MSc Program
Renewable Energy in Central and Eastern Europe

On the relevance of large carport installations for future deployment of PV in urban areas (Part 1)

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
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Zurich, 28th of February 2012

Affidavit

I, **Samir Al-Wakeel**, hereby declare

1. that I am the sole author of the present Master Thesis, "**On the relevance of large carport installations for future deployment of PV in urban areas – part 1**", <**140**> pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master Thesis as an examination paper in any form in Austria or abroad.

Zürich, 28.02.2012___________ _______________________________

Date Signature

Preface

As of today most photovoltaic (PV) power plants are either large scale installation on the country side or mainly small size roof-mounted installations on private houses. There are only few mid-size installations in urban areas. Hence, the objective of this master thesis is to prove the technical and economic feasibility of such power plants in the first step. Convenient areas might be public buildings and factory halls in combination with large parking sites from shopping malls and business centers. However, the main subject of interest are the so called PV carports, which are parking areas covered with photovoltaic panels producing electricity for self-consumption or hosting charging stations for electric vehicles in the future. Beside technical, legal and financial clarifications, the acceptance of such solutions shall be evaluated by a survey of selected carrier and supplier. Thereby the set focus is on potential clients located in the DACH region (Germany, Austria and Switzerland). In the second step the results of this work shall be used as a basis for the formulation of a business case delivering a proof of concept and for validation of the business idea to set up and establish a start-up company projecting PV power plants, in particular PV carports as explained above. Hence the focus of that part will be set on the definition of the green field strategy, the marketing plan, the financing model and other related topics. Thereby the following major questions and subjects are going to be addressed in two parts, since the topics to be evaluated would exceed the frame of a single master thesis:

Part 1 covers mainly external subjects as:

1. Evaluation of the appropriate PV technology to be used
2. Overview of legal and regulatory obligations to be met
3. Determination of economic measures relevant for the business case
4. Description of different constraints in the DACH countries
5. Brief introduction to the E-cars market development and deployment
6. Survey of potential clients and analysis of the results

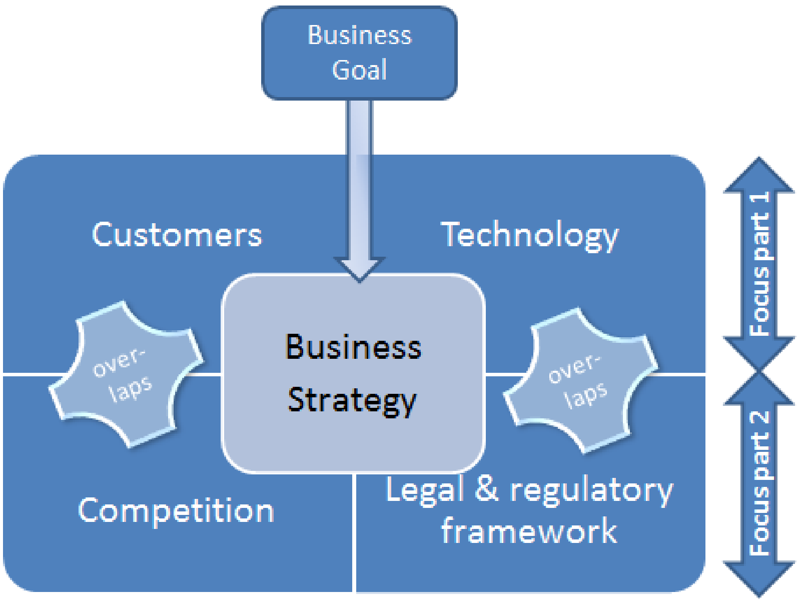
Part 2 covers mainly internal subjects as:

1. Characterization of optimal legal form of the company and evaluation of possible co-operations with suppliers, construction firms and others

2. Formulation of the financing model and definition of the start-up structure regarding budget, business plan, organization and marketing approach
3. Risk analysis of the project realization and the implementation of the start-up company
4. Analysis of the competition with focus on D and CH
5. Analysis of major market entry barriers
6. Formulation of the exit strategy, the outlook and next steps

Even though each part presented is comprehensive and significant by itself, the aim of the two co-authors focusing each on one part is to deliver one big picture, following a jointly developed model and method of approach to deliver a proof of concept, validate the business idea and prepare a business plan to establish a start-up company projecting PV power plants as explained above.

The following figure illustrates the split of the two master's thesis and shows the focus of part 1 and part 2 respectively. However, some overlaps in the proceeded explanations can't be avoided and are partially intended to ease reading and for completion of each part.



Focus areas and the split between part 1 and part 2 of the master's thesis

Abstract

Photovoltaic elements can be installed not only in open spaces but also in built-up environments. The latter is very promising, as in densely populated Europe, large-scale solar farms compete with many other land uses for the best spots and land availability may therefore become a problem in the future.

While the generation of solar electricity in building integrated or roof-mounted installations has been the subject of numerous studies, commercial and industrial size PV carport applications are a rather new phenomenon in the DACH countries.

This work closes that gap by providing some insight about the development in that specific area. Interesting and relevant facts are exposed the proof for its potential and future deployment.

Beside the evaluation of general improvements of the PV technology as such, information about the market development in Austria, Germany and Switzerland can be found.

Finally some trends regarding technology adaption and the awareness for renewable energy from the business and trade market segment are provided.

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Acronyms

A	....	Austria
BIPV	....	Building integrated Photovoltaic
CEO	....	Chief Executive Officer
CH	....	Confoederatio Helvetica (Switzerland)
CO_2	....	Carbon-dioxide
CSR	....	Corporate Social Responsibility
D	....	Germany
DACH	....	Germany – Austria - Switzerland
DAX	....	Deutscher Aktien Index (German stock index)
E-car	....	Electric car
EEG	....	Erneuerbare Energie Gesetz (German renewable energy act)
EnG	....	Energie Gesetz (Swiss energy act)
EPIA	....	European Photovoltaic Industry Association
EWZ	....	Elektrizitätswerke Zürich (Swiss power utility)
FIT	....	Feed-in tariff
GRI	....	Global Reporting Initiative
HW	....	Hardware
IEA	....	International Energy Agency
IPCC	....	Intergovernmental Panel on Climate Change
IR	....	Interest rate
IRR	....	Internal rate of return
kW	....	Kilo Watt (10^3 Watt)
LCOE	....	Levelized cost of electricity
MW	....	Mega Watt (10^6 Watt)
NPV	....	Net Present value
PEST	....	Political, Economic, Social and Technological (analysis)
PJ	....	Peta Joule (10^{15} Joule)
PV	....	Photo Voltaic
PVP	....	Photo voltaic plant
RE	....	Renewable Energy
RES	....	Renewable Energy Sources
SE	....	South East
SW	....	South West
SWOT	....	Strengths, Weaknesses, Opportunities and Threats (analysis)
UNEP	....	United Nations Environment Programme
UNO	....	United Nations Organization
W	....	Watt (derived unit of power)
WACC	....	Weighted average cost of capital
WEF	....	World Economic Forum
WMO	....	World Meteorological Organization

1 Introduction

Although the recovery in the world economy since 2009 has been uneven, and future economic prospects remain uncertain, global primary energy demand rebounded by a remarkable 5% in 2010, pushing CO_2 emissions to a new high according to the new report from the International Energy Agency (IEA) [1]. This is the highest increase since the start of measurements. The restriction of global warming to 2 Cº is just “a nice utopia” said Fatih Birol, chief economist of the IEA, at the end of May 2010 in London. "It will be an exceptional challenge if we are going to achieve the goal and keep global warming below two degrees". According to projections of the UNO Panel on Climate Change (IPCC), this means a 50% chance of a rise in the average global temperature of more than 4 Cº by 2100 [2]. “The results would be dire”, warned the British economist Nicholas Stern. “Such warming would disrupt the lives of hundreds of millions of people across the world, leading to widespread mass migration and conflicts. Any sane person would seek to drastically reduce such a risk”. At the same time, the logical consequence after the devastating nuclear catastrophe in Fukushima was the phasing-out of nuclear energy by 2021 in Germany and by 2034 in Switzerland. Focusing on coal or gas power plants instead would be a step towards collective self- destruction. Consequently the most logical approach being advocated by many scientists and policymakers is to slow down the build-up of greenhouse gases significantly through conservation, energy efficiency and a dramatic increase in the use of renewable energy and alternative fuels to reduce the use of coal and oil. However, achieving that goal will require consumers, corporations and governments around the world to make a lasting and meaningful commitment to change. Deployment of Solar Energy could play an important role in that context. Within the European Union’s SET Plan, the Solar Europe Industry Initiative – led by the European Photovoltaic Industry Association (EPIA) – proposes three scenarios resulting in three levels of solar share in the electricity market in Europe: 4% for the Baseline scenario, 6% for the accelerated growth scenario and 12% for the paradigm shift scenario. EPIA is confident about achieving the paradigm shift target, based on the rapid ramp-up of the past decade (average annual growth rate of 40%). The paradigm shift scenario requires a rapid, widespread adoption of smart grid technologies and power storage and further improvements in high quality manufacturing and products all along the PV supply chain [3].

1.1 Motivation

With the implementation of the renewable energy acts combined with various guaranteed supporting measures as feed-in tariffs, capital subsidies, PV-specific green electricity schemas and many others, the number of installed PV plants increased systematically. Germany as one of the first countries in Europe, that has implemented the „Erneuerbare Energien Gesetz" (EEG) in 2000 and reached an installed capacity of about 17.3GW_p or approximately 212W per inhabitant by the end of 2010 [4, 5]. In contrast, Austria implemented its „Ökostromgesetz" only one year later reaching approximately 95.5 MW_p or about 11 W per inhabitant [4, 6]. Finally the Swiss federal government confirmed its energy policy principles and the adoption of the „Stromversorgungsgesetzes (StromVG)" and the "Energiegesetz (EnG)" in 2007 catching up with 110 MW_p [4, 7] respectively about 14 W per inhabitant[1]. Thereby practically all installations were grid-connected and realised either as open field installations or roof-top systems in built-up environments. The latter is seen very promising, as in densely populated Europe, large-scale solar farms and open space compete with many other land uses for the best spots and land availability may therefore become a problem in the future. Current numbers already prove that development as more than 85% of all installations in Austria are roof-mounted [6]. Similar development can be observed in Switzerland, where the majority also has been built mostly on the roofs of buildings. Larger installations (> 100 kW) are usually flat-roof mounted on commercial and office buildings. However, a new trend appeared in 2009 with tilted roof installations on farmhouses with sizes ranging from 30 kW to typically 100 kW. The size of residential systems increased from 3 kW in earlier years up to 15 kW. It can be further stated, that the general trend is going towards the usage of the whole roof facing South (SE to SW) and not only a part of it [7].

While the mentioned "classical" roof-mounted installations on buildings are becoming a de-facto a standard, PV installations on mid and large size parking areas, so called **carports** are a relatively new phenomenon. There are basically no studies about that kind of implementations and the available information is very limited. Therefore the aim of this work is to provide some insight about the

1 The stated data (e.g. absolute numbers of installed capacities, percentage, quota etc.) may slightly vary in this document since different sources were used.

development in that sector and to deliver a proof of concept regarding feasibility and profitability of such implementations. Of cause, a large variety of parking areas (e.g. private, public and office parking areas, etc.) exist. However, the focus in this work is set on parking areas of large shopping centres from retailers, do-it-your-self shops (DYS), home-centres and furniture stores in the DACH region (Germany, Austria and Switzerland).

1.2 Core objectives

The aim of this master thesis is to provide the information and data relevant for the establishment of a start-up company projecting **large PV carport installations**. Thus, the main objective is to deliver arguments to proof the concept and for the validation of the business idea. Thereby different aspects are subject of evaluation, such as the technical and economic feasibility on one side, the potential and the market acceptance of such solutions on the other side. In doing so, the focus is set on the DACH countries and in particular large shopping centres like retailers, do-it-your-self shops (DYS), home-centres and furniture stores as possible target market segment.

Consequently following topics are going to be evaluated and the related questions answered:

- Evaluation of the appropriate PV technology to be used
- Overview of legal and regulatory obligations to be met
- Determination of economic measures relevant for the business case
- Description of the different constraints in the DACH countries
- Brief introduction to the E-cars market development and deployment
- Survey of potential clients and analysis of the results
- Motivation and social acceptance for PV carport deployments

In a second step, which is not subject of the master thesis the findings of part 1 – Technology and Customers - and the findings of part 2 - Competition and Legal & Regulatory Framework according to figure 1 will be analyzed in detail and the data used as basis for the formulation of the business case and for the establishment of the company.

1.3 Citation of main literature

In this work, mainly publicly available reports, various studies and official publication of accredited associations and federal bodies were used. Furthermore published information on the www from adequate sources was called in. For specific topics expert books, papers and proceedings were consulted. All the used sources are summarized under the references in chapter 8. Some of them are also quoted below the citation. The following listing provides the most important sources used:

- Publications from the International Energy Agency (IEA)
- European Photovoltaic Association (EPIA)
- European Commission / Joint Research Centre Institute for Energy
- Austrian, German and Swiss Federal Office of Energy
- Photovoltaic Austria - Federal Association, Austria
- Bundesverband Solarwirtschaft, Germany
- Swissolar- Swiss Solar Energy Professionals Association

1.4 Structure of work

As described in the preface, the aim of the two co-authors focusing each on one part is to deliver one big picture, following a jointly developed model and method of approach to deliver a proof of concept, validate the business idea and prepare a

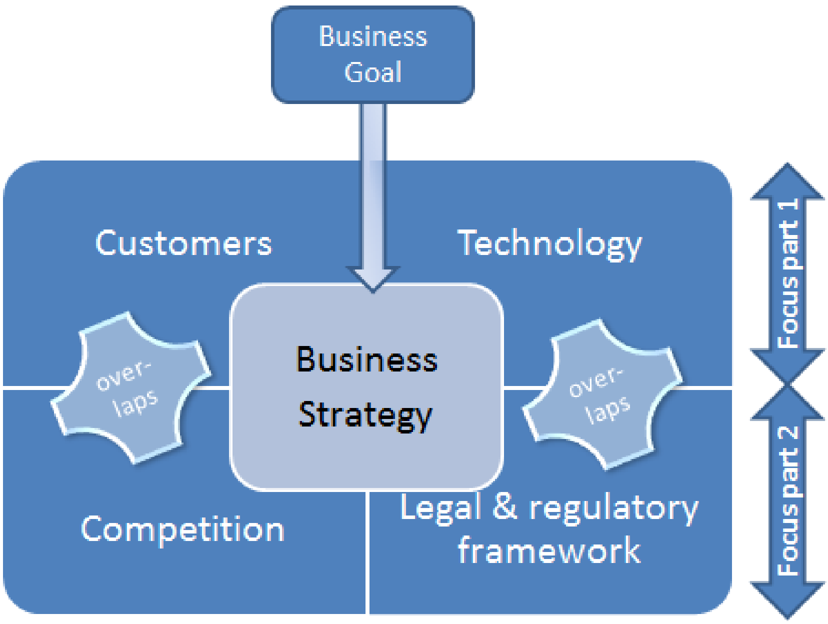

Figure 1: Structure of work and focus areas of part 1 and part 2 of the thesis

business plan to establish a start-up company projecting PV carports power plants. Figure 1 above illustrates the split between the topics to be covered in the two master theses. While both authors bear in mind the same business goal, a modified basic set-up framework on the basis of Porter's (1980) Five Forces Model indicating the main market players, respectively the competitive forces was established. The investigation of these four main topics will help to develop the business strategy.

Part 1 with focus on Customer and Technology are subject of this master's thesis. However, some overlaps with the other two main topics may occur and can't be avoided, it's partially even intended to ease reading and for completion of each part.

1.4.1 Business Strategy

Even though not subject of this work a brief explanation about the intended strategy development process shall be delivered as an introduction to the whole concept here. Generally business strategies specify the resource and offers which are needed to achieve the market position intended [8]. Thereby some main questions must be answered upfront as:

- What customer groups will be served and with what products and services are going to be offered ?
- Which generic business strategy will be followed to do this ?
- What competitive advantages will have to be built up on the level of market offer ?
- What resources will be required to maintain these competitive advantages ?

To answer those question and as a part of the development process for the definition of the business strategy, the environmental analysis, also known as PEST analysis is a helpful tool and widely used approach. **PEST** analysis stands for "**P**olitical, **E**conomic, **S**ocial, and **T**echnological analysis" and describes a framework of macro-environmental factors used in the environmental scanning component of strategic management. In this work some of these factors, mainly technological, economic and social will be considered.

1.4.2 Technology

Technological factors usually include technological aspects such as R&D activity, technology incentives and the rate of technological change. They can determine barriers to market entry and the future development expected. In the context of this work, current development of PV technologies will be elaborated and related aspects like cost development of PV modules and systems, efficiencies of different technologies, their life expectancy and degradation effects examined. Additionally and where appropriate, economic and legal aspects that are in direct relation influencing the business case will be discussed as well.

1.4.3 Customers

Customers represent the target group that will be elaborated and assessed by an online questionnaire. In the PEST analysis terminology influencing factors regarding environmental and social aspects will be discussed here. While environmental factors as the predominant global warming may shape the strategy of the target group towards the adoption of specific measures like CO_2 reduction or support of RES, social trends and public opinion in contrast may positively or negatively influence these management strategies. In this context the public opinion regarding acceptance of PV carports will be evaluated based on available publications. Environmental impacts of the PV technology as such are not subject of this work.

1.4.3.1 The target group

It is obvious that a large variety of parking areas (e.g. private, public and office parking areas, etc.) exists. However the focus in this work is set on parking areas of large shopping centres from retailers, do-it-your-self shops (DYS), home-centres and furniture stores in the DACH region (Germany, Austria and Switzerland).

1.4.3.2 Questionnaire

To evaluate the activities, strategy, motivation and willingness to adapt renewable energy sources and particularly the implementation of PV carports an online questionnaire will be send out to the selected target group. This will be taken as a basis for the formulation of the market potential and its attractiveness. Questions to be addressed are:

- What is the size of useful area for a PV installation ?
- What is the yearly energy consumption ?
- What are the concrete measures and spending taken regarding CO_2 and energy savings ?
- Is there a “clean energy strategy“ in place ?
- What are the targets and future developments ?
- Is there a vehicle pool (number of cars, consumption, km/year) ?
- Statistical data regarding size, number of employees, turnover, customers ?
- Any plans to install a PV power plant (on roof, car park) ?
- What would be the requirements, obstacles, motivations to do so ?

1.4.4 Remaining topics

The other two remaining main topics “Competition” and “Legal & regulatory framework” will be touched only briefly here as they will be discussed and evaluated in detail in part 2 by the second author in his master’s thesis.

1.5 Chapter overview

In summary following topics will be covered in the corresponding chapters:

Chapter 1: covers the introduction, the motivation and describes the structure of the document.

Chapter 2: focuses on topics not directly related to RES but relevant for the understanding of the market conditions. Different concepts as corporate social responsibility, social acceptance and the diffusion of innovation are introduced.

Chapter 3: exposes the method of approach and the methodology applied in this work. It further delivers an overview of relevant mathematical, physical and economic rules.

Chapter 4: delivers an overview of all relevant information needed for the evaluation and delivers a general back ground insight on the different topics.

Chapter 5: sums up all the results and delivers the answers to the questions raised. All findings are interpreted within the context and according to their relevance.

Chapter 6: finally reflects the conclusions of the findings and describes the outlook.

2 Social Responsibility

Today, business around the world recognizes obligations not only to stockholders, but also to multiple stakeholders; and sees that alongside its traditional role as a wealth creator, it also has social and environmental responsibilities. Popular publications such as The Economist [9] and The Wall Street Journal, which once scoffed at such notions, now feature stories, studies and even special issues on the many facets of citizenship. Leading scholars, the media, policy makers, business leaders and working people around the world agree the age of corporate citizenship has arrived. Whether the term in use is corporate citizenship, social responsibility, corporate social responsibility (CSR), sustainability or some combination thereof, it is making its way forward on the agenda of most companies and countries [10]. Thereby the focus from terms concerning ethics and morality as presented the first time in 1991 by Carroll in his CSR pyramid model [11] have developed further shifting from a traditional view of corporate citizenship as providing jobs, earning profits, and paying taxes towards a more encompassing look at the impact of business on society. In the public discussion and in the media the call for open discussions about high manager salaries, transparency of reporting, global social problems like social inequity as a result of globalisation, environmental issues as climate change and global warming has increased [12].

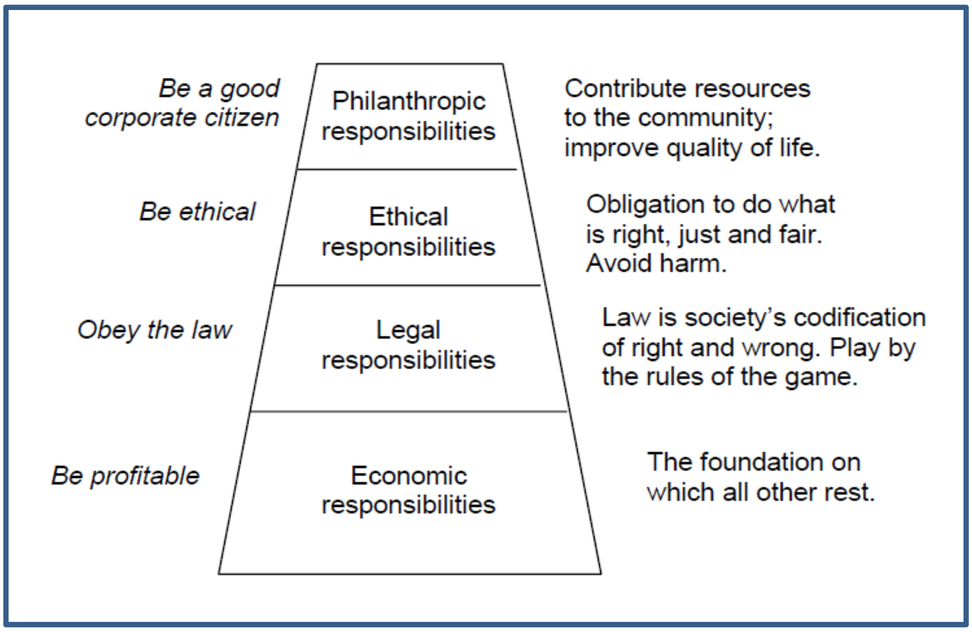

Figure 2: The Pyramid of Corporate Social Responsibility [12]

Even though the benefits of CSR strategies are recognized by many business leaders, its implementation in most companies are not yet sophisticated nor sufficiently elaborated. Possible explanation for this divergence is that the perception of profit seeking is seen in contradiction to CSR benefits [13]. However, matter of fact is that the economic ability of an enterprise and its social responsibility are belonging together as two sides of the same coin, because only companies with reasonable profits are also able to act in favour of its employees, the society and the environment. This is meanwhile an accepted certainty by many institutional investors as it can be observed in different stock indices like the Dow Jones Sustainability Index[2] [14] or the FTSE4Good and other regularly performed "good company" [15] ratings. These listed companies are considered as industry benchmark for portfolio and fund managers as well other professional investors. However, as indicated in the Figure below, Germany for example is unfortunately still lacking for strong promoters of corporate social responsibility.

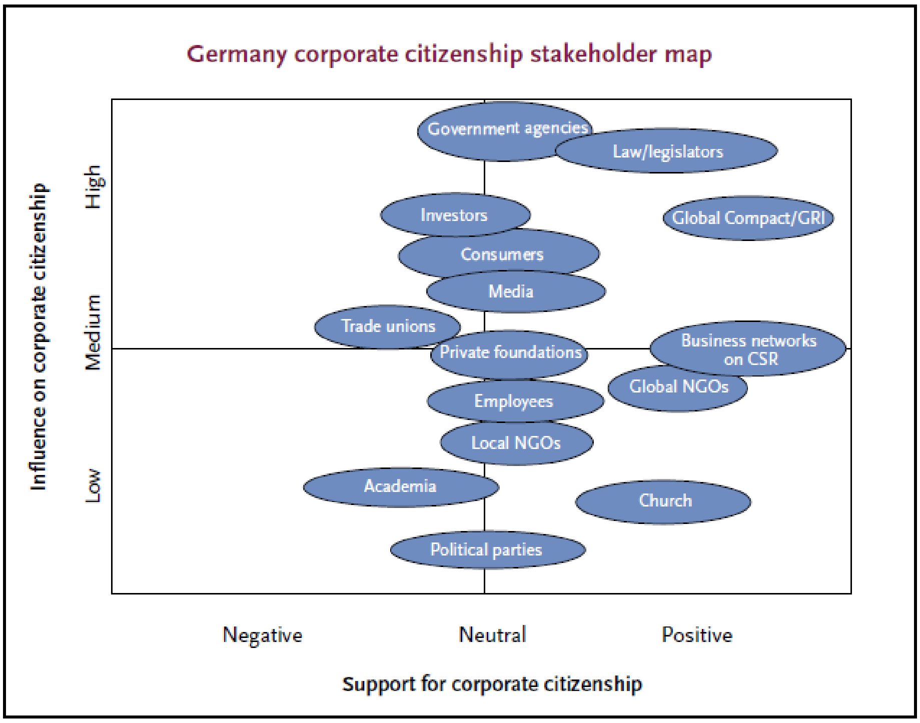

Figure 3: CSR stakeholder map from Germany [13]

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2 The Dow Jones Sustainability Europe Index is composed of European sustainability leaders as identified by SAM through a corporate sustainability assessment. The index represents the top 20% of the largest 600 European companies in the Dow Jones Global Total Stock Market Index based on long-term economic, environmental and social criteria. The underlying research methodology accounts for general as well as industry-specific sustainability trends and evaluates corporations based on a variety of criteria including climate change strategies, energy consumption, human resources development, knowledge management, stakeholder relations and corporate governance. The Dow Jones Sustainability Europe 40 Index was first calculated on July 2010.

While the movement has begun, corporate citizenship has not yet “taken off” as it has in other European countries. Most stakeholders sit somewhat indifferently in the middle ground and certain groups can be identified as more supportive of corporate citizenship than others [16].

Nevertheless it can be stated that CSR can be seen as a strategic success factor for a company. Due to its open communication and its engagement, the reputation increases attracting qualified and loyal employees, investors, customers and suppliers resulting in a positive competitive position. A high ranking reputation also facilitates strategic alliances and mergers through confidence and goodwill. Finally, the significant value of a company’s reputation will create the brand of that company. Therefore it must be considered as a long term investment. The legendary Warren Buffet ones said: “it takes ten years to impose a positive image to a company, but only seconds to lose it”. It’s therefore not surprising, that responsibly acting companies more often are economically successful in the long run [17]. The key factors can be summarized as follows:

- Optimisation of the risk profile and improvement of risk management
- Ability to attract, motivate and retain talented employees
- Increase of reputation and brand equity
- Effectiveness at learning and innovation, especially in complex and dynamic environments
- Better investor relations and access to capital, especially in terms of the growing socially responsible investment community
- Increased competitiveness and market positioning, in terms of gaining entry to new markets and building or sustaining customer loyalty in existing markets
- Operational efficiency, in terms of reducing input and transaction costs, increasing process efficiencies and improving quality of products and services
- Licence to operate, in terms of responding to and influencing regulation, as well as public opinion and confidence.

2.1 The Role of Environment & Renewable Energy

Today, front and center on the CSR agenda are concerns over climate change and environmental sustainability. Surveys indicate that over 50% of consumers and business leaders sampled in ten countries rate “environmental issues, including climate change” as the most important issue facing business [18].

One of the first important initiatives in that regard was launched by the UN in July 2000. The UN Global Compact[3] is a leadership platform for the development, implementation and disclosure of responsible and sustainable corporate policies and practices. Endorsed by chief executives, it seeks to align business operations and strategies everywhere with ten universally accepted principles in the areas of human rights, labour, **environment** and anticorruption. With more than 8,500 signatories in over 135 countries, the UN Global Compact is the world’s largest voluntary corporate sustainability initiative. The principles 7 to 9 hereby focus on environment and renewable energy:

- Businesses should support a precautionary approach to environmental challenges (Principle 7);
- undertake initiatives to promote greater environmental responsibility (Principle 8); and
- encourage the development and diffusion of environmentally friendly technologies (Principle 9)

Other institutions are following as the joint statement of a task force of the World Economic Forum CEOs that was developed in partnership with The Prince of Wales in 2003 [19]. In that statement 46 international business leaders have signed a paper on Global Corporate Citizenship manifesting their will to implement the guidelines and to provide a framework for other companies and leaders to follow. Responsibility for the environmental takes thereby a dominant position as shown in the Figure below. Maintaining environmental quality, adopting clean and eco-efficient production processes, sharing environmental technologies and for some industries, engaging in global challenges such as climate change and biodiversity protection are only few aspects that are propagated[4].

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3 Source: http://www.unglobalcompact.org/Issues/Environment/ , 26.01.2012

4 Source: https://members.weforum.org/pdf/GCCI/GCC_CEOstatement.pdf , 26.01.2012

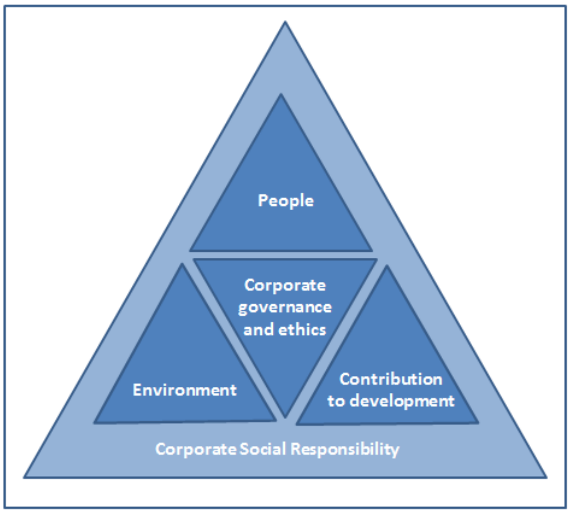

Figure 4: CSR framework

Considering measures regarding environmental aspects involves self-evidently initiatives promoting renewable energies, energy efficiency and CO_2 reduction. An assessment study performed in 2008 with 15 top executives from various companies listed on the German stock exchange (DAX) name the development and implementation of renewable energy under the top 10 activities to be considered under the CSR strategy [12].

2.1.1 Reporting

More than 10’000 individuals and 3’000 listed companies have helped to develop the standards of the Global Reporting Initiative[5] (GRI), an organisation based in Amsterdam, trying to create a single global measure for CSR performance. In the DACH countries so far only 150 companies have used this standard in 2010 [20].

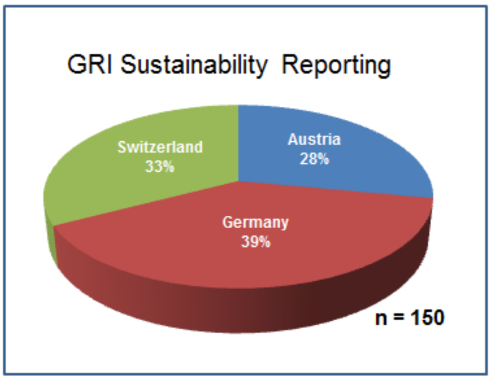

Figure 5: GRI reporting in DACH

5 Source: https://www.globalreporting.org , 26.01.2012

2.2 Social Acceptance

Social acceptance is identified as a very important constraining factor in achieving the target of increasing the share of renewable energy in many countries. At the same time it can be a potentially powerful barrier to the development of renewable energy projects as it was often reported in case of wind and biogas power plants [21, 22 and 23]. This could have been avoided if the force of social acceptance would not have been neglected respectively better understood. In the past social acceptance was rarely discussed in academic and industry literature as an important factor in the diffusion of renewable energy technology, as policy makers and developers have often assumed that high levels of public approval for renewable energy technology generally would translate into acceptance and approval for individual projects. However, specific siting decisions have generated local resistance and controversy in some cases. It is therefore of great importance to understand the forces and rational of social acceptance. An often cited publication explaining social acceptance in detail is from Wüstenhagen [24]. He has introduced three dimensions of social acceptance that are crucial for understanding the current conflicts between general public acceptance for renewable energy technologies and the difficulties that some specific projects are facing. The figure below visualise the three dimensions of social acceptance.

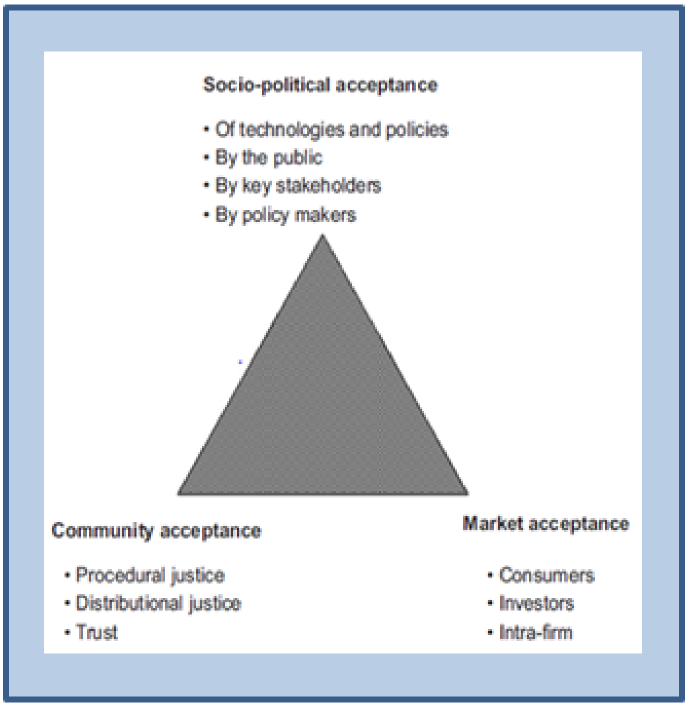

Figure 6: The triangle of social acceptance of renewable energy innovation

These three dimensions are the so called “socio-political acceptance”, the “community acceptance”, and finally the “market acceptance”.

Socio-political issues include "the process of how individuals and organizations make decisions, resolve conflicts, form partnerships, respond to government policies and engage with public issues" (McCormick, 2007). This dimension refers to the social acceptance on the wide and general level of policies and technologies related to a new energy system. Stakeholders and policy makers involved in discussing "renewable policies" become crucial when addressing planning issues or promoting local involvement initiatives. Thus, the assessment of their levels of acceptance is an area of increasing interest for social researchers.

Community acceptance in contrast refers to the specific acceptance of siting decisions and renewable energy projects by local stakeholders, particularly residents and local authorities. This is the arena where the debate around “not in my back yard” unfolds, where some argue that the difference between general acceptance and then resistance to specific projects can be explained by the fact that people support renewable energy as long as it is not in their own backyard.

And finally **market acceptance** which can also be interpreted as the process of market adoption of an innovation. This is based on Rogers’ Theory of the Diffusion of Innovation (2003), and argues that individuals decide to adopt or not to adopt a particular technology by evaluating characteristics of the technology itself. A technology achieves broad social acceptance by being adopted by the majority of individuals in society.

In summary, as described above, social acceptance can be defined on a societal, community, and individual scale. All levels of social acceptance may not apply to all technology projects but rather to a particular technology or a particular project. Solar technology in general is however the most positively regarded form of new renewable energy technology so far and public resistance is rather rare according to Eurobarometer’s polls. Nevertheless conflicts and resistance can appear (e.g. aesthetic reasons for BIPV or to large ground mounted PV installation in the nature) and therefore the subject must be handled carefully and proved on case by case basis [25, 26].

2.3 Adaption model

The fundamental theory of the diffusion of technologies was developed and is described comprehensively by Rogers (1983). He describes the innovation process by means of a cumulative S-shaped with the following typical categories of adopters: (i) innovators, (ii) early adopters; (iii) early majority; (iv) late majority; (v) laggards. Regarding the individual decision-making processes with respect to the innovation and market penetration respectively adoption or rejection of a technology by customers, the same categories can be defined as different stages: (i) Knowledge; (ii) Persuasion; (iii) Decision; (iv) Implementation; (v) Confirmation [27].

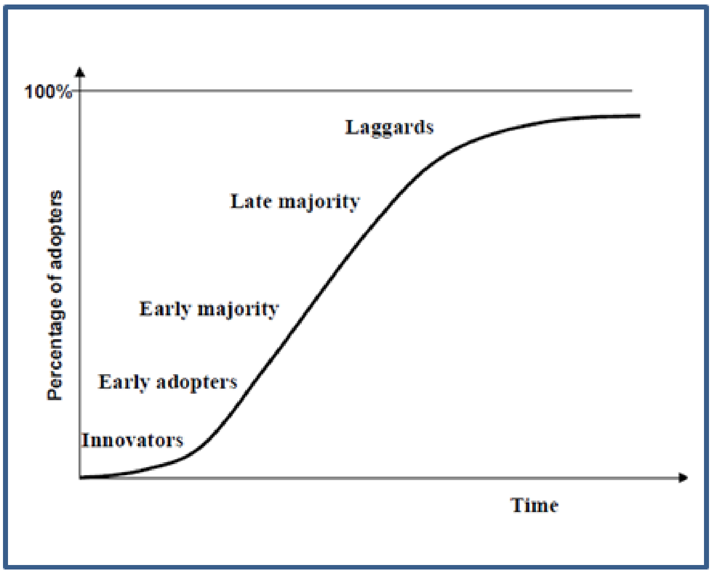

Figure 7: Diffusion of innovation graph

Villiger et al. (2000) have extended this analysis to describe the market penetration of green product innovations in in the food, clothing and electricity sectors [28]. Following their terminology, the development of the green market can be divided into four phases: (i) introduction, (ii) early growth, (iii) take-off, and finally (iv) maturity. While the main indicator of these phases is the increasing market share of green products over time, they can also be distinguished by:

- the types of customers that choose the products (from innovators through early adopters, early and late majority to laggards),
- the types of suppliers that sell green products (from Davids through Pioneer Goliaths to a mix of Davids, Goliaths, and New Entrants), and finally

- the types of products dominating the green market (from high-end environmental products through a broader range of environmental qualities to standardised, labelled products for the mass market).

