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Long term and global perspectives for building integrated photovoltaic systems in urban areas

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Affidavit

I, **Wolfgang REHART**, hereby declare

1. that I am the sole author of the present Master Thesis, " Long term and global perspectives for building integrated photovoltaic systems in urban areas ",
   56 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
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Abstract

The Building Integrated PhotoVoltaic (BIPV) technology is the most promising technology to fulfill the requirements of sustainability, decentralized production and security of supply in the urban areas. The BIPV be analyzed according the present population, built up area respectively area which can be utilized and the electricity demand of three different cities.

What can be the potential now and what can be feasible up to now with the BIPV, what is possible up to 2030 with BIPV in the urban areas, and what can be the share regarding the electricity demand. Considered are the cities Berlin, Barcelona and Vienna, interesting due to different supporting schemes, different irradiation and variable urban structure.

Analyzed will be the present state of each city, with case studies, the population development and the development of the useful area for the BIPV. The utilized area is distinguished between roof- and façade systems. According already existing studies about the determination of the potential outgoing from the ground area, the potential of the cities are calculated.

The result of BIPV potential up to now varies from 21% for Vienna up to 44% for Berlin and 46% for Barcelona regarding their electricity consumption. The potential related to the consumption in 2030 are decreasing for Vienna marginally down to 20%, for Barcelona down to 36% and for Berlin down to 36%.

Using the present appropriate areas of the cities is a crucial point for the BIPV potential. The development of the population has more likely a marginally effect for the potential. The municipalities keep in mind a sustainable land use, which is not quite good for new BIPV potentials. Nevertheless for new buildings and in case of renovation, BIPV should be always considered. About 10% of BIPV potential can be gained from the new buildings up to 2030. The main part of the potential is using the existing areas of the urban

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1 Introduction

The Photovoltaic (PV) technology is one of the most promising technologies for the future to secure the electrical energy demand in the urban area in a sustainable way. In the last 20 years the PV has been established as an environmental friendly and sustainable technology for electricity production. It creates a lot of new and future orientated workplaces. Obviously the photovoltaic systems are the most expensive way up to now to produce electricity, many countries are funding and supporting this technology. The sustainable energy provision, especially the electrical energy provision is a crucial point also for the security reasons. In the urban areas the Building Integrated Photovoltaic (BIPV) systems can be used to make a step forward to this sustainable provision. The areas, which are needed, can be used from the existing buildings; so immediately no new built up areas are needed. New buildings are perfectly qualified to use this kind of producing electricity. Most of the existing areas are today unused, in course of the renovation they can be used in that way. For the new buildings the BIPV systems should be taken into account from the beginning of the planning. So architects and the responsible persons / decision makers of the urban building development are playing a major role to strengthen the position of the photovoltaic technology in the urban area. A successfully integrated PV system into the built environment can help to contribute in general the PV technology in the future as well. The increasing electricity energy consumption makes a sustainable urban development essential. The efficiency and the use of renewable energy is therefore a crucial point and make's it necessary to go further in BIPV.

The PV technology helps to reduce the use of conventionally produced electricity and helps to reduce the negative impacts from the hydrocarbons, and avoid green house gases. This technology can be used where the electricity is immediate needed. A lifetime of approximately 30 years and more can be achieved. With that background it is easy to argue in a sustainable way.

In the use of the PV technology, it can be distinguished between roof mounted, ground mounted and the BIPV systems. The BIPV system can be seen as a multi functional building material; on the one hand it generates electricity and on the other hand it is part of the building envelope. So the BIPV has to fulfill more requirements than a stand alone PV solution like the ground mounted system. This requirement belongs more or less to the building requirements. The BIPV can replace different building elements, from weather proof roofs to various facades or glass facades elements.

The report makes a survey of the status quo of three different cities, and depicts the potentials of the BIPV systems in the context of the increasing electricity demand, population growth. The three cities are Berlin, Vienna and Barcelona.

Berlin is taken due to that fact, that Germany is a leading country that pushes the PV – technology and especially the BIPV systems in a tremendous way and Berlin is one of the northernmost cities of the three, with a global horizontal irradiation up to 1140kWh/m^2; Photovoltaic Geographical Information System (PVGIS).

Austria PV industry is well developed due to the strong dependency to Germany, but the home market regarding installation of PV power plants, is not well developed. The fact, that the supporting schemes are not stable, most of the companies export their products.

Spain with Barcelona has similar frame conditions using PV technologies like in Germany, but with a higher global horizontal irradiation of approximately 1.750kWh/m^2.

This report should show the actual state of the BIPV systems in the three different cities and the development till now, and makes a future scenario, regarding the population development, increasing electricity demand and the useable area for such PV systems. The scenarios should show in which way a sustainable provision with electricity can be possible under certain frame conditions in these cities.

1.1 Core objectives

This work should help to show the right way in the development in the BIPV systems, so the decision makers have an indicator for their work, what is feasible and makes sense to do, and what can be achieved from the sustainable electrical energy provision with the BIPV systems in the urban area. The following core objectives are always related to the three cities.

What is the status quo for the building integrated PV systems in urban area till now?

What influence has the growing electricity demand and what can be the share of the BIPV systems in the year 2030 in the different cities under the consideration of the population development and under the development of the built up areas?

1.2 Building Integrated Photovoltaic BIPV

Building Integrated Photovoltaic stands for Photovoltaic systems which are producing electricity and replace conventional building elements / materials of the building envelop like roof, facades, balconies and sun shading systems. They are incorporated into the building construction of new buildings respectively installed in case of renovation on existing buildings.
The definition of the "International Energy Agency Photovoltaic Power Systems Program" defines the following criteria for BIPV:

PV systems which are planned and designed for new buildings suitable in the context of the building, which fulfills design requirements like color composition, material and shape and the requirements of the building itself in an innovative concept.

PV plants which are mounted afterwards on roofs without the criteria before are not counted as BIPV, except they are belonging to urban structures. The criteria of energy efficiency regarding their position and orientation of the modules to the sun, has to be obligatory fulfilled.

The following BIPV systems can be distinguished regarding their requirement for the building (see figure 1):

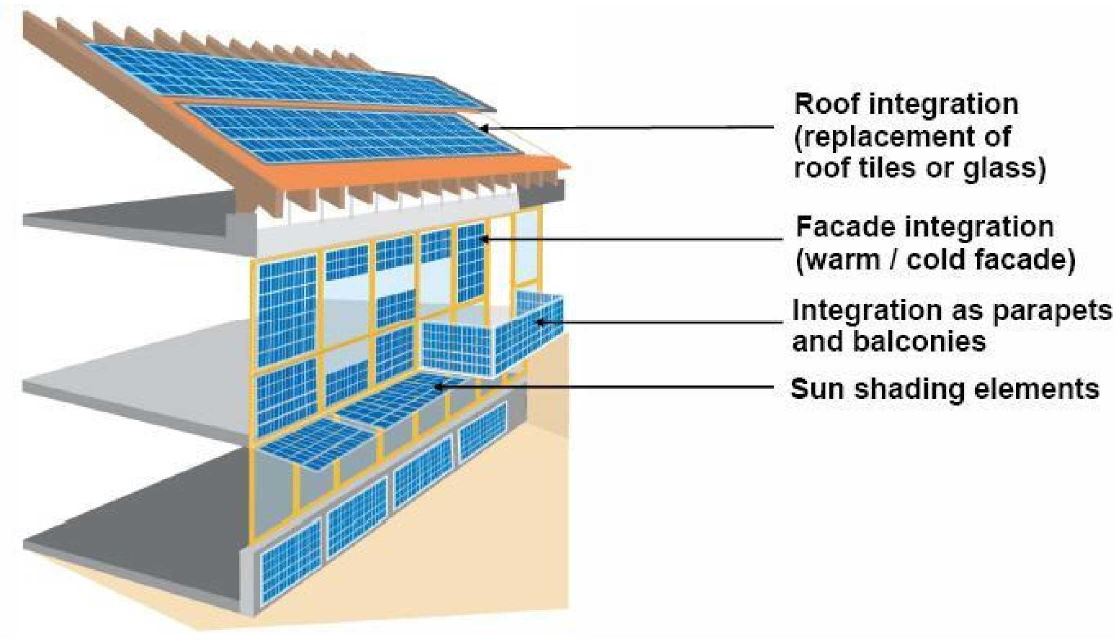

figure 1 BIPV types

- Roof integrated systems
- Façade integrated systems / integration as parapets and
- Shadowing systems

In the case of façade integrated or shadowing systems the use of different transparent modules is possible. This modules transfer a part of the light into the inner of the building; this are crystalline or micro perforated amorphous transparent modules.

There exists three main parts which the BIPV system has to be complied:

1. The angel of inclination and the orientation has to be considered. Modules should be mounted for an optimal tilt between 10° and 60°.It depends on the geographical latitude; see
figure 2.

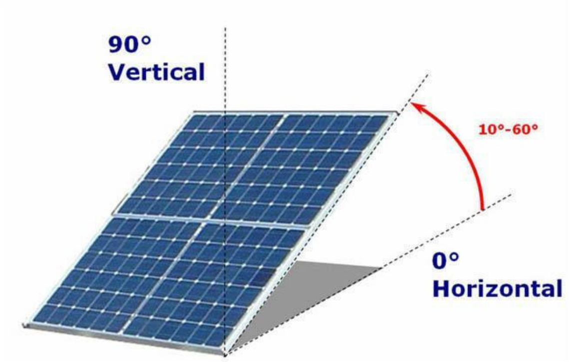

figure 2 Optimal angle

The orientation of the PV plant should always as far as possible to south orientated. The angel between the south and the real orientation is called azimuth (see

figure 3 red angle)

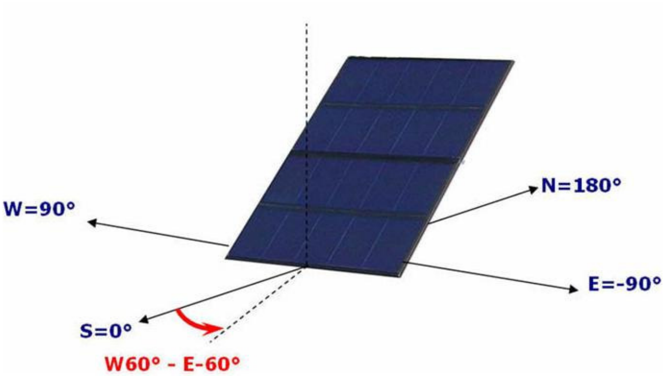

figure 3 Optimal orientation

Depending on the tilt, an azimuth between 60° east to 60° west is possible with losses of about 10%. The azimuth is counted negative for angles to the east and counted positive for angles to the west. In

figure 4 you can see the irradiation percentage of an building envelope.

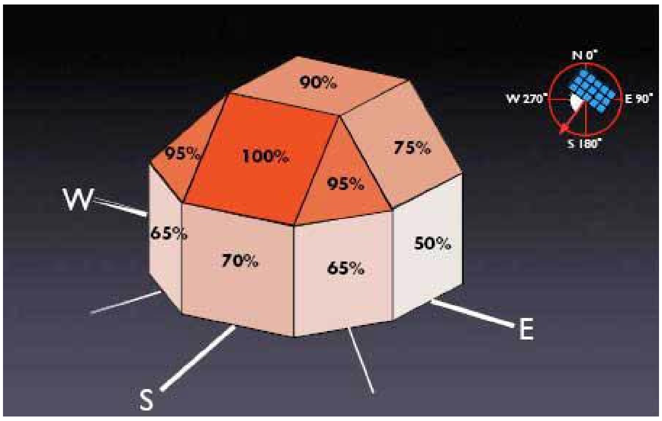

figure 4 Solar irradiation percentage

2. Second the shading of the modules must be minimized, because partially shading leads to a significant power descent. In the planning of the plant the shading of other buildings, trees or some parts of the building it elf has to be taken into account.

