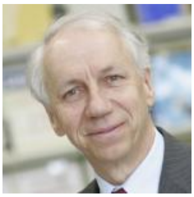

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