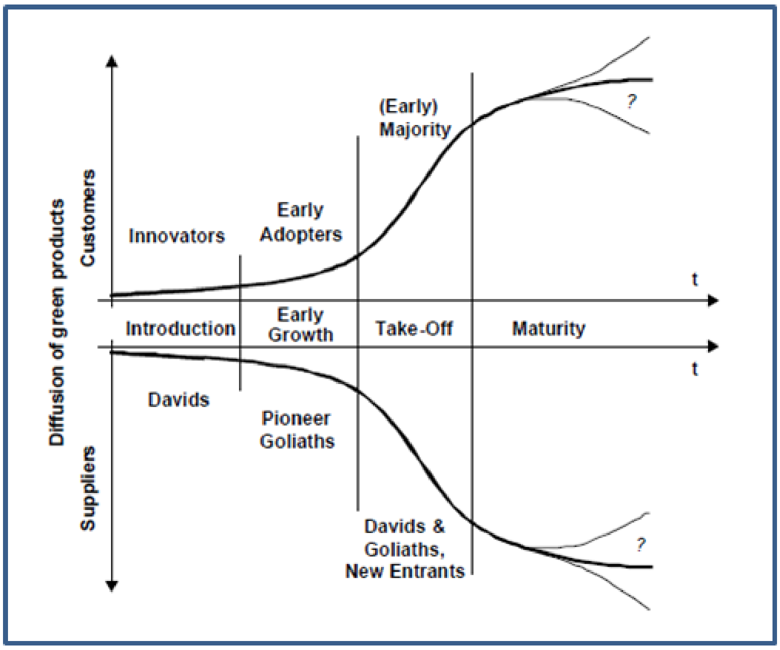

Figure 8: Diffusion of green products over time among customers and suppliers

One last relevant interpretation to be discussed here was introduced by Nordmann (2003) setting the diffusion curve in the context of demand and supply of the PV market [29]. His explanation is summarised below:

“New markets are starting with innovative, pioneer companies and - most important - pioneer customers who are willing to pay a high price for a new attractive product or solution, even if it is not economical. The market share of these pioneer customers is estimated to be 5.5%. If this part of the market has been developed successfully the next sequence of the market development can begin. The pioneer costumers influence the opinion leaders. Those are curious about the next step on the road map in advanced energy technology. A critical number of pioneer customers are needed to attract the opinion leaders to enter into the market. Such costumers can be: the government, on national- state- and local level, educational institutions as universities, colleges, schools but also individual investors. The market share of the opinion leaders is estimated to be approximately 13.5%. The third step of market penetration is the involvement of the early majority. This group is attracted and learns from the opinion leaders. The suppliers of the PV- technology have to convince this larger group, estimated to be approximately 35% of the whole market. These investors expect the product to be not only technologically mature, but also somehow economical. Another 34% of the market is called the late majority. They are hard to catch. It is almost impossible to generate the demand to the last market share, the hesitators 16%. They need a long time to adapt new ideas and to apply new products and solutions".

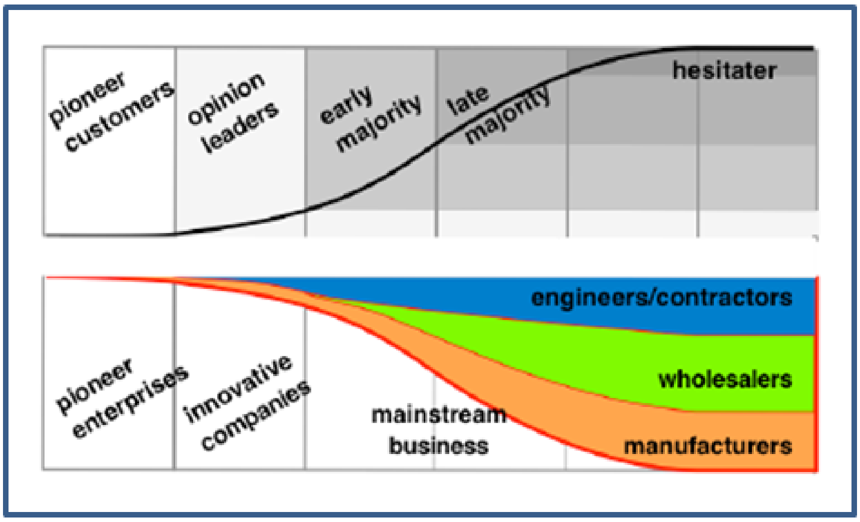

Figure 9: Diffusion of the PV market in terms of supply and demand

Looking at the supply side, the market must be recognized as global, while all markets on the demand side are local. Adapting the diffusion model to recent progress in the PV market developments regarding supply and demand, one has not only to distinguish among the different stages but also among the market segments on a national and international level.

Hence, the level of diffusion is best expressed by looking at the total produced capacity from the supply side. On the other hand, the installed PV capacity for a local market (demand) can be determined according to the cumulated installed capacity (Wp/capita) for each country. The year-by-year increase per capita in installed capacity is an indicator for the speed of the diffusion process.

3 Method of approach

Following overview describes the research approach applied. After the stipulation of goals and the formulation of the main questions to be answered in this work, the different building blocks were defined.

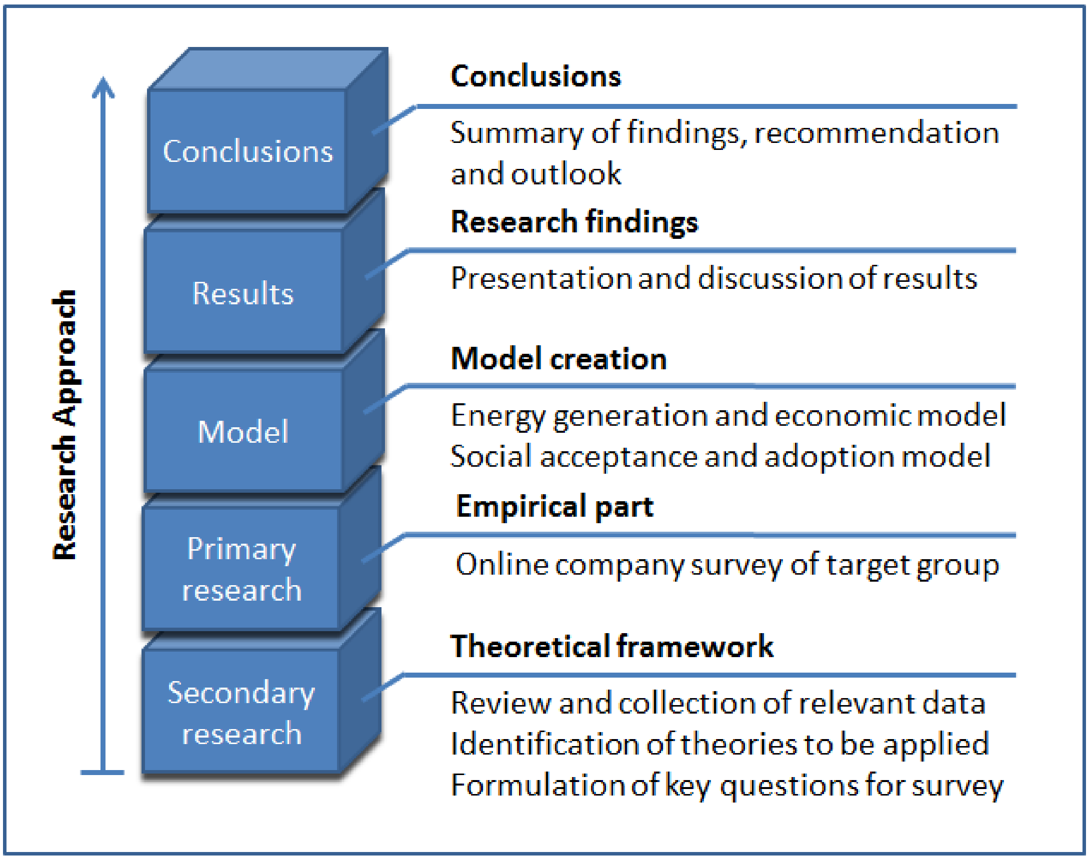

Figure 10: Research Approach

3.1 Theoretical Framework

The secondary research builds the basis of the work as relevant data had to be collected and reviewed. Main sources used were publicly available reports, various studies and official publication of accredited associations and federal bodies. Beside that published information on the www from adequate sources were called in. For specific topics expert books, papers and proceedings were consulted.

3.2 Empirical Part

The primary research is based on the online survey conducted with 100 companies. The focus was set on the top retailers, do-it-your-self shops, home-centres and furniture stores in the DACH region.

3.3 Model creation

In its very basic nature model development can be viewed as a process with three main steps. In the first step the problem is specified that the model is intended to address and the input parameters are defined. In step two the model framework is defined according to assumptions and basic conditions and the mathematical model is applied. The final step represents the results.

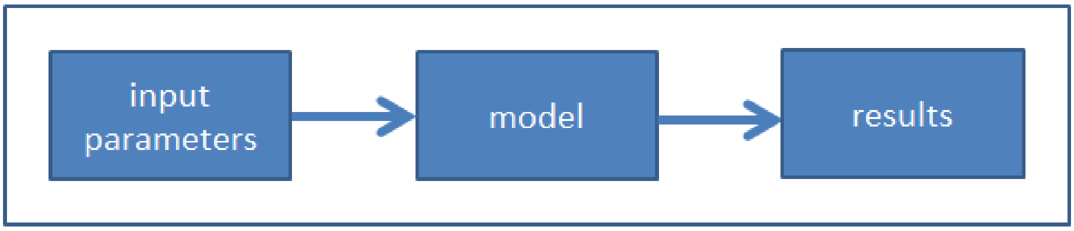

Figure 11: Model creation

For the validation of the business idea and the concept regarding the establishment of a company or a business dealing with PV carport installations mainly three models are of relevance. These are the following:

1) **Energy production model**
2) **Economic model**
3) **Adoption model**

These three models will be subsequently introduced and discussed in detail. All influencing parameters and input data to be applied by these models are subject of the research carried out in Chapter 4 and Chapter 5. Main aspects and background information concerning the adaption model was already explained in Chapter 2.

3.3.1 PV energy production model

First of all it must be stipulated that PV modules are rated on the basis of the power delivered under Standard Testing Conditions (STC) of 1 kW/m² of sunlight, a PV cell temperature of 25 degrees Celsius (°C) and an air mass of 1.5. The power is thereby determined by measuring current and voltage while varying the resistance. The output power is expressed in “peak Watt” or W_p nominal capacity[6].

[6] The conditions are specified in standards such as IEC 61215, IEC 61646 and UL 1703.

In the practice the approach for determining the energy generation of a PV installation is done usually in four steps as shown in the figure below.

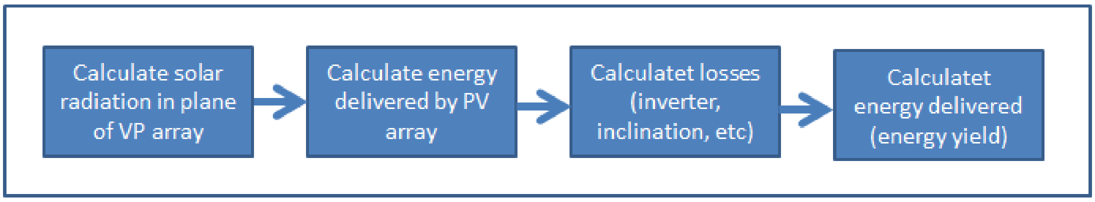

Figure 12: PV energy production model

The energy production of a PV system and the amount of the output power are basically influenced and by the following main factors:

- solar irradiation at a given location
- performance of the PV modules
- ability of the PV modules to capture the maximum available solar irradiation with respect to some losses based on:
    - the orientation, inclination, mounting fixed or tracker, etc.
    - other external factors as temperature, shading, dust, dirt, etc.
- the technical design (inverters – central, decentral, transformers, etc.),
- quality of components (efficiency of modules, inverters, transformers, cabling, etc.)

For the calculation of the energy production by a PV plant on a given location, many professional software programs exist today[7].

However, for rough estimations the normalised method can be recommended. Thereby the energy yield for a PV plant in a given location can be calculated based on data available from a reference plant [30, 31 and 32].

The basic equations for the calculation of the energy yield of a given PV system and relevant influencing factors however are introduced and briefly explained here as well as the most common terms used in PV system dimensioning [33].

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[7] http://www.mike-zehner.de/downloads/PV-Softwarekatalog-V1.2-20110210.pdf 26.01.2012

The nominal module efficiency

The nominal efficiency of a PV module is the conversion efficiency that is observed when the module is subjected to light with the intensity of $1kW/m^2$ under STC as explained earlier. The peak power (or nominal power) of the module is related to the module area *A* and the nominal efficiency η_{pv} by:

$$\boxed{P_{\text{peak}} = G_0 * A * \eta_{\text{pv}}}$$

Equation 1: Nominal PV module efficiency

The nominal efficiency of the PV module can be usually obtained from the manufacturer's data sheet. Average values for crystalline silicon is 0.84, while slightly better at 0.92 for amorphous silicon.

The relative module efficiency

Should the conditions differ from the standard testing conditions (STC), the nominal module efficiency must be multiplied by a relative module efficiency η_{rel}. This factor is dependent on changes in temperature, intensity of the incoming light and ratio of diffuse radiation to direct radiation. The instantaneous power supplied by the module can be expressed as follows:

$$\boxed{P_{\text{peak}} = G_0 * A * \eta_{\text{pv}} * \eta_{\text{rel}}}$$

Equation 2: Relative PV module efficiency

P_{peak}	…………	Nominal output of PV module	…………	[kW]
G_0	…………	Irradiation intensity at STC	…………..	$= 1kW/m^2$
A	…………	Area of the module	…………	[m^2]
η_{PV}	…………	Module efficiency at STC	…………	[1]
η_{rel}	…………	Relative module efficiency	…………	[1]

The relative efficiency is not constant and varies during the course of the day. Typical values for range between 0.8 and 0.9.

The target yield

The target yield is the theoretical annual energy production (on the DC side of the module), only taking into account the energy of the incoming light and the modules nominal efficiency.

The Performance Ratio

The Performance Ratio *PR* is the ratio between actual yield (i.e. annual production of electricity delivered at AC) and the target yield. It is also often called “Quality Factor” and is independent from the irradiation and therefore useful to compare different systems. It takes into account all pre-conversion losses, inverter losses, thermal losses and conduction losses. Hence, useful to measure the performance ratio throughout the operation of the system, as deterioration could help pinpoint causes of yield losses[8].

$$PR = \frac{Actual\ Yield_{AC}}{Target\ Yield_{DC}} = \eta_{pre} * \eta_{rel} * \eta_{sys}$$

Equation 3: The Performance Ratio

PR	…………	Performance Ratio	…………	[1]
η_{pre}	…………	Pre-conversion efficiency	…………	[1]
η_{rel}	…………	Relative module efficiency	…………	[1]
η_{sys}	…………	System efficiency	…………	[1]

The pre-conversion efficiency reflects the losses incurred before the beam hits the actual semiconductor material, caused by shading, dirt, snow and reflection of the glass. The system efficiency reflects electrical losses caused by wiring, inverter and transformer. The module itself is defined by a nominal efficiency and relative efficiency as explained earlier.

8 http://www.greenrhinoenergy.com/solar/technologies/pv_energy_yield.php 08.03.2012

The Energy Yield of a PV System

The energy yield E of a PV system can be finally expressed by the following equation:

$$\boxed{E = G * A * PR * \eta_{pv}} \longrightarrow \boxed{\frac{E}{A} = G * PR * \eta_{pv}}$$

Equation 4: Energy yield per area

Thereby G represents the yearly sum of global irradiation that hits the module at a specific geographic location. Values of G can be obtained from databases, measurements, or – in the first instance – from an irradiation map. It is measured in kWh/m^2.

Sometimes, the energy yield is expressed relative to the peak power of the module, which is independent from the area A of the module. Hence, the influence of the PV installation size (A) can be eliminated by dividing the energy produced (E) by the nominal power (P_{Peak}) of the PV generator.

$$\boxed{E = P_{\text{peak}} * \frac{G}{G_0} * PR} \longrightarrow \boxed{\frac{E}{P_{\text{peak}}} = \frac{G}{G_0} * PR}$$

Equation 5: Energy yield per rated power

E	…………	Yearly Energy yield	…………	[kWh]
G	…………	Yearly sum of global irradiation received by the modules	…………	[kWh/m^2]
A	…………	Size of modules	…………	[m^2]
PR	…………	Performance ratio of power plant	………..	[1]
η_{PV}	…………	Module efficiency	…………	[1]
P_{peak}	…………	Nominal output of PV module	…………	[kW]
G_0	…………	Irradiation intensity at STC	………….	= $1 kW/m^2$

The energy yield per rated power notation is a very useful ratio, since the energy yield *E* is a measure of the earnings potential while the peak power reflects the cost of the system.

However, the peak power in the above formula (equation 5) is the module's peak power, not the installed capacity P_{sys}. For the calculation of the total installed capacity of a PV system following equation must be considered:

$$\boxed{P_{\text{sys}} = P_{\text{module}} * \eta_{\text{sys}}} \quad \text{with } P_{\text{module}} \text{ defined as: } \quad \boxed{P_{\text{module}} = \frac{G}{G_0}}$$

Equation 6: Installed capacity of a PV plant

3.3.2 Economic Models

Investment evaluations of energy systems generally include an assessment of the projected benefits compared to the estimated costs of the system. The direct financial benefit of a PV system (carport) is primarily the value of energy generated. These benefits and the direct economic costs of a PV may be viewed as:

Projected Benefits = Value of Electricity Generated
Estimated Costs = Capital Costs + Periodic Costs + Replacement Costs

However, as for any other investment decisions and financial evaluations the capital budgeting rules are valid for PV carport investments in the same way. In capital budgeting usually six methods are used to rank projects and to decide whether or not they should be accepted for inclusion in the capital budget [34].
These are:

1. payback method,
2. discounted payback
3. net present value (NPV)
4. internal rate of return (IRR)
5. modified internal rate of return (MIRR)
6. profitability index (PI)

These methods can be used in combination or solely based on the specific requirements. Of cause multiple derivations from these general methods are possible. According to EIA following five partly adapted methods of investment analysis are recommended to be applied in building investment decision which applicable to PV carport investments [35].

- payback analysis,
- net benefit analysis (NPV),
- saving-to-investment ratio (SIR),
- adjusted internal rate of return (AIRR), and
- life-cycle cost (LCC) analysis.

A short assessment of the usefulness of these methods in evaluating the economics of building integrated PV (e.g. carport) applications is provided on the following pages.

Payback Period

The payback period is the minimum time it takes to recover investment costs. The payback period for an energy system is calculated as the total investment cost divided by the first year's revenues from energy saved, displaced, or produced. In payback analysis, the unit of measurement is the number of years to "pay back" the investment cost.

$$Payback = Year\ before\ full\ recovery + \frac{Uncovered\ cost\ at\ start\ of\ year}{cash\ flow\ during\ year}$$

Equation 7: Payback time of an investment

Projects with short payback periods are perceived to have lower risks. Simple payback analysis takes into account only first costs and energy savings at present cost. This method omits several significant cost factors, including the cost escalation rate and the cost of capital. Thus, simple payback analysis can overestimate the actual payback period and, consequently, the length of time to recoup the investment.

The two main variations are payback after taxes and discounted payback. Payback after taxes includes and evaluates marginal tax rates and depreciation schedules. In the discounted payback method, future years' revenues are considered to have less value than current revenues. Discounted payback is the time between the point of initial investment and the point at which accumulated savings (net of the accumulated costs) are sufficient to offset the initial investment costs. Costs and savings are adjusted to account for the changing value of money over time.

The payback method is often used as a rough guide to cost-effectiveness. If the payback period is significantly less than the expected system life, the project is likely to be considered cost effective.

Net Benefit Analysis

Net benefit analysis can be used to express the net difference between the benefits and costs of one energy system relative to an alternative in present or annual value Euros. Net benefits, also called net present values (NPV), represent the difference between the present value of benefits (revenue or savings) and the present value of costs of the alternative. A system is cost-effective if the net saving or net benefit is positive.

$$NPV = CF_0 + \frac{CF1}{(1+k)^1} + \frac{CF2}{(1+k)^2} + \frac{CF3}{(1+k)^3} + \ldots + \frac{CFn}{(1+k)^n} = \sum_{t=0}^{n} \frac{CFt}{(1+k)^t}$$

Equation 8: Net present value

CF	……..	cash flow at a period t	……	[€]
k	……..	projected cost of capital	……	[%]

Savings-to-Investment Ratio

The savings-to-investment ratio can be used to compare savings to costs of one energy system relative to an alternative energy system. For positive net savings, the SIR must be greater than one. The higher the ratio, the greater the savings realized relative to the investment.

Adjusted Internal Rate of Return

The adjusted internal rate of return (AIRR) is a discounted cash flow technique that measures the annual yield from a project, taking into account reinvestment of interim receipts at a specified rate. With this methodology, estimating the cost-effectiveness of a project involves comparisons of the calculated AIRR of a project to the investor's minimum acceptable rate of return (MARR). The project is cost-effective if the AIRR is greater than the MARR.

The AIRR is calculated by taking the nth root of the ratio of the terminal value (TV) of all cash flows (except investment costs) to the present value of investment costs (PVI) and then subtracting one.

$$PVI = \frac{TV}{(1+MARR)^n} \quad \text{->} \quad MARR = \sqrt[n]{\frac{TV}{PVI}} - 1$$

Equation 9: Minimum acceptable rate of return

The AIRR may be contrasted with the internal rate of return, which computes the yield on original investment and is calculated by a trial-and-error process that involves selecting compound interest rates and discounting the cash flows until a rate is found for which the net value of the investment is zero.

Life-Cycle Cost Analysis

In Life-Cycle Cost Analysis (LCC), all relevant present and future costs (less any positive cash flows) associated with an energy system are summed in present or annual value during a given study period (e.g., the life of the system). These costs include, but are not limited to, energy, acquisition, installation, operations and maintenance (O&M), repair, replacement (less salvage value), inflation, and discount rate for the life of the investment (opportunity cost of money invested). The unit of measurement is present value or annuity. A comparison between the LCC of the energy system to an alternative determines if the system in question is cost-effective. If the LCC is lower than that for the base case and in other aspects is equal, and the project meets the investor's objectives and budget constraints, it is considered cost effective and the preferred investment.

Summary of economic methods

While the methods of investment analysis presented can be helpful in making a variety of investment decisions, they are not equally well suited for all types of decisions. All of the methods, in most cases, can be used to determine if a PV carport system is expected to be a cost effective addition to a building, other things being equal. For this purpose, the payback method is the least reliable, but in many cases, will also provide a clear indication of cost effectiveness and can be used as a screening tool.

For the purpose of designing and sizing PV carport systems, either the net benefits method or the lifecycle cost method is recommended. As long as net benefits increase or life-cycle costs decline as more expensive designs are chosen or as system size is increased, it pays to go to the more costly design or larger system. The savings-to-investment method and the adjusted rate of return method can also be used for designing and sizing PV carport systems, but it is imperative that these methods be applied to incremental amounts rather than to totals in order to serve as a reliable guide.

For the purpose of ranking non-mutually exclusive investment alternatives, the SIR method and the AIRR method are the preferred measures. In most cases, choosing projects in descending order of their SIR or AIRR until the budget is spent will result in maximum returns to the investor. The choice among technologies and the designing and sizing of the candidate systems can be combined in an overall optimization approach.

Criteria for cost-effectiveness can be subjective depending on the investment decision-maker. Some general guidelines are to define cost-effectiveness as any energy project with a SIR greater than one, AIRR greater than the discount rate, LCC lower than the next best alternative energy system, and simple payback period less than the life of the PV carport system.

The following table delivers an overview of the minimum financial evaluation criteria to be considered while preparing a PV carport project.

Evaluation Criteria	Economic Measure
Payback Period (PP)	PP < Life of PV carport construction
Saving to Investment Ratio (SIR)	SIR > 1
Adjusted Internal Rate of Return (AIR)	AIR > Discount Rate
Net Present Value (NPV)	NPV > 0
Life-Cycle Costs (LCC)	Lower than LCC for an alternative project

Table 1: Minimum financial evaluation criteria

3.3.3 Adoption Model

The diffusion of innovations concept according to Rogers and the various interpretations were already introduced and discussed in detail in Chapter 2. However, the link between the theory and its relevance to the investigations carried out in this master thesis are based on the techno-economic approach chosen here. Thereby trends in innovation and price developments, in short the interaction between technology and markets are the relevant factors. They have to be interpreted according to their market share and their adoption rate as indicated in the figure below.

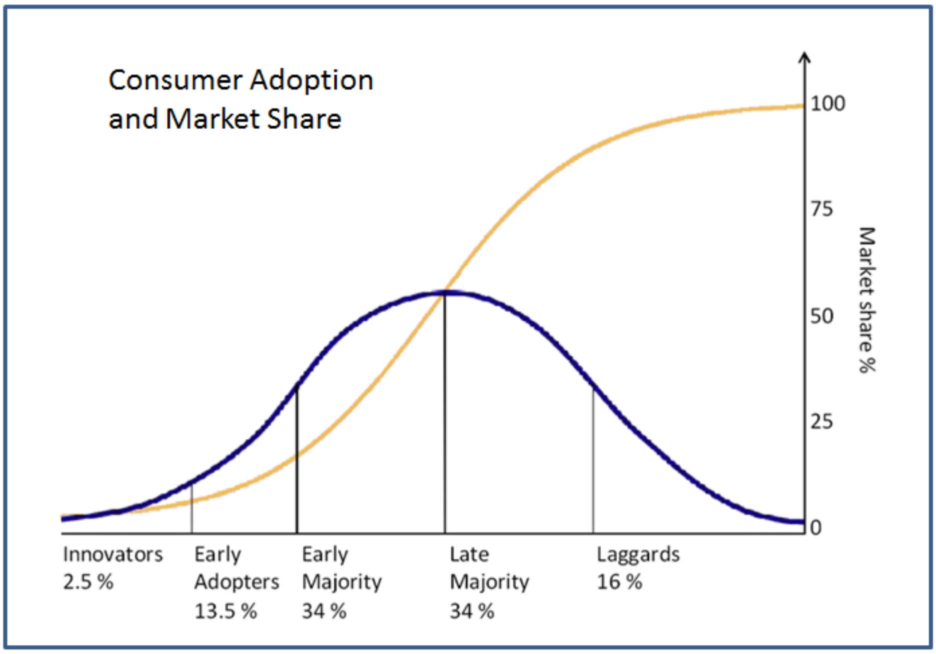

Figure 13: Consumer Adoption (blue) and Market Share (yellow)[9]

9 Source: http://en.wikipedia.org/wiki/Diffusion_of_innovations ; 26.01.2012

4 Documentation of data and data collection

In this chapter all subject related information and data necessary to answer the questions rose in this master thesis will be discussed in detail.

4.1 Energy consumption in DACH

Demand for energy and associated services, to meet social and economic development and improve human welfare and health, is steadily increasing. In the DACH countries the electric power consumption reached a value of approximately 680 TWh or 2'430 PJ in 2010. That number reflects all consumer of electricity (e.g. households, business and industry).

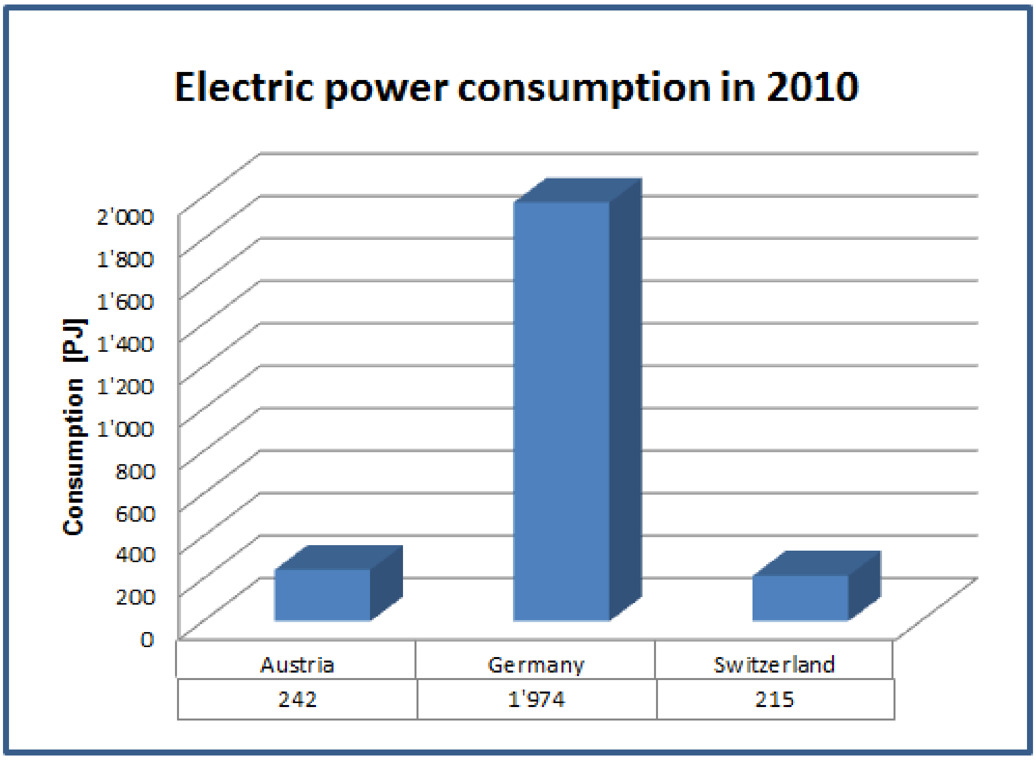

Figure 14: Yearly electric power consumption in DACH countries

Of cause it is not surprising that Germany with a nearly 10 times larger population than Austria or Switzerland will consequently have a bigger demand requirement in a similar range considering a comparable level of industrialization in the three countries. Therefore it seems more appropriate to compare energy consumption per inhabitant. Here the results indicate the highest yearly per capita consumption in Austria, followed by Switzerland. Germany with 6'700 kWh per inhabitant shows the lowest consumption as shown in the figure below.

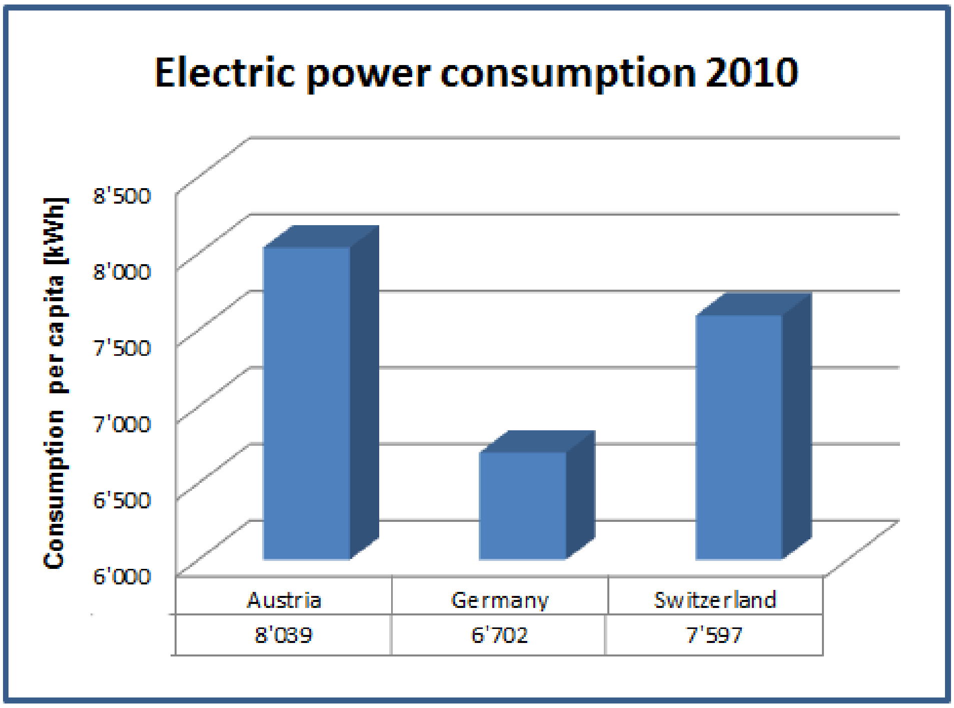

Figure 15: Yearly per capita electricity consumption for DACH countries

While the electric power consumption per inhabitant[10] is relatively comparable, the power generation mix in contrast highly differs for the three countries. Following figure illustrates the electricity mix of the three countries in 2010.

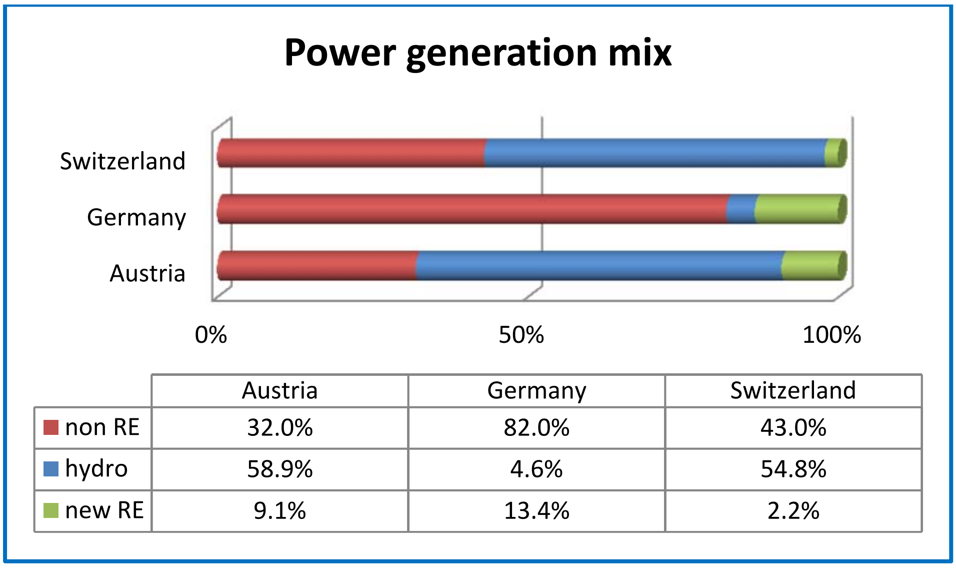

Figure 16: Electricity mix in DACH countries

10 Number of inhabitants in DACH according to official statistics from 2010.
Sources: http://www.statistik.at/web_de/presse/043751
http://www.bfs.admin.ch/bfs/portal/de/index/themen/01/02/blank/key/bevoelkerungsstand/02.html
http://www.bfe.admin.ch/themen/00526/00541/00543/index.html?lang=de&dossier_id=00772

4.2 Renewable Energy in DACH

Even though Germany exhibits the biggest portion of new renewable energy sources (e.g. wind, solar, PV, biomass, etc.) compared to Austria and Switzerland, the pictures changes drastically if hydro-electric power generation as a “traditional” renewable energy is considered. Main part is based on fossil fuels where coal accounts for about 42% and natural gas 14%, while nuclear accounts for about 22% of total power generation mix.

Austria in contrast does not maintain any nuclear power plants and the non-renewable part of approximately 32% derives from thermal power generation based on fossil fuels. The opposite case is valid for Switzerland where the major part of non-renewable electricity is coming from nuclear power production and accounts for approximately 40%.

Looking only at the renewable mix including hydro the following results derive, showing that the PV fraction still play in all three countries a minor role compared to the rest.

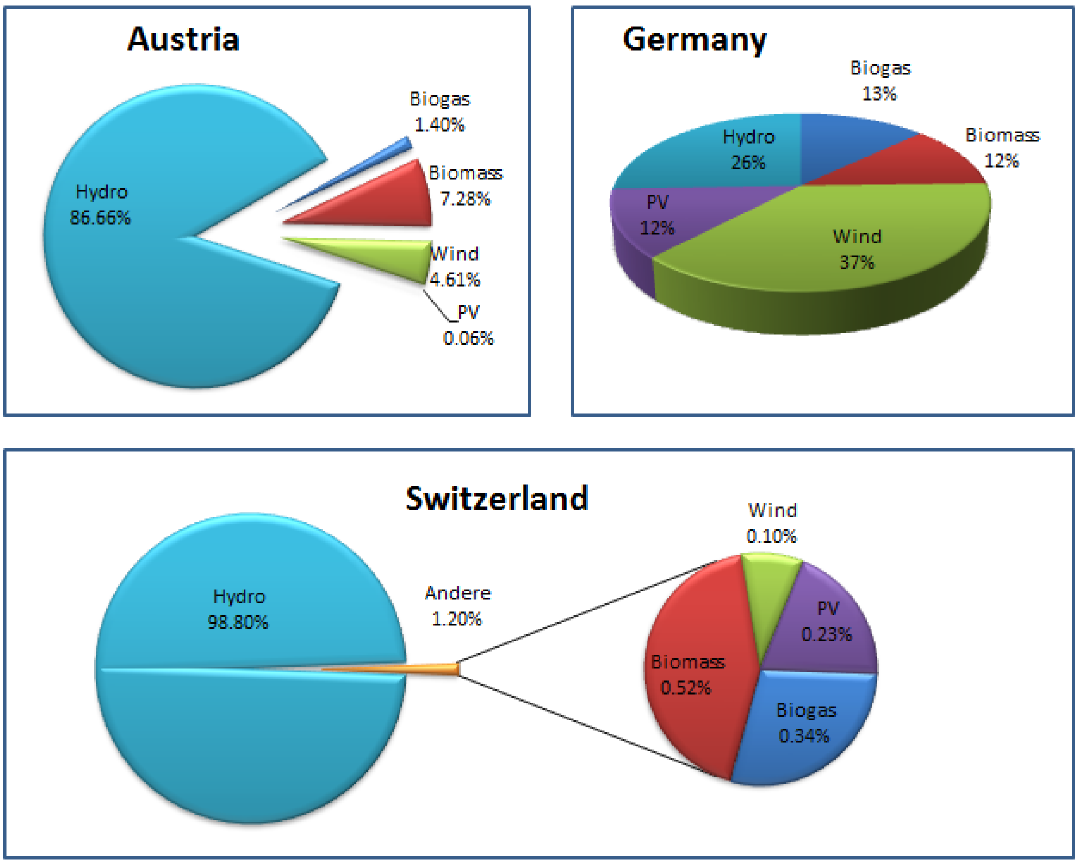

Figure 17: Renewable energy in DACH

4.2.1 Country specific target measures

In January 2008 the European Commission published the 20-20-20 package. This package defines the target measures valid for each member state. On EU level, 20% reduction in its greenhouse gas emissions and the increase to 20% of the final energy consumption from renewable sources are committed, both by 2020. In order to achieve the overall EU renewable energy target of 20% the proposal includes individual targets for each Member State[11]. The target measure for Austria is 34% and for Germany 18% of RES. Switzerland's target measure for new RES is set to 7%-10% until 2035[12].