In figure 5 you can see some shading examples.

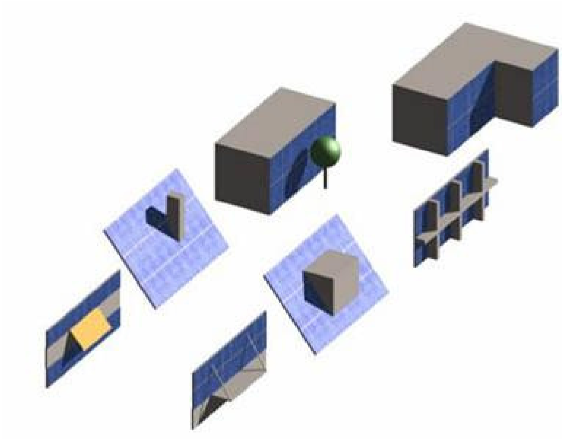

figure 5 Shading examples

3. The ventilation of the modules. Increasing temperatures has a negative impact of the power output of the plant. Preventing such negative influence, can be done by making a passive ventilation on the back of the modules. The influence of the temperature depends which module material is used. For mono-crystalline modules the coefficient of losses is -0,4 %/°C to -0,5%/°C, and for thin-film modules it varies from -0,1%/°C to -0,2%/°C.

1.3 Methods and data

The BIPV systems will be analyzed for the three different cities according their area, the inhabitants and the annual power output which can be achieved with BIPV systems. The data of the area, the inhabitants, and electricity consumption will be taken from the national local energy authorities, respectively from the statistical organizations from each country. The quality and quantity are always seen in respect of the accuracy of these authorities and organizations.

As mentioned in the previous chapter the terminus Building Integrated Photovoltaic Systems depicts systems which can be seen more than only roof mounted devices. Regarding the data of the cities, and the definition of BIPV from the "IEA-Photovoltaic Power Systems Program" it will be not distinguished between the roof mounted and the BIPV systems itself. This is more or less applicable for PV-systems, which are mounted additional on existing buildings. This PV - systems are representing not quite the BIPV itself, but in urban areas it is applicable. For new buildings where the architects can take the PV into account for their planning there will be real BIPV systems in sever sense, which are integrated in the building with all the requirements to BIPV plants.

1.3.1 Definitions

From each city the capita, the area and the electrical energy consumption will be shown in the context with the BIPV systems. The BIPV systems will be classified regarding installed power kWp and the annual electrically energy output:

- Capita: C [1]
- Area of the city: A [km^2]
- Electrical energy consumption of the city: V [kWh]
- BIPV:

  Installed power: P [kWp]

  Annual output E [kWh]

- Used area per capita a [$km^2/1$] a = A/C

From the used area per capita only the built up area of the city is relevant for the calculation of the existing BIPV potential. Green areas, streets and other areas of the cities are not taken into account for the potential calculation.

- Built up area per capita ba [$km^2/1$] ba = f * a where f is the factor of the built up area of the city.

1.3.2 Assumption[1]

Based on case studies and data which are presented from Gutschner Marcel, Novak Stefan, there are some rules of thumb regarding the analysis and potential estimation for BIPV. The estimation of the BIPV potential starts with the whole roof and façade areas. The areas will be corrected according the architectural eligibility and the solar suitable area. A weighted value

[1]This chapter is mainly based on the analyze of Gutschner

consider building structure, shading and historical elements. It can be depicted with 60% of roof area and 20% of façade area, which are suitable areas. The solar yield is set with 80% of the maximum local annual solar input. Considering roof and façade for individual locations, the available area potential is reduced by 50% for facades and nearly 55% for roof mounted systems, see table 1.

	Roof	**Façade**
Ground floor area [m²]	1	1
Gross area [m²]	1,2	1,5
	60% Architectural suitable	20% Architectural suitable
Architectural ar²ea [m²]	0,72	0,3
	55% Solar suitable	50% Solar suitable
Solar suitable area [m²]	0,4	0,15

table 1 Suitable area

The methodology of the report is the calculation of the roof and façade areas from the ground floor area. According to this report about 40 % of the roof area and about 15% of the façade area from the suitable built up areas are appropriate to use for BIPV. This means in relative terms, that from a ground floor area of 1m^2 about 0,4m^2 of roof area, and about 0,15m^2 of façade area is suitable. Applicable to the different cities, a potential calculation can be made with the built up are per capita, solar irradiation and the efficiency of the conversion from sunlight into electrical energy.

For the potential calculation tilt angle of 30° will be assumed for the roof mounted PV – systems, façade systems are seen with a tilt angle of 90°.

The areas of the cities are differentiated corresponding to their built up are and the remaining areas. Relevant for the calculation is the built up area. From this built up area it will be assumed according area assessments that 30% can be utilized for PV applications. Regarding the structure of the cities, the average numbers of storeys have to be kept in mind. The average number of storeys will be assumed with 4. This destines the area for the calculation. With these frame conditions the BIPV potential can be determined for each city.

1.3.3 Calculation of the BIPV potential of the city

The BIPV potential will be calculated separately for roof and façade integrated systems according to the annual energy output depicted in the report “Compared assessment of selected environmental indicators of photovoltaic electricity in OECD cities”.

Annual energy output for the roof systems O_{roof} [kWh/m²]

Annual energy output for the façade systems O_{facade} [kWh/m²]

Potential per inhabitant for the roof integrated PV – systems $P_{roof} = 0,40 * a * O_{roof}$

Potential per inhabitant for the façade integrated PV-systems $P_{facade} = 0,15 * a * O_{facade}$

The potential for the city P [kWh] will be

$P = (P_{roof} + P_{facade}) * C$

The annual energy output considers the losses corresponding to the temperature, angular reflectance effects and losses due cables and inverters. These losses are for the cities according the PVGIS © European Communities, 2001-2008:

- Berlin
  Estimated losses due to temperature: 12.5% (using local ambient temperature)
  Estimated loss due to angular reflectance effects: 3.0%
  Other losses (cables, inverter etc.): 14.0%
  Combined PV system losses: 27.0%

- Barcelona
  Estimated losses due to temperature: 15.1% (using local ambient temperature)
  Estimated loss due to angular reflectance effects: 2.7%
  Other losses (cables, inverter etc.): 14.0%
  Combined PV system losses: 28.9%

- Vienna

  Estimated losses due to temperature: 12.5% (using local ambient temperature)

  Estimated loss due to angular reflectance effects: 2.9%

  Other losses (cables, inverter etc.): 14.0%

  Combined PV system losses: 26.9%

Outgoing from the actual BIPV potential data, the forecast will make a feasible study about the potential in the year 2030 and what can be the share of the BIPV technology in this three cities under the influence of the development of the inhabitants, development of the built up area of the cities and the electrical energy consumption.

1.4 The photovoltaic – technology

This chapter gives a rough survey about the PV technology. The photo effect was 1839 discovered by Bequerel. Sunlight respectively photons causes specific energy levels in a semiconductor. The photovoltaic effect enables to convert the sunlight directly into direct current. Diffuse or direct sunlight generates in solar-cells free electrical charge. A p-n junction is the key element of all efficient photovoltaic cells. This p-n junction consists of semiconductors.

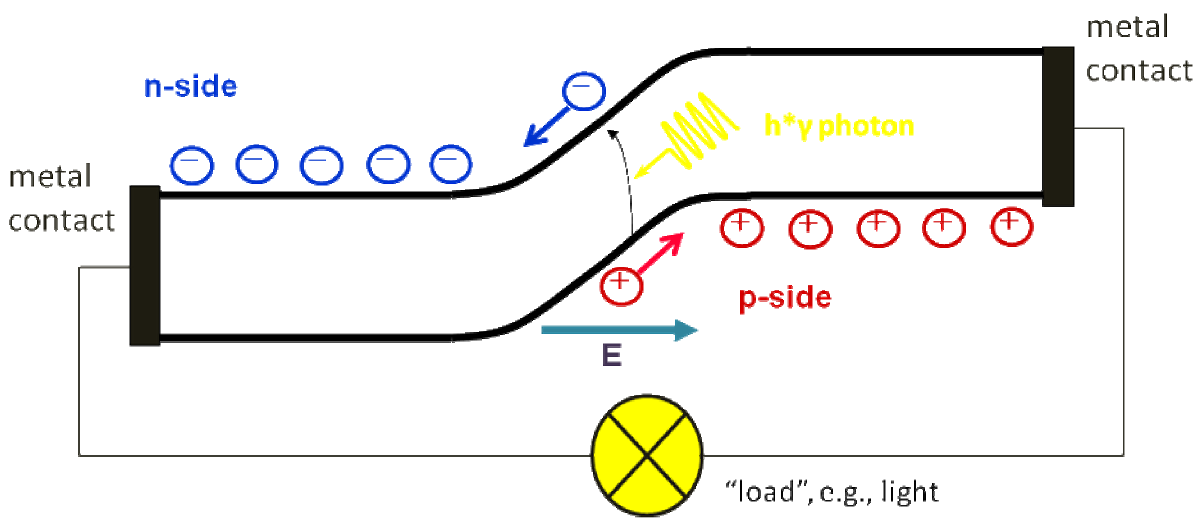

figure 6 PN junction

A semiconductor is a material which is between conductors and insulators (it is not quite a conductor and not quite an insulator). The photons from sunlight generate an electrical voltage. The p-n junction can also described by the band theory of solids; the optically generated free electron and hole will move in response to the electrical field, see figure. Light energy (photon energy) is converted into electrical energy (see figure 6).

Solar cells can be made from crystalline silicon or in form of thin film technology. The crystalline silicon can be distinguished into mono - crystalline silicon and into polycrystalline silicon. The mono - crystalline silicon is sliced from single crystalline boles of grown silicon into ~ 200µm wafers, with a typically efficiency of 15%. Polycrystalline silicon is sliced from blocks of cast silicon (this is less expensive to manufacture than mono - crystalline) with an efficiency of about 14%. Thin film modules are made by depositing extremely thin layers of photosensitive materials on a low cost backing like glass, steel or plastic. There are mainly three types of thin film available, amorphous Silicon a-Si, Copper Indium Diselenide CIS and Cadmium Telluride CdTe. CSI and CdTe can reach an efficiency of about 18% up to now. The thin film technology is an emerging market and it will be the future market.

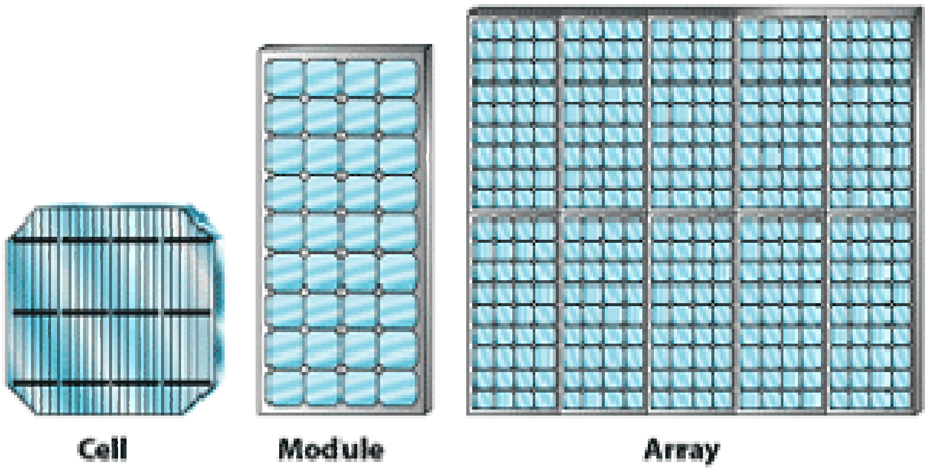

figure 7 Cell, Module and Array

Photovoltaic modules are made up of multiple solar cells. The solar cell usually generates 1,5 – 3 Watt power, and they are the basic building block of solar systems. Modules can be connected together to get any power configuration. Solar arrays are made up of multiple modules, see also figure 7.