4.2.2 PV Market Development

Comparing the worldwide PV market development in terms of installed capacity and by cumulative capacity, Germany holds the leading position in 2010. Austria and Switzerland range within the top 20 nations as shown in the figures below.

Top 30 Solar PV Markets, sorted by Capacity installed in 2010 (kw)

	Country	2008	2009	2010	Cumulative
1	Germany	1,992,000	3,806,700	7,390,922	17,294,000
2	Italy	338,000	717,000	2,319,000	3,500,000
3	Czech Republic	49,000	411,000	1,151,000	1,616,000
18	Austria	4,686	20,209	42,902	95,598
19	Switzerland	11,700	25,700	37,300	110,900

Table 2: Top Solar PV Market – installed capacity[13]

Top 30 Solar PV Markets, sorted by Cumulative capacity (kw)

	Country	2008	2009	2010	Cumulative
1	Germany	1,992,000	3,806,700	7,390,922	17,294,000
2	Spain	2,708,000	17,000	392,000	3,807,000
3	Japan	225,295	482,976	990,979	3,618,144
17	Switzerland	11,700	25,700	37,300	110,900
19	Austria	4,686	20,209	42,902	95,598

Table 3: Top Solar PV Market – cumulative capacity

11 Source: http://ec.europa.eu/energy/renewables/targets_en.htm.

12 Source: http://www.stromzukunft.ch/erneuerbare-energien/energien/

13 Solarplaza is the independent global platform for **knowledge**, **trade** and **events** for the photovoltaic solar energy (PV) industry. http://www.solarplaza.com/ 20.01.2012

Looking at the development of PV installations over the last 20 years an exponential growth in terms of cumulated capacity can be observed. In Germany it starts around 2005 followed by Austria and Switzerland around 2008 as indicated in the following graphs.

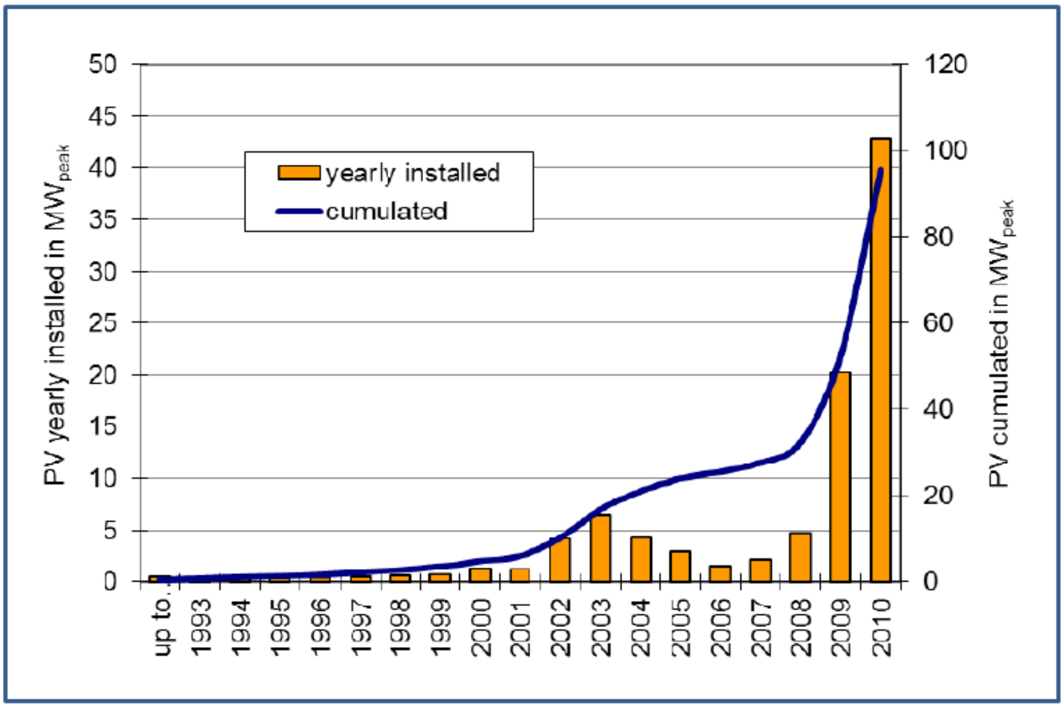

Figure 18: PV installation development in Austria[14]

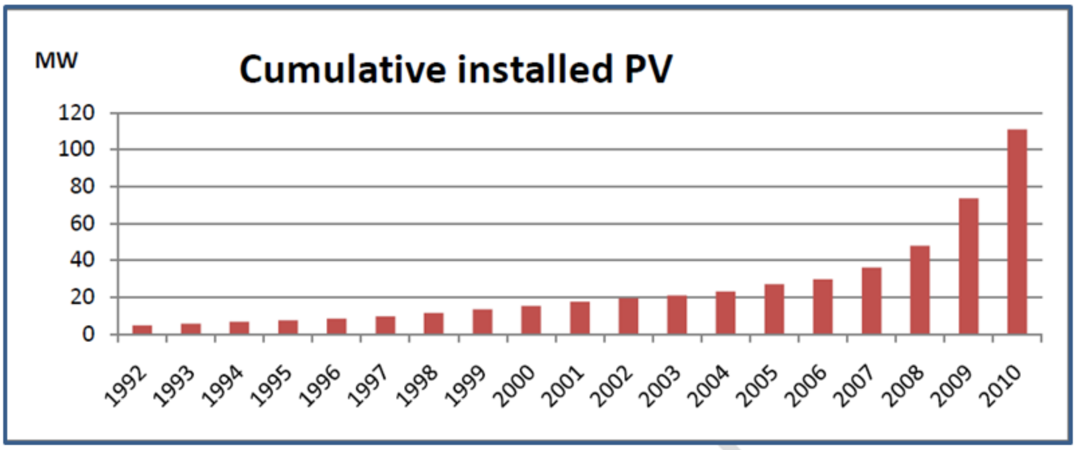

Figure 19: PV installation development in Switzerland[15]

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14 Source: FH Technik Austria / Innovative Energietechnologien in Österreich - Marktentwicklung 2010 [6].

15 Source: National Survey Report of PV Power Applications in Switzerland 2010 [7]

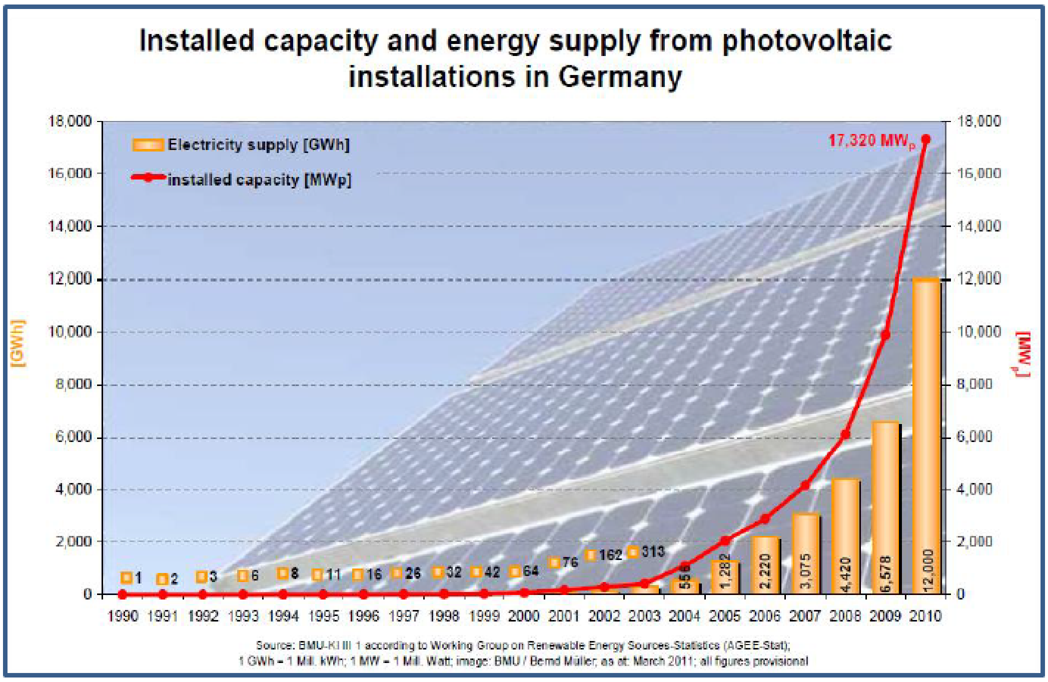

Figure 20: PV installation development in Germany[16]

Comparing the PV installed capacity of the three countries on a per capita basis Germany delivers the highest adoption rate as summarized in the following figure.

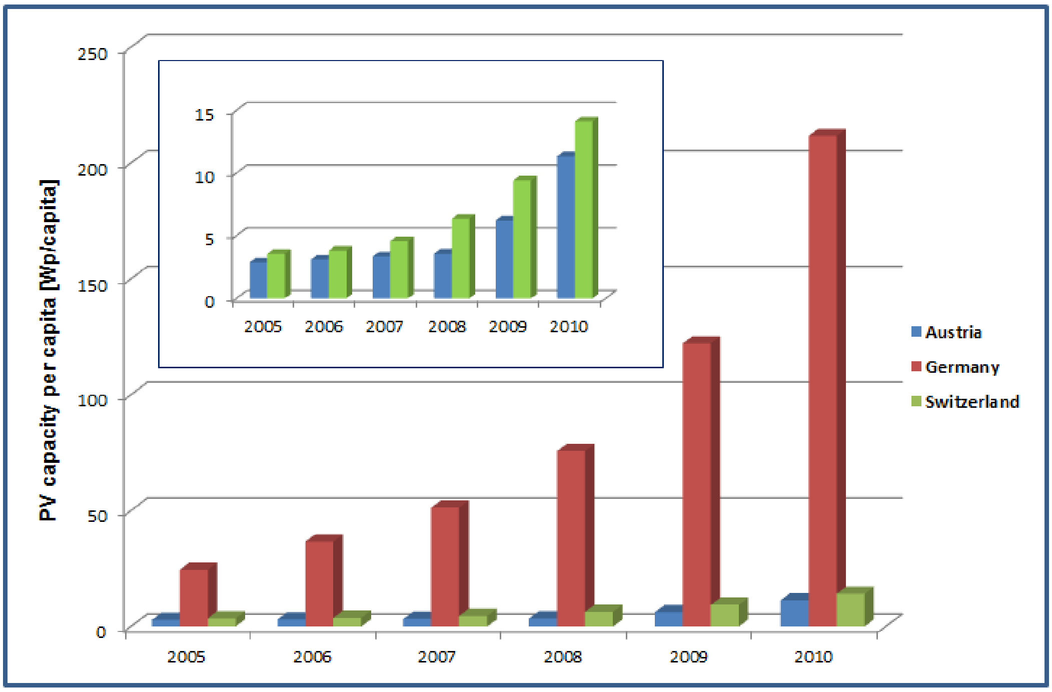

Figure 21: Cumulated installed PV capacity per capita[17]

16 Source: National Survey Report of PV Power Applications in Germany 2010 [5].
17 Number of inhabitants kept constant for the whole period.

4.3 The rational for Photovoltaic

Solar energy is the most abundant energy resource on earth. The solar energy that hits the earth's surface in one hour is about the same as the amount consumed by all human activities in a year. Direct conversion of sunlight into electricity in photovoltaic (PV) cells is one of the three main solar active technologies, the two others being concentrating solar power (CSP) and solar thermal collectors for heating and cooling (SHC). Today, PV provides 0.1% of total global electricity generation. However, PV is expanding very rapidly due to effective supporting policies and recent dramatic cost reductions. PV is a commercially available and reliable technology with a significant potential for long-term growth in nearly all world regions. In the IEA solar PV roadmap vision[18], PV is projected to provide 5% of global electricity consumption in 2030, rising to 11% in 2050 [40].

Beside its high potential and basically everywhere availability one other very important aspect shouldn't be neglected. The advantage of **land used** per generated electric energy compared to other RE technologies. PV plants need a considerably smaller area for the same yield as summarized in the following table [41].

PV: The Land-Area Advantage

Technology	Converter Efficiency (%)	Capacity Factor (%)	Maximum Packing	Land per year for: GW	Land per year for: GWh
Flat-Plate PV	10%–20%	20%	25%–75%[d]	**10–50 km²/GW**	**5000–25,000 m²/GWh**[k]
Wind	Low to 20%[a]	20%[c]	2%–5%[e]	100 km²/GW[g]	140,000 m²/GWh[i]
Biomass	0.1% total[b]		High—plants compete for sunlight	1000 km²/GW[h]	500,000 m²/GWh[i]
Solar Thermal or PV Concentrators	15%–25%	25%	10%–20%[f]	20–50 km²/GW[h,i] 20 km²/GW[j]	10,000–20,000 m²/GWh

[a] www.windpower.org
[b] 0.5% or less light-to-biomass; then 33% to electricity; 0.1% total
[c] Site dependent
[d] Tilted arrays at high latitudes versus flat ones at the Equator; room between for maintenance
[e] Pimentel 2002; Dohn Riley et al.
[f] Tracking arrays need wider separation to avoid shadowing
[g] Hansen 2003
[h] Hughes 2002
[i] Pimentel 2002
[j] Cohen 2003
[k] At 15% module efficiency, 12% module-to-system operating efficiency losses

Table 4: The PV land-area advantage[19]

18 Source: http://www.iea.org/papers/2010/pv_roadmap.pdf, 31.01.2012

19 PV FAQ's (2004), Published by the National Renewable Energy Laboratory, U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy

From the environmental perspective two main aspects in favor of PV technology shall be mentioned here, the **energy payback time** and the **ecological footprint**. PV systems, like every other product, do need energy for manufacturing, but PV systems pay back this energy input within 1 to 3 years, depending on cell type and location. During its expected lifetime of 30 years, the PV system produces therefore 10 to 30 times the energy it originally consumed.

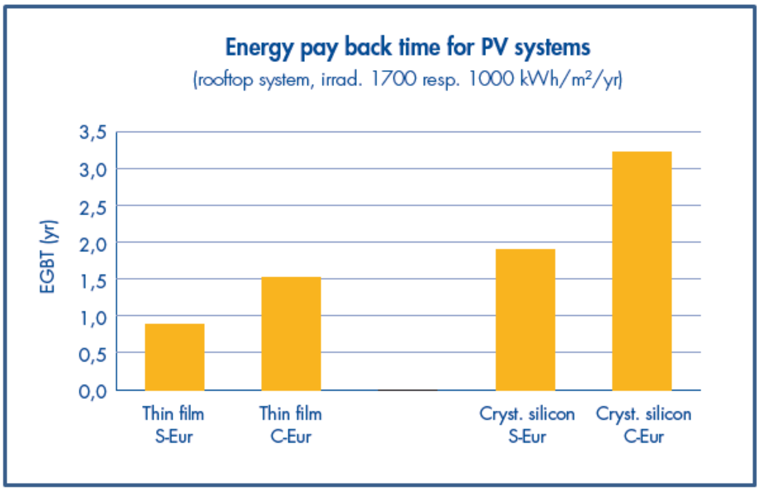

Figure 22: Energy payback time for PV systems[20]

During their life-cycle they release some emissions to the environment as fossil fuels are still used in the process of manufacturing. The health and environmental impacts of such emissions may be expressed in monetary terms as “external costs”. For current PV installations in South-Europe the external costs are about 0.15 eurocents per kWh, which are comparable to wind energy, and much lower than the external costs of the fossil fuel technologies that PV displaces.

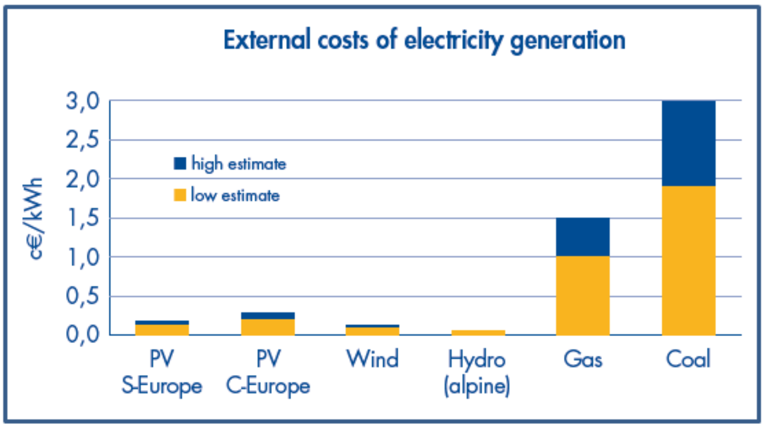

Figure 23: The PV land-area advantage[21]

20 Source: Alsema, E. et al (2006). 21st European Photovoltaic Energy Conference, Germany.

21 Source: Fthenaki, V. et al. (2006). Progress In Photovoltaics, MRS´Symposium Proceedings.

4.3.1 Photovoltaic Application

As early mentioned PV systems directly convert solar energy into electricity. The basic building block of a PV system is the PV cell, which is a semiconductor device that converts solar energy into direct-current (DC) electricity. PV cells are interconnected to form a PV module, typically up to 50-200 Watts (W). The PV modules combined with a set of additional application-dependent system components (e.g. inverters, batteries, electrical components, and mounting systems), form a PV system. PV systems are highly modular, i.e. modules can be linked together to provide power ranging from a few watts to tens of megawatts (MW). Hereby two main PV application types can be distinguished, the so called “Off-grid” and “On-grid” systems. The grid-connected PV plants feeds electrical energy directly into the electric utility grid, while the distributed ones further need batteries for storage. In the case of carports only grid-connected PV plants are considered. The system size for residential applications is typically in the 2 to 10 kWp range. For commercial buildings, the system size can range up to 100 kWp, for **carports** even higher dependent on the available area.

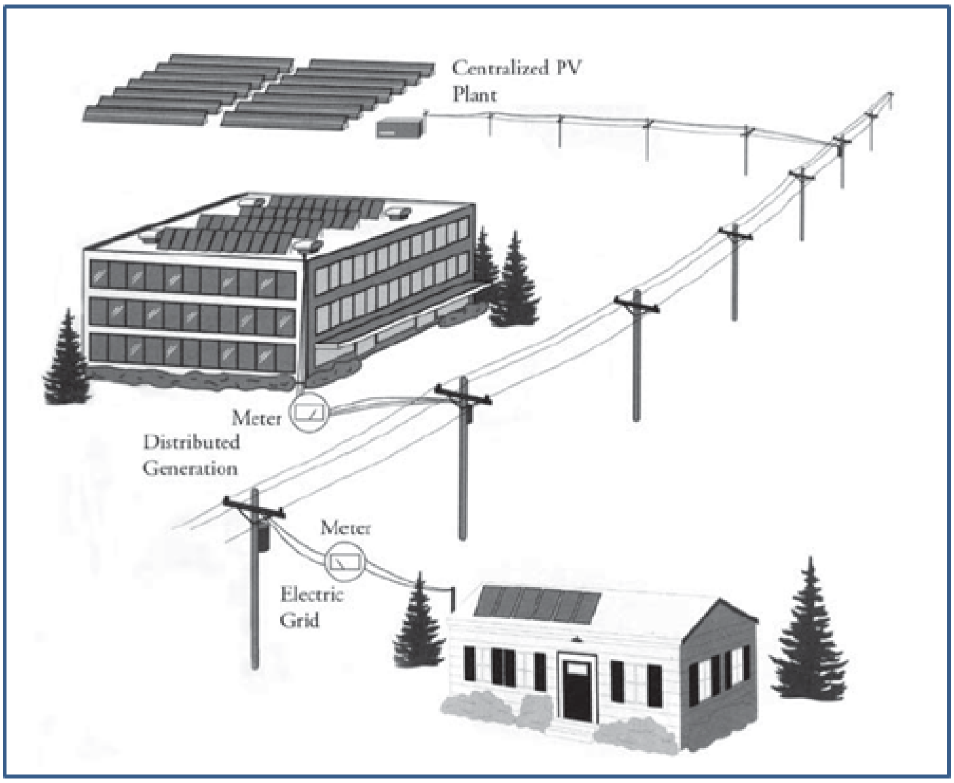

Figure 24: Grid-Connected PV System Schematic[22]

22 Source: Clean Energy Project / RET Screen International. www.retscreen.net, 20.01.2012

4.3.2 Technology performance

There are different types of PV technologies available today. The oldest and so far worldwide most used technology is based on crystalline silicon.

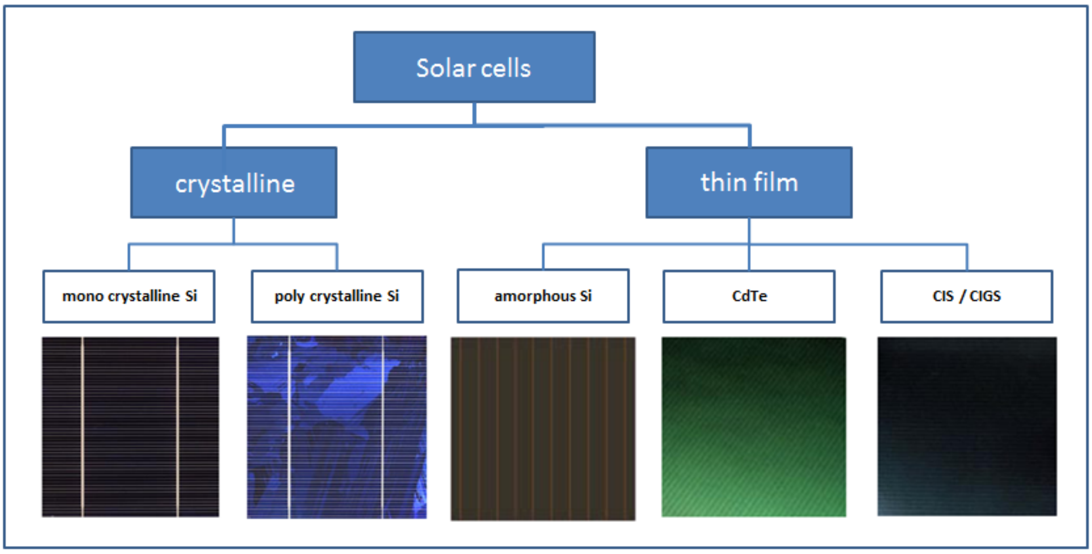

Figure 25: Overview PV types

Crystalline silicon (c-Si) modules represent 85-90% of the global annual market today. C-Si modules are subdivided in two main categories:

i) mono-crystalline[23] (sc-Si) and
ii) multi-crystalline (mc-Si).

Thin films currently account for 10% to 15% of global PV module sales. They are subdivided into three main families:

i) amorphous (a-Si) and micromorph silicon (a-Si/μc-Si),
ii) Cadmium-Telluride (CdTe), and
iii) Copper-Indium-Diselenide (CIS) and Copper-Indium-Gallium-Diselenide (CIGS).

Emerging technologies encompass advanced thin films and organic cells. The latter are about to enter the market via niche applications. Novel PV concepts aim at achieving ultra-high efficiency solar cells via advanced materials and new conversion concepts and processes. They are currently the subject of basic research [42, 43].

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23 There are also some hybrids made of thin mono crystal silicon surrounded by ultra-thin amorphous silicon layers as the so called HIT (**H**eterojunction with **I**ntrinsic **T**hin Layer).

4.3.3 Efficiency

Efficiency is a measure of how much of the sunlight striking the cell is converted into electrical energy versus being dissipated as heat. There are several types of PVs in use today including crystalline (single and poly) silicon (cSi), thin film and concentrated PV (CPV). Power generation efficiencies for the average systems range from 14%- 20% for single crystalline cSi, 13-16% for polycrystalline cSi, 8-13% for thin film and 25-38% for CPV. HIT modules may reach levels up to 17% [44, 45].

Technological advances such as Sharp Corporation's use of a tri-layer cSi, have increased efficiencies to 36.9%[24]. This involves the use of indium-gallium-arsenide layers to convert light energy at multiple wavelengths into electrical current. For CPV based systems, Boeing's Spectralab has developed tri-layer cells with efficiencies of 41.6%[25]. However, these are mostly only on cell level under lab conditions and commercially not yet available.

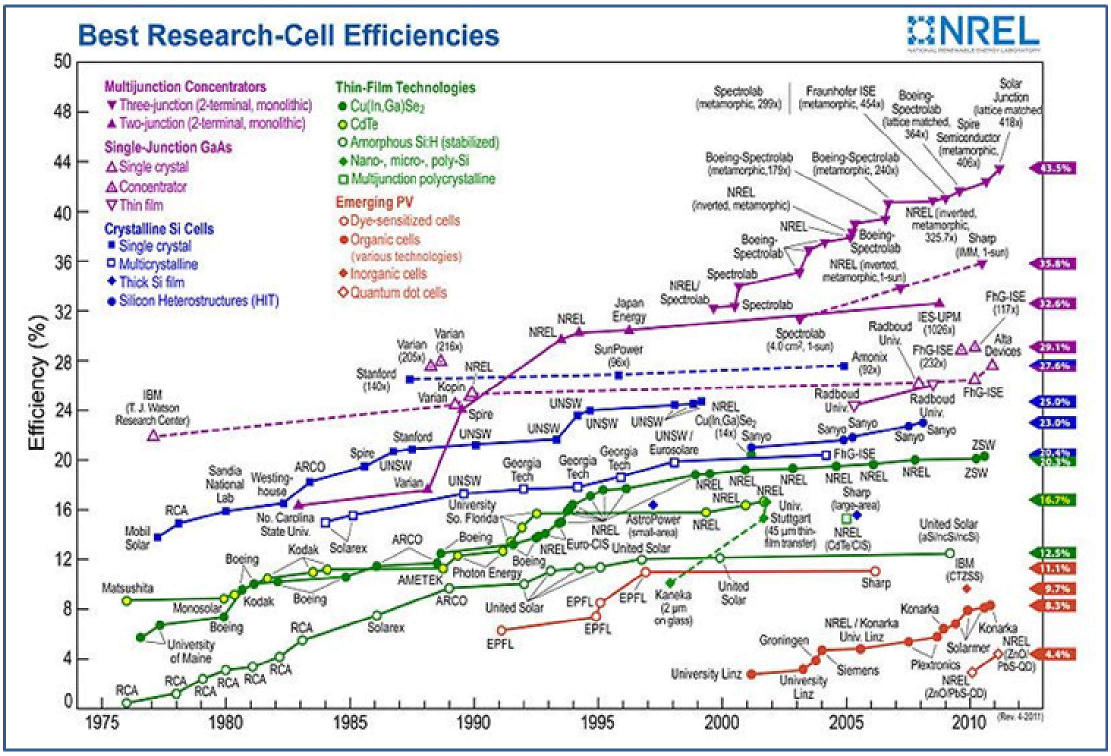

Figure 26: Overview of PV cell efficiency records[26]

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24 Sharp Corporation news release as of November 2011 http://sharp-world.com/corporate/news/111104.html , 10.02.2012

25 Boeing Spectralabs website FAQ, http://www.spectrolab.com/faqs-terrestrial.htm , 10.02.2012

26 These records are from solar companies, universities, and national laboratories. Source: http://www.nrel.gov/ncpv/images/efficiency_chart.jpg , 31.01.2012

Today commercially available PV modules are summarized in the following tables[27].

#	Company	Module Efficiency	Module Type	Cell Efficiency
1	Sunpower	20.40%	E20 / 333 SOLAR PANEL	22.80%
2	AUO Solar	19.50%	PM318B00	
3	Sanyo Electric	19.00%	HIT-N240SE10	21.60%
4	Jiawei	18.30%	JW-S100	21.01%
5	Crown Renewable Energy	18.30%	Summit 100LM	
6	JA Solar	16.84%	JAM5(L)-72-215/SI	19.10%
7	Trina Solar	16.40%	TSM-210DC80	18.10%
8	CNPV Solar	16.20%	CNPV-105M	18.80%
9	Yingli Solar	16.20%	Panda 265 Series	18.50%
10	Jetion	16.20%	JT315SAc	18.30%

Table 5: World's Top 10 Solar PV Module Efficiency (Mono-Crystalline)

#	Company	Module Efficiency	Module Type
1.	Solland Solar	16.00%	Sunweb
2.	Siliken	15.70%	SLK72P6L-305
3.	LDK Solar	15.67%	LDK-200P-24(s)
4.	Vikram	15.63%	Eldora 280 (300)
5.	Wiosun	15.54%	E300P
6.	A2peak	15.50%	P3-235-60 (250)
7.	CNPV solar	15.40%	CNPV-300P
8.	Latitude Solar	15.30%	Latitude P6-60/6 (250)
9.	JA Solar	15.29%	JAP6-60-250
10.	China Sunergy	15.24%	CSUN295-72P

Table 6: World's Top 10 Solar PV Module Efficiency (Poly-Crystalline)

#	Company	Module Type	Module Efficiency
1.	**Miasole**	MS140GG	13.1%
2.	**Q-cells**	Q. smart UF 95	12.7%
3.	**Solar Frontier**	SF155-L	12.6%
4.	**Avancis**	Powermax	12.6%
5.	**Global Solar Energy**	PowerFLEX BIPV 300W	12.6%
6.	**Yohkon Energia**	YEC 200-160	12.3%
7.	**Nanosolar (US)**	Nanosolar Utility Panel	12.0%
8.	**Honda Soltec**	HEM130PCB	11.6%
9.	**New Energy Solutions**	NESI-CIGS	11.4%
10.	**HelioVolt**	HVC-190X	11.3%

Table 7: Top 10 Solar PV Module Efficiency (CIGS)

27 Solarplaza is the independent global platform for **knowledge**, **trade** and **events** for the photovoltaic solar energy (PV) industry. http://www.solarplaza.com/Top-10/, 20.01.2012

4.4 Solar irradiation and energy yields

Solar irradiance is a measure of how much solar power is radiated by the sun and intercepted at the top of the Earth. The intensity varies throughout the year depending on the seasons. It also varies throughout the day, depending on the position of the sun in the sky, and the weather. While the unit of irradiance is expressed by (W/m^2), irradiation in contrast is (kWh/m^{2}yr) as defined by the international standard norm IEC 61724. For PV applications and the calculation of the energy yield the irradiation is the measure usually used.

The map below represents yearly sum of global irradiation [kWh/m^2] on horizontal and optimally inclined surface for a 10-years average of the period 1981-1990. The same colour legend represents also potential solar electricity [kWh/kWp] generated by a 1 kWp system per year with photovoltaic modules mounted at an optimum inclination and assuming system performance ratio of 0.75.

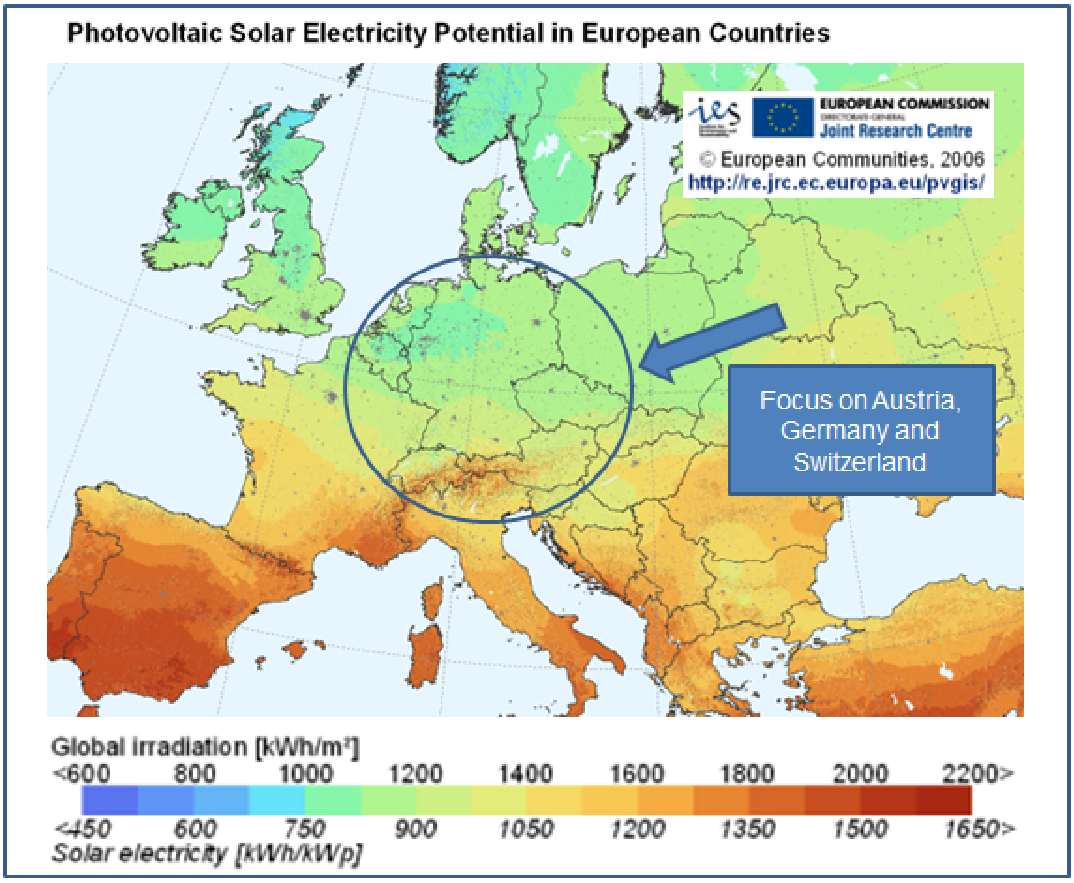

Figure 27: PV Solar electricity potential in DACH[28]

[28] Source: http://re.jrc.ec.europa.eu/pvgis/cmaps/eur.htm#DE; 22.01.2012

As indicated on the map the solar irradiation for the focus area is very similar for Austria and Switzerland, and the most southern part of Germany. While in the Alps maximal irradiation values can be observed, lower values apply for the lowland regions. However, the intensity of solar irradiation strongly depends from the geographic (latitude, longitude, altitude), the physical location (ground or roof-mounted, etc.) and the geographic orientation as well as the tilt degree. Optimal values can be achieved by a South orientation and a 30° inclination angle. Nevertheless, still reasonable yields can be reached if the installation is not optimal oriented as shown in the figure below. The values indicate the rough energy yield in % compared to optimal positioning (South / 30°).

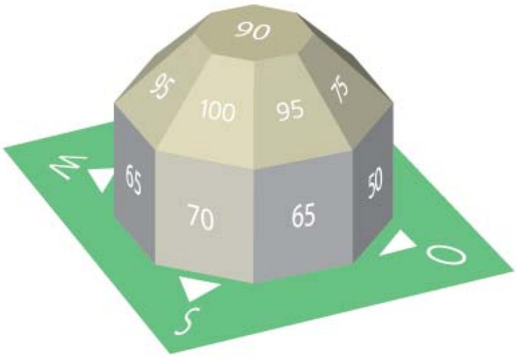

Figure 28: Optimal orientation[29]

Following table delivers the absolute country minimal, average and maximal measured values of the yearly irradiation [kWh/m^2] for a horizontal, optimal and

Austria	horizontal	optimal	vertical
min	922	957	511
min urban 5%	1'084	1'231	893
country average	**1'175**	**1'377**	966
max urban 95%	**1'217**	**1'420**	992
max	1'510	1'978	1'511

Table 8: Yearly irradiation in Austria

[29] Source: http://www.swissolar.ch/de/waerme-von-der-sonne/technik/; 22.01.2012

vertical orientated installation. Apart from that the irradiation levels for built-up residential areas is indicated. Hereby the minimal values represent a 5% and the maximal values a 95% occurrence of the irradiation levels in urban areas.

Germany	horizontal	optimal	vertical
min	949	984	537
min urban 5%	958	1'087	754
country average	**1'014**	**1'157**	804
max urban 95%	**1'106**	**1'264**	847
max	1'381	1'795	1'368

Table 9: Yearly irradiation in Germany

Further detailed solar irradiation maps for horizontal and for optimal orientation for all three countries can be found in the appendix.

4.5 Time effects

There are several time rerated factors influencing the energy yield of a PV plant and consequently the business case. Therefore must be considered in the calculations respectively in the applied models. The most important factors will be discussed in short here.

4.5.1 Life expectancy

The definition of lifetime is a difficult task as there does not yet appear to be a fixed catastrophic failure point in module ageing but more of a gradual degradation. Therefore, if a system continues to produce energy which satisfies the user need it has not yet reached its end of life. However, electric performance measurements of silicon PV modules exposed during long-term to outdoor applications indicate better results than the initial warranty levels of 10% decrease in electricity production after 10 years. Remarkably more than 65% of measured modules (53 module types originating from 20 different producers fabricated in the 80's) exposed for 20 years exceeded that criterion. Hence, the useful lifetime of solar modules is not limited to the commonly assumed 20 years [46].

According to the Guidelines on Life Cycle Assessment of Photovoltaic Electricity the recommended life expectancy of photovoltaic components and systems differentiates between the components [47].
Following values are recommended:

- **Modules**: 30 years for mature module technologies (e.g. glass-tedlar encapsulation), life expectancy may be lower for foil-only encapsulation;
- **Inverters**: 15 years for small size plants (residential PV); 30 years with 10% of part replacement every 10 years (parts need to be specified) for large size plants like utility PV (Mason et al. 2006);
- **Structure**: 30 years for roof-top and façades and between 30 to 60 years for ground mount installations on metal supports.
- **Cabling**: 30 years

Many manufacturers currently give a double power warranty for their products, typically 90% of the initial maximum power after 10 years and 80% of the original maximum power after 25 years.

4.5.2 Degradation

Degradation rate is driven primarily by various failure modes attributable to the cell module. Many of these failure modes may become less significant with newer generations or types of PV modules due to technological improvements in the design and manufacture of the modules (solder interconnects, seals, etc.). This may likely decrease the degradation factor but to what degree remains unknown, until more long-term field data becomes available. Additionally, degradation factors are likely to differ for thin film and CPV systems.
From the literature and based on multiple comparative analyses the following main conclusions crystalline Si PV modules can be derived [48, 49]:

- The average power of a set of modules in field operation decreases linearly over time.
- The yearly degradation rate for crystalline silicon PV modules ranges from 0.3 to 3%, newer publications indicate a range from 0.5% to 1%.

- The degradation seems to be constant during the wear-out period of the product. During the first year, somewhat higher degradation rates were observed in some studies.
- The power distribution of the modules tends to broaden over time, i.e. the standard deviation of the power distribution increases over time.

Considering annual performance degradation factor that ranges from 0.5% to 1.5% per year; extending this out to 30 years, simulations show a power generation degradation of 15%, 26% and 36% respectively as shown in the table below.

Module Degradation Rate/Yr	Module System Performance on Year 30	Cumulative Median Energy Output (% of 0.5% baseline) in kWh
0.5%	85%	7,000,000 (100%)
1.0%	74%	6,500,000 (93%)
1.5%	64%	6,000,000 (85%)

Table 10: PV module degradation[30]

However, inverter failure appears to be a likely failure mode but in long term simulations, it does not manifest itself as a significant performance degradation factor for PV systems. This is likely due to such equipment being readily available and replaceable.

Current inverters have an average lifespan of about 7 to 10 years, meaning that they might have to be replaced two to three times over the lifetime of a PV system. The warranty that a manufacturer is willing to provide is a good indication of an inverter's reliability.

The Figure below illustrates default inverter warranty data. As inverter reliabilities increase, manufacturers have started to offer longer warranties. In 2008, a majority of manufacturers were comfortable giving default 5-year warranties (around 60% -

[30] Due to the lack of sufficient long-term data, Sandia conducted a 30-year projected computer simulation to predict the cumulative energy output of a cSi PV system over time with respect to several factors. These included solar irradiance, PV module performance, and equipment availability (six components including the inverter). They varied the parameters through 11 separate computer simulations.

see brown graph) as opposed to 1–3 year warranties as was the case few years ago (see yellow graph). In addition, a growing number of manufacturers have begun offering customers optional warranties with up to 10 years of coverage for an additional fee. This suggests that inverter companies are becoming increasingly confident in the reliability of their products.

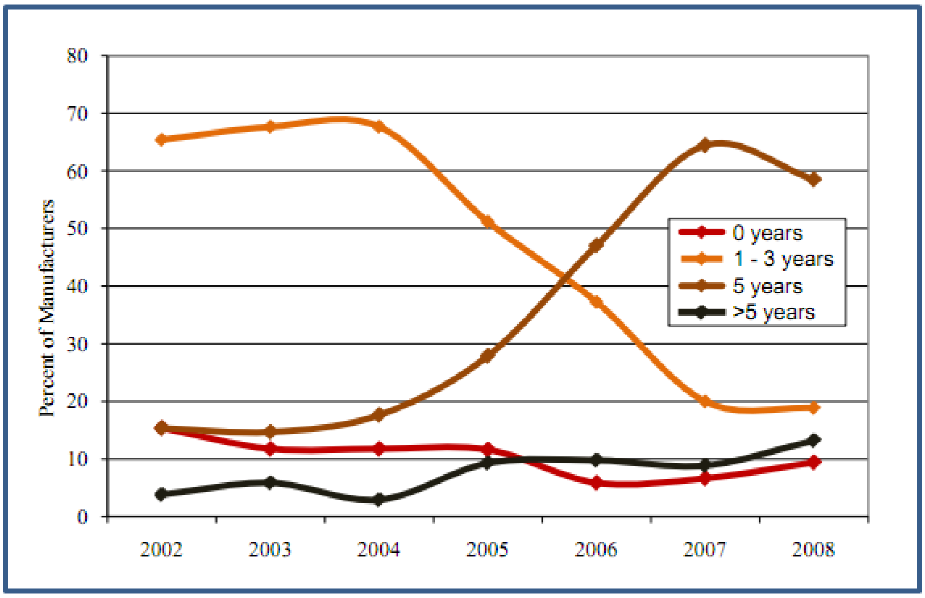

Figure 29: Inverter default warranty duration offered by manufacturers[31]

In terms of the inverter efficiency some progress was achieved as well. Small inverters up to 5kWp reached efficiency levels close to 98%. The following table summarizes today's best in class commercially available inverters.

#	Manufacturer	Inverter Efficiency	Inverter Model
1.	Steca	98.60%	StecaGrid 3600
2.	Sunways	97.80%	NT5000
3.	Fronius	97.70%	IG TL 5.0
4.	Diehl AKO	97.70%	4800 TL
5.	Voltwerk	97.70%	VS 5
6.	Solaredge	97.60%	SE4000
7.	Mastervolt	97.50%	SunMaster ES4.6
8.	Mitsubishi Electrics	97.50%	PV-S4200
9.	Solutronic	97.40%	Solplus 50
10.	Refu	97.40%	Refusol 500K

Table 11: Top 10 World's Most Efficient String Inverters (< 5 kW)[32]

31 Source: Knoll and Kreutzmann 2008, Photon International 2002–2008 from http://www1.eere.energy.gov/solar/pdfs/46025.pdf ; 14.02.2012

32 Source: http://www.solarplaza.com/top10-inverters-5kw-efficiency/, 14.02.2012

4.6 Costs

Costs are one of the main driving factors for the success or failure of a project, business idea or technological innovation. Hence, cost and price development of PV technology, operating cost, but also valid supporting schemes in DACH will be disclosed in this section.

4.6.1 Module price trends

The PV module prices for all commercially available types show a decreasing tendency in the last few years. Due to the breaking down of the PV market in Spain in 2009 prices dropped significantly by 35% for European and Japanese crystalline products and by 45% for Chinese respectively. This enormous drop in price created a high demand in 2010 leaving the prices to sink by a moderate 5% to 15%.

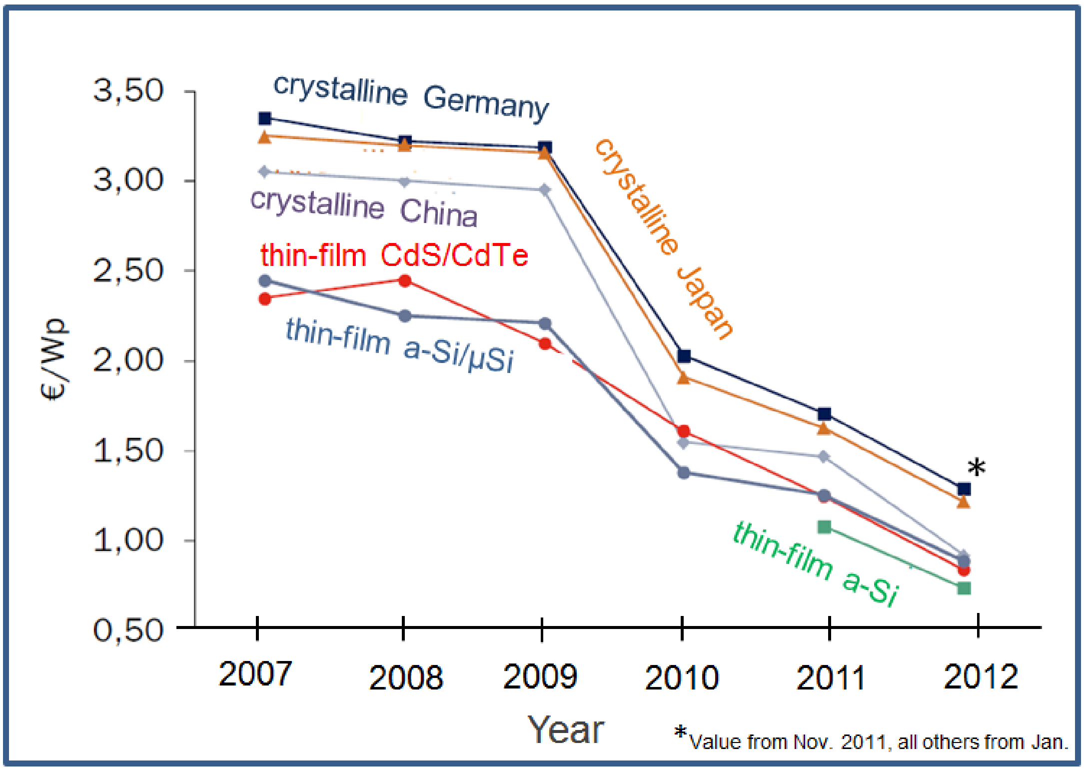

Figure 30: PV module price developments[33]

Over the past three years an average yearly price drop of 26% to 30% for crystalline and about 26% for thin-film modules could be observed.

[33] Source: Bank Sarasin Report (2011). Solarwirtschaft: Hartes Marktumfeld – Kampf um die Spitzenplätze. CH-4002 Basel. www.sarasin.ch

However, mass production and the economy of scale effect lead further to price deductions. This trend can be expected still in the near future. A good price indicator is the PV module sport market price index report published every month. The listed prices represent the average international wholesale PV modules quotations.

Module type, origin	€ / Wp	Trend since 12/2011	Trend since 01/2011
Crystalline Germany	1.07	- 4.5 %	- 37.3 %
Crystalline China	0.79	- 2.5 %	- 46.3 %
Crystalline Japan	1.05	- 4.5 %	- 35.6 %
Thin film CdS/CdTe	0.68	- 6.8 %	- 45.5 %
Thin film a-Si	0.60	- 6.3 %	- 44.2 %
Thin film a-Si/µ-Si	0.76	- 7.3 %	- 39.8 %

Table 12: Wholesale PV price trends in January 2012[34]

4.6.2 Turnkey prices of PV systems

The price for an entire PV system vary widely and depend on a variety of factors including system size, location, customer type, connection to an electricity grid, technical specification and the extent to which end-user prices reflect the real costs of all the components. Hereby grid-connected systems consist of the following main components:

- The PV modules
- The inverter converting DC power generated by the cells into AC grid
- Balance of System (BoS) equipment that include the wiring, racking systems and various other components)
- Installation work and project management

On average, system prices for the lowest price off-grid applications are roughly double those for the lowest price grid-connected applications. This is attributed to the fact that off-grid systems require storage batteries and associated equipment.

34 Source: http://www.solarserver.de/service-tools/photovoltaik-preisindex.html , 14.02.2012 In cooperation with the international PV trading platform pvXchange, Solarserver presents a monthly index of wholesale prices for thin film and crystalline PV modules

According to EPIA's observation in the member countries, today in average the biggest part of a PV system's initial installed cost arise from the PV modules, followed by the costs for the installation. Inverter cost hereby accounts in average for about 8%–9%, the BoS for about 12%-16% as indicated in the figure below [50].

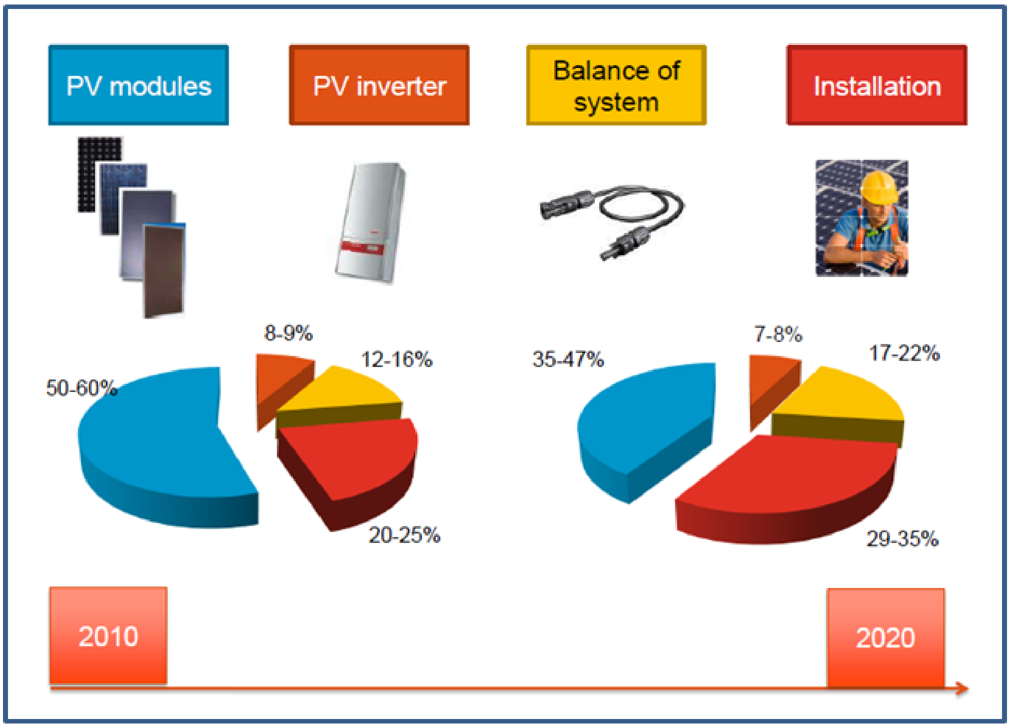

Figure 31: Expected cost developments of main components of a PV system

However, by 2020 a further decrease of the component cost can be expected, leading to a shift in costs from HW- components towards labor cost.

Following the international trend from the last three years not only module prices dropped but the prices for turn-key projects in general. However, price decreases of whole systems do not reflect the same price development as it could be observed for modules only.

Figure 32 below indicates the price developments for PV turn-key projects in the DACH countries during the last decade. The numbers are based mainly on national survey reports from the three countries. The costs represent average prices for all segments and technologies and may vary up to ± 20% according to the used source particularly for Austria and Switzerland [5, 6, 7, 51 and 52].

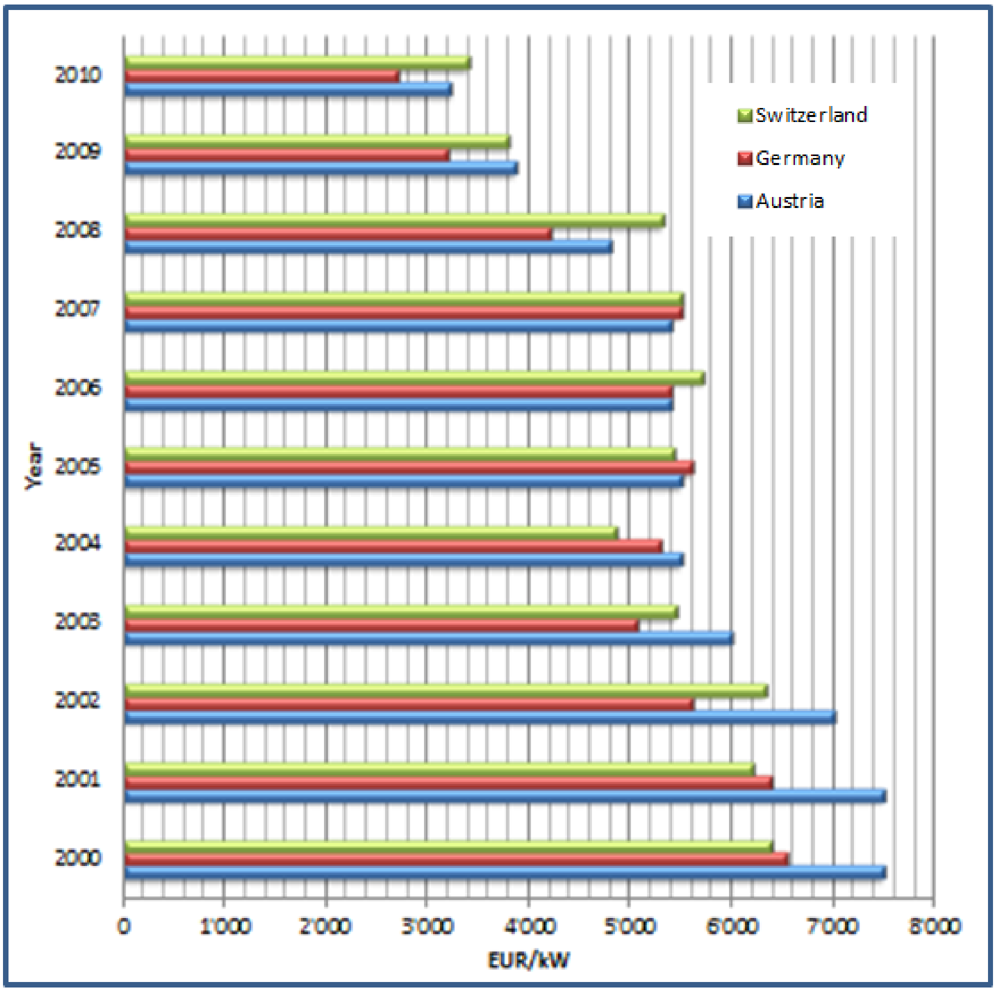

Figure 32: Average price development of PV turn-key projects in DACH[35,36]

In Germany as Europe's market driver and as a result of his early implemented Renewable Energy Sources Act (EEG) with attractive supporting schemes, mainly the feed-in tariffs, the price drop in turn-key PV systems was so far extraordinary compared to Austria or Switzerland.

However size of the PV plant in terms of energy yield, technology used and the design applied (i.e. ground-mounted, roof-top mounted or integrated in the building (BIPV)) strongly influence the final turn-key cost. It's therefore appropriate to distinguish between the different installation types. A common segmentation is

35 Source: National Survey Reports of PV Power Applications / IEA [5, 7 and 51], Innovative Energietechnologien in Österreich - Marktentwicklung 2010 / Technikum Wien [6] and Photovoltaikstudie - Ermittlung der Preise von Solarstromanlagen in der Schweiz [52].

36 Prices for Switzerland and Austria may vary up to 20% acording to used source.

based on energy yields respectively the size of the plant:

- Residential applications: 1kWp to 10 kWp
- Commercial applications: 10 kWp to 100 kWp
- Industrial Applications: > 100 kW

In Germany roof-top mounted installations account for about 85% of all implementtations, followed by ground mounted installations that account for about 11%. With about 1% the building integrated implementations (BIPV) play a negligible role. In contrast for Switzerland this market segment corresponds to 25 % of the installed systems. The majority of systems are realised as building applied systems (74 %) whereas ground based systems only account for 1 %. In Austria the major part accounts with about 86% for roof-top mounted installations followed by ground mounted with about 6.5%. Roof integrated mounting represent about 6.5% and façade integrated a bit more than 1% [5, 6 and 7].

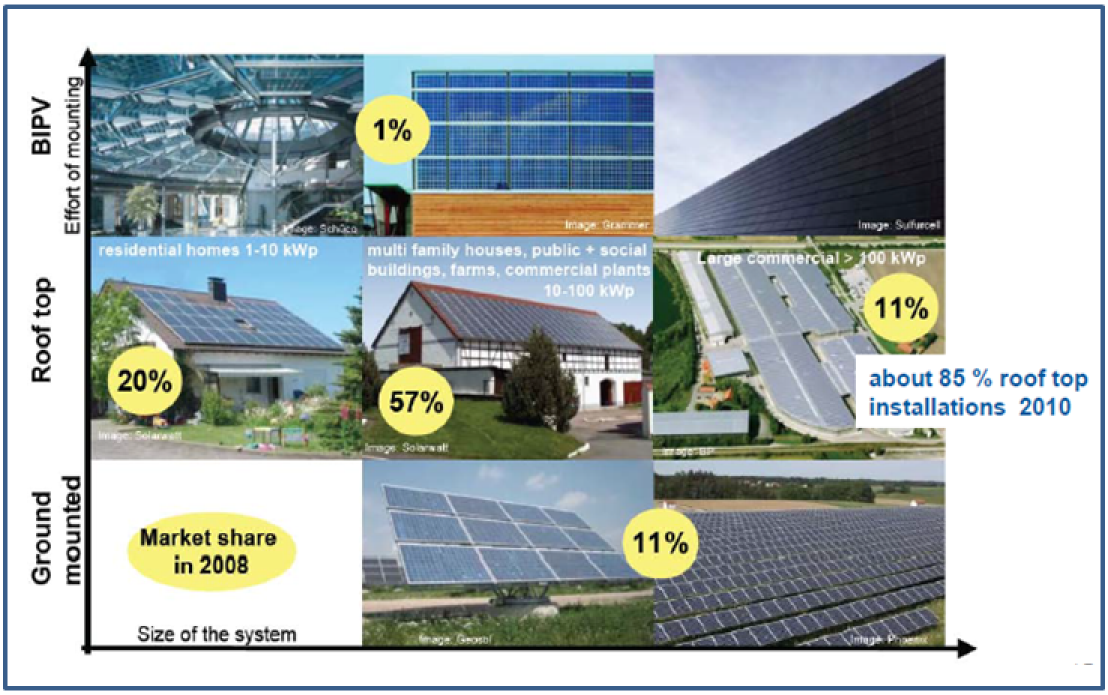

Figure 33: PV market segments in Germany[37]

Average turn-key prices for 2010 of typical PV applications in DACH based on energy yield respectively the plant size are summarized in the following figure:

[37] Dr. Wissing, L. (2011). PV Market in Germany. In: Presentation " 21st International Science and Engineering Conference 2011 PVSEC-21, Fukuoka, Japan"

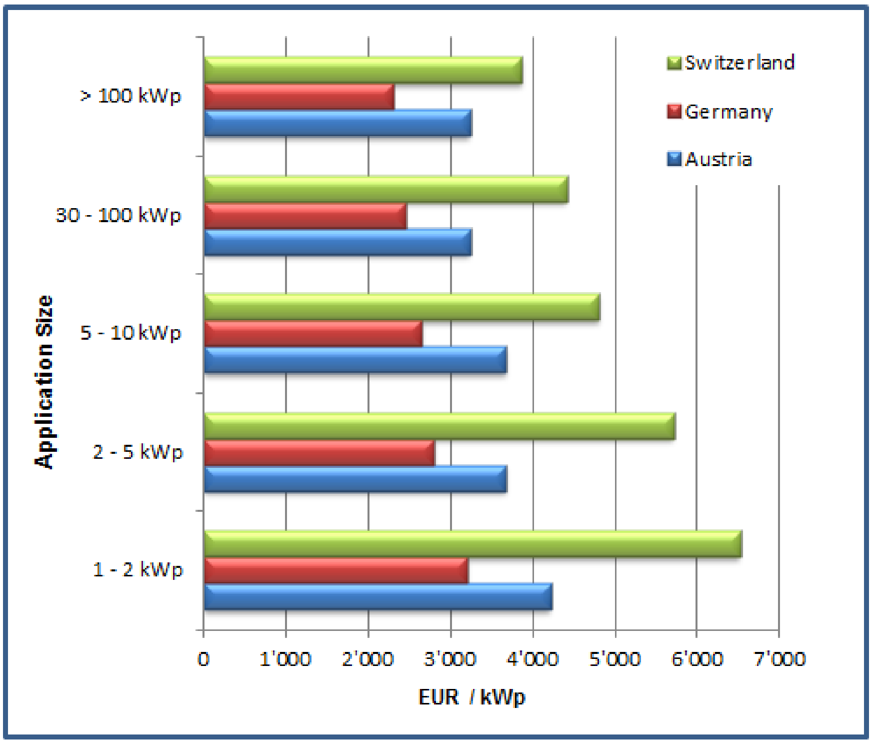

Figure 34: Average PV turn-key project costs in 2010[38,39]

The prices are related mainly to roof-top and grid-connected installations. Hence, costs of such systems are usually higher compared with ground-mounted installations. The prices in Switzerland are the highest among the three countries, mainly due to import costs and the high cost of living resulting in relative high salaries. The average monthly salary of a PV installer lies at CHF 5’000 or ca. € 4’145 and project planning is charged at CHF 150 t0 200 per hour or ca. € 125 to 165 € per hour levels. Not to neglect the relatively high FIT which have an impact on the overall costs of systems [52]. Only Germany as the most mature market compared with the other two countries shows significant lower turn-key prices. However, these are average prices and may vary up to ± 20% according to used source. This is particularly valid for Austria and Switzerland [5, 6, 7, 51 and 52]. For actual prices of an average turnkey solar PV power system in Germany, the wholesale prices shown in **table 12** must be multiplied by a factor. For crystalline modules a factor of approx. 1.5 - 1.9, for thin film PV modules a factor of 1.8 – 2.5 applies.

38 Source: National Survey Reports of PV Power Applications / IEA [5, 7 and 51], Innovative Energietechnologien in Österreich - Marktentwicklung 2010 / Technikum Wien [6] and Photovoltaikstudie - Ermittlung der Preise von Solarstromanlagen in der Schweiz [52].

39 Prices for Switzerland and Austria may vary up to 20% acording to used source.

4.6.3 Operations and maintenance costs

Operations and maintenance (O&M) is a significant contributor to the lifetime cost of PV systems, and reducing the O&M costs of system components is an important avenue to reducing lifetime PV cost. The data, however, are difficult to track, because O&M costs are not as well documented as other PV system cost elements which is due in part to the long-term and periodic nature of O&M. According to various studies the annual O&M costs ranged from 0.12% for utility-scale generation to 5%–6% for off-grid residential hybrid systems as a percentage of installed system cost [53].

A study carried out in Switzerland in 2008 show that the operation costs per kWh energy yield decrease with the size of the PV system and the specific yield of the PV system.

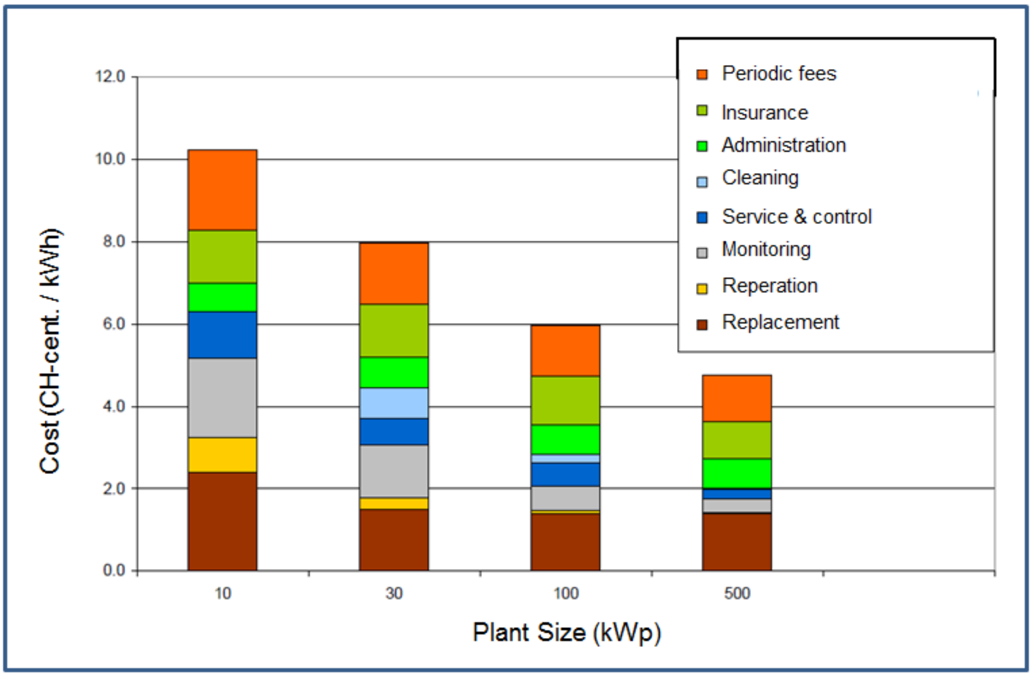

Figure 35: Operation & maintenance cost based on PV plant size[40],[41]

Operation costs of a system with 10kWp are about 8.3 cent/kWh or 10 CH-cent/kWh, whereas costs of a 30kWp system are about 6.64 cent/kWh or 8 CH-cent/kWh and those of a 100kWp system about 5 cent/kWh or 6 CH-cent/kWh. The

[40] Swiss Report on O&M costs in Switzerland (2008). Used information about the cost situation was collected by literature study, but also in interviews and surveys with PV experts and PV owners. All results were discussed and reviewed at a workshop with about 20 Swiss PV experts.

[41] Currency exchange rate: 1 CHF cent = 0.83 EUR cent (1 EUR = 1.2 CHF)

major part of the costs accounts for facility management and for spare parts, especially for the inverter [54].

However, it is expected that in future, costs for facility management will decrease further, mainly because they are partly linked with the capital costs (e.g. insurance costs). Optimisation potential exists in several aspects of facility management, for example in monitoring of the system and fast reaction in case of a malfunction. Realistic values range between 1% and 3% of the investment cost for roof-mounted systems.

4.7 Legal and regulatory obligations

Basically all three countries support PV deployment and installations applying mainly the so called feed-in tariff (FIT) mechanism. Beside that some of the Federal States have additional special investment support schemes. However, there are no special obligations to be met apart from clear defined procedures that must be followed (e.g. construction and grid connection permit). Of cause each county has developed own approach procedures. They will not be discussed further here as they will be elaborated in detail in the part 2 of the master thesis (for further details see Chap. 1.4 explaining structure and focus of this work).

4.7.1 Feed in tariffs

The feed-in tariff for PV systems basically distinguishes between three different categories of systems, namely ground based, building applied and building integrated systems (BIPV) for which the highest tariff can be usually obtained. The applicable feed-in tariff also depends on the size of the PV system. In this way, a differentiated scheme is used which is based on regular market analysis to follow the dynamics of the market. However, beside the different tariffs valid in each country the validity time of the FIT is a major differentiator and a crucial factor for investment decisions.

Country	FIT validity
Austria	13 years
Germany	20 years
Switzerland	25 years

Table 13: FIT validity in DACH

In **Austria** the Ökostromverordnung (eco electricity degree) sets the following new tariffs for 2012 valid only for PV systems covered by the Ökostromgesetz (Eco Electricity Law)[42].

System Size / System Type	5 to 20 kWp	> 20 kWp
On buildings or noise barriers	0.276 €/kWh	0.23 €/kWh
Free-standing systems	0.25 €/kWh	0.19 €/kWh

Table 14: Austrian Feed-in-tariffs (FIT) valid in 2012

For systems smaller than 5 kWp, private persons can apply for investment subsidies offered by the Climate & Energy Fund (budget in 2011 at € 35 million). The applications are supported on the basis “first come first serve”. Some of the Federal States have additional investment support schemes.

According to the EE-G in **Germany** following tariffs are valid for new installations starting from 1st January 2012:

System Size / System Type	< 30 kWp	30 to 100 kWp	>100 to 1 MWp	> 1 MWp
Roof-top and noise barriers	0.2443 €/kWh	0.2323 €/kWh	0.2198 €/kWh	0.1833 €/kWh
Roof-top with self- consumption up to 30%	0.0805 €/kWh	0.0685 €/kWh	0.0560 €/kWh (1	
Roof-top with self- consumption > 30%	0.1243 €/kWh	0.1123 €/kWh	0.0998 €/kWh (1	
Ground-mounted installations in conversion and transitional areas	0.1876 €/kWh	0.1876 €/kWh	0.1876 €/kWh	0.1876 €/kWh
Other ground-mounted installations	0.1794 €/kWh	0.1794 €/kWh	0.1794 €/kWh	0.1794 €/kWh

(1 valid for > 100 to 500 kWp

Table 15: German Feed-in-tariffs (FIT) valid in 2012

In addition, there is an automatic increase or decrease of the digression rate if the installed capacity is above or below certain values in the year before. In order to monitor this, all new systems which become operational after 1st January 2009, have to be registered in a central PV system register. The digression rates will be lowered

42 Source: http://www.pvaustria.at/content/page.asp?id=70, 18.02.2012

or increased in the next year if the following installed capacities are undercut or exceeded. Installations in 2011 and resulting digression in 2012:

- > 3,500 MW + 3% < 2,500 MW – 2.5%
- > 4,500 MW + 6% < 2,000 MW – 5%
- > 5,500 MW + 9% < 1,500 MW – 7.5%
- > 6,500 MW + 12%
- > 7,500 MW + 15%

The **Swiss** regulation regarding support of Renewable Energy and in particularly of PV is pretty comparable to the system in Austria. However, the FIT scheme is more detailed distinguishing more installation capacity classes. The actual valid FITs are summarized in the table below.

Feed-in tariffs valid for new decisions
incl. VAT 8%

Installation category capacity class	Feed-in tariff 2010 [ct./kWh]	Feed-in tariff 2011 [ct./kWh]	Feed-in tariff from 1.1.2012 [ct./kWh]	Feed-in tariff from 1.3.2012 on [ct./kWh]	Costs-reference for 2012 investment costs CHF/kW	maintenance costs ct./kWh
Freestanding ≤10 kW	53.3	42.7	39.3	36.5	4083	6.0
≤ 30 kW	44.3	39.3	36.2	33.7	3711	6.0
≤ 100 kW	41.8	34.3	31.6	32.0	3478	6.0
≤ 1000 kW	40.2	30.5	28.1	29.0	3219	5.0
> 1000 kW		28.9*	26.6	28.1	3154	4.5
Roof-mounted ≤10 kW	61.5	48.3	44.4	39.9	4537	6.0
≤ 30 kW	53.3	46.7	43.0	36.8	4123	6.0
≤ 100 kW	50.8	42.2	38.8	34.9	3864	6.0
≤ 1000 kW	49.2	37.8	34.8	31.7	3577	5.0
> 1000 kW		36.1*	33.2	30.7	3504	4.5
Roof-integrated ≤10 kW	73.8	59.2	54.5	48.8	5733	6.0
≤ 30 kW	60.7	54.2	49.9	43.9	5073	6.0
≤ 100 kW	54.9	45.9	42.2	39.1	4437	6.0
≤ 1000 kW	50.8	41.5	38.2	34.9	4004	5.0
> 1000 kW		39.1*	36.0	33.4	3869	4.5

* Not yet applicable for 1.1.2011; tariff for installations ≤ 1000 kW is being applied
Source: Swiss Federal Office of Energy

Table 16: Swiss Feed-in-tariffs (FIT) valid in 2012[43]

Some of the Federal States have additional investment support schemes[44]. Since the market development in Switzerland, which was formerly mainly driven by green power marketing schemes of power utilities, has experienced a strong development in the framework of the new feed-in tariff support scheme, the Swiss legislation explicitly foresees the possibility of switching between the feed-in tariff and the

43 Source: http://www.swissolar.ch/fileadmin/files/swissolar/solarstrom/KEV-Tarife_2012_en.pdf , 18.02.2012

44 For further details see: http://www.swissolar.ch/fileadmin/files/swissolar/f%C3%B6rderung/Infodossier_Foerderung_PV.pdf 18.02.2012

voluntary green power marketing approach. However, the tariffs of these green power schemes strongly depend on the geographic location respectively the catchment area of the power utility that provide the grid connection. The Figure below delivers an overview of the most popular power utilities and their Green power tariffs.

Power Utility	Green Power Tariffs CH-cent/kWh (€-cent/kWh)
EWZ (Zurich)	20.00 (16.60)
EWL (Lucerne)	19.50 (16.19)
CKW (central CH)	10.90 (9.05)
EKZ (Zurich)	9.80 (8.13)
BKW (Berne)	9.75 (8.09)

Table 17: Swiss Green Power Tariffs[45]

EWZ (Elektrizitätswerke Zürich) was one of the first power utilities offering green power tariffs. The figure below summarizes the major differences between FIT and green power tariffs within EWZ's offer.

ewz.solarstrombörse according to Art.7b, direct marketing of electricity	**KEV** according to Art.7a, feed-in tariff system
▪ Market based model ▪ Sale of energy and ecological benefit via products (voluntary) ▪ Admission of most efficient PV power plants ▪ Size independent acceptance of plants ▪ 20 year-supply contracts	▪ Fixed payment rates ▪ Payed by consumers due to surcharge on grid use ▪ No specific standards to be reached ▪ Prioritised acceptance of large PV power plants ▪ 25 year-supply contracts ▪ Redelivery of electricity to electricity companies

Table 18: Green power vs. FIT[46]

45 From May 2011, VAT excluded.
Currency exchange rate: 1 CHF cent = 0.83 EUR cent (1 EUR = 1.25 CHF)

46 Source: Wunnerlich, P (2011). Presentation: „ewz solar power exchange -15 years of experienceewz". EWZ

4.7.2 Main Barriers

Beside the periodic adaption of the FIT levels according to market penetration, the installed capacity and prise erosions of PV systems, **Austrian and Swiss** regulations have also implemented a budget cap limiting the financing means available for PV. Looking back to the past years, the yearly available budget was reached in a very short time leading to long waiting list of projects to be approved. Due to that fact in Switzerland the valid budget cap was revised at the end 2010 so that 10% of the available budget is allocated to PV systems only. Nevertheless waiting lists could still not be completely handled.