A PV power plant can be operated connected to the grid. Therefore an inverter is needed to enable the feed in of electricity to the grid. And the off grid systems, which uses batteries for storing the electrical energy.

2 The status quo of the cities Berlin, Vienna and Barcelona

German Federal Government implements packages that ensure the provision with renewable energies in an efficient and economic way. In the electricity sector 12,5% by 2010 and 20% by 2020 should be produced from renewable energy sources. For the PV market the "Renewable Energy Act (EEG)" is the driving force to complies the targets. Due to this EEG Germany is now the leading country with the highest annual PV installations up to 2007.

In Austria the development is also very well in the manufacturing sector. But due to that fact of missing continuing support schemes, the export rate of the producing companies is very high. Innovative PV systems are installed in Europe or in other countries outside Europe. Contrariness to the legal situation, Austrian PV market is still growing and the export is preliminary dominated in the booming Germans market.

Spain already has critical year 2008, because of a new legal act, which rationalized the exceptional increase in 2008 of the PV market from that very good feed tariff of 0,44€ per kWh. In 2008 Spain was the leading country with 2.661 MW installed power capacity. The Royal Decree 1578/2008 reduces the feed in tariff of about 30% and ensures better figures for the roof and façade PV installations. This can expect more installation in the urban areas. Also a capacity limit of 500MW is set in 2009; this will reduce the growing in Spain in comparison to the previous years.

The state funding has the effect that Germany, Italy and Spain are the leading BIPV markets in Europe.

The most important market is Germany and the market is still increasing. This will be subserved with the production- and distribution network itself. The BIPV market is still a nice market with about 1% share of the total photovoltaic market Nordmann Thomas (2005) also caused of the higher cost, but there is an increasing interest by planers and architects and decision makers.

The following picture shows the global irradiation in kWh/m2 over Europe.

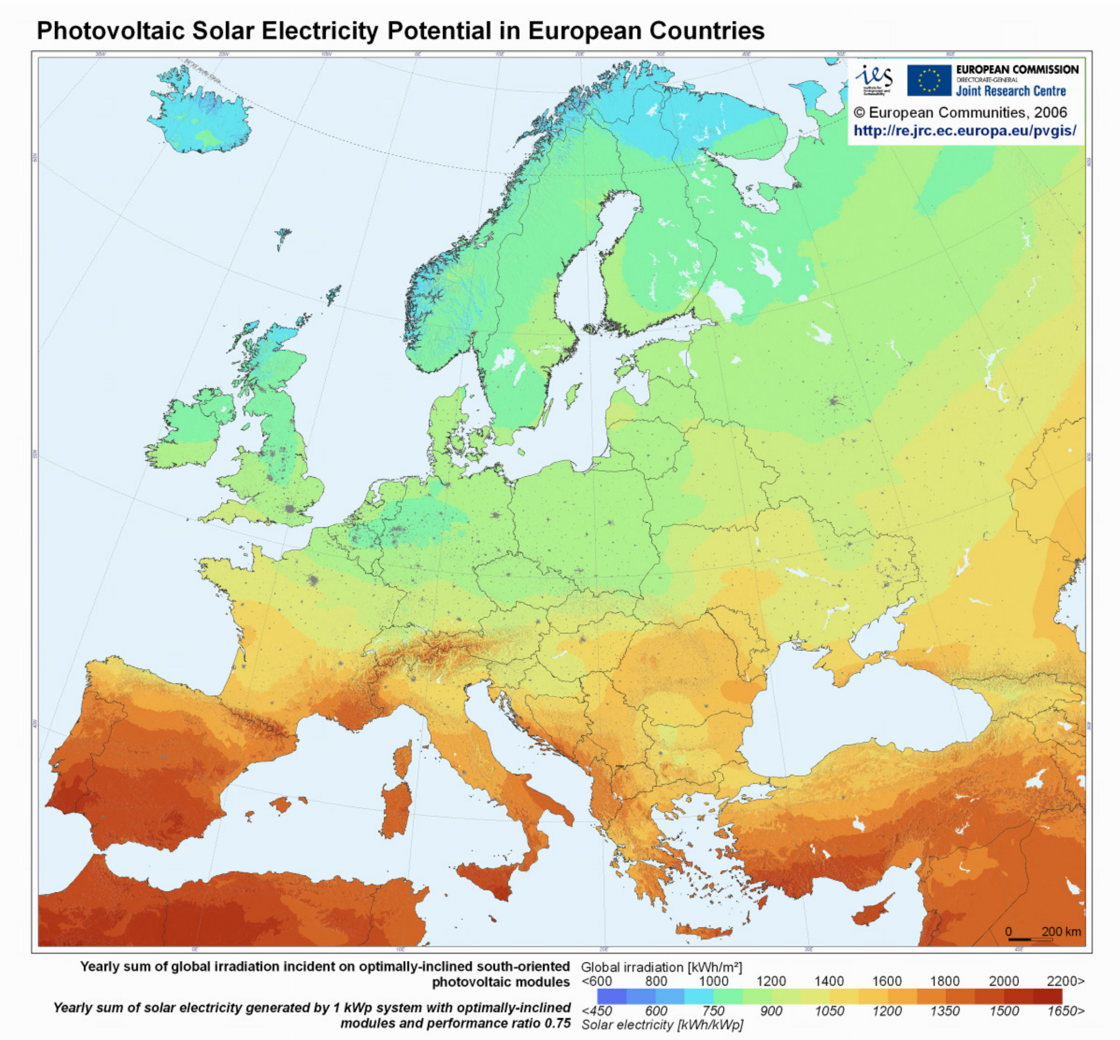

figure 8 Solar irradiation from Europe

The choice for these three different cities in Europe is due to different irradiation, the different political and legal frame conditions respectively different support conditions. This chapter shows the actual state of the BIPV systems in these cities, in correlation with their population, and their global horizontal irradiation. It will be analyzed the population development of the cities and the useable area for the BIPV systems till now. The statistical data are illustrated by case studies. The outcome of this related data are discussed in chapter 2.4.

2.1 Berlin

Germany, especially Berlin is the leader in Europe of usage of photovoltaic applications and in research and development. The region Berlin-Brandenburg is today the leading region in the PV market not only in Germany but also in Europe. There is the highest concentration of research and development, producers and suppliers, many solar associations and well educated personal. In this region the fast growing industry ensures innovative products along the value chain. The national target on the renewable energy sector is to provide 20% of electricity by end of 2020 from renewable energy sources. The Germans Renewable Energy Act with the amendment in 2004 and 2008 regulates the incentives respectively the feed in tariffs in the photovoltaic sector. The feed in tariffs are fixed for 20 years decreased by 5% each year. The degression rate is now raised from 5% to 8% in 2009 and 2010 to consider the market conditions. The degression rate can be adapted yearly in steps of 1% depending on the market the year before. At the beginning with 2009 the owner of new PV plants are forced the register their systems in the German Federal Network Agency. Only those registered plants are allowed to receive the determined feed in tariffs.

Berlin focused on the use of renewable energies, solar energy and biomass wood. The county Berlin provides roof areas to install PV plants for private investors; this program is called "Solardachbörse Berlin". Standardized leas contracts guarantee an economic operation of such plants. The "Solaranalgenkatatster" represents statistical data regarding the installed PV plants in view of geographical distribution, technical and economical aspects and rated the plants to their installed power.

2.1.1Population, irradiation, installed BIPV systems,

Berlin has an area of 892km2 and a population of 3.431.675 in the year 2008, this correspond to a population density of 3.847 inhabitants per square kilometer. From 1999 to 2000 the population decreased by 4.498 people, and increased from 2001 slightly except from 2002 to 2003. The population has only a difference from about 40.000 inhabitants from the year 1999 to 2008. (1,3% of the population in the year 2008); see table 2 Inhabitant of Berlin, Statistisches Landesamt Berlin. The development of the population can be seen more or less stable the last decade.

Year	**Inhabitant**
1999	3 386 667
2000	3 382 169
2001	3 388 434
2002	3 392 425
2003	3 388 477
2004	3 387 828
2005	3 395 189
2006	3 404 037
2007	3 416 255
2008	3 431 675

table 2 Inhabitant of Berlin

The following figure 9 shows the solar irradiation of Germany. The irradiation varies from 1000kWh/m2 in the northern regions up to 1400kWh/m2 in the southern regions of Germany. Berlin has an average irradiation of about 1000 kWh/m2 to 1150kWh/m2, Source Photovoltaic Geographical Information System (PVGIS).

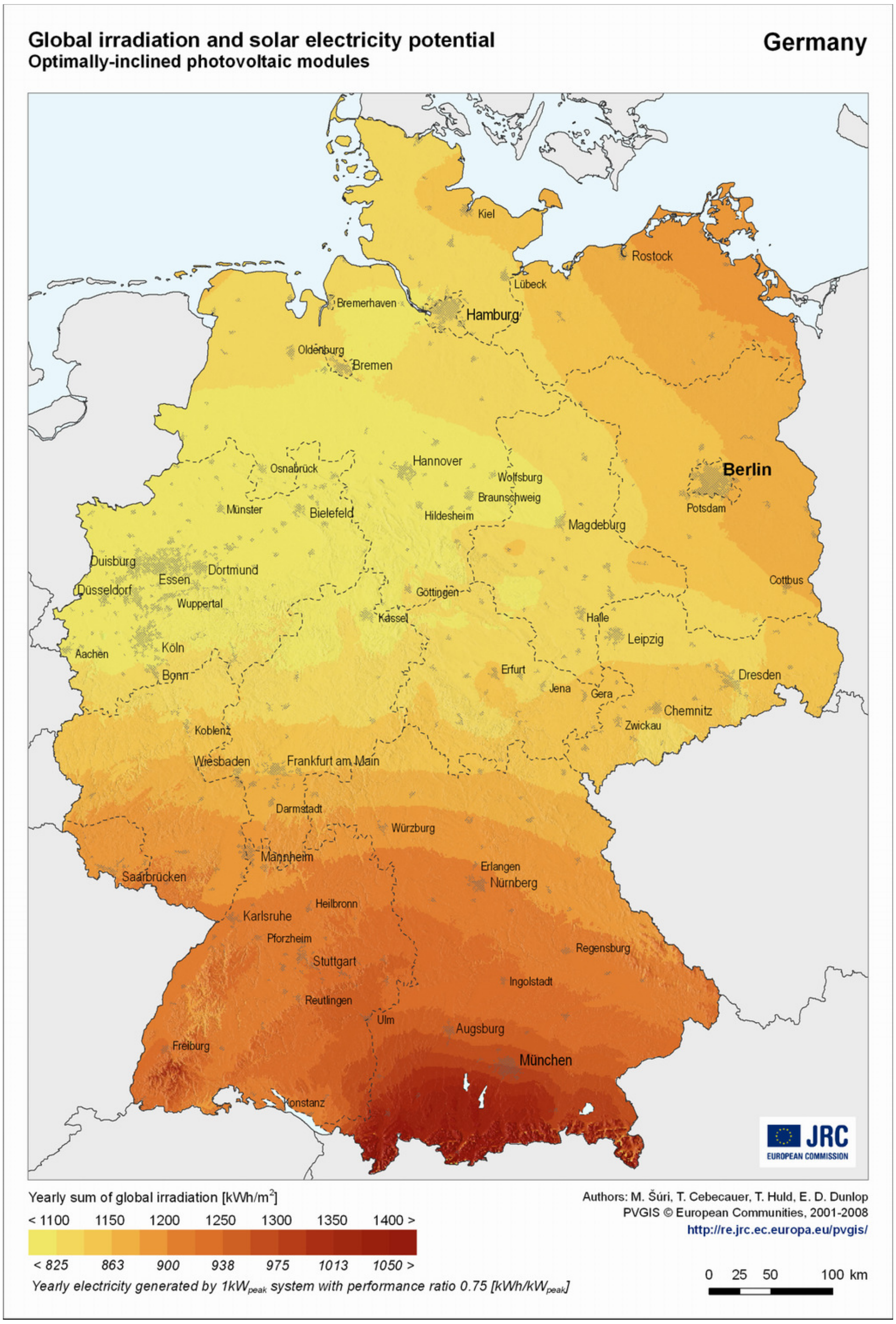

figure 9 Irradiation of Germany

In Berlin are 3585 photovoltaic systems installed. From these 3585 systems, 2000 are not connected to the grid. According to the German market distribution (of grid connected PV installations) that about 29% are ground mounted applications reduced by 10% due to a urban areas

Number of installed PV systems (see figure 10) in Berlin with a rated power of 9,853MWp. About 409 PV installations are greater than 5kWp; from these greater applications it can be assumed that there are 40% are building integrated systems. The average installed power of each PV systems is 6,22 kWp and average used area is about 14 m^2. In figure you can see the yearly installed PV systems in Berlin, Source: Solaranlagenkataster.

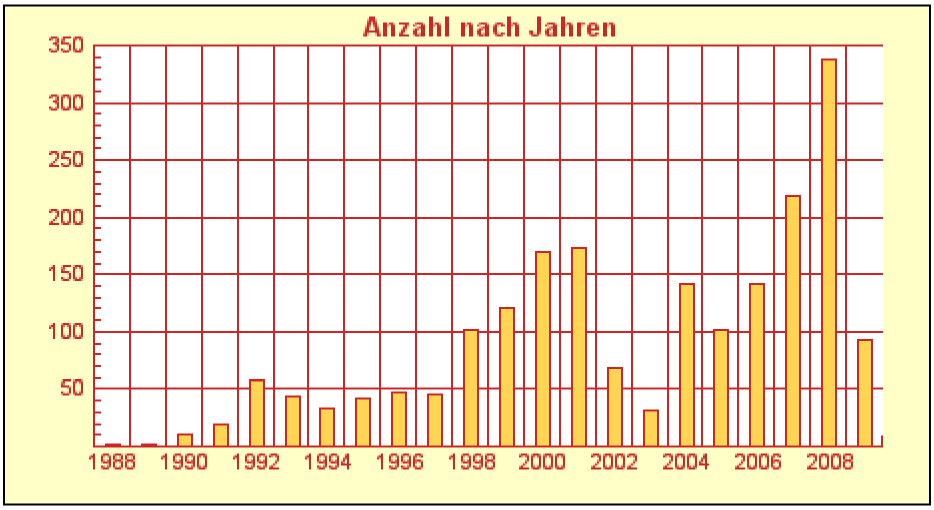

figure 10 Number of installed PV systems in Berlin, Source: Solaranlagenkataster

2.1.2 Case studies

1. The main Railway station in Berlin (Deutsche Bahn AG) shows what can be technical be realized in a tremendous way. The station hall with about 290 meter length is used to integrate the modules in the glass roof. The tilt angle varies from 7° up to 19° against to the horizontal line. It has an installed area with1.870 m2 and 189kWp. The plant is put in operation in the middle of the year 2002. The production of electrical energy is about 160.000kWh per year. The plant consists of 780 glass – glass modules, which are separately produced for the curved glass roof (see figure 11).

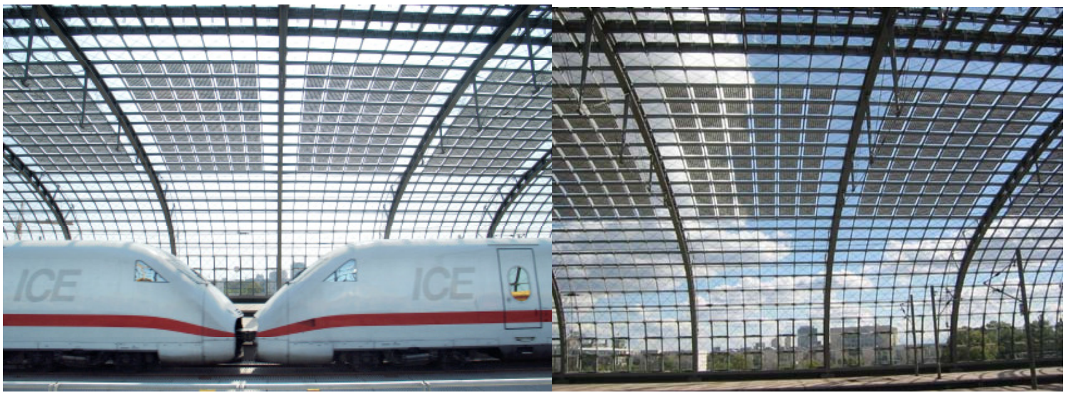

figure 11 Berliner main railwaystation; Source: Solar economy Germany

2. The next BIPV installation shows a façade integrated example. This architectural eye catching PV façade is on the south side of the building. The building belongs to “Ferdinand-Braun Institute for Hyper-Frequency”, and the BIPV plant starts its operation in the year 2007. It is an example for an elegantly shaped solar wall with about 640 m2 and 39kWp electrical power. The power plant consists of 730 modules, arranged in twelve rows with eight meters height and about 80 meter length. (see figure 12).

figure 12 Ferdinand-Braun Institute for Hyper-Frequency, Source: Sulfurcell solar technics Ltd.; Meeder A. et all

3. Federal ministry of economy with an area of 1076 m2 and 102kWp electrical power. The plant is roof integrated and south-west orientation and the put in operation in 1998. The plant consists originally of 712 glass – glass laminate modules. In year 2000 there were some problems with delamination of the modules. After exchange the plant consists of 676 glass-glass modules. The annual energy output is about 75.000kWh (see figure 13)

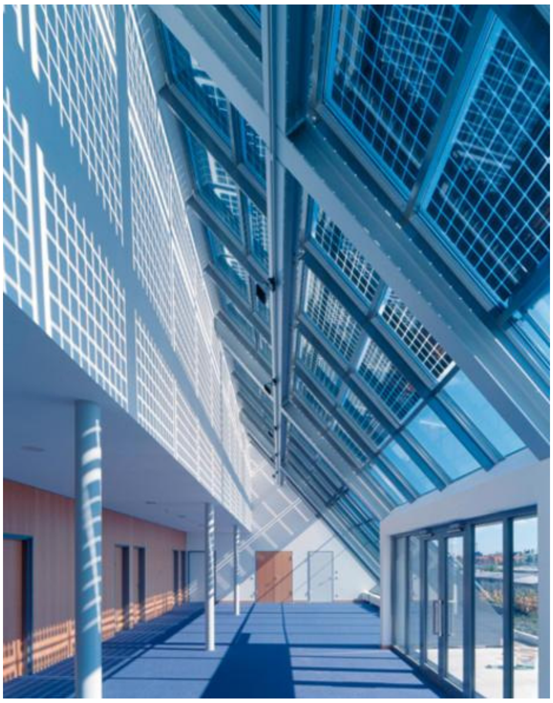

figure 13 Federal Ministry of Economy; Source: Scheuten Solar

2.1.3 Potential of Berlin

As depicted above Berlin has an area of A=892km2 and 3.431.675 inhabitants.

The built up area of Berlin are 21% of area of Berlin that are 187km2. That results in a=55m2 per inhabitant. The utilized area is according the assumption 4m² per inhabitant.

The annual energy output for Berlin is for roof systems 839kWh/m² and for façade systems 584kWh/m², IEA-PVPS Task10, (2006).

O_{roof} = 839 kWh/m² and

O_{facade} = 584 kWh/m²

Potential per inhabitant for the roof integrated PV – systems

$P_{roof} = 0{,}40 * a * O_{roof} = 1.342\text{kWh}$

for the façade integrated PV-systems $P_{facade} = 0{,}15 * a * O_{facade} = 350\text{kWh}$

The potential for the city

$P = (P_{roof} + P_{facade}) * C = 5.807\ \text{GWh}$

Year	Electric energy consumption [GWh/y]
2002	12.917
2003	12.603
2004	12.810
2005	11.797
2006	13.082

table 3 Electrical Energy Consumption of Berlin

The electricity consumption for Berlin was from 2002 up to 2004 increasing. From 2004 to 2005 there was a descent of 11.797 GWh and followed by an increase in 2006. In 2006 the consumption was 13.082 GWh. According to the calculation the potential using BIPV in Berlin is about 65%. This means that 44% of the energy consumption of the city Berlin can be obtained from the renewable energy of photovoltaic.

2.2 Vienna

Austria development on the photovoltaic market is strongly influenced from the German market. According to the strait relation in Austria is also a positive development in the PV market. In contrast to the funding of the photovoltaic in Germany, in Austria the policy is not quite stable funding PV projects. Due to this discontinuous funding respectively volatile policy the PV market has its maximum in the year 2003. At this time the implementation of the federal Green Electricity Act takes place. The feed in tariffs makes it attractive to invest into PV projects. But this feed in tariffs was restricted to a limit of 15WM installed power national wide. Before that, the funding was based on local and regional incentives. In the next three years there were no federal support of PV systems and the installed power decreased dramatically. An amendment of the Green Electricity Act at the end of 2006 leads to a change in the PV market, which makes it attractive again to invest. So in 2007 the turnover takes place, and in 2008 the market were doubled in relation to 2007. But the historical peak in the year 2003 is still far away.

In Vienna there were 90 PV systems connected to the grid at the end of 2004 with 416kWp installed power, and an annual energy output of 330MWh. In 2005 15 further plants were approved from the Vienna government, and in 2008 there were 32 plants approved with an installed power of 400kWp, Magistratsdirektion Klimaschutzkoordinationsstelle Wien.

2.2.1 Population, irradiation, installed BIPV systems

The population is since the year 1991 with 1.539.848slightly increasing. But there was a period of stagnation from 1994 till 1998.. Since 2001 there is an increase from 12.000 up to 25.000 per year. In 2006 and 2007 a stable increase of 13.000 a year takes place. The federal state Vienna has the most dynamical population development from Austria; see also table 4.

Vienna has an area of 414km2 and a population of 1.684.553 in the year 2008, this correspond to a population density of 4.069 inhabitants per square kilometer, Source: Statistik Austria

Year	**Inhabtiant**
1991	1.539.848
2001	1.550.261
2002	1.583.814
2003	1.598.626
2004	1.626.440
2005	1.651.437
2006	1.664.146
2007	1.677.867
2008	1.684.553

table 4 Inhabitants of Vienna

The following figure 14 show the solar irradiation of Austria The irradiation varies from 1900kW/m2 in some regions in the alps to 1200 – 1300 kW/m2 the the lower regions. Vienna has an irradiation from 1300kW/m2 up to 1400kW/m2.