According to the **German Solar Industry Association** the main legal-administrative barriers for roof-mounted PV installation were derive from grid connection permits and administrative processes as indicated in the table below:

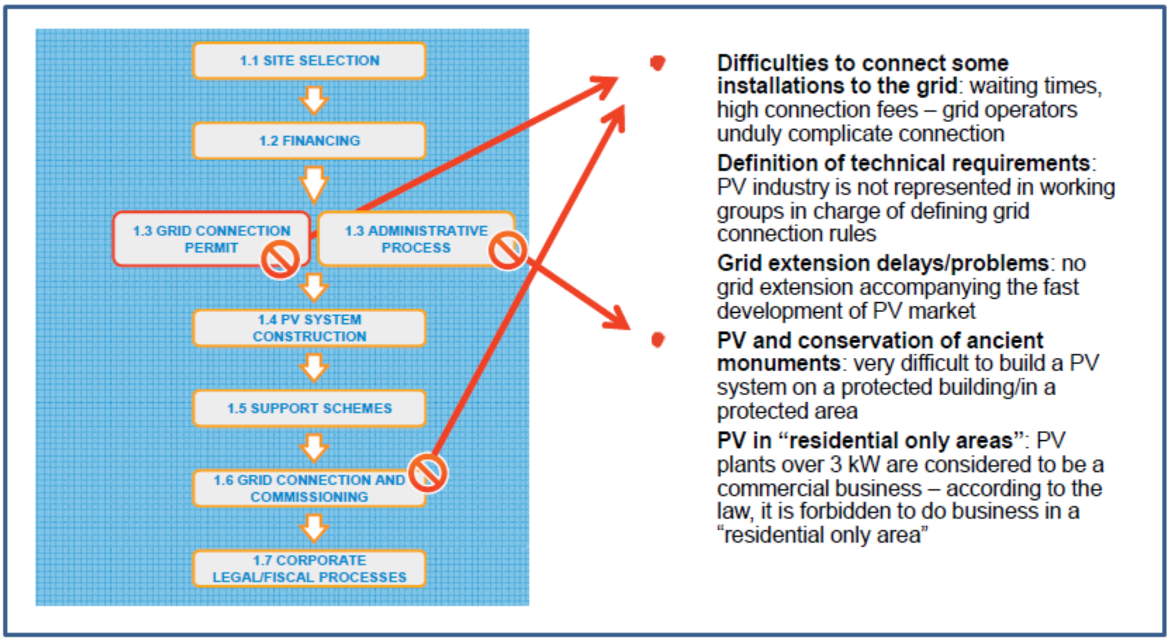

Table 19: Legal-administrative barriers in Germany[47]

[47] Source: Chrometzka, T. (2010). Presentation: "Market development and legal-administrative barriers in German". German Solar Industry Association.

4.8 Electricity price development

Even though electricity prices remained relatively stable in the last two to three years the overall evolution shows an upward trend. In Austria the price of electricity for the residential sector rose by approximately 40% since 2006, in Germany and Switzerland by about 20% during the same period and there are no indications that this trend will not continue in the future.

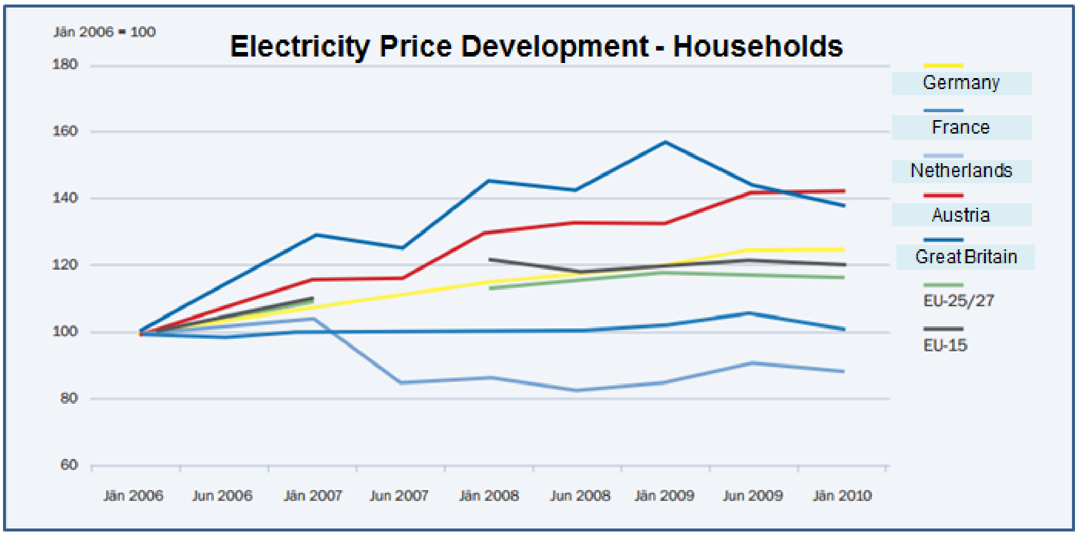

Figure 36: Electricity price development - residential segment[48]

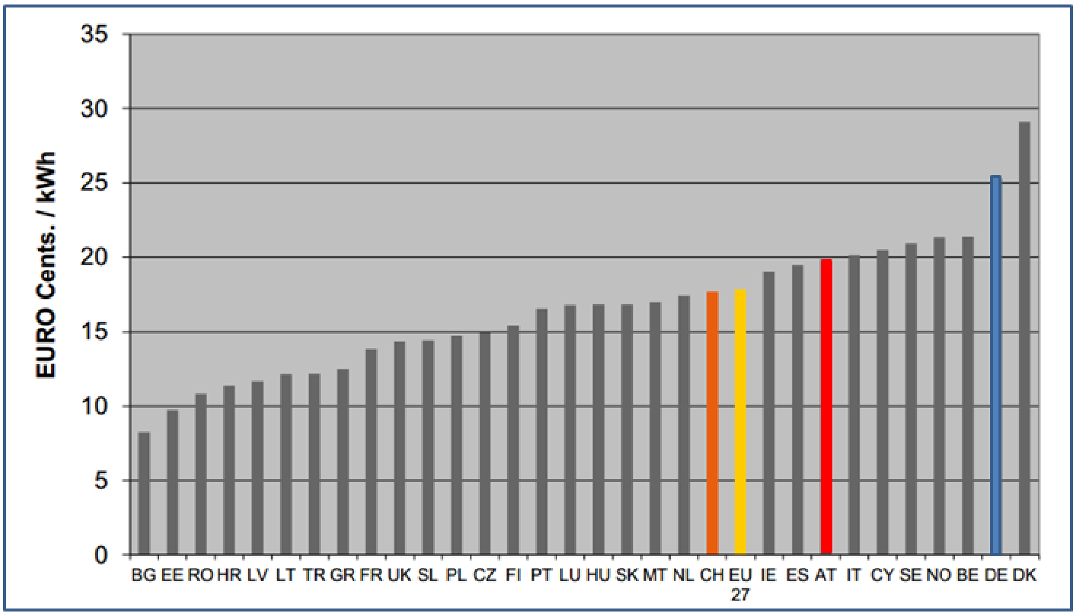

Figure 37: Electricity prices residential segment in 2011 (VAT incl.)[49]

48 Source:http://www.e-control.at/portal/page/portal/medienbibliothek/presse/dokumente/pdfs/econtrol-marktbericht-2010.pdf ; 18.02.2012

Herby the electricity prices vary according to yearly consumption respectively the market segment served. While the average prices in 2011 for the residential segment (up to 7'500 kWh/a) ranged between 18 and 26 Eurocent per kWh incl. VAT, the prices for the industry segment (>500’000 kWh/a) in contrast lied around 14 Eurocents per kWh VAT excl. as shown in the figures 33 and 34. The electricity prices for the business and trade segment can be expected within that range of the two extremes.

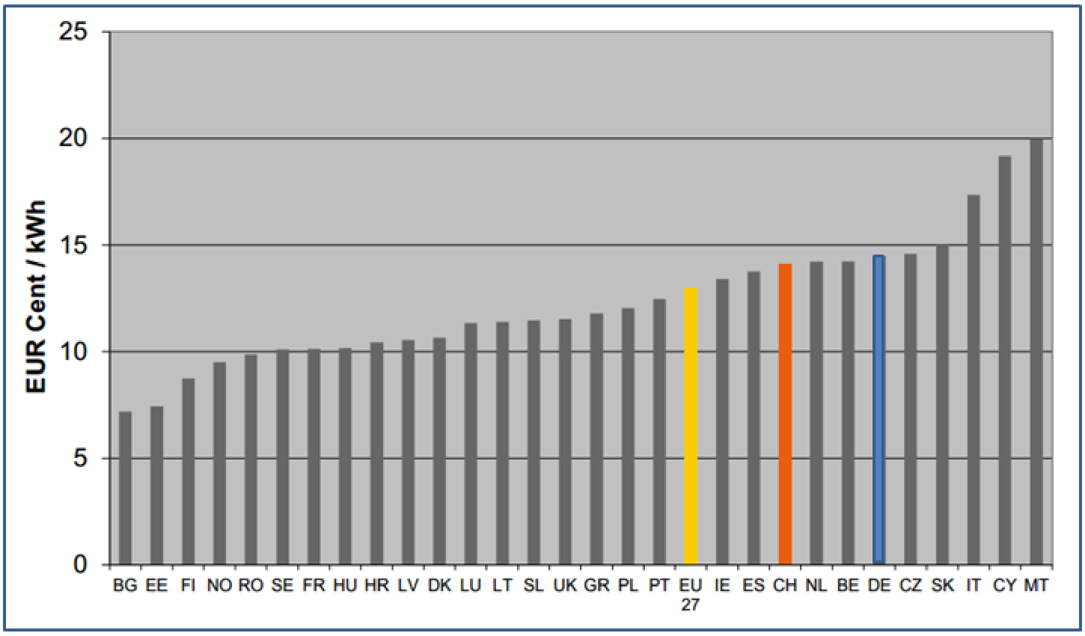

Figure 38: Electricity prices industry segment in 2011 (VAT excl.)[50]

4.8.1 Grid Parity

Grid parity is the point at which alternative means of generating electricity produces power at a levelised cost (LCOE) that is equal to or less than the price of purchasing power from the grid. Reaching grid parity is considered to be an important point in the development of new sources of power, the point at which it becomes a contender for widespread development without subsidy support. The term is most commonly used when discussing renewable energy sources, notably PV, wind and other RES.

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49 Source: http://www.strom.ch/uploads/media/VSE_08_Strompreise_11-2011.pdf ; 18.02.2012

50 Source: http://www.strom.ch/uploads/media/VSE_09_Strompreise_11-2011.pdf ; 18.02.2012

It is widely believed that a wholesale shift in generation to these forms of energy will take place when they reach grid parity[51].

Focusing on the LCOE of PV only, grid parity can be achieved for most continental Europe countries except Great Britain by 2020 as indicated in the figure below. However, studies performed by EPIA predict a more differentiated picture regarding grid parity. Thereby Central Europe (Austria, Switzerland and Southern Germany) will reach grid parity by 2020 while the northern part of Europe will need up to 10 years more. (The EPIA grid parity map is included in the appendix under Chap. 9.2)

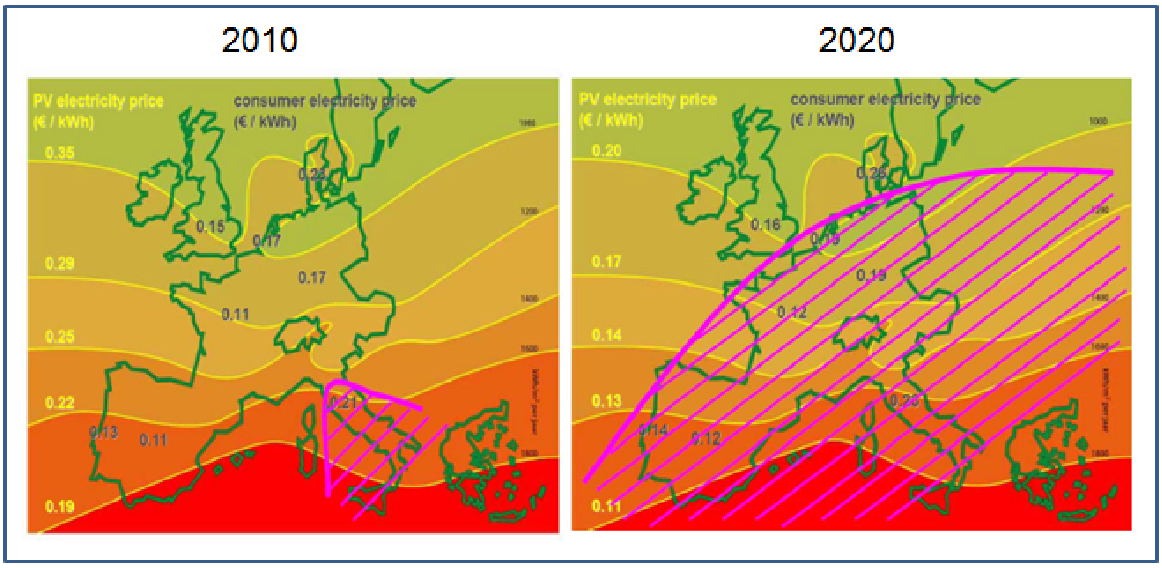

Figure 39: Grid parity in Europe[52]

When and where grid parity finally will be reached of cause largely depends on the R&D progress in PV technologies and the price evolution of PV system.

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51 Source: http://www.strom.ch/uploads/media/VSE_09_Strompreise_11-2011.pdf ; 18.02.2012

52 Source: Baumgartner, F. (2008). Presentation „Was kann der Solarstrom leisten?“ Zürcher Hochschule für Angewandte Wissenschaften ZHAW in Winterthur. Original Source: Wim Sinke, W. (2006). Euro PV Technology Platform. Brussels.

4.9 Target customers

The target customers represent the market segment in DACH that has been addressed in this work. These are mainly big supermarkets, food retailer chains, furniture stores and alike that have one thing in common, namely large parking areas for their clients that could be transformed into PV carports. Due to that fact and due to the noted visibility of such plants and the large interaction with the public, this niche market segment seems predestinated for the evaluation and for elaborating the proof of concept of PV installations in urban areas as the main subject of this master thesis.

The rational for that idea is not that fallacious as the following example proves. One of the first PV carport installations on a supermarket parking area was realized in Krawczyk / Germany for the EDEKA food retailer by BELECTRIC in July 2011.

Figure 40: PV Carport at the EDEKA-Supermarket in Krawczyk[53]

53 Source:http://www.windkraft-journal.de/2011/09/29/solar-frontier-und-belectric-realisieren-pv-parkplatzuberdachung/ ; 19.02.2012

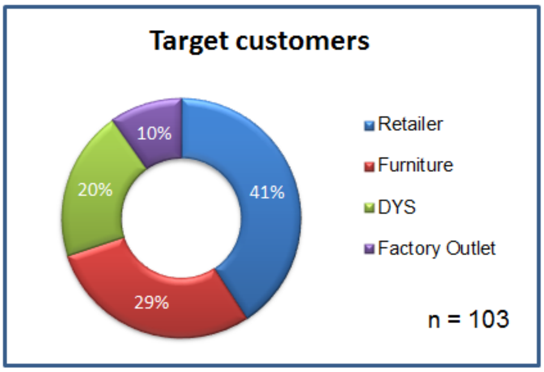
Thereby the new thin-film technology (CIS-modules) from Solar Frontier with a total installed capacity of 340kWp was used. According to BELECTRIC's CEO in Germany, Mr Martin Zembsch, the PV plant should produce about 340'000 kWh of electricity per year and save at the same time the equivalent of approximately 230 tons of CO_2 yearly[54].

4.9.1 Survey of the target group

The selection of the companies was based on Top retail market rankings related to their market penetration (e.g. number of point of sales and sales area), public publicity, size and business volume from the EHI institute[55], the Lebensmittel Zeizung.net[56] and other online publically available data[57]. The rankings overview is summarised in the annex under chapter 9.3 .Thereby the focus set was on:

- Supermarket chains (mainly food retailer)
- Furniture stores
- Do it yourself (DYS) shops
- Factory outlets

In total around 100 companies in were addressed in the three countries Austria, Germany and Switzerland as shown in the figures below:



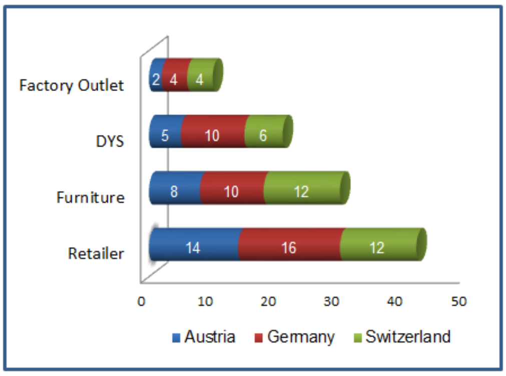


Figure 41: Distribution of the addressed customers

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54 Source: http://www.edeka-krawczyk.de/index.php/filialen-oeffnungszeiten ; 19.02.2012

55 EHI is a scientific institute of the retail industry. The 550 members of EHI include international retail companies and their associations, manufacturers of consumer goods and capital goods, and various service providers. http://www.handelsdaten.de ; 10.01.2012

56 Source: http://www.lebensmittelzeitung.net/business/handel/rankings/pages/; 10.01.2012

57 Source: http://de.wikipedia.org/wiki/Einkaufszentrum; 10.01.2012

The following figure provides an overview of all addressed companies. For internationally acting companies the respective branch in each country was contacted separately. Contact details were derived from the official web-sides. Where available the responsible people in charge of environment, marketing or PR were addressed directly. However, most companies do not disclose the contact data, so that in most cases only the general e-mail addresses have been used.

	Retailer (mainly food)	Furniture Dealer	Do-it-yourself	Factory Outlet
Austria	REWE Group, MERKUR, BILLA, PENNY, BIPA, SPAR, Hofer, LIDL, METRO GROUP, METRO, MEDIA-SATURN, MPREIS, pfeiffer, MARKANT Österreich, Zielpunkt, Nah&Frisch, ADEG	IKEA, XXXLutz, kika, Leiner, interio, de Witt Küche & Wohnen, RUTAR, Europa Möbel	BAUHAUS, bauMax, HORNBACH, OBI, hagebau	Parndorf Designer Outlet, Salzburg Designer Outlet
Germany	EDEKA, REWE Group, ALDI, Kaufland, LIDL, TENGELMANN, ALDI, METRO GROUP, real,-, METRO, dm, Schlecker, NORMA, ROSSMANN, Müller, famila	IKEA, Höffner, XXXLutz, porta, ROLLER, SEGMÜLLER, POCO Domäne, OTTO, tejo, möbel mahler, SCHAFFRATH	OBI, BAUHAUS, Praktiker, HORNBACH, toom, globus, EURO BAUSTOFF, EMV-PROFI, BayWa	Berlin Designer Outlet, zweibrücken the style outlets, Wertheim Village, Ingolstadt Village
Switzerland	MIGROS, coop, ALDI, LIDL, SPAR, Lekkerland, MANOR, Landi, DENNER, Volg, GLOBUS	IKEA, Pfister, Conforama, micasa, toptip, interio, diga, möbel hubacher, möbel märki, FLY, OTTO'S, Lumimart	JUMBO, coop bau+hobby, DO IT+GARDEN MIGROS, OBI, BAUHAUS	FOX TOWN, Outletpark Murgenthal, FASHION FISH, OUTLET AUBONNE

Table 20: Name of companies addressed for online survey

4.9.2 Questionnaire

The companies were addressed by a cover letter sent by e-mail providing them the link to an online questionnaire situated on the official web-sides of the TU Vienna[58]. It contained 13 different questions related to energy consumption, renewable energy, carports and some other statistical data. Cover letter and online questionnaire were written in German.

Figure 42: Extract of the online questionnaire

Below all the questions are summarized in a compressed form. The original wording and structure of the questionnaire can be found in the annex under Chap. 9.3.

58 http://newenergy.zserv.tuwien.ac.at/index.php?id=10174

Question 1:

- Does your enterprise regularly publish sustainability reports ?
  ⇨ Yes, since… / no
- If it does, what standard is used ?
  ⇨ GRI / own report / other

Question 2 / 3:

- Is the reduction of electricity / CO_2 part of your sustainability strategy ?
  ⇨ Yes / no
- What are the target values for 2012 and until 2020 ?
  ⇨ Absolut and in % for 2012 / and until 2020 ?

Question 4:

- Is your enterprise engaged in renewable energy projects ?
  ⇨ Yes / no / is planned
- If it does, what kind of projects are supported ?
  ⇨ Own projects / support of external projects / other

Question 5:

- How are these projects financed ?
  ⇨ Equity capital / debt capital / subsidies / other
- How many % of the yearly turnover are used in average for those projects ?
  ⇨ nothing / 1% - 5% / 6% - 10% / 11% - 15% / other

Question 6:

- What RE technology is mainly supported ?
  ⇨ None / PV / Solar thermal / Wind / Hydro / Geothermal / other
- Would you support electro mobility in one of the following means ?
  ⇨ Provide electro mobile charging stations / convert own vehicle fleet into electro mobiles / other

Question 7:

- Would your enterprise allocate suitable roof areas for PV energy generation?
  ⇨ Yes / no / some installations already available. The installed capacity is…
- Are you aware about the PV carports concept ?

  ⇨ Yes / no

Question 8:

- Would your enterprise allocate suitable parking lots to be converted into PV carports for energy generation?
  ⇨ Yes / no / some installations already available. The installed capacity is…
- Which of the following arguments is most valid to motivate your enterprise to install PV carports ?

⇨ None / CO_2 reduction / customer service / image

Question 9:

- How many point of sales (outlets) are available in Austria / Germany / Switzerland ?
  - ⇨ None / up to 10 / up to 25 / up to 50 / up to 100 / other….

Question 10:

- What is the average number of parking lots per point of sales ?
  - ⇨ < 50 / 50 to 99 / 100 to 149 / 150 to 199 / 200 to 249 / 250 to 299 / 300 to 349 / 350 to 399 / 400 to 449 / 450 to 499 / > 500 / other
  - ⇨ The total number parking lots for all point of sales is….

Question 11:

- Some statistical data regarding energy consumption in the last years ?
  - ⇨ Total energy consumption (GWh) …..
  - ⇨ Specific energy consumption (kWh / revenue) ….
  - ⇨ Specific energy consumption (kWh / sales area) …

Question 12:

- General remarks (optional):
  - ⇨ Please provide your comments and feedback…

Question 13

- Closing remarks (optional):
  - ⇨ Please provide the name of your enterprise…
  - ⇨ Please indicate the number of employees…
  - ⇨ Please provide your contact information…

The original wording and structure of the questionnaire can be found in the annex under Chap. 9.3.

5 Renewable Energy in urban areas

Urban environments are highly populated and built out. Modifications, upgrades and even maintenance to the grid can result in construction disruptions. Fossil fuel based distributed generation requires fuel storage, can be noisy, and increases emissions in urban areas already affected by poor air quality. Other renewable energies require either land or fuel resources that are scarce in the overbuilt environment: hydropower requires high level differences or interception of large water flows; biomass needs vast areas of fertile soils; wind energy, even using building mounted generators, has limited applicability in high density developments; deep heat mining can cause small earthquakes that are not appreciated in cities as happened in 2006 in Basel/Switzerland. There, drilling work for a planned geothermal power plant triggered a small earthquake that caused minor damage to buildings. The continuation of that project was finally terminated due to the large protests from the public[59].

Hence, the deployment of the solar electricity production in the urban environment is highly suitable and bares many advantages compared to other RES, as PV systems can be attached or integrated to buildings in a built-out land use scenario. They can be built at any scale and only need well oriented support and a low voltage electric grid, while producing the energy close to the consumer [55].

According to some IEA studies evaluating the potential of building-integrated PV, the possible contribution of PV electricity to the demand of a particular city lies between 25% and 40% for an average city in the DACH region, depending on the city structure and considering all the well-oriented roof and façade surfaces with the available technology [56]. However, these studies did not include the potential for the deployment of so called **solar carports**.

This type of PV application is receiving an increased attention lately. At the last **Intersolar Europe** in 2011, the world's largest exhibition for the solar industry, latest trends and developments were presented. Beside the progress in R&D, technology improvements and the PV market development, a steady focus shift more towards innovation for new applications and system design could be observed.

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59 http://www.swissinfo.ch/eng/Home/Archive/Man-made_tremor_shakes_Basel.html?cid=46232 19.02.2002

Topics like “Smart Grid”, “Smart Building and E-mobility” as well as “Smart PV Cities” are gaining on dominance. Thereby the exploitation of new areas for PV deployments, in particular **carports** enjoyed a great attention. Solar carports build a very interesting and promising alternative compared to ground-mounted PV plants as no area is lost. Beyond that the industry explores new concepts how to use the produced electricity for the **electric vehicle** charging that is expected to grow in the future[60].

5.1 Solar Carports

While “classical” ground-mounted, roof-mounted installations on buildings or even BIVP are becoming a de-facto a standard, PV installations on mid and large size parking areas so called **solar carports,** are a relatively new phenomenon. There are basically no studies about that kind of implementations and the available information is very limited so far.

Figure 43: PV Carport at Lausitzring in Germany[61]

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60 Source: http://www.solarserver.de/solar-magazin/nachrichten/aktuelles/2011/kw20/intersolar-europe-zeigt-neueste-photovoltaik-trends-zukunft-des-sonnenstroms-auf-der-weltweit-groessten-fachmesse-der-solarwirtschaft.html ; 19.02.2002

61 Source: Professionelle Solar Montagesysteme. Park@Sol Carports. Schletter GmbH. 19.02.2012

However, first small size implementation as shelters for bus stops, information stands or parking lots are date back to 2001 [57]. Other publications related to PV installations in urban areas and to traffic infrastructure mainly focus on PV noise barriers as “non-standard” application that were introduced for the first time in Switzerland in 1989 [58]. A very interesting and more recent publication illustrates the potential of photovoltaic carports to cover the energy demand of road passenger transport. The paper is based on simulations that were carried out for 48 parking lots in Frauenfeld, a typical Swiss medium-sized city of 22 665 inhabitants. Covered with solar carports, these parking lots alone would cover 15–40% of the energy demand by the city’s road passenger transport [59].

In general PV carports are basically considered to be a building. Therefore similar provisions are valid as for construction works. Usually an application for construction permit (building application) including construction plans, structural analysis about the statics and a concept of the de-watering are required. However, the construction licencing procedure varies from country to country and even from province to province. In some cases there is no need for a planning approval, advisable thus is to check the effective provision with the local authorities.

In principle there is no need for an adaption of the land-use plan because parking areas are considered as areas for business & trade in contrast to areas for living, work and agriculture [60].

However, beside the legal aspects a PV system integrated into non-building structure like a PV carport need to consider a range of other criteria such as irradiation, shading, orientation, visual impact, available surface and other technical requirements. Past experience has also shown that theft and vandalism can be a problem for the introduction of PV in these kinds of applications and must therefore be considered and taken care of.

5.1.1 Types of carports

A large variety of different constructions and design types of carports exists. Depending on the size of the planned PV carport (weight, height, etc.) and the location, wood, aluminum or steal constructions can be used. Thereby the three most common types of structures are corner supported, single center post and cantilevered. The decision as to what type of structure to use is highly dependent on the end users requirement. Traits or characteristics brought into consideration include overall cost, vehicle size and height, number of vehicles, city code, environmental conditions, subterranean conditions, amount of PV power needed and visual appearance. With respect to the three structure types the corner supported is the most common one [61].

Figure 44: Different solar carport designs[62]

62 **Top left**: ParkGreen is a Carport with a PV solar energy system for all types of vehicles. A unit of ParkGreen consists of a metal structure and complete integrated PV system with a installed power capacity of 3.6 kWp. ParkGreen has the option to incorporate a charging point for electric vehicles. An intelligent solution of communication ensures the data aquisition, the visualisation and remote plant monitoring of the PV system. The LED-lightning, de-icing-and snow melting system and the charging point for electrical vehicles can be controlled via GPRS. http://www.parkgreen.es/rcs/docs/ficha_eng.pdf , 20.02.2012

Top right: Solarladestation Point.One from EIGHT GmbH & Co. KG, Germany http://www.klimamensch.de/magazin/private-mobilitaet/klimafreundliche-autos/news.html 20.02.2012

Bottom: Solar Carport from New Power Project GmbH, Germany http://newpower-project.de/carport-systeme.html ; 20.02.2012

Beside the mounting construction of the carports roof, there are technically two other categories, when installing PV panels on parking lots as shown in figure 39 above. The first one is to cover only the parking spaces (i.e. the area immediately above the parked vehicles but not the access lanes) with a roof resting on beams, on which the PV panels are installed respectively integrated. The second category of constructions is to cover the whole parking lot, including the parking spaces and the access lanes as one large roof.

One further interesting option adapted from the cable car and ski lift technology was recently introduced on the market by Solar Wings[63]. Here the PV modules are fixed on cables that are drawn across the parking lot.

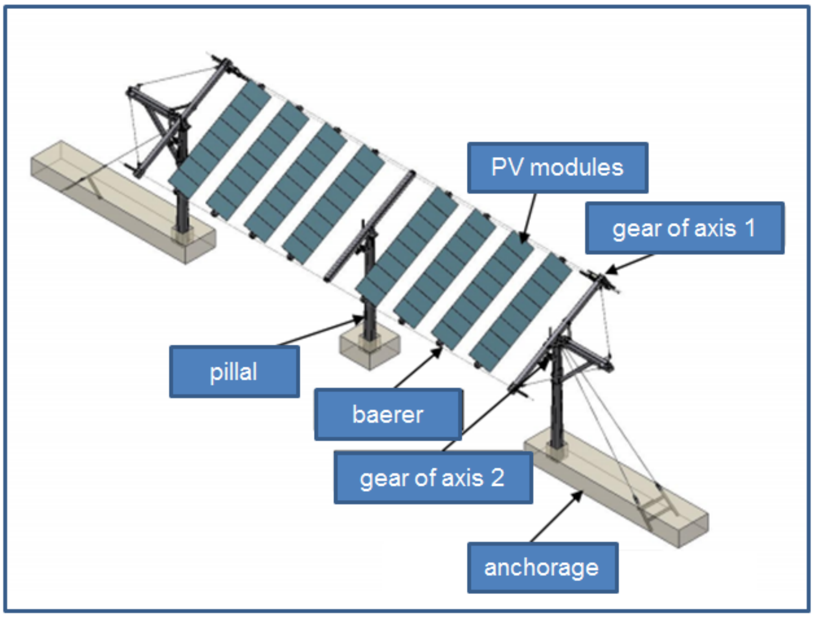

Figure 45: Solar Wings design[64]

Due to the tracking system enabling to optimise the position of the PV modules towards the sun, energy yields can be increased significantly. While single-axis systems reach a 15% – 25% surplus of electricity production, double-axis system can even reach 20% to 30% in Germany. In Southern Europe levels up to 30% can be achieved [62].

63 Source: http://www.solarwings.ch/ ; 20.12.2012
64 Source: http://www.flumroc.ch/downloads/solar/Photovoltaik_de.pdf ; 20.12.2012

According to the on-going research at the Zurich University of Applied Science (zhaw) in corporation with Solar Wings further improvements of that type of system are possible. By the implementation of a planar mirror further solar irradiation is linked to the PV module increasing the gain in energy yield up to 50% [63].
However, these systems are currently not yet commercially available.

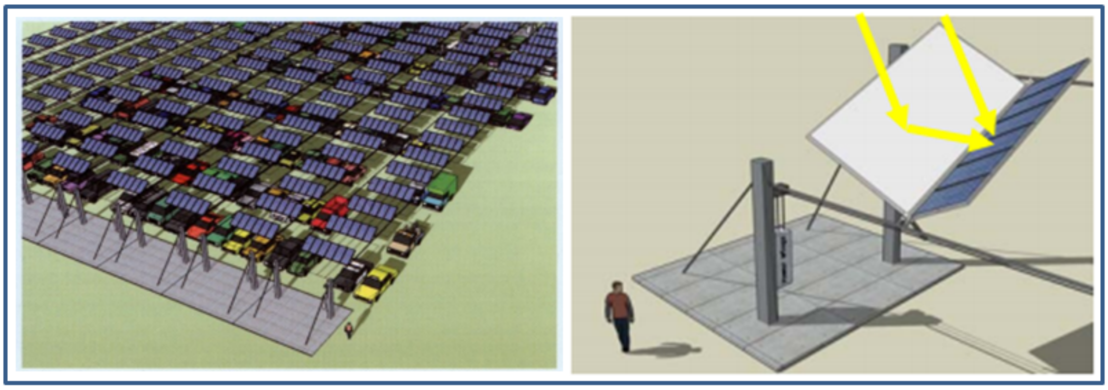

Figure 46: Solar Wings carport concept[65]

In summary both options, the roof-mounted type as well as the Solar Wings type have specific advantages and disadvantages. While the option with a complete roof provides not just PV electricity but also shade for the vehicles in summer and protection against snow and ice in winter, the Solar Wings type does not form a closed surface due to the gaps between the PV elements. On the other hand it needs less material and also less space. The only elements of the construction that are fixed to the ground are a small number of beams. Also, there is no need to align the PV panels with the parking spaces, which makes it easier to orient them towards the sun.

[65] Sources:

Left Figure:
https://home.zhaw.ch/~bauf/pv/papers/baumgartner_2010_Solar%20Wings_Skilifttechnik_ep_Photovoltaik_1_2010.pdf ; 20.02.2012

Right Figure: http://www.bmf-ag.ch/media/SolarWings.pdf ; 20.02.2012

5.1.2 Carport Supplier

How many PV carport supplier and project developer in that segment really exist on the market is a task not easy to answer. However, checking the number of possible supplier on the Top 50 Solar[66] search engine indicates that about 1'240 companies are registered in DACH providing all kind of services related to PV. Checking on PV carport supplier only, shows that about 27 companies are listed. This makes about 2%. It's of cause just a rough indication, nevertheless proving that the market in that segment is not yet saturated considering the fact that only few PV carports were build up to now. The most common supplier developing and installing large scale PV carports in Germany are summarized in the table below.

Company name	www-address
Avaris Energy GmbH	www.avaris-energy.de
BCW Brandenburg Carportwerk GmbH	www.carport.de
edel+stahl DESIGN GmbH	www.exclusivcarport.de
Enerix Alternative Energietechnik GmbH & Co KG	www.solarplusport.de
Heinrich Trick Baukonzept GmbH	www.trick-baukonzept.de
Gehrlicher Solar AG	www.gehrlicher.de
Gewa Garagenbau GmbH	www.gewa.de
Holzbau Gröber GmbH	www.sunside-carports.de
ID Carpe	www.id-carpe.de
iKratos Solar- und Energietechnik GmbH	www.ikratos.de
Iliotec Solar GmbH	www.iliotec.de
Juwi Holding AG	www.juwi.de
Mp-tec GmbH & Co. KG	www.mp-tec.de
PS Service/Projekte GmbH	www.perfectsolar.de
Schletter GmbH	www.schletter.de
Solar-Perfect	www.solar-perfect.de
SolarWorld AG	www.solarworld.de
Sonneninitiative e.V.	www.sonneninitiative.de
Sovello AG	www.sovello.de
VARIUS	www.varius.at
VM Edelstahltechnik	www.vm-edelstahltechnik.de

Table 21: PV carport supplier in Germany

66 Source: http://www.top50-solar.de ; 18.02.2012

5.2 Market potential

To evaluate the exact number of suitable large parking areas that could be transformed into PV carports is not possible, just as it's impossible to allocate the available parking areas to a specific customer segment (e.g. business, trade, industry, etc.) without appropriate statistical data. Nevertheless, two possible approaches are going to be presented here that could deliver rough estimates. The focus thereby will be set mainly on the potential in Switzerland. While the potential in Austria will be assumed as comparable to Switzerland, for Germany a multiplication factor is needed, that accounts and reflects the ratio in terms of country size, geography and number of inhabitants. The two methods are:

- Estimates based on building integrated PV plants
- Estimates based on sales area of shopping centers

However, it's appropriate to define the PV carport segments in terms of size and output power first. The three main segments can be defined as residential, commercial and industrial PV systems. Residential applications cover the range between 1 to 10kWp, commercial 10 – 100kWp, while industrial applications start at 100kWp reaching levels of multiple MWp.

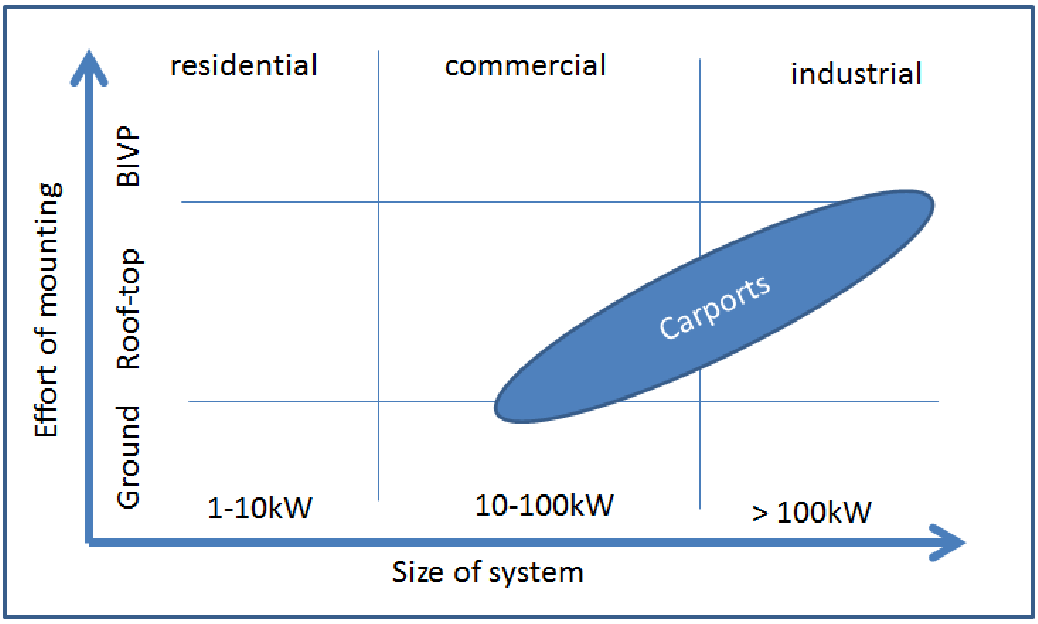

Figure 47: PV Carport segmentation based on system size

The focus in this work is set on commercial and industrial applications starting with minimum size of 100kWp. Since the power output is always related to a certain area available it is meaningful to set it in relation to the size of a parking lot.

The typical area size of a passenger vehicle parking lot in the DACH countries is 12.5 m^2. Hence, the minimal size of a commercial PV carport can be set to 5 parking lots considering typical commercially available PV module technology as indicated in the figure below. However, parking lots for minimum 20 and more vehicles are in the focus set here.

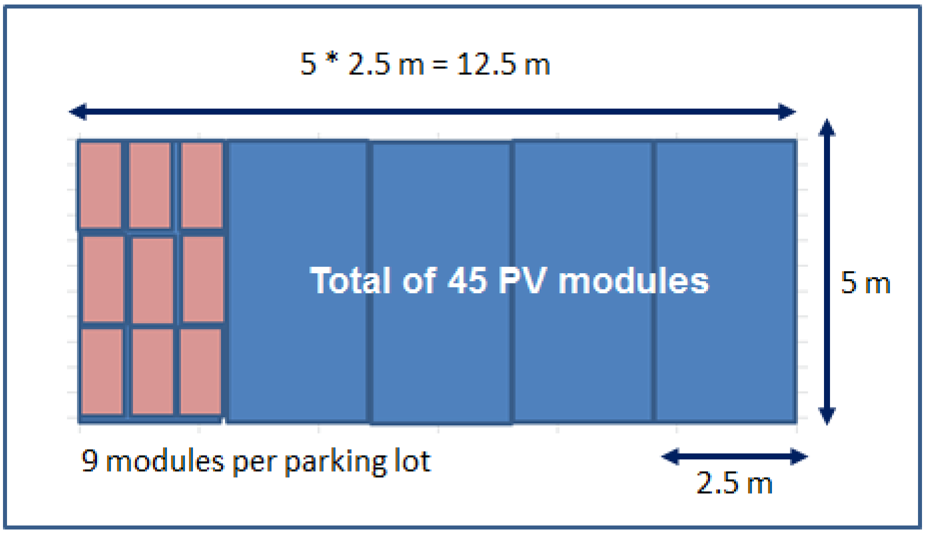

Figure 48: Minimum size of a commercial PV Carport

Determining the potential of buildings and neighborhoods for the generation of solar electricity has been the subject of numerous studies to date. Another option is the installation of PV elements on transport infrastructure itself. The most prominent study on this subject was carried out by Nordmann and Clavadetscher, who analyzed extensively the PV potential of noise barriers along Swiss motorways [64]. The surface covered by parking lots represents yet another unexplored potential for the generation of PV solar energy.

According to the Swiss land use statistics (Arealstatistik) from 1994, parking lots cover 26.5 km^2 or 0.06% of the national territory[67]. Because of Switzerland's growing population and prospering economy, the size of the parking areas has almost certainly increased since the year of the survey [59]. Furthermore, only lots with 10 or more parking spaces are identified as parking areas. Smaller lots are treated as part of the surrounding land use (e.g. housing area, industrial area), so the statistics systematically underestimate the overall surface area for parking[68]. Using the same ratio for Austria and Germany leads to areas of 50 km^2 and 214 km^2 respectively. This equals to roughly 23'240'000 parking spaces of the size defined (2.5 m x 5m) or about 32'000 soccer fields.

Applying the rules of thumb defined by EPIA to estimate the architecturally suitable part of the buildings surface (roof) with good solar yields in relation to the buildings ground floor area may be an appropriate approach to be used here. The potential is expressed by the so called "utilization factor". For buildings in Western Europe the utilization factor is 0.4 [56].

To estimate the potential area suitable for PV carports for the segment group as defined under chapter 4.9. (large supermarkets, food retailer chains, furniture stores, etc.), the number of parking lots must be known. Since no statistic could be found providing that figure, the number of parking lots will be estimated based on the sales are of these shops.

According to some studies carried out in Germany the average number of parking lots for shopping centres lies between 50 and 100 per 1'000 m^2 of sales area [65]. Usually large shopping centres are situated in the city agglomeration where enough space is available. Hence also the number of parking lots is greater compared to city centres. Considering Germany's 644 largest shopping centres[69] with 16 million m^2 of sales area and applying the 100 parking lots per 1'000 m^2 rule, results in a total of

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67 Sources: http://www.bfs.admin.ch/bfs/portal/de/index/themen/02/03/blank/data/gemeindedaten.html ; 19.01.2012

68 According to the information from Mr. Bayeler; Swiss Federal Statistical Office FSO; Land use Statistics. 23.01.2012

69 Source: http://www.markenartikel-magazin.de/handel/artikel/details/100398-anzahl-der-einkaufszentren-in-deutschland-steigt-weiter/ ; 23.01.2012

1.6 Mio parking lots. Assuming that only 50% are situated outside and not in car parks the number is reduced to 800'000 parking lots for Germany only. For Austria's largest 201 shopping malls and retail parks[70] the number of parking lots applying the same ratio reaches about 170'000 parking lots.

According to the Credit Suisse Economic Research from 2006[71], Switzerland holds one of the highest ratios in sales area relative to the number of inhabitants, 1.6 m^2 per capita compared to 1.3 m^2 per capita for Germany and Austria. The total sales area is 11.97 million m^2 as indicated in the figure below.

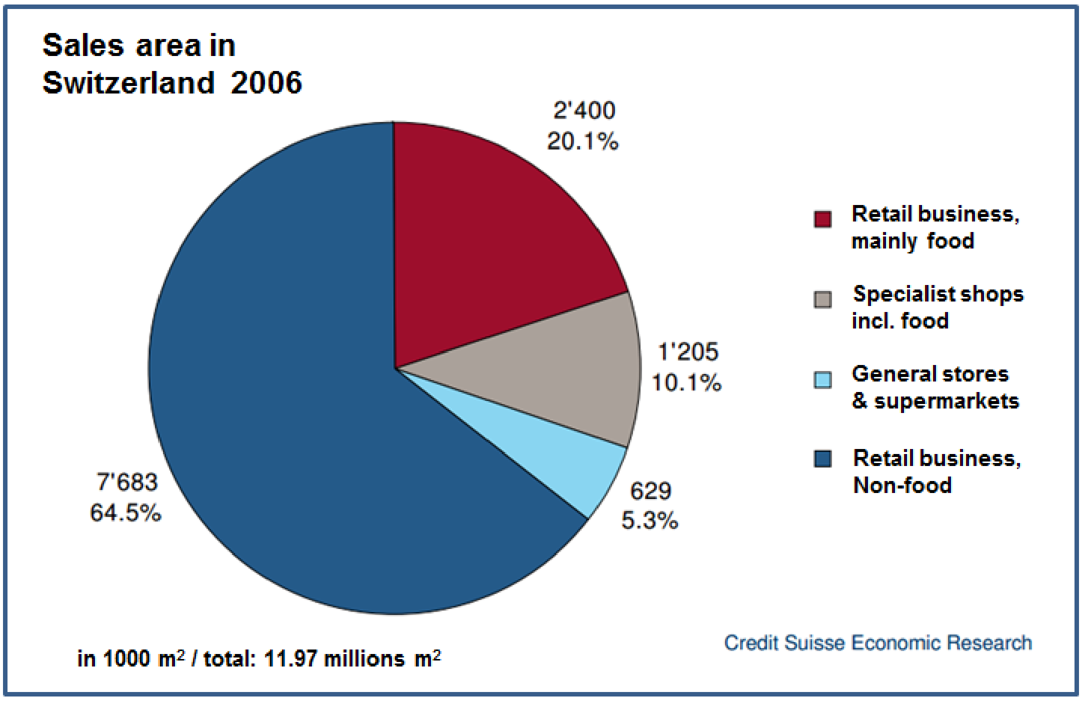

Figure 49: Sales area in Switzerland

Approximately 50% of all stores are located in city centres and will therefore not be considered, since the great portion of parking lots in Swiss cities is located in car parks. About 30% accounts for stores in the agglomeration, which makes a very rough estimate of 4 million m^2 of sales area.

70 Source: http://www.standort-markt.at/pictures/file_1309173450-0f0b9f2c42e7be00847b08f74fa97e07.pdf ; 23.01.2012

71 Source: http://www.curem.ch/images/horizonte-15-10-08/pdfs/Hasenmaile_Fredy_Retail_Asset_Markt_081015.pdf : 23.01.2012

Applying the 100 parking lots per 1'000 m² of sales delivers 400'000 parking lots. Assuming that only 50% are outside the number of parking lots 200'000 are remaining.

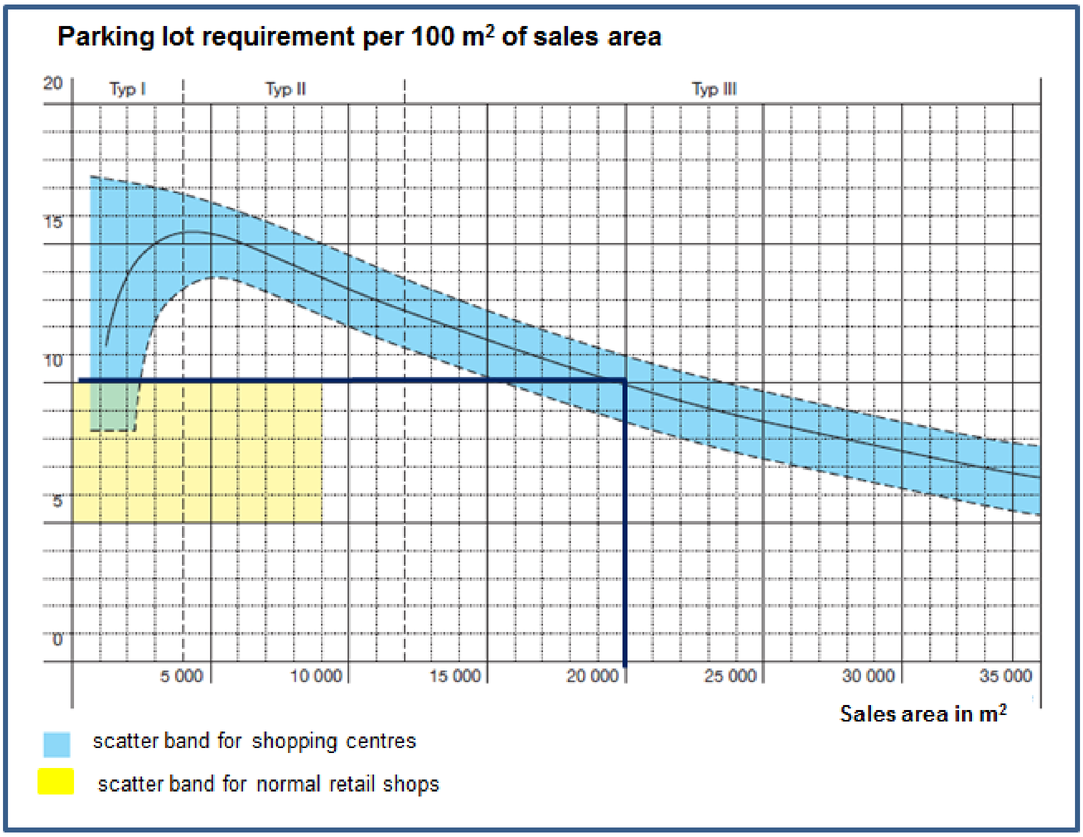

Figure 50: Number of parking lots proportional to sales area[72]

Summing up all potentially available parking lots of the target customers (retailer, shopping centres, etc.) in Austria, Germany and Switzerland delivers approximately 1.2 million parking lots or 15 km² suitable to be converted into PV carports.

Considering that up to now more than 90% of all shopping centres and retailer have not realized any PV carports yet, the potential is high and the outlook for that niche market is promising unless other market barriers are dominating.

72 According to Swiss norm 640290 valid for shopping centres to determine the number of parking lots in proportion to the available sales area [66].

Example: 2'000 ± 200 parking lots for a sales area of 20'000 m².

5.3 Energy yield vs. area

Various PV technologies deliver different energy yields for the same area used. Hence, it's evident that the choice of the "right" PV technology is a major factor in determining the yearly energy yields for a given parking area to be transformed in a PV carport.

As shown in the figure below, modern HIT modules (Heterojunction with Intrinsic Thin layer) deliver the best results in terms of energy yields in relation to the area required. Mono and poly crystalline silicon modules deliver comparable results, while amorphous silicon module energy performance is slightly better it requires up to 2.5 x more space compared to the other types.

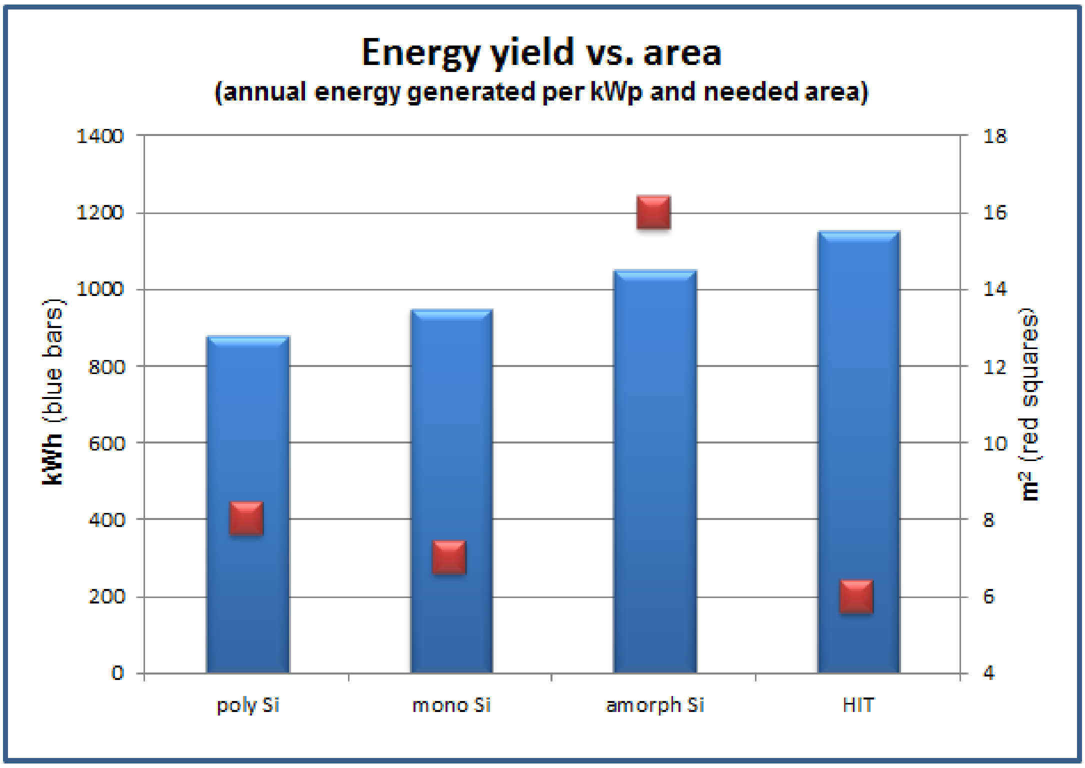

Figure 51: Energy yield vs. area for different PV technologies

However, mono and poly crystalline PV modules represent a mature technology with well know long-time performance effects (e.g. degradation). Thin film technology in contrast may bear a certain risk as no evidence regarding long-term behaviour for this rather new type of PV exists today.

5.4 Price & Profitability

Beside the energy yields delivered by a certain PV technology the price of the chosen PV module types represents of cause one other important factor in the investment decision process for PV carport implementations.

While the best in class technologies were presented and discussed in previous chapters, the quality of performance (module efficiency, energy yield, long-term effects) for a given technology still can vary according to product and producer. These differences in quality are finally reflected in the price of the module.

For commercially available standard applications, crystalline silicon modules are usually the most expensive compared to mono crystalline or thin film technologies. However, there is no one price for a certain technology but rather a price range. The figure below indicates the current[73] price levels and the overlap (yellow marked field in figure 48 below) for turnkey installations.

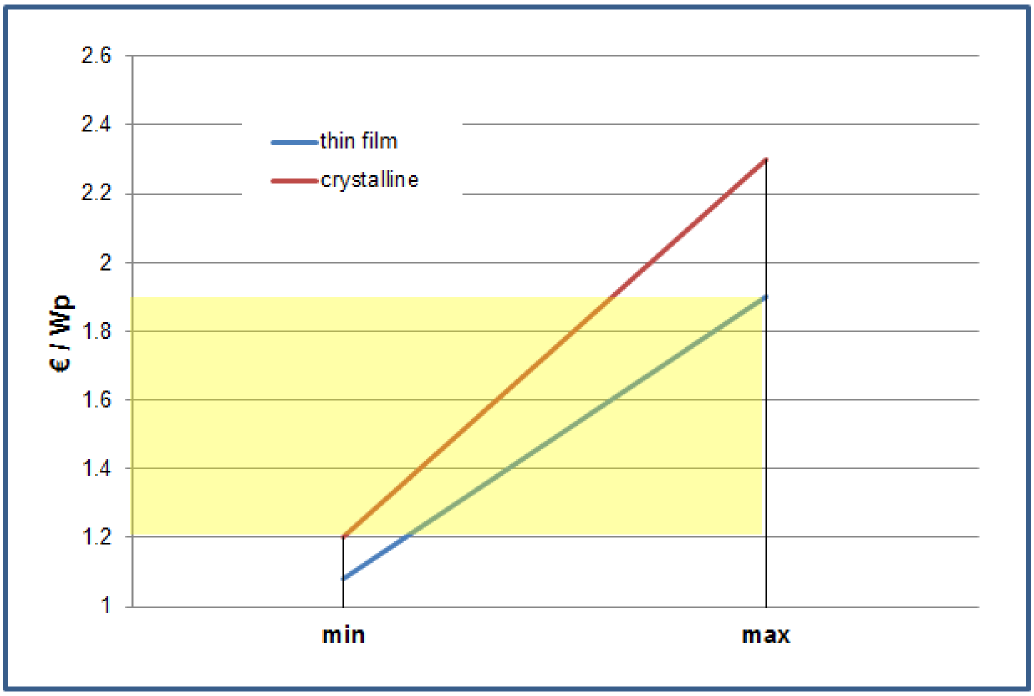

Figure 52: Price comparison of different PV module types

Thus it is appropriate to decide and prove from case to case what technology shall be used according to quality requirements, risk tolerance and even esthetic preferences.

73 Average prices from December 2011.

But finally and in most cases economic measures from financial evaluations based on capital budgeting as explained in chapter 3.3.2 are the predominant driving forces for the realization of a project. The most common measure and one of the first indicators for investment decisions is the profitability. Usually it's named in finance as rate of return (ROR), also known as return on investment (ROI), rate of profit or sometimes just called return.

The profitability expresses the ratio of money gained or lost on an investment relative to the amount of money invested. The amount of money gained or lost may be referred to as interest, profit/loss, gain/loss, or net income/loss whereas the money invested may be referred to as the asset, capital, principal, or the cost basis of the investment. ROI is usually expressed as a percentage.

As explained earlier the supporting measures (FIT) or the gain for generated electricity (kWh) from a grid connected PV carport installation varies according to size, respectively installed capacity (kWp) for each country. The table below shows the current valid tariffs for roof-mounted PV installations in Austria, Germany and Switzerland.

FIT 2012	< 30 kWp	30 -100 kWp	100 – 1MWp	> 1 MWp	validity
Austria	0.230 €/kWh	0.230 €/kWh	0.230 €/kWh	0.230 €/kWh	13 years
Germany	0.2443 €/kWh	0.2323 €/kWh	0.2198 €/kWh	0.1833 €/kWh	20 years
Switzerland [1]	0.3047 €/kWh	0.3304 €/kWh	0.2625 €/kWh	0.2542 €/kWh	25 years

1) For Switzerland following classifications apply: ≤ 30 kWp / ≤ 100 kWp / ≤ 1 MWp / > 1 MWp
FIT valid from 1.03.2012. Exchange rate: 1 CHF = 0,82805 € (1 € = 1,20766 CHF)

Table 22: Different FIT for PV carport installations according to installed capacity

Consequently the profitability is dependent from the energy yield for a given installation (kWh/kWp), the investment costs (€/kWp) of that installation and the amount of the FIT received for a particular PV plant size (kWp) and its type of installation. For PV carport installations the FIT for roof-mounted applications are valid. All other influencing measures are related to those three factors. These are mainly the cost for operation and maintenance that can be expressed as % of the investment and taxes on the earnings.

Calculating the theoretical profitability applying the discounted cash flow methods as explained earlier for a typical commercial size PV carport installation (roof- mounted with installed capacity of 100kW) in Germany following profitability levels can be achieved for different energy yields[74]:

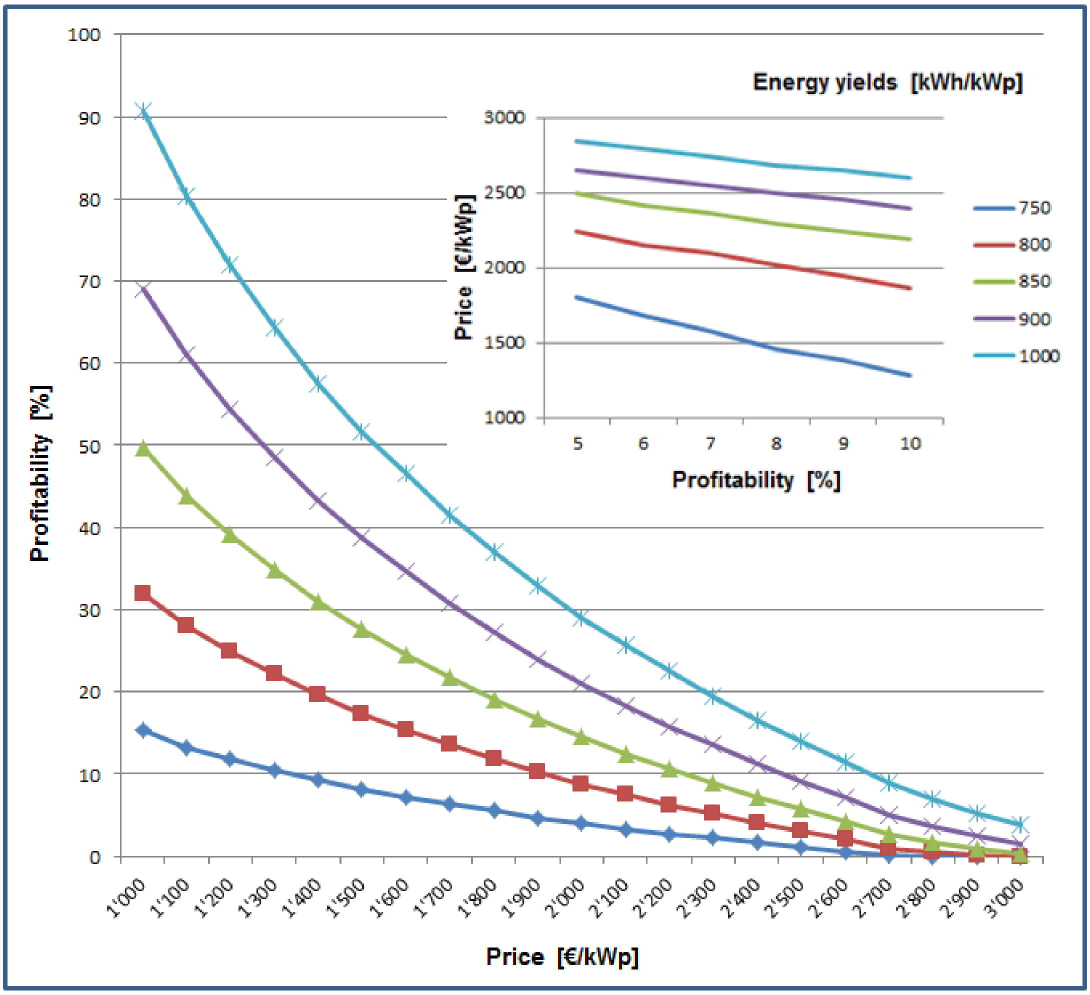

Figure 53: Expected profitability according to PV output power in Germany

Evidently, the lower the investment cost the better the profitability as shown in the figure above. Higher energy yields lead of cause to better financial performance, consequently the profitability is higher.

The small inlet in the graph is an extract of the theoretical profitability levels indicating the currently expected market prices (€/kWp) for PV modules and thus the profitability range that can be expected on the market.

74 Tax effects disregarded. Maintenance costs assumed as 1.5% of total investment.

Is a project profitable in Germany, it will be in any case in Switzerland and Austria, as Germany has adapted the most aggressive FIT (low) compared to the other two, assuming that investment costs are similar for all three countries and neglecting tax aspects. However, the investment decision finally depends on the minimum acceptable rate of return which can be achieved as indicated in figure 53 above. These rates imply that in the best case no bank loan is required and the project is financed by own financial means. Is debt financing required, the payment of the interest rates must be incorporated which leads at the end to lower rates of return, respectively the profitability of the project. Nevertheless, profitability is still given considering currently charged interest rates from banks in the range of 1.56 % to 7.66 % depending from the retention time of the loan and the financial reliability of the applicant[75]. However, profitability must be checked case by case.

In summary, at first glance Switzerland seems to be most attractive in profitability terms due to the high level of FIT and their validity duration, followed by Germany and finally by Austria for a typical PV carport installation. Considering the large market potential in Germany due to his market size, it would be probably the most attractive market. This finding corresponds with a study carried out by the Bank Sarasin as shown in the figure below[76].

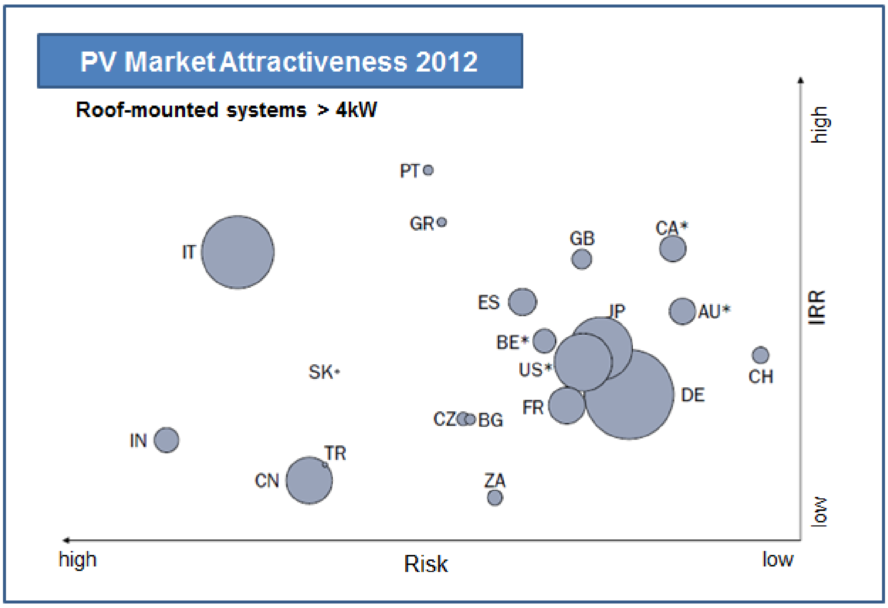

Figure 54: Market attractiveness for PV installations

75 Source: Photon Magazine 2/2012

76 Source: Bank Sarasin Report (2011). Solarwirtschaft: Hartes Marktumfeld – Kampf um die Spitzenplätze. CH-4002 Basel. www.sarasin.ch

5.5 PV carport show case

This simple hypothetical show case of a PV carport installation shall demonstrate the potential and the energy yields achievable for a common Swiss urban area. IKEA Spreitenbach was chosen for this purpose.

5.5.1 A PV carport for IKEA

Spreitenbach is a typical community in the agglomeration of the city of Zurich with many shopping centres and furniture stores, well reachable by private traffic. Most shops provide therefore for their customers parking possibilities.

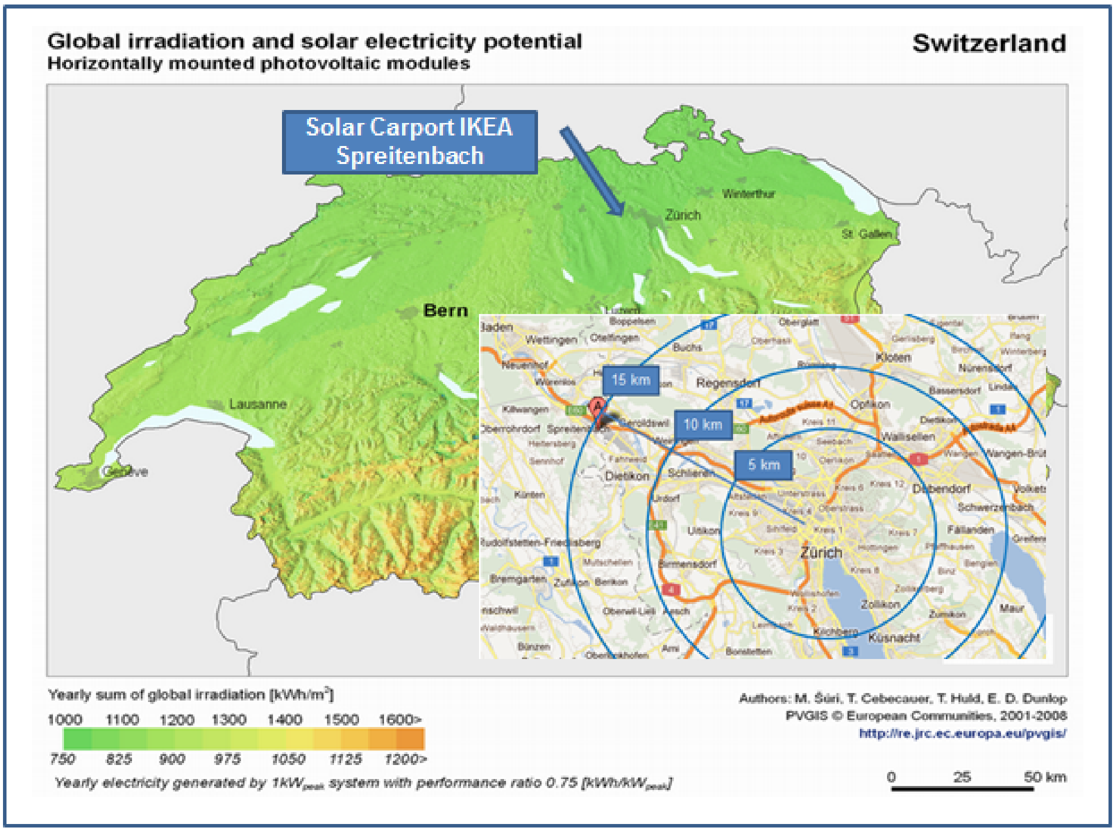

Figure 55: Average solar irradiation at Spreitenbach[77]

As indicated in the irradiation map above, the geographic location of Spreitenbach represents the average irradiation levels valid for Switzerland and comparable with Austria and the South of Germany.

[77] Own assembly. Source of irradiation map: http://re.jrc.ec.europa.eu/pvgis/cmaps/eu_hor/pvgis_solar_horiz_CH.png ; 22.01.2011

Figure 56: Photo of the IKEA store in Spreitenbach[78]

Figure 57: Parking area at IKEA Speitenbach[79]

For the simulation a common commercially available HIT-type crystalline silicon PV module[80] was chosen. According to the geographic location and the orientation of the parking area an azimuth of 45º was determined. The available area is set to approximately 3'200 m^2 counting only the marked parking lots on the left side (256 parking lots). Further details are summarized in the figure below.

78 Source: http://www.qype.com/place/145447-IKEA-AG-Spreitenbach/photos/2267174 20.02.12
79 Source: Picture from Google Earth. 20.02.2012
80 Source: http://www.solarplaza.com/top10-crystalline-module-efficiency/#sanyo ; 20.02.2012

Feature	PV Module
Type	Crystaline silicon HIT-N240SE10
Efficiency	19 % (STC)
Nominal power	240 W/m²
Price	ca. 500 €

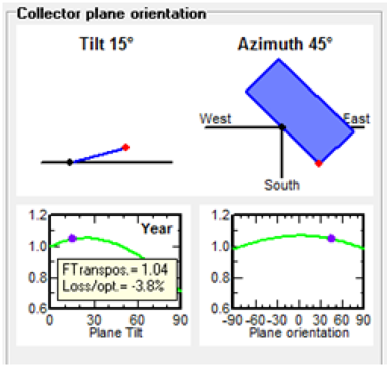

Figure 58: Characteristics of the PV installation

For the given location and the size assumed an average energy yield of approximately **472MWh/year** can be gained.

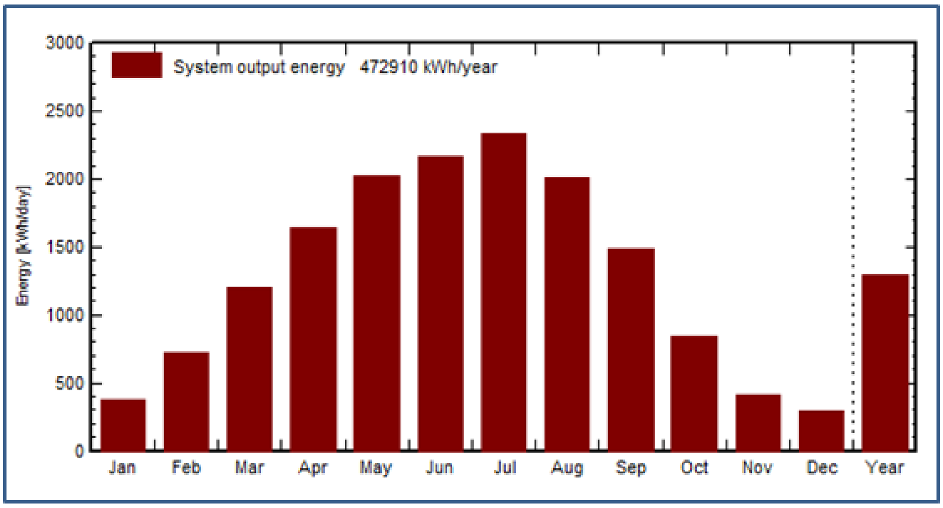

Figure 59: Yearly PV carport energy output

472MWh/year is equal to the yearly average energy consumption of about 95 Swiss households[81]. However, shopping centres and IKEA in particular have a specific energy consumption of around 70kWh/m^3 of sold goods. Hence, that amount of self-generated electricity could cover a substantial part of the typical energy consumption sources as [67]:

- illumination
- ICT infrastructure
- ambient cooling / heating
- hot water

81 Source: http://aew.ch/internet/aew/de/wissen/informationen/downloads.-ContentLeft-0011-File.File.FileRef.pdf/typischer_haushalt-stromverbrauch_SEV-VSE-Bulletin_19-2007.pdf ; 20.02.2012

5.6 CSR, Environment & Renewable Energy

With the help of the survey and the answers to the online questionnaire provided by the targeted market segment as described in chapter 4.9 some insight about the CSR (customer social responsibility) related to the environment and renewable energy should have been gained. The focus set thereby was to prove the awareness and to receive some information about the application of renewable energy sources and in particular PV technology for carports as a possible application. Further questions were related to company measures regarding CO_2 reduction and electricity saving targets. The approach and all questions are summarized in chapter 4.9.2 and in the annex.

Target customers invited to participate on the survey were large retail chains, furniture shops, Do it yourself (DYS) stores and a few factory outlets, 103 in total as shown in the figure below. These companies represent the top 20 in their specific market segment in DACH.

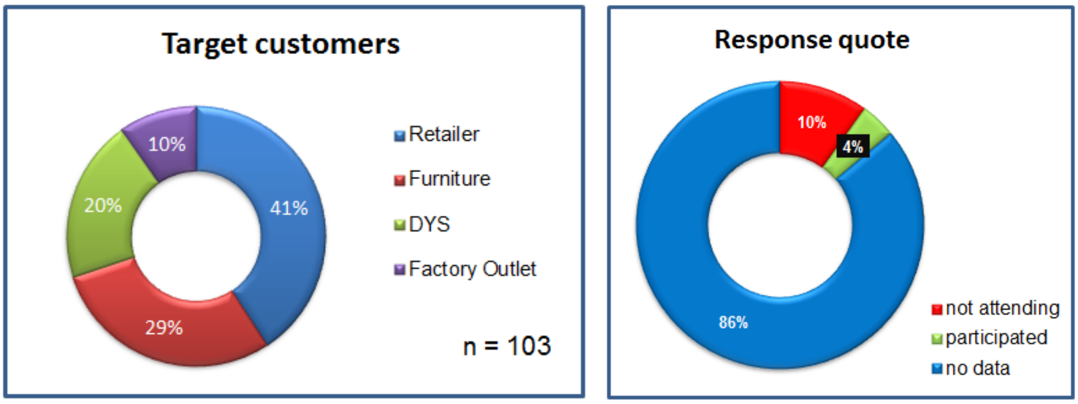

Figure 60: Target group & response quote

Unfortunately only very few have participated and filled out the questions. The response quote reached only 4%. The quality of the answers however was rather poor and not sufficient to make any reasonable conclusions or to elaborate a trend. 10% refused to participate due to not having enough resources to answer to each survey. From the remaining 86% not data received.

Since the survey did not deliver any useful results an alternative research approach was chosen and carried out.

5.6.1 Alternative survey

For the alternative survey the same target group as for the online questionnaire was chosen except the outlet stores. These were not considered in the qualitative survey. This was based on the examination of publicly available information on the www-side of each of the 95 company related to RES. The distribution of the different market segments and among the DACH countries is shown in the figure below.