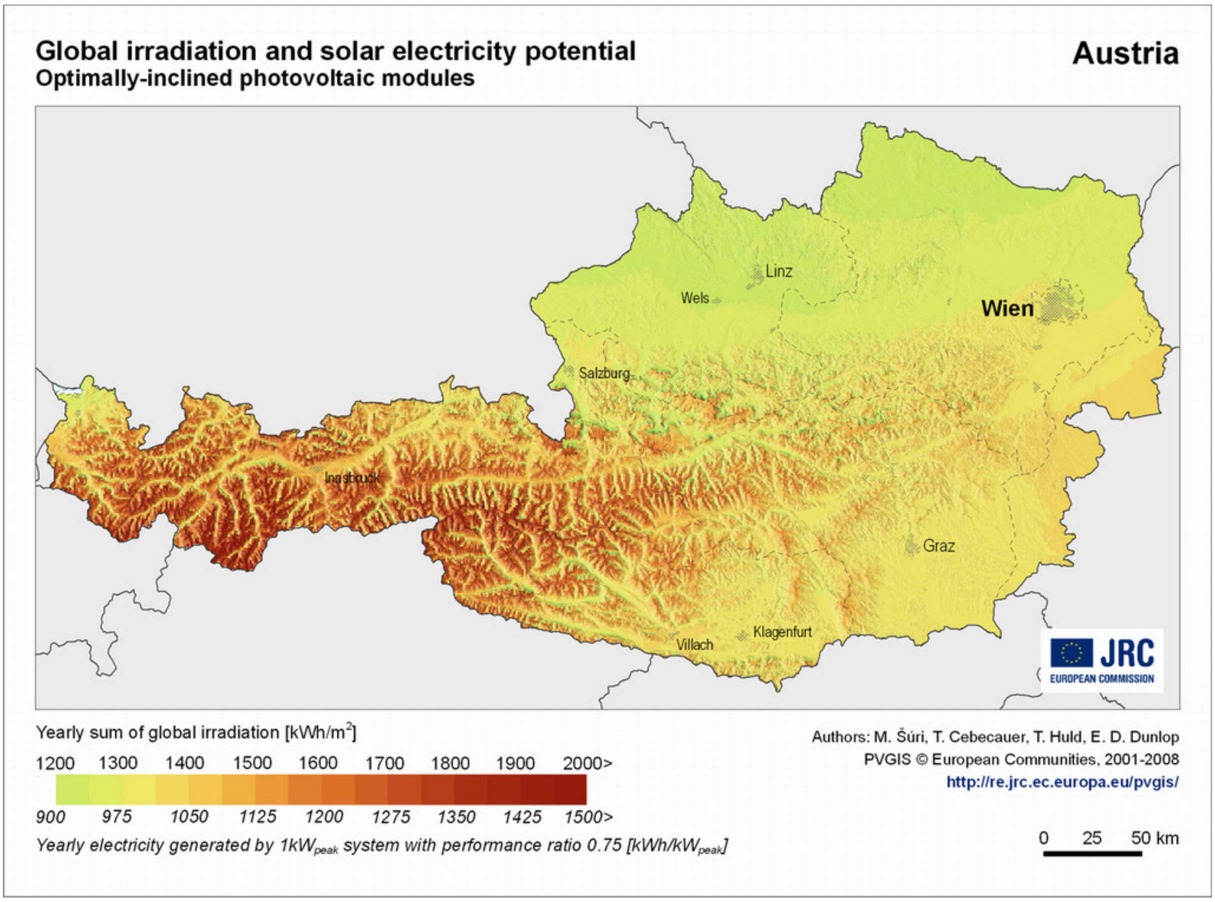

figure 14 Global Irradiation of Austria

Due to that fact that there exists no statistical data of the installed PV plants of Vienna, the plants are rated at least to 137 plants at the end of 2008 with approximately 1000kWp installed power and 783MWh a year, Fanninger G. (2007).

2.2.2 Case studies

1. The Energybase is an office building with façade integrated photovoltaic modules. The design is six rows with an optimum angle for the irradiance. This is a harmonic solution to fulfill design and technical requirements. The plant is about 400m2 and has an installed power of 47.5kWp. The annual energy output is about 42.000kWh. Beside the BIPV systems the Energybase uses the latest innovative concepts of renewable

energies to fulfill the requirements of passive house standards, to hold the energy consumption at a very low level; e.g.: there were also 300m2 of solar thermal collectors installed. This will be reached under the south orientation of the Energybase and the special shape of the south façade. The figure 15 shows the south façade and one of the PV modules.

figure 15 Energybase; Source: ATB/TBB

2. The next case is in a historical building surrounding area; the so called "Bartensteinblock" The power plant, is an administrative office block, distributed over four historical buildings. It consists of 141 modules with 12,05kWp, 138 modules with 11,40kWp, 115 modules with 6,55kWp and 62 modules with 3,85kWp of installed power. The overall plant has 456 solar modules with an area of 476m2, and a installed power of 33,85kWp. The energy output per year is about 33.000kWh; see figure 16

figure 16 Administrative office block; Source: Municipality of Vienna

3. The chamber of commerce installed 447m² modules and with 55kWp installed power. The plant has 374 mono-crystalline modules (see figure 17). Beside the electricity production the PV-modules are design to fulfill the constructional and shape functions as well. The modules are integrated in the south east façade of the building, and used in black color. The energy output per year is about 34.000kWh. The plant is put into operation in June 2009. Beside the integration of the PV plant the building were thermic renovated and other energy saving measures are made. This should reduce the energy costs of the building of about 25%.

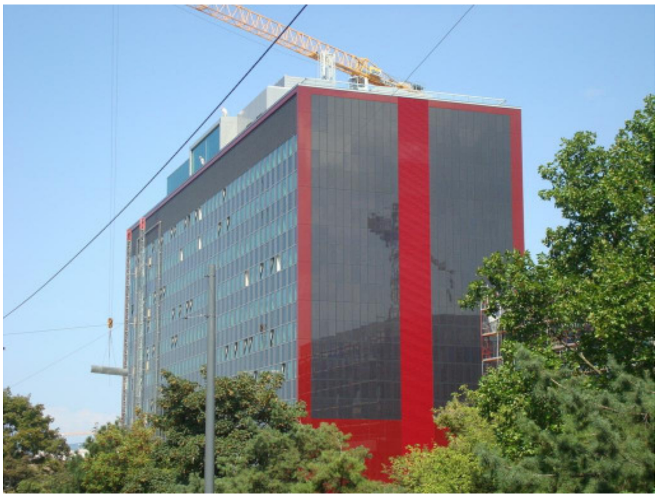

figure 17 Chamber of Commerce; Source Chamber of Commerce

2.2.3 Potential

As depicted above Vienna has an area of A=414km² and C=1.684.553 inhabitants.

The built up area of Vienna are 11,3% of area of Vienna that are 46,8km2. That results in a=27,7m² per inhabitant. The utilized area is according the assumption 2m² per inhabitant.

The annual energy output for Vienna is for roof systems 906kWh/m² and for façade systems 598kWh/m², IEA-PVPS Task10, (2006).

O_{roof} = 906 kWh/m² and
O_{facade} = 598 kWh/m²

Potential per inhabitant for the roof integrated PV – systems
$P_{roof} = 0{,}40 * a * O_{roof}$ = 724kWh

and for the façade integrated PV-systems $P_{facade} = 0{,}15 * a * O_{facade}$ = 179kWh

The potential for the city $P = (P_{roof} + P_{facade}) * C$ = 1.522GWh

The electricity consumption for Vienna was

Year	Electrical Energy consumption [GWh]
2000	7.630
2001	7.404
2002	7.155
2003	7.497
2004	7.382
2005	7.595
2006	7.692
2007	7.238

table 5 Energy consumption of Vienna

The consumption were in 2000 and 2006 nearly the same with 7.630, 7.692 GWh. In 2007 there was a decrease to 7.238 GWh (see table 5). According to the calculation the potential using BIPV in Vienna is about 21%. This means that nearly one quarter of the energy consumption of the city Vienna can be obtained from BIPV.

2.3 Barcelona

Barcelona is the second largest city in Spain, has a major economic centre with principal Mediterranean ports. It is also an important culture centre, a well know tourist destination, and also well known for its famous architecture. Barcelona is supporting the use of renewable energy since 1998 and belongs to one of the biggest renewable energy markets in the world. In Spain are 99% grid connected systems in the PV market, and they have a very high amount of large scale PV installations (30MW up to 60MW). But this is now changing from the large ground mounted installations to building integration in the cities. Since 2006 the Technical Building Plan was implemented to establish obligatory requirements in the building sector. One part of the Technical Building Code regulates the usage of PV systems and enforces the installation of PV on new large buildings. From 1998 the use of renewable energy was promoted against the non renewable sources. In 1999 the city passed a guideline which says to use hot water demand for new or renovated buildings with at least 60%. In 2000 there came also the PV market get going. The city council of Barcelona declared the Plan for energy improvement in Barcelona (PEIB), which has to fulfill the following requirements:

Reduction of atmospheric emissions
Reduction of the conventional energy consumption
Increase the share of the renewable energy.

For this PEIB the Barcelona Energy Agency was established in 2002 to create a new territorial and local energy model based on the principles of the sustainability. For new buildings the electricity provision should be 10 – 12 % by end of 2010, suggested by PEIB. The PEIB carried out, that the PV technology will be the most promising sustainable technology for Barcelona, which is well structured and the solar yield is about 1193kWh/m².

The feed in tariffs where often changed in the past. The latest legal act for the PV – systems is the Royal decree 1578/2008 (Real Decreto 1578/2008). It considers an installed capacity limit yearly adapted, and the tariffs are calculated according to the installation capacity from the last year. It also distinguish between installations on roof or facades which are funded with

0,34 € smaller than 20kW and 0,32€ greater than 20kW and all other installations which are funded with 0,32€.

2.3.1 Population, irradiation, installed BIPV systems

Barcelona has a population of over 1.615.908 inhabitants and an area of 101km², this corresponds to population density of 16.000 inhabitants per square meter. The inhabitant increasing steadily with about 0,9% per year; see table 6.(Source Department of Estatdistica).

Year	**Inhabtitant**
2000	1.496.266
2001	1.505.325
2002	1.503.884
2003	1.582.738
2004	1.578.546
2005	1.593.075
2006	1.605.602
2007	1.595.110
2008	1.615.908

table 6 Inhabitants of Barcelona

From the 101 km² the built up area is 54%.

The following figure 18 shows the irradiation of Spain. The irradiation varies from about 1300kWh/m2 in the north - west regions up to 2100kWh/m2. The irradiation of Barcelona is about 1500kWh/m2 up to 1700kWh/m2.