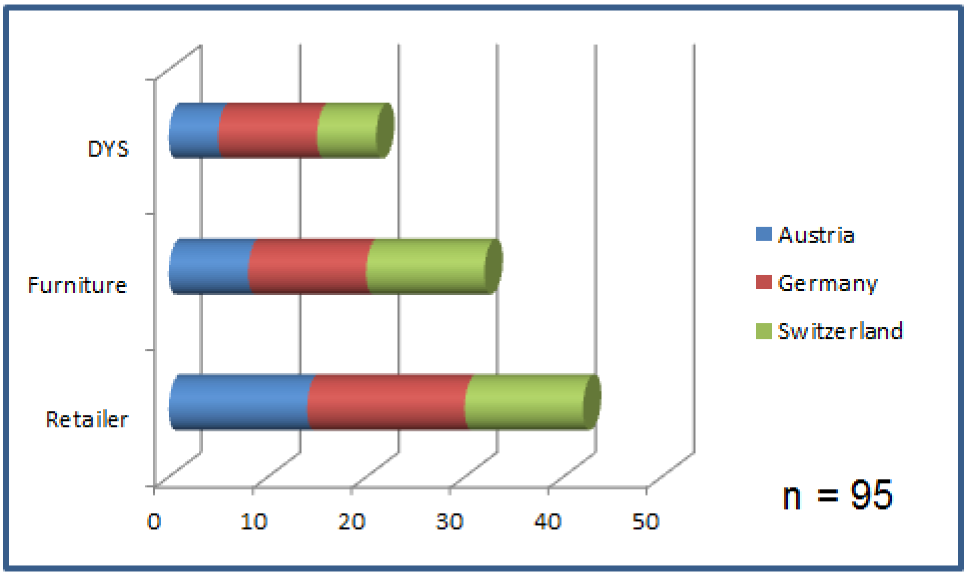

Figure 61: Target group of the alternative survey

The findings are to be evaluated as subjective reflecting only the information available on the official company web-sides. Corporate social responsibility in terms of the involvement in social projects, corporate governance, fair trade, recycling or support of the nature and environment and alike were not considered. Only statements and actions directly related to the support and the utilization of RES were checked and considered. Further, it can’t be obviated that the companies are involved in some way but do not publish it on the web. Nevertheless, the results should deliver some indication about the communication and presentation of the activities related to RES towards the public.

In the first step only information regarding RES and sustainability were checked. Thereby it was distinguished if the company publishes an official sustainability report or only provides some information on the web-side. If both were available, consequently both were counted. For internationally acting companies like IKEA, REWE Group, Schwarz Group et al. the web publication from each country were checked separately and accounted, thus comparison must be done on a country level and not as total. However, the reports on corporate level were counted only ones.

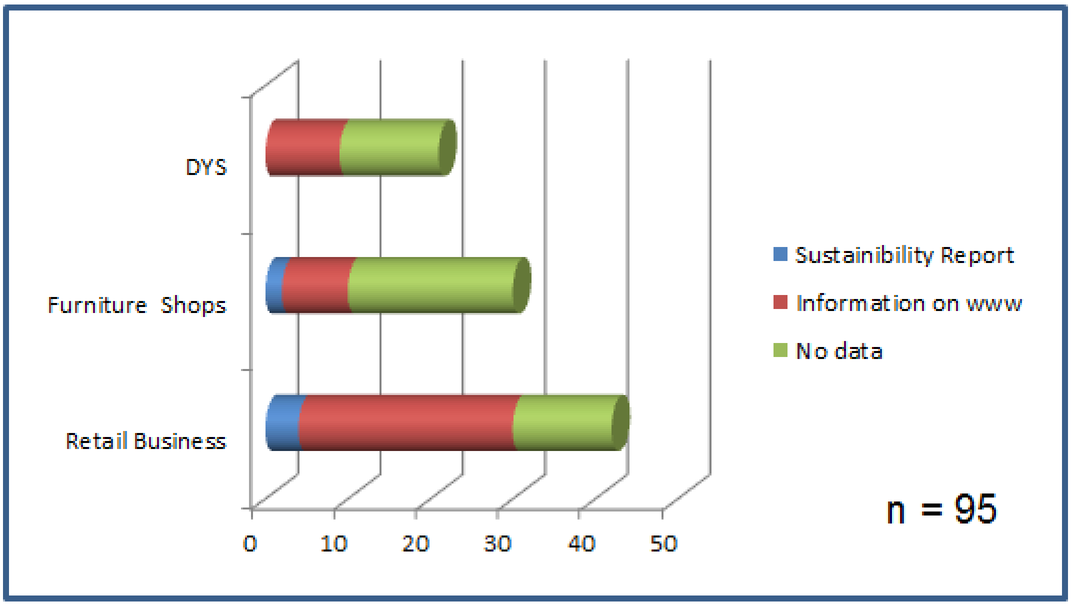

Figure 62: Target group of the alternative survey

Comparing the three segments, retail business seems to be most active compared to the other two. DYS propagate sustainability and energy efficiency but rather on the products offered than as part of the company's strategy. The quality of the information varies very strongly from rather poor to excellent, however that aspect was not considered.

Reports from the retail business are provided by the Rewe Group (DA), Kaiser's Tengelmann (D), Migros (CH) and Coop (CH). Only Migros and Coop apply the GRI reporting standard. From the furniture segment only Otto GmbH and IKEA publish sustainability reports.

Though some companies do not publish official reports, it doesn't necessary mean that CSR is not an integral part of the strategy as can be seen on the following example.

SPAR has adapted an integrated CSR strategy covering economic, ecologic and social aspects.

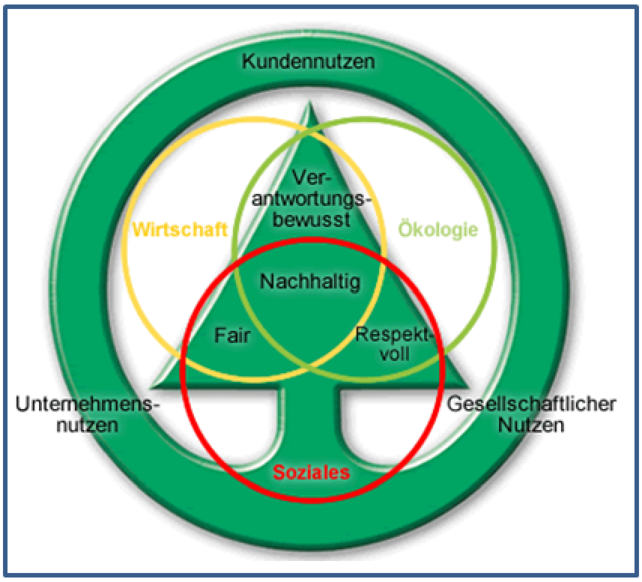

Figure 63: Triple Bottom Line approach of SPAR

One other example is represented by IKEA's Sustainability Direction that outlines the priorities for 2015. They shall influence the entire value chain, from product design and development to the very end of a product's life:

- Offering a range of products that are more sustainable
- Taking a leading role towards a low carbon society
- Turning waste into resources
- Reducing the water footprint
- Taking social responsibility

More specific programs regarding RES and the environment were also introduced like the "IKEA Goes Renewable" (IGR). This project has the aim to reduce carbon dioxide emissions from IKEA buildings, while on the long-term all IKEA buildings shall be supplied with 100% renewable energy. Specific energy efficiency targets stipulate that the current average performance of existing stores are close to 70 kWh/m^3 of sold goods and shall be reduced to 45 kWh/m^3. New stores in some other locations have even the potential to limit their energy consumption to 25–30 kWh/m^3 of sold goods[82].

[82] Source: IKEA Sustainability Report 2010 ; 20.02.2012

In the second step some more detailed information regarding RES and sustainability were checked. The focus thereby was set on:

- Are there any CO_2 reduction targets
- Are there any electricity consumption reduction targets
- Is PV technology used or supported
- Are other RES beside PV used or supported
- If RES used but not from own production
- Is e-mobility supported or made available
- Are charging station provided
- Are PV carports installed

Also from this perspective the retail business seems to be most active compared to the other two. A very dominant approach can be observed in CO_2 reduction and energy efficiency increase of the buildings as presented in following example.

Figure 64: Öko-BILLA building[83]

According to BILLA Austria the new shop concept "Öko-BILLA" that was recently introduced shall achieve up to 50% of energy savings compared to conventional shops. The first market of this type was opened in Perchtoldsdorf using roof-mounted PV modules, LED-lightning and other low energy applications. A charging station for electrical vehicles is available as well. The shop shall serve as test lab for the new concept and to be adapted in other chain stores in the future. Similar concepts are adapted by other retail shops (e.g. the GreenBuilding from Hofer).

83 Source: http://www.billa.at/Metanavigation/Nachhaltigkeit/Oeko_BILLA_Perchtoldsdorf/dd_bi_subpage.aspx ; 20.02.2012

Regarding the support and the use of RES, PV technology plays the most dominant role compared to other renewables. From the retail market segment, basically all top 5 in each country are supporting PV (see listing in annex). From the furniture segment it's IKEA and Otto and finally from the DYS stores Toom, an affiliate of the REWE Group and Baywa, both in Germany. However, beside PV geothermal heat pumps are often used but also wind energy was mentioned.

Figure 65: Roof-mounted solar PV on an EDEKA shop in Germany[84]

The PV is mainly used as roof-mounted installation. None of the companies mentioned any PV carport implementation. Since not all electricity consumption can be provided by own means, the REWE Group and dm are committed to purchase electricity from renewable sources only.

84 Source:http://www.edeka-gruppe.de/Unternehmen/de/verantwortung/umwelt_2/umwelt_1/umwelt.jsp ; 20.02.2012

Figure 66: Roof-mounted solar PV at dm in Germany[85]

Following figure summarize the results of the alternative survey. The ratios are relative to total number of companies for each of the three market segments.

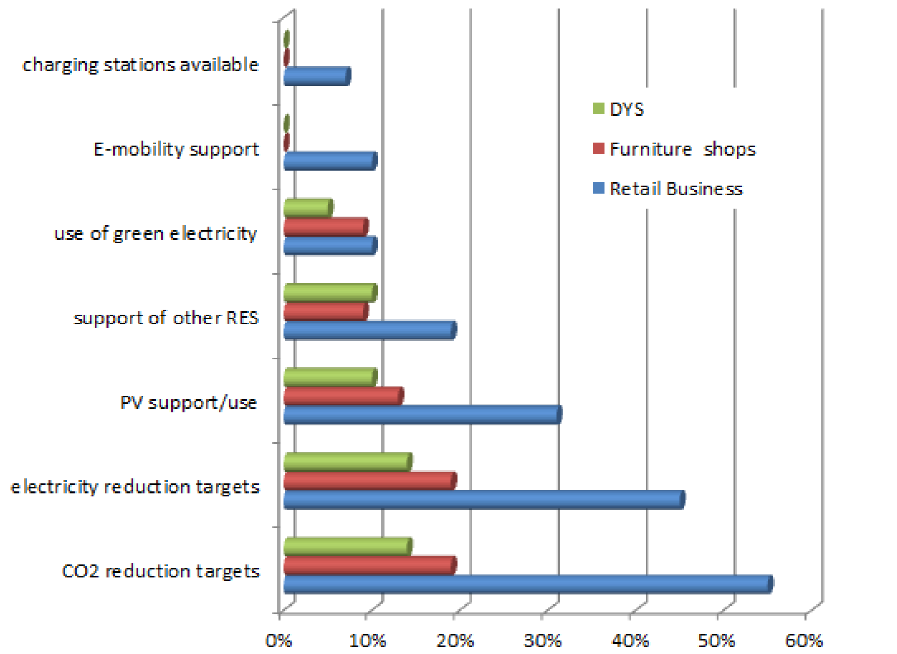

Figure 67: Results of the alternative survey

85 Source:http://www.dm-drogeriemarkt.de/cms/servlet/segment/de_homepage/unternehmen/werte-kultur/nachhaltig-handeln/24934/oekostrom_bei_dm.html ; 20.02.2012

Regarding mobility and environment two main direction of impact can be observed. First, the propagation of public transport and second some first advances towards e-mobility. Companies supporting e-mobility are BILLA and MERKUR, both affiliates of the REWE Group in Austria and MIGROS in Switzerland.

Figure 68: MERKUR's e-mobility advert[86]

However, this doesn't hide the fact that practically all offer parking areas for conventional cars for their clients and customers. The reality is likely as shown the picture below.

Figure 69: Typical opportunity for PV carport implementation[87]

Considering that the evaluated companies represent the top of each segment, it can be concluded that renewable energy sources and in particular PV technology are

86 Source: http://www.merkurmarkt.at/Ihr_Markt/Nachhaltigkeit/Elektro_Auto/Elektro_Auto_/me_Default.aspx; 20.02.2012

87 Source: http://www.moebel-mahler.de/index.php ; 20.02.2012

well recognized alternatives. There is however great potential for improvements as PV adaption in that market segment has just started. Why no PV carports are supported can unfortunately not be answered by this survey.

5.7 E-mobility

Transport accounts for 31% of Swiss greenhouse gas emissions due to the high degree of oil dependence in transport energy supply. The values for Germany and Austria are comparable in relation to the population. The emissions of transport could be reduced significantly if all the vehicles that run on fossil fuels would be replaced by electric vehicles powered by photovoltaic solar energy. Compared with other sources of renewable transport energy, photovoltaic generation of electricity has two advantages: it requires little space and can also be applied to built-up areas or transport infrastructure as explained earlier.

Still main constrain for a quicker market adaption in the past derived mainly from the resistance among the car producers and thus the high prices compared to mass production of traditional combustion engine vehicles [68]. A further main limiting factor is the battery performance. Following figure indicates the critical enablers according to their relevance for the broad deployment of electric vehicles.

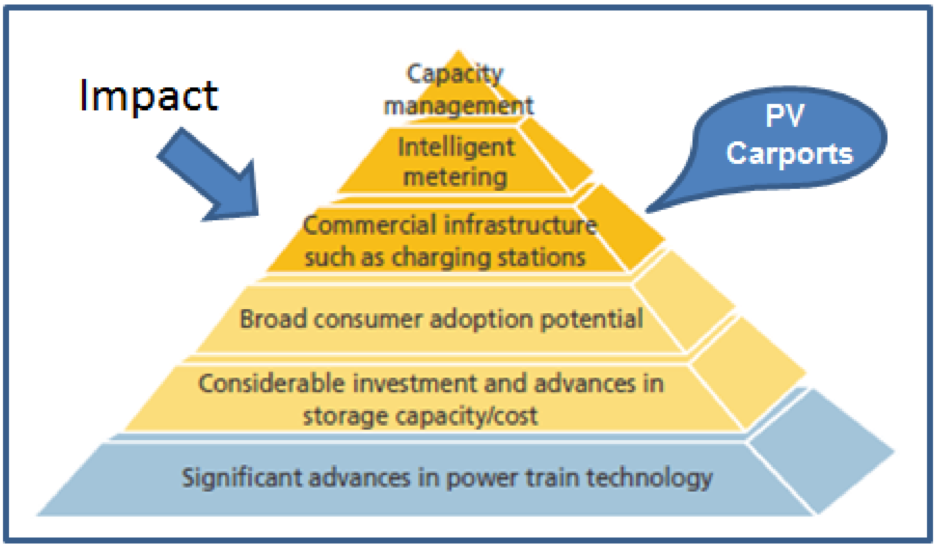

Figure 70: Critical enablers for electric vehicle deployment[88]

[88] Source: http://www.oliverwyman.com/media/OW_UTL_EN_2009_Electric_Vehicle_Market.pdf; 20.02.2012

Anyhow some changes in favor of the e-mobility can be observed. One of them is the announcement of the German federal government that has set a goal to put **one million electric vehicles** on German roads by 2020[89]. But also the goal of France to have 100'000 vehicles on its roads by 2015 is rather ambitious. Other countries such as the U.S., Japan and China have also recognized the enormous potential of electric mobility and are encouraging their industries with major programs in support of electrically powered traffic. The basic technologies regarding electric drives, energy storage and network infrastructure are well-developed.

However, there is still a need for further research, optimization and integration within the value added chain and even a longer way to go if Mc Kinsey's forecast of produced E-cars by the major car producer in 2015 do not even reach 1 million vehicles as indicated in the figure below.

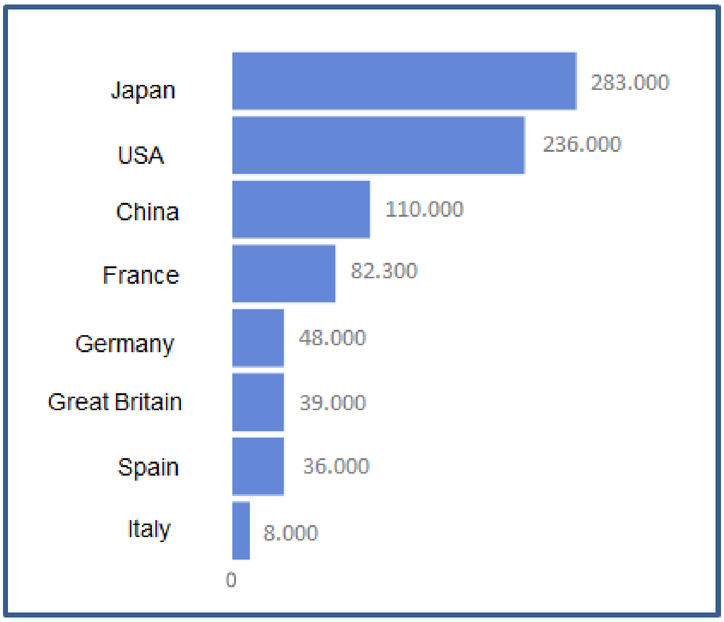

Figure 71: Mc Kinsey forecast of produced e-cars by 2015[90]

Nevertheless, a good dozen of mass produced e-cars are already available on the market today and further are to be expected. Meanwhile the average battery cruising range reaches distances up to 120 km. The price in contrast is still about 10'000 Euro higher compared to comparable combustion engine vehicles[91,92].

89 Source:http://www.unendlich-viel-energie.de/uploads/media/Abstract_Financial_Barriers__Electric_Vehicles.pdf ; 26.02.2012

90 Source: selected countries from the Mc Kinsey Report in WirtschaftsWoche from 29.11.2010

91 Source: http://www.e-mobile.ch/index.php?pid=de,2,21 26.02.2012

Even though performance of the batteries has increased in recent years due to intensive R&D, common arguments hindering the deployment of e-cars remain. Thereby several studies delivered the proof that for most drivers in European cities, the distance for normal average usage is not necessary a limiting issue.

A study carried out in Switzerland in 2005 shows that on Swiss average the distance driven a day did not exceed 37 km or 98 of driving minutes. People living in the city center did not exceed in average 33 km while people on the country side reached distances of 42 km as indicated in the figure below.

Figure 72: Driving behavior in urban areas

That study proofs that e-mobility has absolutely a potential to adapt in the future and that the argument regarding battery performance can be neglected for the day to day usage. Nevertheless prices must reach the level of competiveness compared to traditional cars. However, potential **PV carports with installed charging stations** can further assure the security and comfort of driving ones spread all over in the urban area.

The other major remaining constrains are:

- The missing charging infrastructure and density of distribution
- The increase of green electricity demand

[92] Source : http://www.oekomotive.net/index.php/fahrzeugvz/elektro 26.02.2012

5.7.1 Future development

Switzerland

In 2010 around 500 battery electric vehicles (BEV), 11’000 hybrid electric vehicles (HEV) and plug-in-hybrid vehicles (PHEV) and around 30’000 electric bicycles were counted on Swiss roads. These vehicles represent less than 2% of total passenger cars. However, due to CO_2 reduction measures the Swiss government is in favor for a larger deployment. Thereby four different scenarios were defined [69]:

- Scenario 1: Business as usual – representing the reference scenario with continuative support measures.
- Scenario 2: Technology leap – reduction of battery cost by 2015 through regional development program
- Scenario 3: National development program – bonus payments for electric vehicle holders (CHF 2’000.-)
- Scenario 4: Economic slump – Stagnation of economy leading to reduced development budgets and delay of innovation

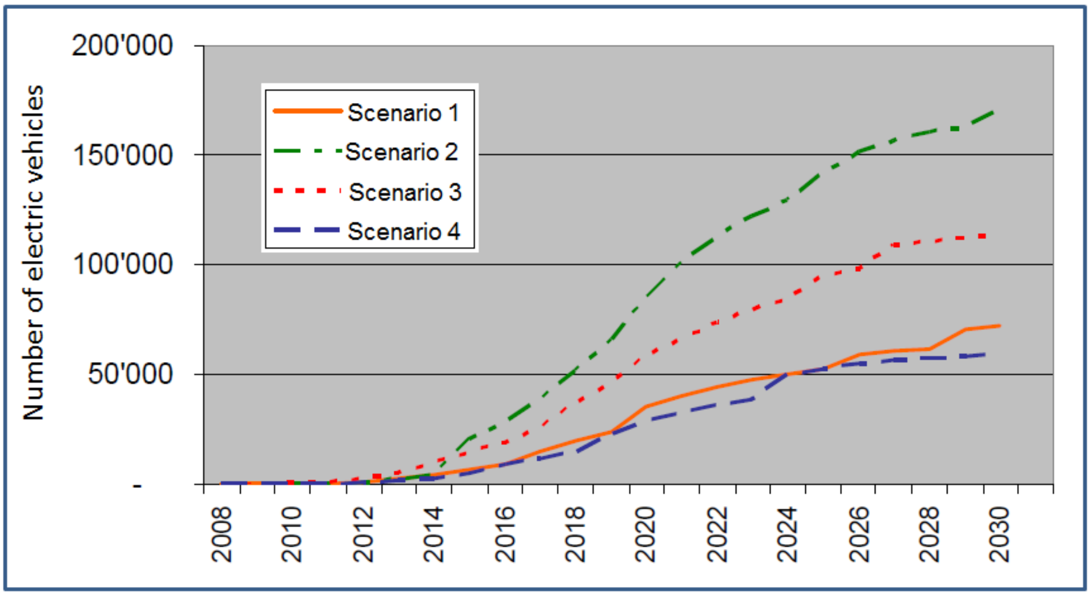

Figure 73: Readmission deployment of E-cars in Switzerland

The scenarios are based on the three common technologies:

- Hybrid Electric Vehicle (HEV)
- Plug-In-Hybrid (Plug-In Hybrid Electric Vehicle, PHEV)
- And the Battery Electric Vehicle (BEV)

Dependant of the scenario the deployment of electric vehicles will range between 16.8 % in the best case and 11.8% in the worst case relative to total amount of passenger vehicles in 2020 as shown in the figure below. However, in any case this development will require additional supply of green electricity.

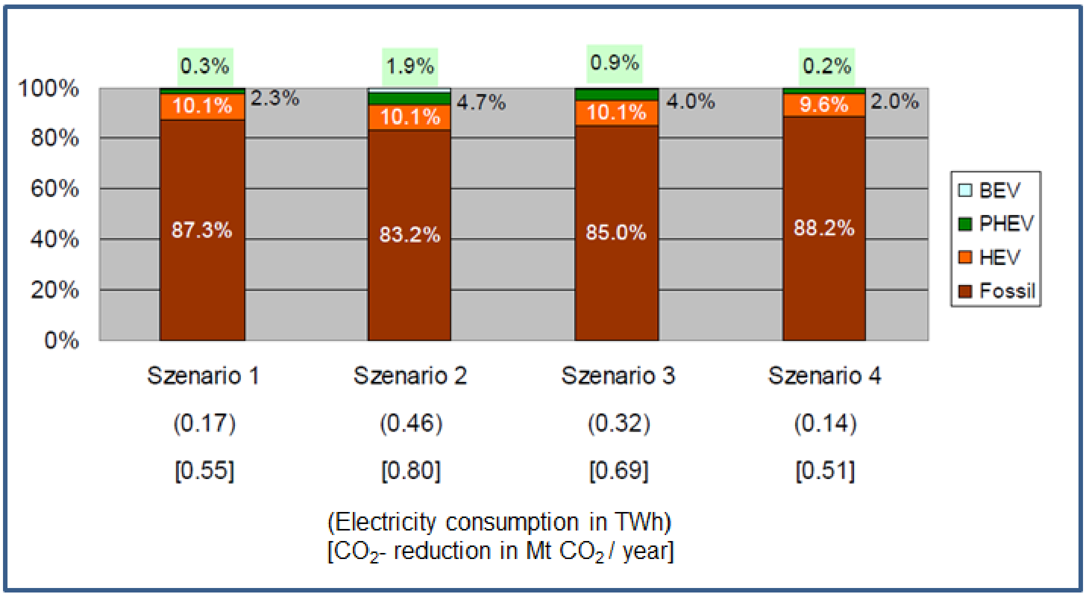

Figure 74: E-car deployment for Switzerland by category and scenario in 2020

Austria

Similar development can be observed in Austria. According to the Austrian federal environmental agency forecast the deployment of electric vehicles shall reach comparable levels to Switzerland as indicated in the figure below [70].

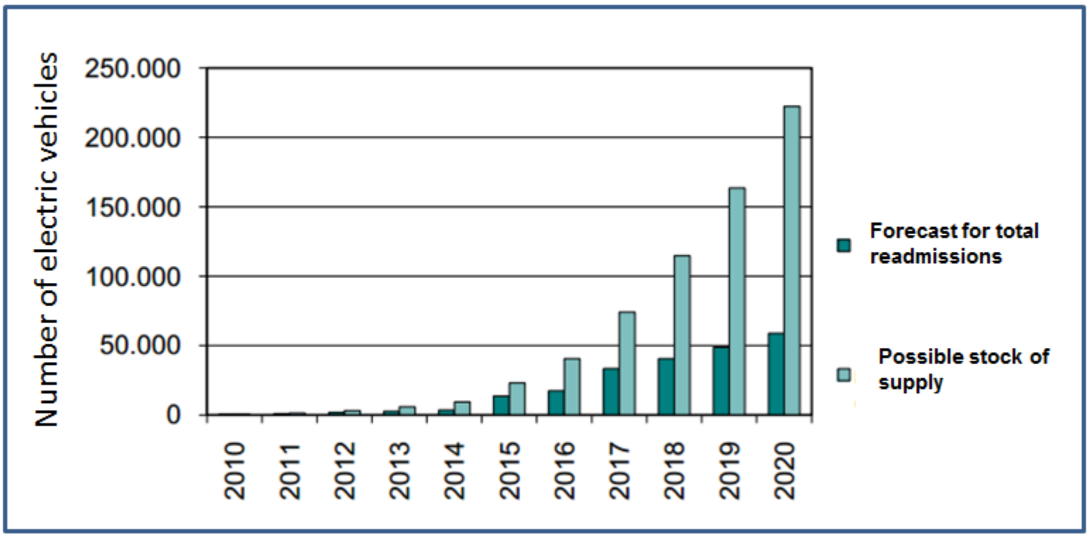

Figure 75: E-car deployment forecast for Austria

Germany

According to German's Renewable Energies Agency forecast, the deployment of electric vehicles is expected to reach:

- 1'000'000 vehicles by 2020
- 10'000'000 vehicles by 2030
- and finally 40'000'000 vehicles by 2050 as indicted in the figure below.

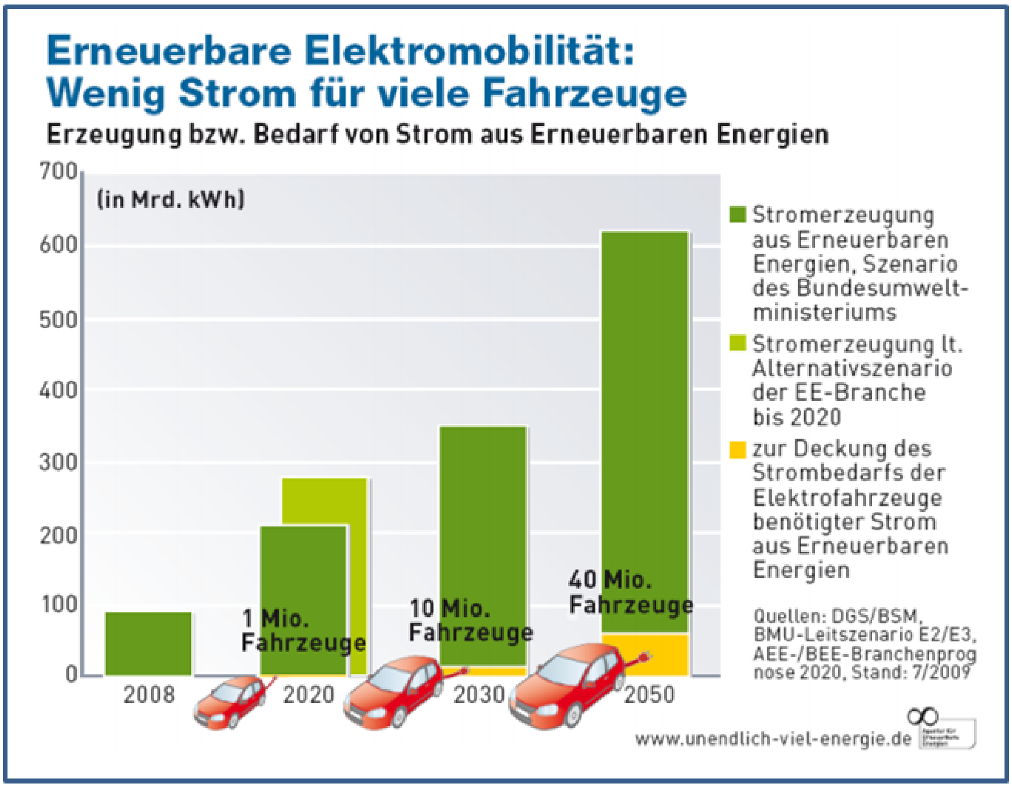

Figure 76: Green electricity forecast according to e-car adoption in Germany[93]

This development requires not only enormous quantities of green electricity (yellow field indicates the demand) but also the corresponding infrastructure and production capacity.

5.7.2 Impact on Green electricity supply

The deployment of increasing number of electric vehicles in DACH in the future will require additional supply of green electricity and the corresponding infrastructure (e.g. charging stations). **PV carports** may play a dominant role in such a scenario and close the emerging gap in green electricity demand.

93 Source:http://www.unendlich-viel-energie.de/uploads/media/Energieimpuls_OWL_Klimafreundliche_Elektromobilitaet_Endbericht_mai10_02.pdf ; 26.02.2012

6 Conclusions

Solar photovoltaic electricity has the potential to be a major energy solution, sustainably orientated for urban areas of the future. Thereby cities and the business can reflect the commitment of the community by supporting initiatives and reducing administrative obstacles. However, since PV carport is a novel energy solution application and practically no mid-size commercial installation at the shop around the corner exist innovators are requested.

Planning a new business, I'd like to be one of these innovators proving the potential and increasing public awareness that finally leads to greater community support, acceptance and wide adoption. Hence, the aim of this master thesis was to provide the information and data relevant for the establishment of a start-up company projecting **large PV carport installations**.

In doing so, the main objective was to deliver arguments for the proof of concept and to validate the business idea through the evaluation of different aspects, such as the technical and economic feasibility on one side and the potential and market acceptance of such solutions on the other side. Thereby, the focus was set on the DACH countries and in particular large shopping centres like retailers, do-it-your-self shops (DYS), home-centres and furniture stores as possible target market segment.

6.1 The findings

It is a suitable time to reform the energy system, since it was created during the growth phase of a highly industrialized society. Our society is on the brink of an energy crisis and faces multiple global environmental problems. These allow a great opportunity for technological innovation in our society. To implement this innovation effectively it is important to carry out promotions of energy and environmental conservation policies by recognizing the negative effects on the external economy.

PV Technology & Carports

Analysis of the diffusion of PV power generation in DACH, in terms of its efficiency and effectiveness, shows that efficiency of the PV system is increased by progressive technological innovation, making it possible to reduce the costs of running the system. Low cost develops incentives for potential adoption of systems so many parties from the different segments as residential, commercial and industrial will therefore introduce PV systems and where appropriate PV carports. Further findings related to technology & carports are:

- Steady improvement of PV technologies in terms of performance and efficiency is observed. Crystalline Silicon is still dominating the market however modern HIT modules (Heterojunction with Intrinsic Thin layer) are very attractive regarding energy yield per square meter needed.
- PV carports are a fairly new application especially in terms of commercial and industrial sizes > 100kW.
- Different types of carport construction and several suppliers exist on the market, however no signs that the market is yet saturated. An interesting concept of carport design is introduced by Solar Wings, where modules are fixed on cables that are drawn across the parking lot.
- Double-axis tracking systems can generate 20% to 30% more electricity compared to fix-mounted.

Economic & Price Developments

Financial support measures as FIT and other subsidies of the governments helped many parties to introduce PV system on different scales. As a result, technological innovations have been further developed and utilized with expectations of economical rent. This development will further pave the way to build large-scale PV technologies for various facilities as carports in the future. Some further findings are:

- Lowest turn-key costs in Germany are between 2’500 and 3’500 €/kWp, around 15% higher costs we find in Switzerland and Austria. However, costs of PV modules are expected to decline by 20% in Germany over the next two to three years.
- Cost of electricity are expected to increase slightly following the trend of the last years and grid parity of PV for Switzerland, Austria and South Germany to be reached in the next few years, most probably in 2015.
- Profitability is the most critical and crucial question to answer. In general the larger the PV installation the higher the profitability. However, many factors

have influence (FIT, interest rate, module cost, energy gains, green electricity price, etc.) and thus must be proved on a case by case.

- Most attractive support regime (FIT) in 2012 for typical commercial-size PV carport installations (roof-mounted > 100kWp) regarding level and validity duration can be found in Switzerland with 25 years, followed by Germany with 20 years and finally Austria with only 13 years.

Market Potential & Adaption

Analysis of motivational factors points out that in general many parties (individuals and corporations) are willing to introduce RES and in particular PV systems not taking into consideration economical profit balance. The human nature shows a sense of responsibility for the environment as well as a sense of achievement of electric power generation. Some proving facts are summarized below:

- Increased awareness regarding energy efficiency and the implementation of RES has been observed among the surveyed market segment (top 30 retail, furniture and DYS stores) leading to the assumption that earlier or later others will follow according to the adoption model theory.

- PV is well accepted by the public and resistance is rather small compared to wind and biogas plants. However, size and location of the PV installations may cause resistance and has to be checked case by case.

- PV market attractiveness in the near future among the three countries is highest in Germany, followed by Switzerland. However, developments of the ongoing discussing related to cut-backs in supporting scheme (FIT) must be followed very carefully.

- There is a great potential in DACH considering all the parking areas available, nevertheless PV carports will remain a niche application as long enough other areas are available that do not need any special constructions.

- The selected market (top 30 retail, furniture and DYS stores) represent an ideal market for PV carport deployments in urban areas due to already existing parking infrastructure.

- The future deployment of electric vehicles may have a positive effect in boosting PV carport installations, since ideal to close the emerging gap regarding the existence of charging infrastructure and the green electricity supply.

6.2 The obstacle

Analysing the obstacle for the deployment of PV in urban areas and in particular PV carports as possible application no dominant show stopper have been identified. However, the sum of several aspects may lead to delays or derogation in the worst case. Below a summary of the most influential facts:

- PV carports are seen as buildings, therefore FIT for roof-mounted application are valid and certain construction approvals necessary.
- Most barriers for roof-mounted PV installation derive from grid connection permits and administrative processes. Design may evoke public resistance.
- Negative changes in FIT supporting measures reducing profitability or general slow-down of PV deployment due to infrastructure deficiencies (e.g. electric power grid, power storage capabilities, etc.)
- Irradiation levels less attractive in Northern Germany compared to the South, Switzerland and Austria.
- Higher investment cost for PV carports compared to ground installations reducing profitability and attractiveness.

6.3 The outlook

In analysing technology developments, customer behaviour, market acceptance and the potential of PV carport deployments, the first step of the investigations has been successfully terminated. Despite the obstacles described above, positive facts are dominant encouraging further analysis. Hence, in the second step the findings of part 2 – (Master Thesis analyzing Competition and Legal & Regulatory Framework) will be proved in detail and the resulting data and findings of both parts will be used as basis for the formulation of a business case, leading to establish a company projecting PV carport installations in DACH.