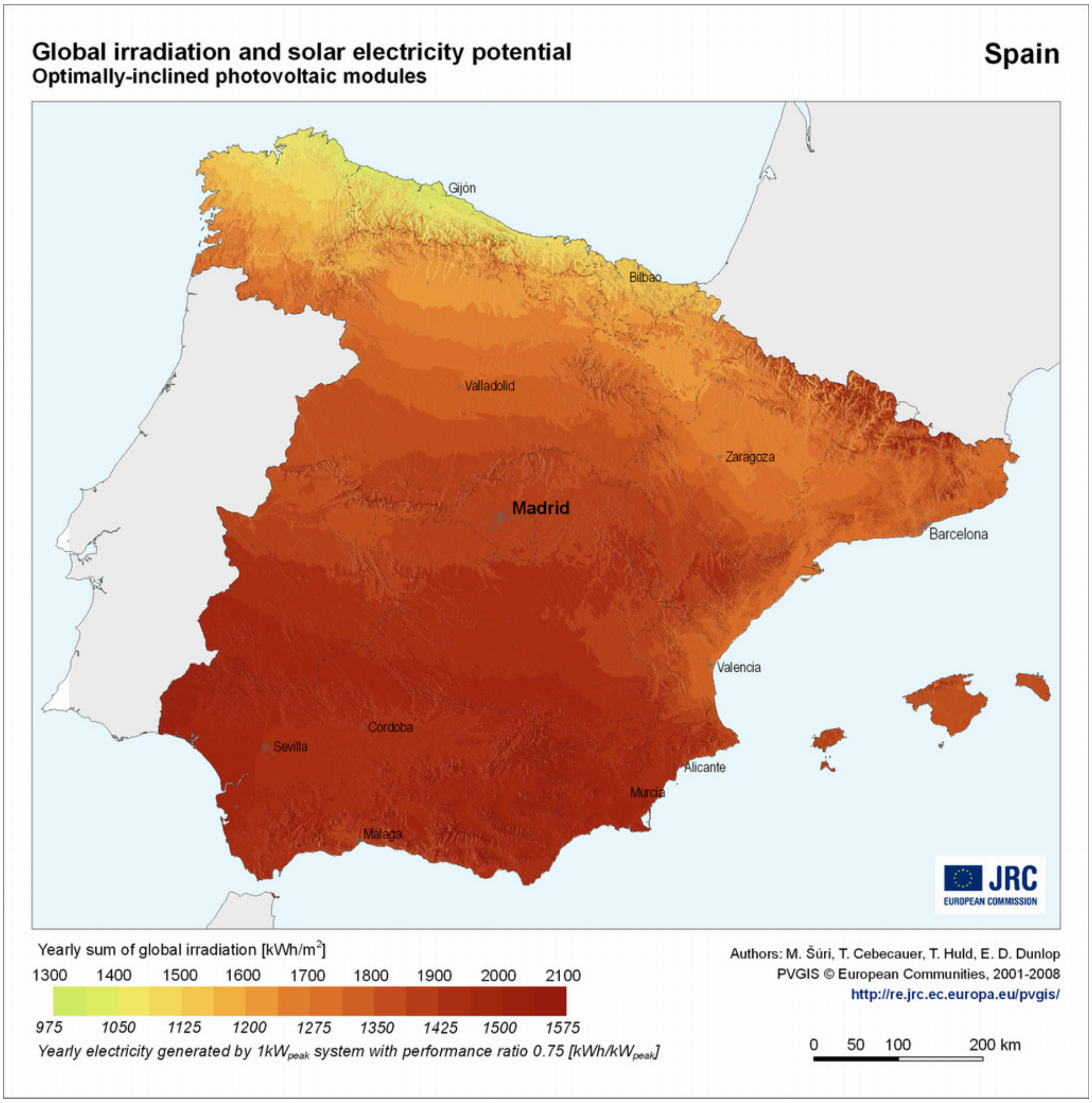

figure 18 Global irradiation of Spain

According the statistical data from the Barcelona Energy Agency there are 39 PV plants in public buildings with a total installed power of 1,65MWp, an yearly energy output of 1,93 GWh installed This plants have an area of about 13.548m2.

2.3.2 Case studies

1. PV Pergola located in the Esplanade Forum of Barcelona. It was built for the “Forum of Cultures 2004”. This was an forum for cultural diversity, sustainable development and peace for the world. So this PV pergola was a highlight entering the forum entrance. It is an impressing view to see this large PV pergola constructed like a

monument for the PV technology. The construction is a big structure with four pillars of different heights and out of it a slope with a tilt angle of 35° oriented to the south (see figure 19). The maximum is 50 meters. It covers 3.780m2 and has an installed power of 443kWp with 2686 modules mounted. The energy output per year is about 552.976kWh.

figure 19 Pergola in the Esplanade Forum; Source: Barcelona Energy Agency

2. The new Barcelona City Council was one of the vanguard promoting sustainable energy and installed their PV plant in 2002. It has 352m2 and a installed power of 45,96kWp.The rated energy output per year is 53.000kWh.

figure 20 Barcelona City Council; Source: Barcelona Energy Agency

3. The next project got the EUROSOLAR award in Spain 2006. The interworking between university and the private company and the integration of the nearly invisible PV system was decisive to got this award. It is an office building from the company SCHOTT. Due to renovation transparent PV modules are incorporated into the south

west façade with color printed glass elements. The transparency of the modules is 10%. The PV system consists of 27 modules with 1,35kWp. The annual energy output is measured in 2007 with 1.270kWh.

figure 21 SCHOTT office building; Source:Torsten Masseck, 2006

2.3.3 Potential

Barcelona has an area of A=101km² and inhabitants of C=1.615.908

The built up area of Barcelona is 54% of the total area; this is 54,5km². That results in a=30m² per inhabitant. The utilized area is according the assumption 2,5m² per inhabitant.

The annual energy output for Vienna is for roof systems 1.193kWh/m²kWp and for façade systems 759kWh/m²kWp, IEA-PVPS Task10, (2006).

O_{roof} = 1.193 kWh/m² and
O_{facade} = 759 kWh/m²

Potential per inhabitant for the roof integrated PV – systems
$P_{roof} = 0,40 * a * Pp * O_{roof}$ = 1.193kWh

and for the façade integrated PV-systems $P_{facade} = 0,15 * a * Pp * O_{facade}$ = 284kWh

The potential for the city $P = (P_{roof} + P_{facade}) * C$ = 2.388GWh

The electricity consumption for Barcelona was

Year	Electrical Energy consumption [GWh]
2000	4.387
2001	4.504
2002	4.606
2003	4.779
2004	4.889
2005	5.081
2006	5.184
2007	5.105

table 7 Energy consumption of Barcelona

The consumption was steadily increasing since 2000 from 4.387 GWh up to 5.184 GWh in 2006. In 2007 there was a decrease down to 5.105 GWh. According to the calculation the potential using BIPV in Barcelona is about 46%. This means that nearly the half of the electrical energy consumption of the city can be obtained from PV systems.

2.4 The comparison of the three cities

The three cities are different regarding their area, the largest city is Berlin with 892km2 followed by Vienna and the smallest one is Barcelona. The area, respectively the built up area of each city has a great impact determining the PV potential of each city. The accuracy of public authorities of this built up areas is influencing the value of the PV potential. Berlin with 3.431.675 inhabitants has nearly doubled inhabitants than Vienna and Barcelona, both about the same with 1.600.000 inhabitants. But Barcelona and Vienna differ in the area of the city. Originating from the result Berlin and Barcelona have the highest potential using the PV technology in their cities. The potential for these two cities is nearly the same regarding their electrical energy consumption. Berlin and Barcelona are able to obtain two third of their electricity from the PV, whereas Vienna can only get nearly one quarter.

In Berlin the potential for the roof integrated systems is fourth times higher than for the façade integrated systems. With the roof integrated systems you can get nearly 4.600 GWh per year, and with the façade systems you can get 1.200 GWh per year. In Berlin there are 4m² per inhabitant disposable using PV.

Vienna is able to get 1.220GWh per year from the roof integrated BIPV, and 300GWh from the façade integrated. The disposable are per inhabitant is 2m²; this is half of Berlin.

Barcelona with slightly more square meter per inhabitant, 2,5m2 is able to produce 1.930GWh with the roof systems and 460GWh with façade systems.

	Berlin	**Barcelona**	**Vienna**
Area [km²]	892	101	414
Inahbitant[1]	3.431.675	1.615.908	1.684.553
m² per Inhabitant[m²/1]	4	2,5	2
Roof [GWh]	4.605	1929	1.219
Façade [GWh]	1.202	459	303
Eelectrical Energy Consumption[GWh]	13.082	5.105	7.238
Potential[GWh]	5.807	2.388	1.522
Perecentage of Consumptoin [%]	44	46	21

table 8 Comparison of the three cities

As seen in table 8 Berlin and Barcelona have nearly the same potential regarding their electrical consumption, although the global irradiation differs between 1.000kWh/m² in Berlin up to 1.700kW/m² in Barcelona. Vienna has BIPV potential of 21% take the consumption of the year 20007 as reference. The potential is not only determined by the irradiation, also a great impact has the building area and the potential which can be utilized.

3 Potential of the BIPV systems in the year 2030

The PV market itself and especially the BIPV market in future will play a major role in the renewable energy market. But this must be supported by financial promotion and political regulation furthermore till PV becomes commercially competitive in the conventional power networks. Due to this fact the need for national and international strategies and implementation plans is needed. BIPV is proposed to fit in best way for urban buildings and for the domestic sector for many reasons. The building envelope allows installation on already freely available areas for a so called dual use. The BIPV enables to make future buildings energy efficient and pleasant to live in it.

Europe has already a good basis on the market; mainly driven from Germany and Spain since the last 15 years. The global cumulative PV market is at the end of 2008 nearly 15GW. Europe is the leading market with about 9GW, followed by Japan with 2.1GW and the US with 1,2GW; see also figure 22 .

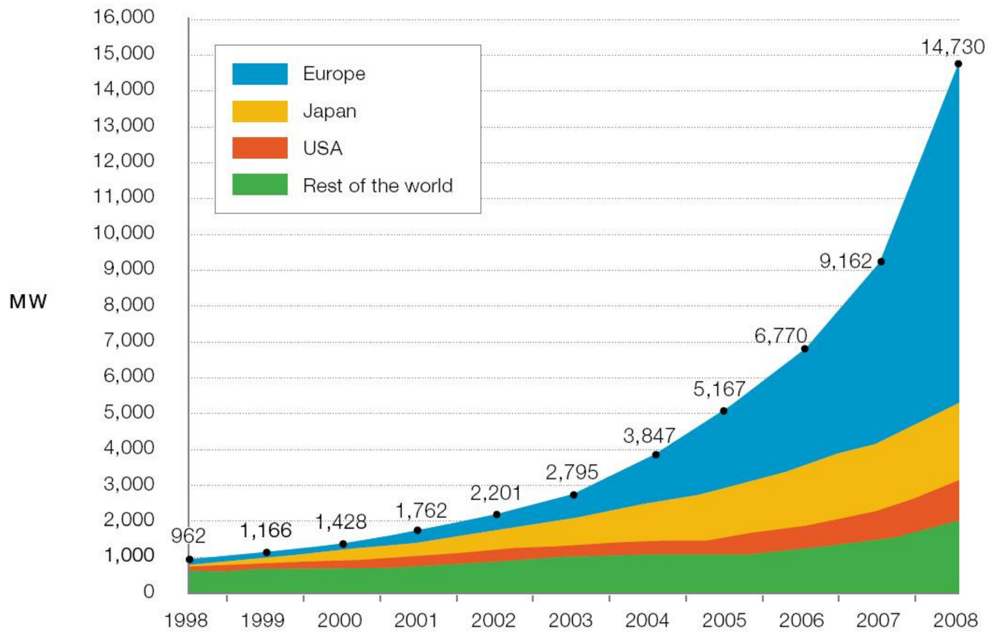

figure 22 Global cumulative PV market; Source: EPIA European Photovoltaic Industry Association (2009)

Spain has in 2008 a extraordinary growth with 2.600 MW which represents 45% of the global market share in 2008. Germany with 1.500MW installed power capacity is continuing the steadily growth. Austria with nearly 4,7MW is far behind of the leading countries in Europe.

This chapter shows the potential of the BIPV under the influence of the population development regarding the area development, the electricity demand. Considered will be the time frame till 2030. The outcome is an achievable energy provision with BIPV systems under the different scenarios in the year 2030. This can help to obtain the right decisions for a sustainable electricity provision in the urban areas in the European Union.

3.1 Consideration of the population respectively area development till 2030

3.1.1 Population / area development of Berlin

The population development of Berlin is seen in the basic scenario for the year 2030 with 3.476.000 inhabitant, Senatsverwaltung für Stadtentwicklung Ref. I A (2009). In the next few years a slightly increase up to a maximum in the year 2023 with 3.480.000 and after 2023 slight decrease. The development of Berlin is always seen in country wide context. Therefore the whole population development of Germany is since the year 2002 regressive. But in contrast the congested urban areas are still growing. Three scenarios are considered:

Scenario Basic: Identifiable economical and demographical development of the federal state from the past are shifted to a future scenario.
Scenario growth: In this scenario the economical frame conditions are considerable increasing permanently.
Scenario shrinking: This scenario goes out from a permanently stagnation of the economy.

The variant Basic is the one with the highest plausibility. The figure 23 shows the three scenarios.

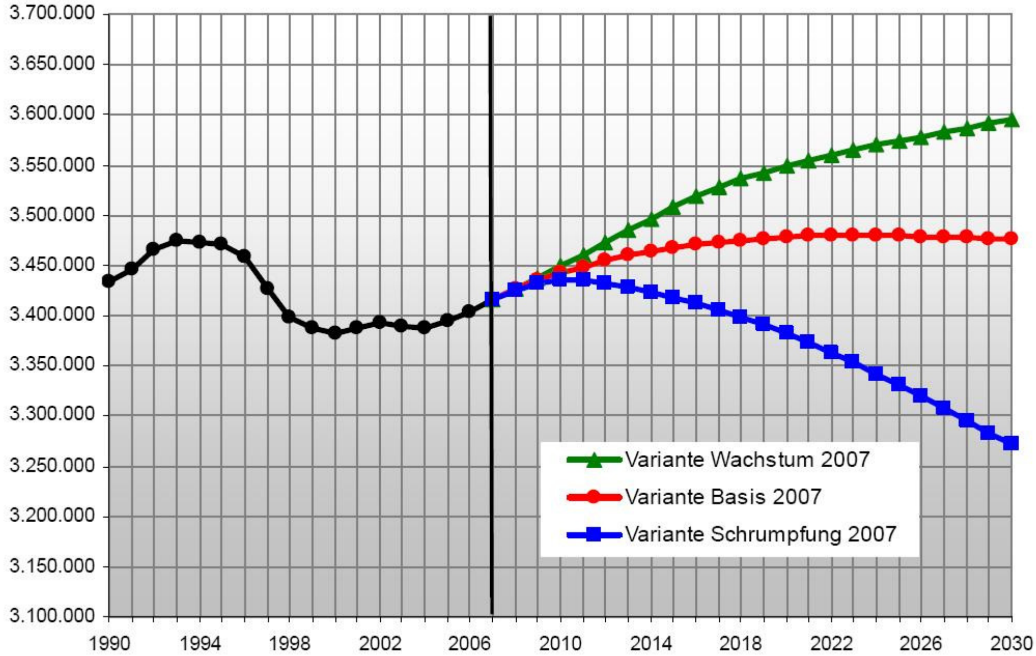

figure 23 Population development of Berlin; Source Senate of Urban Development Ref. I A (2009)

Berlin has in the last decade an area consumption of about 19km². According the area assessment leads this to 2.000m² per day, what is a conservative estimation. Due to lack of data smaller than 10.000m² this value has to be seen in context of the federal average. The federal average is with about 3.000m² per day is more suitable for Berlin, Berger Dr. Hartwig (2009). The development of the built up area is seen with approximately 0,18% per year.

3.1.2 Population / area development of Vienna

The population development in Austria is steadily increasing, however with big distinctions of the federal states. The federal states in the East and West are growing faster than that ones in the South like Carinthia and Styria. Vienna is increasing steadily since decades. The latest forecasts for Vienna says the highest population development of the nine federal states, see also figure 24 .

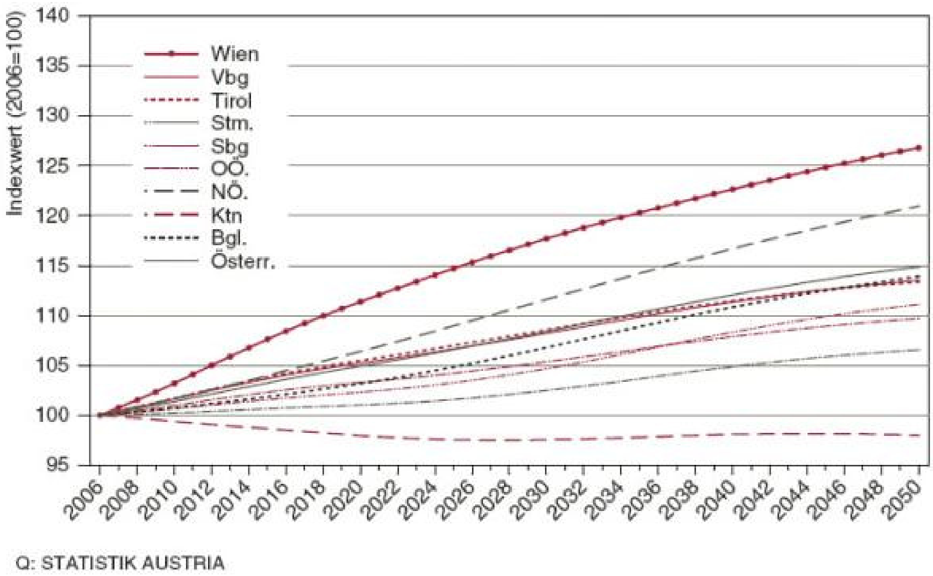

figure 24 Population development of Austria; Source Statistics Austria

This increase is mostly secured due to immigrations. About 40% of all the immigrants came to Vienna. This will lead to a population in 2030 of 1.951.118 inhabitants (surplus of 16% seen in relation of 2007); see table 9. In about 30 years Vienna could be again a 2 million metropolis like in 1910, Statistik Austria.

2007	2010	2015	2020	2030
1.684.553	1.711.335	1.781.095	1.840.688	1.951.118

table 9 Population development of Vienna

The development of the built up area in Austria is seen with different growing rates depending the federal states. Lower Austria and Styria have the greatest increase of the built up areas, however Vienna has only slightly increase. This is contradistinction to the population forecast, which is explicable due to the utilization of the inner city potential use. According to the Environmental Federal Agency, the development of the area can are seen in 0,25% per year of the built up area from 2001 up to 2009. Take this as basis for the forecast regarding the population development it can be seen as a realistic value.

3.1.3 Population / area development of Barcelona

Barcelona with about 1.6 million inhabitants and the area of 101km² has one of the highest densities in Europe. The congested urban area has 4.9 million inhabitants. The size of the population has been stabilized the recent years and will be forecasted up to 2030 with about the 1.6 million like in 2008. No significant change in the population density in Barcelona. However the suburbs in the surrounding area are growing steadily.

The average increase of the built up are will be predicted with 0,15% per year, in accordance with Berlin an Vienna.

3.2 Consideration of the increasing electricity consumption till 2030

The electricity consumption in the EU increased the last 15 years by 1,71% per year. The main part of the increasing demand are the service and residential sector with 2,97% per year, however the industrial sector with 0,95% per year was much lower. The trend of increasing electricity demand is furthermore prolonged. But however the past the demand will be lower than then last 15 years. From 2010 up to 2020 the increase will be 1,5% per year and from 2020 it will be down to 0,7% per year; see figure 25; Source: European Commission Directorate-General for Energy and Transport (2008).

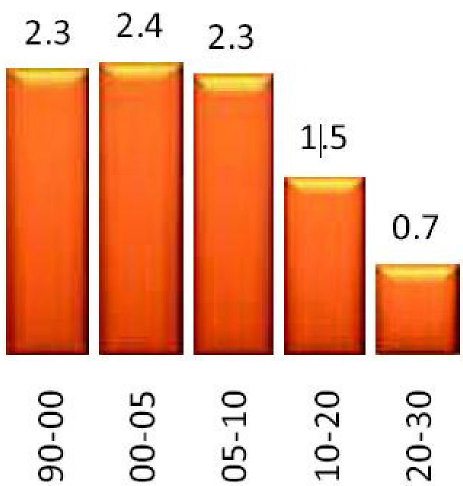

figure 25 EU electricity growth; Source European Commission Directorate-General for Energy and Transport (2008)

The electricity will have a share of 23% of the total energy demand in 2030, in contrast with 17% in the year 1990 and 20% in the year 2005.

In Germany the total final energy demand decreased from 1990 to 2005 from 228.372 ktoe down to 218010 ktoe. From 2005 a continuous increasing takes place and will reach a demand of 231.866 ktoe in the year 2030.

	1990	1995	2000	2005	2010	2015	2020	2025	2030
Final Energy Demand:[ktoe]	228372	222379	220163	218010	223580	228220	229460	231126	231866

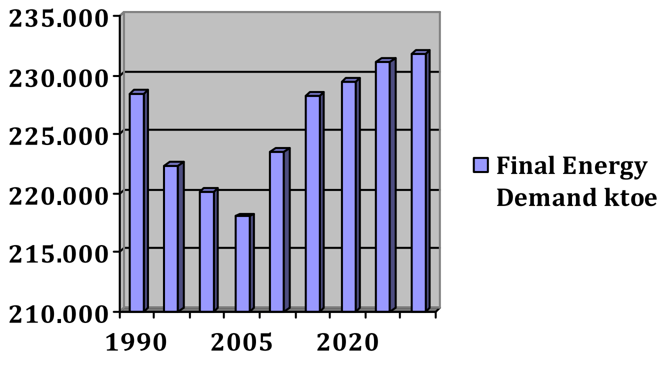

figure 26 Final Energy Demand Germany 1990 - 2030

The final electricity demand is still growing up to 53.320ktoe; and it will stabilized at this level for the next years.

	1990	1995	2000	2005	2010	2015	2020	2025	2030
Final Electricity Demand:[ktoe]	38391	38912	41496	44497	47627	50269	51625	52783	53320

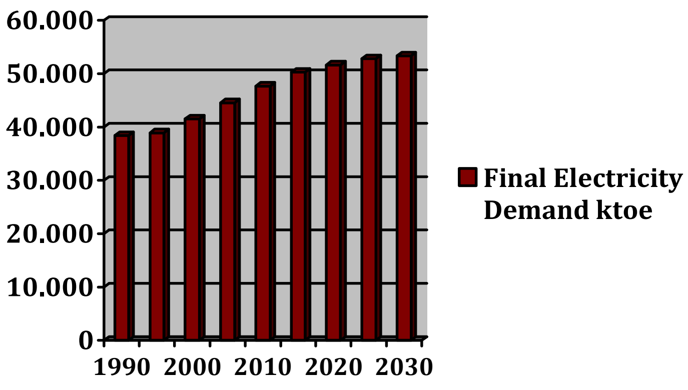

figure 27 Final Electricity Demand of Germany 1990 - 2030

In Austria the final energy demand is increasing as well. From 1990 up to 2005 there was a high increase (see figure 28); it raised from 19.057 ktoe up to 22.913 ktoe in 2005 (21%) and from about 2020 it will be came to saturation by 2030 (increase of 2,7%).

	1990	1995	2000	2005	2010	2015	2020	2025	2030
Final Energy Demand:[ktoe]	19057	20919	22913	27309	29327	30706	31646	32184	32510

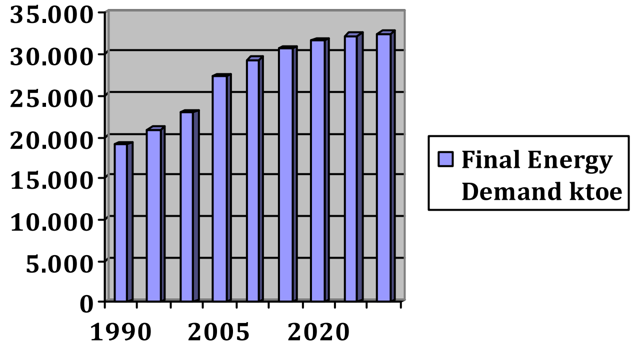

figure 28 Final Energy Demand Austria 1990 – 2030

	1990	1995	2000	2005	2010	2015	2020	2025	2030
Final Electricity Demand:[ktoe]	3669	3953	4474	4884	5291	5723	6106	6384	6584

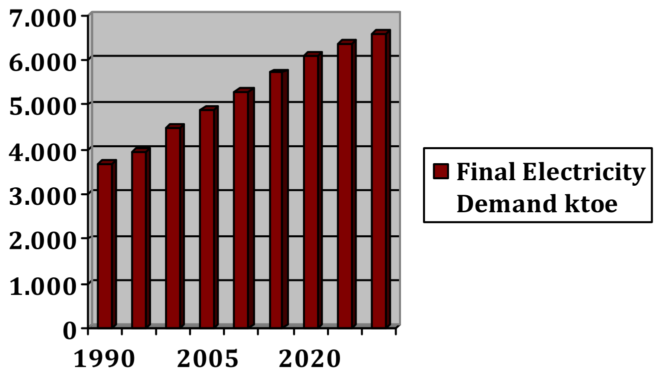

figure 29 Final Electricity Demand Austria 1990 - 2030

In Spain the final energy demand was growing fast the last decades up from 1990, what stands in relation with the tremendous economical development.