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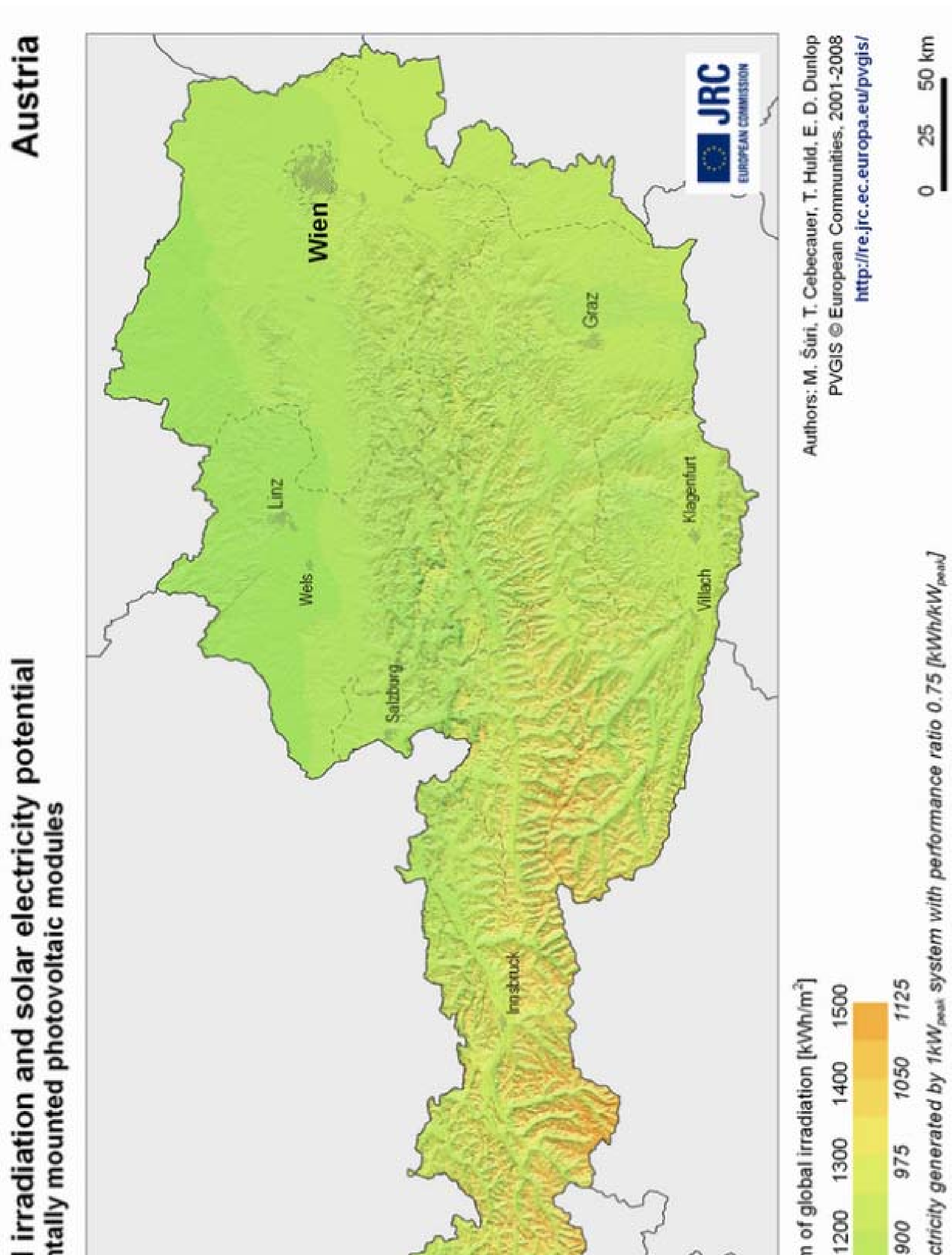
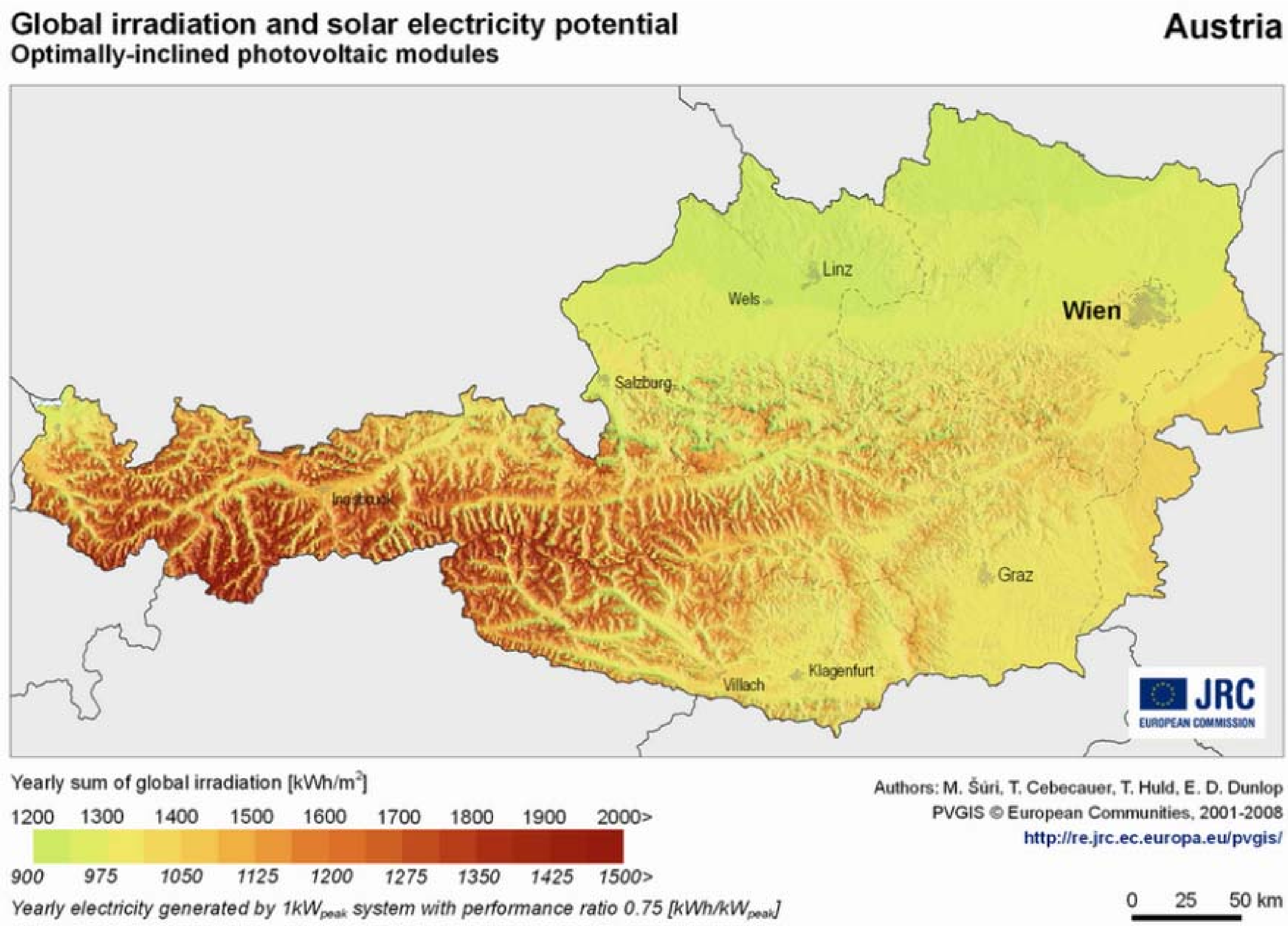
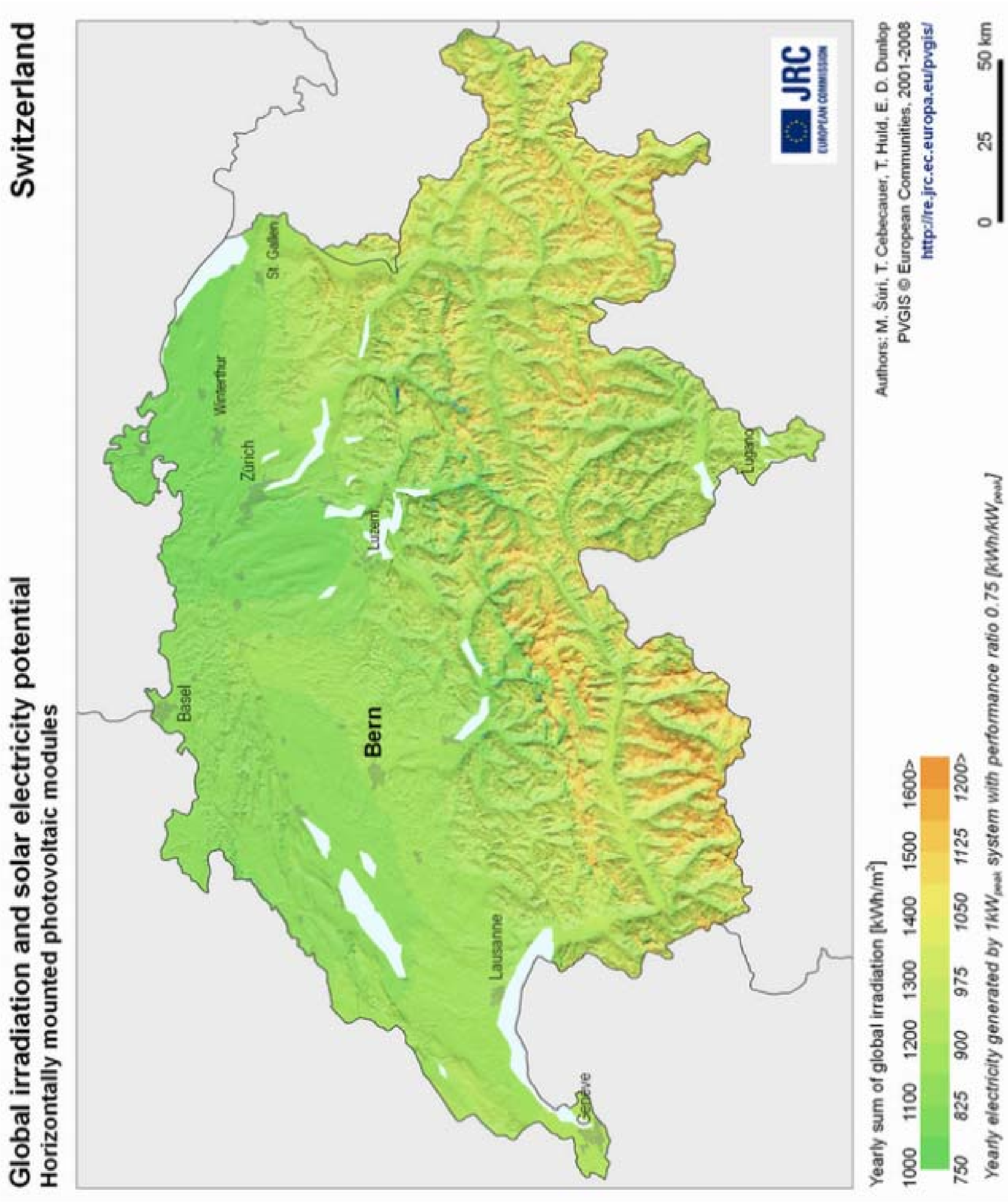
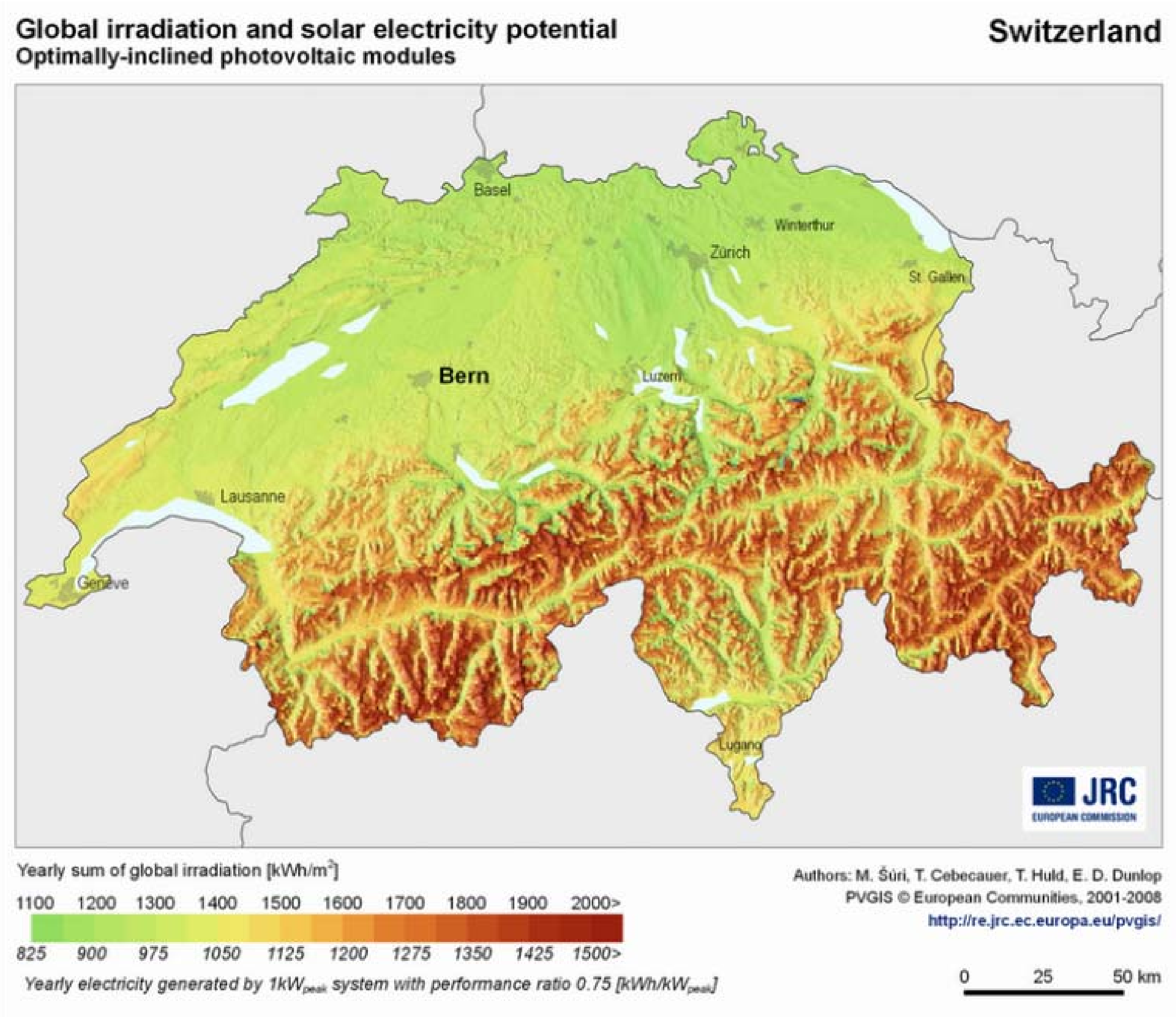
9 Annexes

9.1 Global irradiation

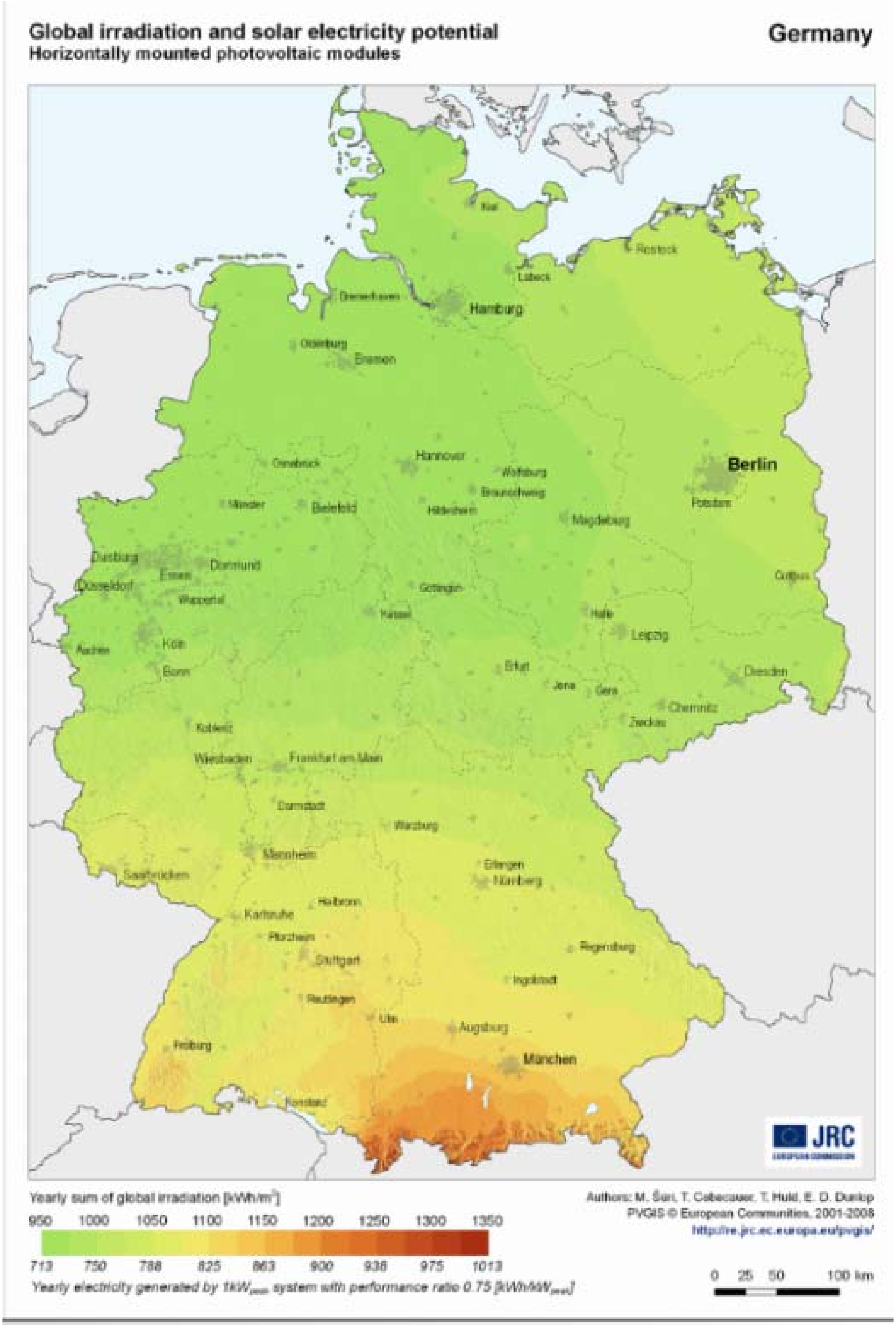



Global irradiation and solar electricity potential
Optimally-inclined photovoltaic modules
Austria
Linz
Wels
Wien
Salzburg
Graz
Klagenfurt
Villach
JRC
EUROPEAN COMMISSION
Yearly sum of global irradiation [kWh/m²]
1200 1300 1400 1500 1600 1700 1800 1900 2000>
900 975 1050 1125 1200 1275 1350 1425 1500>
Yearly electricity generated by 1kWpeak system with performance ratio 0.75 [kWh/kWpeak]
Authors: M. Šúri, T. Cebecauer, T. Huld, E. D. Dunlop
PVGIS © European Communities, 2001-2008
http://re.jrc.ec.europa.eu/pvgis/
0 25 50 km


Global irradiation and solar electricity potential
Horizontally mounted photovoltaic modules
Switzerland
Basel
Zürich
Winterthur
St Gallen
Bern
Luzern
Lausanne
Genève
Lugano
JRC
EUROPEAN COMMISSION
Yearly sum of global irradiation [kWh/m²]
1000 1100 1200 1300 1400 1500 1600>
750 825 900 975 1050 1125 1200>
Yearly electricity generated by 1kW$_{peak}$ system with performance ratio 0.75 [kWh/kW$_{peak}$]
Authors: M. Šúri, T. Cebecauer, T. Huld, E. D. Dunlop
PVGIS © European Communities, 2001-2008
http://re.jrc.ec.europa.eu/pvgis/
0 25 50 km



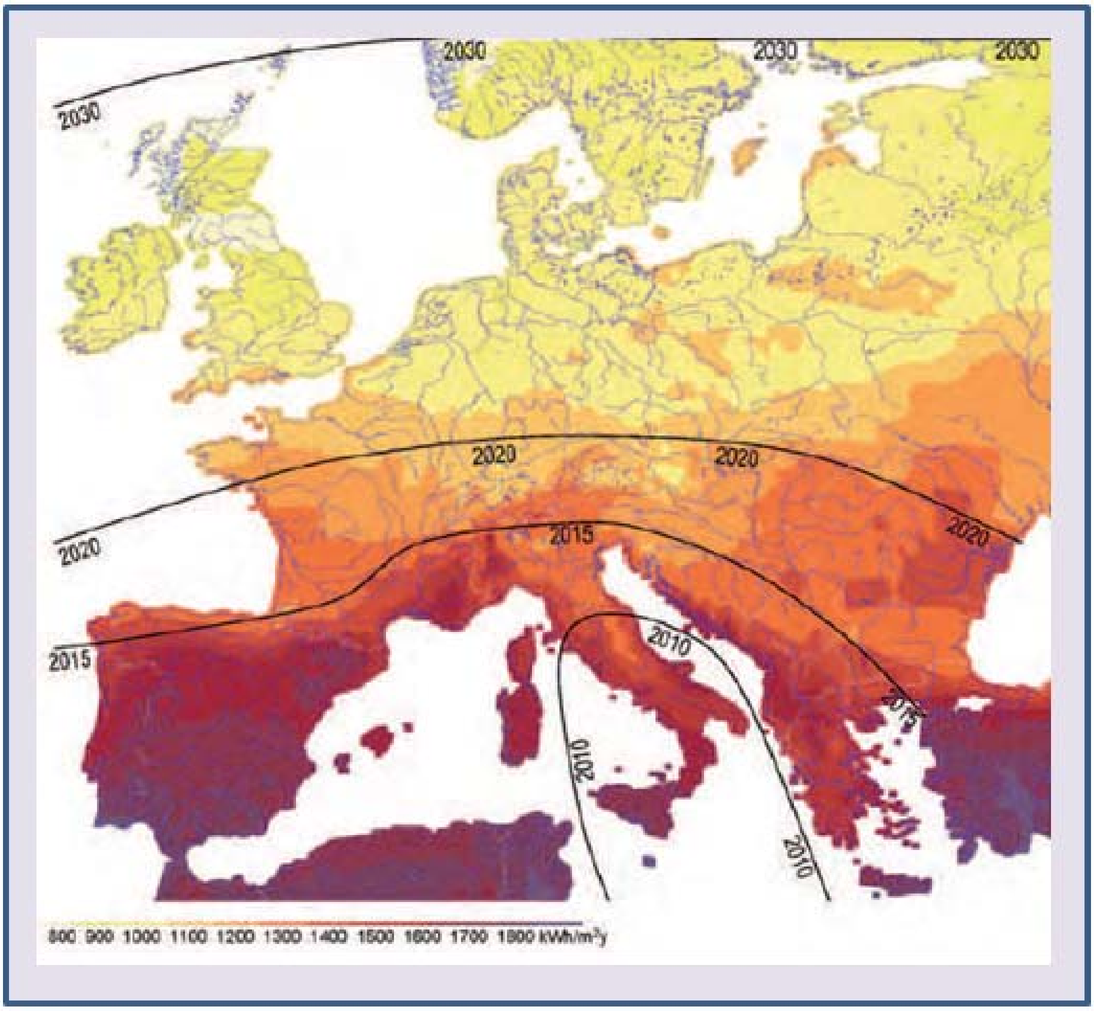
Global irradiation and solar electricity potential
Optimally-inclined photovoltaic modules
Switzerland
Basel
Winterthur
Zürich
St. Gallen
Bern
Luzern
Lausanne
Genève
Lugano
JRC
EUROPEAN COMMISSION
Yearly sum of global irradiation [kWh/m²]
1100 1200 1300 1400 1500 1600 1700 1800 1900 2000>
825 900 975 1050 1125 1200 1275 1350 1425 1500>
Yearly electricity generated by 1kWpeak system with performance ratio 0.75 [kWh/kWpeak]
Authors: M. Šúri, T. Cebecauer, T. Huld, E. D. Dunlop
PVGIS © European Communities, 2001-2008
http://re.jrc.ec.europa.eu/pvgis/
0 25 50 km


Global irradiation and solar electricity potential
Horizontally mounted photovoltaic modules
Germany
Hamburg
Bremen
Berlin
Hannover
Magdeburg
Dortmund
Düsseldorf
Leipzig
Dresden
Chemnitz
Frankfurt am Main
Mannheim
Nürnberg
Stuttgart
Augsburg
München
JRC
Yearly sum of global irradiation [kWh/m2]
950 1000 1050 1100 1150 1200 1250 1300 1350
713 750 788 825 863 900 938 975 1013
Yearly electricity generated by 1kWpeak system with performance ratio 0.75 [kWh/kWpeak]
Authors: M. Šúri, T. Cebecauer, T. Huld, E. D. Dunlop
PVGIS © European Communities, 2001-2008
http://re.jrc.ec.europa.eu/pvgis/
0 25 50 100 km


Global irradiation and solar electricity potential
Optimally-inclined photovoltaic modules
Germany
Hamburg
Bremen
Hannover
Berlin
Magdeburg
Dortmund
Leipzig
Dresden
Frankfurt am Main
München
JRC
Yearly sum of global irradiation [kWh/m²]
< 1100 1150 1200 1250 1300 1350 1400 >
< 825 863 900 938 975 1013 1050 >
Authors: M. Šúri, T. Cebecauer, T. Huld, E. D. Dunlop
PVGIS © European Communities, 2001-2008
http://re.jrc.ec.europa.eu/pvgis/
0 25 50 100 km

9.2 Grid Parity

EPIA's forecast for grid parity in Europe.



9.3 Company Rankings

Retail Business in DACH:

For Austria:

Rang	Unternehmen	Food-Umsatz 2011 in Mio. Euro	Vertriebslinien-Umsatz 2011 in Mio. Euro
1	Rewe Group	5.623	7.044
2	Spar Österreichische Warenhandels AG	4.173	5.442
3	Aldi Süd	2.812	3.312
4	Schwarz-Gruppe	883	1.034
5	Metro Group	601	901
6	Pfeiffer	580	750
7	MPreis	504	587
8	Zielpunkt	464	540

Quelle: Planet Retail (zum Teil geschätzt) - Januar 2012

For Germany:

Rang	Unternehmen	Food-Umsatz 2010 in Mio. Euro **	Veränderung zum Vorjahr in Prozent	Anteil Food in Prozent
1	Edeka*	40.880	+3,2	90,2
2	Rewe*	26.992	+2,9	71,8
3	Schwarz-Gruppe	23.030	+3,7	81,1
4	Aldi-Gruppe	20.090	+4,1	82,0
	Aldi Süd, Mülheim			
	Aldi Nord, Essen			
5	Metro	11.669	-2,2	38,6
6	Lekkerland	7.821	+/-0	99,0
7	Schlecker	3.956	-9,5	92,0
8	dm	3.667	+8,7	90,0
9	Rossmann	2.596	+10,5	75,5
10	Bartels-Langness	2.343	+11,9	77,5

Quelle: TradeDimensions / Lebensmittel Zeitung / Stand: März 2011

* inkl. Außenumsatz des SEH
**Bruttoumsätze (inkl. MwSt.)

For Switzerland:

Rang	Alternativtext	Food-Umsatz 2011 in Mio. Euro	Vertriebslinien-Umsatz 2011 in Mio. Euro
1	Coop Schweiz	10.722	13.946
2	Migros Genossenschafts-Bund	10.513	14.566
3	Aldi Süd	1.145	1.356
4	Schwarz-Gruppe	712	835
5	Spar Switzerland	687	913
6	Manor	493	2.347
7	Lekkerland	374	400
8	Casino	164	276

Quelle: Planet Retail (z.T. geschätzt) - Januar 2012

The major DIY companies in Germany:

Competitors	Number of stores	Share of stores in East Germany (without Berlin)	Selling space (in sq m million)	Gross sales density (in € / sq m)	Owner structure
OBI	340	20%	2.61	1.362	Tengelmann (food retailer), 50% Franchise
Praktiker / Max Bahr	340	24%	2.14	1.359	Listed company, 100% free float
Bauhaus	127	7%	1.24	2.084	Family Baus
toom / Marktkauf	361	32%	2.23	1.058	Rewe (food retailer)
hagebau	660	18%	1.96	1.165	Cooperation concept
Hornbach	90	12%	0.97	2.218	Listed company, 21% Kingfisher, 38% Family Hornbach
globus / hela	78	21%	0.66	1.900	Family Bruch
Hellweg Die Profi-Baumärkte	81	33%	0.62	946	Family Semer
BayWa	85	26%	0.24	1.381	Listed company, DIY < 10% of the business,

Source:

http://www.praktiker.com/pb/site/praktiker_com/get/355157/110906_Praktiker_handout.pdf

9.4 Online Survey

9.4.1 Example of the covering letter

Sehr geehrte Damen und Herren

Der Einsatz und die Nutzung der erneuerbaren Energie soll auch in urbanen Gebieten gefördert und gesteigert werden. Dies ist das Thema meiner **Diplomarbeit**, wobei es in dieser Online-Befragung zunächst um die **Überprüfung des Potentials und die Bereitschaft, freistehende Parkplatzflächen in Solaranlagen** umzuwandeln, zu ermitteln geht.

Durch den Einsatz sogenannter Carports (Unterstand für PKWs) kann die Nutzfläche doppelte Verwendung erfahren, indem:

- Autos vor der Witterung geschützt werden
- Stromerzeugung durch die Photovoltaik-Anlage

Diese Umfrage ist an grosse Waren- und Möbelhäuser sowie diverse Detailhändler in Deutschland, Österreich und der Schweiz (DACH-Region) mit grossen Kunden-Parkplatzflächen gerichtet, zu denen auch Ihr Unternehmen zählt.

Ihrer Meinung zu diesem Thema interessiert uns daher sehr !

Falls Sie nicht die richtige Ansprechperson sind, bitte ich Sie dieses Mail an den Verantwortlichen im Bereich Nachhaltigkeit, Ökologie, Public Relations oder Facility Management weiterzuleiten. Vielen Dank !

Wir freuen uns sehr, wenn Sie bis zum 6. Februar 2012 an unserer sehr kurzen Umfrage (13 Fragen, ca. 5 min) auf http://newenergy.zserv.tuwien.ac.at/index.php?id=10174 teilnehmen.

Die Umfrage ist anonym und die Daten werden nicht weitergegeben. Wenn Sie an den Ergebnissen der Studie interessiert sind, tragen Sie bitte am Ende der Umfrage Ihre Kontaktdaten ein.

Für Rückfragen stehe ich Ihnen gerne zur Verfügung.
Besten Dank für Ihre Teilnahme !

Mit freundlichen Grüssen

Samir Al-Wakeel
Student MSc Program
Renewable Energy in CEE / TU Wien

Tel. +41 79 471 1003
E-Mail: **samir.al-wakeel@gmx.ch**

MSc Program
Renewable Energy in CEE

9.4.2 Original wording and structure

MSc Program
Renewable Energy in CEE

Willkommen !

Vielen Dank, dass Sie sich die Zeit für die Teilnahme an der Umfrage nehmen.

Diese Befragung ist anonym. Sie ist Teil meiner MSc Abschlussarbeit in Renewable Energy in CEE an der TU Wien und in Zusammenarbeit mit dem Energiepark Bruck/Leitha.

Bitte klicken Sie auf **Weiter** um mit der Umfrage zu beginnen...
(13 Fragen / ca. 5 min)

Weiter

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Renewable Energy in CEE

Frage 1:

Erstellt Ihr Unternehmen regelmässig einen Nachhaltigkeitsbericht (Report)?
Zutreffendes ankreuzen

- ☐ ja, seit ____ *Bitte Jahr eintragen*
- ☐ nein

Wenn ja, welcher Standard wird verwendet ?
Mehrfachauswahl möglich

- ☐ GRI (Global Reporting Initiative) ist eine internationale Organisation, die allgemein anerkannte Richtlinien für die Nachhaltigkeitsberichterstattung aufstellt.
- ☐ eigener Report
- ☐ andere: ____

Zurück Weiter

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Renewable Energy in CEE

Frage 2:

Sind Massnahmen zur Reduktion des Stromverbrauchs ein Bestandteil Ihrer Nachhaltigkeitsstrategie ?
Zutreffendes ankreuzen

☐ ja (Stromverbrauch) ☐ nein

Welche Zielwerte sind für 2012 und bis 2020 vorgesehen ?
Bitte Werte eintragen

absolut	*%*	
		Reduktion Stromverbrauch 2012 gegenüber Vorjahr
		Reduktion Stromverbrauch bis 2020

Zurück Weiter

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Frage 3:

Sind Massnahmen zur Reduktion des CO_2 Ausstosses ein Bestandteil Ihrer Nachhaltigkeitsstrategie ?
Zutreffendes ankreuzen

☐ ja (CO_2) ☐ nein

Welche Zielwerte sind für 2012 und bis 2020 vorgesehen ?
Bitte Werte eintragen

absolut	*%*	
		Reduktion CO_2 Ausstoss in 2012 gegenüber Vorjahr
		Reduktion CO_2 Ausstoss bis 2020

Zurück Weiter

MSc Program
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Frage 4:

Engagiert sich Ihr Unternehmen auch im Bereich der erneuerbaren Energie ?
Zutreffendes ankreuzen

- [ ] ja
- [ ] nein
- [ ] ist geplant

Wenn ja, in welcher Form ?
Mehrfachauswahl möglich

- [ ] durch eigene Projekte
- [ ] Förderung fremder Projekte
- [ ] andere: ______

Zurück | Weiter

MSc Program
Renewable Energy in CEE

Frage 5:

Wie werden diese Projekte finanziert ?
Zutreffendes ankreuzen

- [ ] durch eigene Mittel
- [ ] Fremdkapital
- [ ] Fördermittel
- [ ] andere: ______

Wie viele Prozent des Umsatzes werden durchschnittlich pro Jahr für solche Projekte aufgewendet ?
Zutreffendes ankreuzen

- [ ] keine
- [ ] andere: ______
- [ ] 1 bis 5 %
- [ ] 6 bis 10 %
- [ ] 11 bis 15 %

Zurück | Weiter

MSc Program
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Frage 6:

Welche Technologien werden dabei vor allem unterstützt ?
Mehrfachauswahl möglich

- keine
- Photovoltaik
- Solarthermie
- Windenergie
- Kleinwasser
- Geothermie
- andere:

Würde Ihr Unternehmen auch die Elektromobilität in einer der folgenden Formen fördern ? *Mehrfachauswahl möglich*

- ja, Elektrotankstellen für Kunden bereitstellen
- ja, eigene Fahrzeugflotte auf Elektromobile umrüsten
- andere:

Zurück Weiter

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Frage 7:

Würde Ihr Unternehmen geeignete Dachflächen für Photovoltaik-Anlagen zur Stromproduktion zur Verfügung stellen?
Zutreffendes ankreuzen

- ja
- nein
- Anlagen bereits vorhanden. Die installierte Leistung beträgt:

Ist auch das Photovoltaik-Carport Konzept bekannt (Unterstand für PKW mit Solarmodulen zur Stromproduktion) ?
Zutreffendes ankreuzen

- ja
- nein

Zurück Weiter

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Frage 8:

Würde Ihr Unternehmen geeignete Parkplatzflächen zur Umwandlung in Carports zur Verfügung stellen?
Zutreffendes ankreuzen

☐ ja ☐ nein ☐ Anlagen bereits vorhanden. Die installierte Leistung beträgt: ☐

Welche der folgenden Argumente würde Ihr Unternehmen motivieren vorhandene Parkplätze in Carports umzuwandeln ?
Zutreffendes ankreuzen. 1 -> trifft zu; 2-> trifft eher zu; 3-> weder noch; 4-> trifft eher nicht zu; 5 -> trifft nicht zu

1	2	3	4	5	
☐	☐	☐	☐	☐	keine
☐	☐	☐	☐	☐	Beitrag zur CO_2 Reduktion
☐	☐	☐	☐	☐	Service für Kunden
☐	☐	☐	☐	☐	Image für Unternehmen

Zurück Weiter

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Frage 9:

Anzahl Verkaufsstellen in DACH (Standorte mit freistehenden Parkplätzen) :
Mehrfachauswahl möglich

☐ in Deutschland	☐ in Österreich	☐ in der Schweiz
☐ keine	☐ keine	☐ keine
☐ bis 10	☐ bis 10	☐ bis 10
☐ bis 25	☐ bis 25	☐ bis 25
☐ bis 50	☐ bis 50	☐ bis 50
☐ bis 100	☐ bis 100	☐ bis 100
☐ andere: ☐	☐ andere: ☐	☐ andere: ☐

Zurück Weiter

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Frage 10:

Anzahl freistehender Kunden-Parkplätze:
Zutreffendes ankreuzen

☐ durchschnittlich pro Filiale oder ☐ Gesamthaft

☐ kleiner 50
☐ 50 bis 99
☐ 100 bis 149
☐ 150 bis 199
☐ 200 bis 249
☐ 250 bis 299
☐ 300 bis 349
☐ 350 bis 399
☐ 400 bis 449
☐ grösser 500
☐ andere: ____

Zurück Weiter

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Frage 11:

Einige Kennzahlen zum Energieverbrauch* Ihres Unternehmens...
Bitte Werte eintragen und zutreffendes ankreuzen...

	2007	2008	2009	2010	2011
a) Gesamtenergieverbrauch absolut: *(in GWh)*					
b) Gesamtenergieverbrauch spezifisch: *(in kWh pro ☐ CHF 1'000.- resp. ☐ EUR 1'000.- Umsatz)*					
c) Spezifischer Energieverbrauch Filialen: *(in kWh pro m² Verkaufsfläche)*					

	a)	b)	c)
* Verbrauch aus Strom	☐	☐	☐
und Wärme	☐	☐	☐
und Treibstoff	☐	☐	☐

Zurück Weiter

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Frage 12:

Hier haben Sie Gelegenheit Kommentare und Anregungen zur Umfrage oder zur Strategie und Zukunftsentwicklung Ihres Unternehmens im Bereich der erneuerbaren Energie abzugeben...

Freiwillige Angaben

Zurück Weiter

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Frage 13:

Einige abschliessende Informationen über Ihr Unternehmen....

Ihre Daten werden vertraulich behandelt und nicht veröffentlicht oder weitergegeben. Diese Angaben sind freiwillig, jedoch erbeten um eine bessere Auswertung der Ergebnisse zu ermöglichen.

a) Name des Unternehmens :

b) Anzahl Mitarbeiter:

Wenn Sie an den Ergebnissen interessiert sind, geben Sie bitte hier Ihre Kontaktdaten ein:

a) Kontaktperson:

b) E-Mail oder Telefonnummer:

Zurück Weiter

CONTINUING
EDUCATION
CENTER

MSc Program
Renewable Energy in CEE

CONTINUING
EDUCATION
CENTER

ENERGIE PARK

Vielen Dank

für die Teilnahme an der Umfrage !

Bei Fragen kontaktieren Sie bitte:

Samir Al-Wakeel
Student MSc Program
Renewable Energy in CEE / TU Wien

Tel. +41 79 471 1003
E-Mail: **samir.al-wakeel@gmx.ch**