	1990	1995	2000	2005	2010	2015	2020	2025	2030
Final Energy Demand:[ktoe]	56647	63536	79422	97170	108516	117655	122658	125386	126148

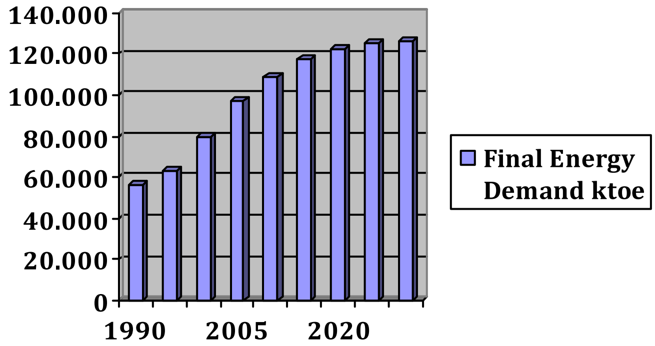

figure 30 Final Energy Demand Spain 1990 – 2030

The electricity demand was according the economic development up to 2008. A saturation will take place about from 2020 to 2030.

	1990	1995	2000	2005	2010	2015	2020	2025	2030
Final Electricity Demand:[ktoe]	10817	12116	16205	20827	24489	27189	28798	29785	30537

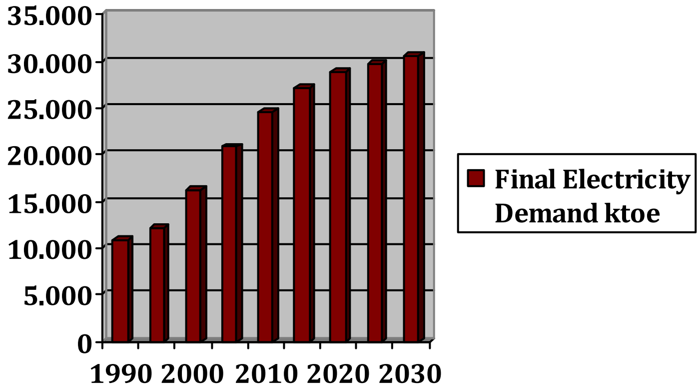

figure 31 Final Elecricity Demand Spain 1990 - 2030

Source: EUROPEAN ENERGY AND TRANSPORT TRENDS TO 2030 — UPDATE 2007 European Commission

3.2.1 Electricity demand for Berlin

The future electrical energy consumption in Berlin by 2030 will be assumed according the data of the Federal State of Germany about the energy demand in 2030 published by the "EUROPEAN ENERGY AND TRANSPORT TRENDS TO 2030 — UPDATE 2007", and the consumption from the past.

With respect to the marginally population development of Berlin and according the electrical energy consumption in the past, the consumption in 2030 can be imbibed. In the last years from 2002 up to 2006 the consumption raised up 6,7% see also table 3. Germany's electrical energy demand is increasing from 2010 up to 2030 by 12%. Take these values, we can predict the electrical energy demand of Berlin in 2030 with 16.614 GWh.

3.2.2 Electricity demand for Vienna

The electrical energy demand of Austria will be predicted from 2010 up to 2030 by 24,5%, see figure 29 Final Electricity Demand Austria 1990 - 2030. Vienna's demand in the past was slightly decreasing form 2000 up to 2007 by 0,7% per year. In the same timeframe, the private household consumption are increased by 0,7%. Taking the population development of Vienna with 14% from 2010 up to 2030, the electricity demand will be predicted with 15% up to 8.323GWh per year.

3.2.3 Electricity demand for Barcelona

The electricity consumption of Spain increased the last two decades by an yearly growing rate of 5,6% per year up to 284TWh in 2005 (see figure 31). This was one of the highest growing rates in the EU. The main influence came from the tremendous economic development of the last decades. The consumption of the commercial and public sector has growing rates more than 7% per year. Similar was development in the private household sector the last decades. The increase of electricity demand will be prolonged up to 327TWh in the year 2020. After that the economy will came to saturation and the growing rates are decreasing. Outgoing from this rates and development of the inhabitants the electrical energy demand of Barcelona is set to 6.840GWh; this is 34% surplus related to the consumption in 2007.

3.3 Potential of BIPV systems in 2030

3.3.1 Potential of Berlin in 2030

The area A=892km2 and 3.431.675 inhabitants in 2008

The built up area of Berlin are 21% of area of Berlin that are 187km².

Increase of 0,18% per year leads to194km². The utilized area is according the assumption 4,19m² per inhabitant.

Potential per inhabitant for the roof integrated PV – systems
$P_{roof} = 0{,}40 * a * O_{roof} = 1.406$kWh

and for the façade integrated PV-systems $P_{facade} = 0{,}15 * a * O_{facade} = 367$kWh

The potential for the city $P = (P_{roof} + P_{facade}) * C = 6.163$ GWh

	2008	**2030**
Inhabitants	3.431.675	3.476.000
Area / inhabitant	4	4,19
Roof [GWh]	4.605	4.887
Façade [GWh]	1.202	1.275
Electrical Energy Consumption [GWh]	13.082	16.614
Potential [GWh]	5.807	6.162
Percentage of the potential	44	37

table 10 Potential of Berlin in 2030

3.3.2 Potential of Vienna in 2030

The area A=414km2 and 1.684.553 inhabitants in 2008

The built up area of Vienna is 11,3%, that are 46,78 km².

Increase of 0,25% per year leads to49,42km². The utilized area is according the assumption 1,9m² per inhabitant.

Potential per inhabitant for the roof integrated PV – systems
$P_{roof} = 0,40 * a * O_{roof} = 688kWh$

and for the façade integrated PV-systems $P_{facade} = 0,15 * a * O_{facade} = 170kWh$

The potential for the city $P = (P_{roof} + P_{facade}) * C = 1.673$ GWh

	2008	**2030**
Inhabitants	1.684.553	1.951.118
Area / inhabitant	2	1,9
Roof [GWh]	1.219	1.342
Façade [GWh]	303	331
Electrical Energy Consumption [GWh]	7.238	8.323
Potential [GWh]	1.522	1.673
Percentage of the potential	21	20

table 11 Potential of Vienna in 2030

3.3.3 Potential of Barcelona in 2030

The area A=101km² and 1.615.908 inhabitants in 2008

The built up area of Barcelona is 54%, that are 54,5km².

Increase of 0,15% per year leads to56,32km². The utilized area is according the assumption 2,64m² per inhabitant.

Potential per inhabitant for the roof integrated PV – systems
$P_{roof} = 0{,}40 * a * O_{roof} = 1.260kWh$

and for the façade integrated PV-systems $P_{facade} = 0{,}15 * a * O_{facade} = 300kWh$

The potential for the city $P = (P_{roof} + P_{facade}) * C = 2.496$ GWh

	2008	**2030**
Inhabitants	1.615.908	1.600.000
Area / inhabitant	2,5	2,64
Roof [GWh]	1.929	2016
Façade [GWh]	459	480
Electrical Energy Consumption [GWh]	5.105	6.840
Potential [GWh]	2.388	2.496
Percentage of the potential	46	36

table 12 Potential of Barcelona in 2030

3.4 Achievable electrical energy with the BIPV systems for Berlin, Vienna and Barcelona in the year 2030

The development of the potential in the three cities is mainly determined by using the existing areas. Using the possibility of BIPV for the new buildings, is also a crucial point for a step forward to sustainable energy supply in the urban areas.

Berlin has now the potential of 5.807 GWh producing out of BIPV. In 2030 this share could raise up to 6.162 GWh. An increase of 6,11% between 2008 and 2030. However the consumption will go up from 13.082GWh to 16.614GWh. It is absolute essential using the existing areas to obtain about 37% of the electricity consumption in 2030, see table 13.

Barcelona can cover 2.496GWh in 2030, 4,5% more in relation to 2008. The potential in 2030 can be seen in context with the consumption, with an share of 36%. The consumption will be enhanced to 6.840GWh.

Vienna with 1.673GWh and the share of 20% has the smallest potential in contrast to Berlin and Barcelona. However due to the development of Vienna (area and population) the drop of the potential is not much high like for Berlin and Barcelona. The decreasing potential of Vienna is only 1%. Berlin and Barcelona have a potential decrease between 7% and 10%.

The potential varies from 20% in Vienna up to approximately 37% in Berlin and Barcelona by 2030. Interesting is the roughly same potential of Berlin and Barcelona, even though they have different irradiation. The same potential can be seen in fact of the different utilized area, 4,19m² per inhabitant in Berlin, down to 2,64m² per in habitant in Barcelona.

	Berlin		**Barcelon**		**Vienna**	
	2008	***2030***	***2008***	***2030***	***2008***	***2030***
Potential [GWh]	5.807	6.162	2.388	2.496	1.522	1.673
Electrical Energy Consumption [GWh]	13.082	16.614	5.105	6.840	7.238	8.323

table 13 Potential in 2030 Berlin, Barcelona and Vienna

The BIPV market is depending on the political framework of each country. Reaching the potentials depends also on the support schemes. The PV technology has worldwide a positive image. Using right architectural concepts and design elements it can be extend reaching the goal that 23% of the electricity generation should be produced from renewable energy sources in the EU-27; European Commission Directorate-General for Energy and Transport (2008).

4 Conclusion

The way of BIPV in the urban area is irresistible, using the present areas in the cities. The geographical site of the city has not much influence of the potential as seen from the irradiation map. Mainly the structure of the city and the built up areas are the determining factors for the potential. In contrast to the irradiation map, Berlin has the highest potential in 2030. The share of BIPV can be 37% of total electricity consumption, followed by Barcelona with 36% and Vienna with 20% of the total consumption.

The influence of the population development has more likely a secondary character. For Vienna the inhabitants are increasing about 250.000 inhabitants up to 2030. Berlin and Barcelona predicted with almost the same inhabitants like in the present. Although Vienna has the maximal increasing amount of inhabitants, the potential increased only by 4,5%. The potential of Barcelona increasing by 9,9% and for Berlin by 6,1%. This is due to the different structures of the cities and the different utilization of the built up areas.

A good economic use of the available area of the city is the facing challenge for each municipality. The administrations have an environmental aspect regarding the land use. This leads to restricted usage of new areas concerning new BIPV potentials. Using the existing areas in the cities is one of the main aspects towards to a sustainable electrical energy supply. Not only the new buildings are able to fulfill great achievable potentials, also the existing ones have a strongly impact. About 10% of the present potential of a city can be obtained from the new buildings up to 2030. This is not to be neglected, however the main part are the existing buildings.

In this work the conversion efficiency of the PV technology respectively of the BIPV is not considered. Keeping an increasing efficiency in mind, the potentials are higher. Examinations about the influence of the efficiency are be clarified, and can be done in further research.

Generally a great potential in the PV market is forecasted the next decades, and the share of the BIPV have also the rights to be considered. Moderate growing scenarios predict an annual growing rate of 21% up to 2020 and 12% up to 2030. With the right strategies like the political and legal framework and the right financing schemes the up to 2030 will be the success for the BIPV.

Utilize the great potential in the urban area, is huge challenge to put the BIPV technology in practice. The potential of the three considered cities, is between 20% to 37 % of the total electricity consumption. In fact this represents a huge potential, which is unalterable to be enlarged.

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