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DIPLOMOVÁ PRÁCE

Solární systémy pro napájení elektrických vozidel

Solar systems for powering electric vehicles

Vedoucí práce: **Ing. Milan Bělík Ph.D.**

Autor: **Bc. Adéla Kuhajdová** **2014**

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Jméno a příjmení:	**Bc. Adéla KUHAJDOVÁ**
Osobní číslo:	**E11N0095P**
Studijní program:	**N2612 Elektrotechnika a informatika**
Studijní obor:	**Technická ekologie**
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1. Introduce main features of electric vehicles.
2. Compare situation in Spain and Czech Republic.
3. Design PV system for charging station.
4. Assess the proposal, its benefits and efficiency.

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	Katedra elektroenergetiky a ekologie

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Doc. Ing. Jiří Hammerbauer, Ph.D.
děkan

L.S.

Západočeská univerzita v Plzni 4 Fakulta elektrotechnická

Doc. Ing. Karel Noháč, Ph.D.
vedoucí katedry

V Plzni dne 14. října 2013

Annotation

The aim of this thesis is to explain the issues of realization photovoltaic systems, which can power electric vehicles and is devided into two sections – theoretical and practical.

In the first part are described in detail aspects of design photovoltaic systems and advantages and disadvatages of electric vehicles. The part is focused on a general introduction to this perspective area of automotive industry. Emphasis is placed on specific development opportunities in the Czech Republic and Spain and their National Renewable Energy Plan 2011- 2020. A large part is dedicated to government support (feed-in tarrif and green bonus) and solar radiation and PV electricity potentional in both countries.

In second, practical part, I tried to design PV system for charging parking lot by using all previous knowledge and resulting evaluation of important aspects.

Key words

Photovoltaic system, Electric vehicles, Feed-in tarrif, Solar radiation, PV electrical potencial, Smart grid.

Solární systémy pro napájení elektrických vozidel

Anotace

Cílem této práce je vysvětlit problematiku realizace fotovoltaických systémů, které umožní dobíjení elektrických vozidel a je rozdělena na dvě části - teoretickou a praktickou.

V první části jsou podrobně popsány aspekty návrhu fotovoltaických systémů a výhody a nevýhody elektrických vozidel. Část je zaměřena na obecný úvod do této perspektivní oblasti automobilového průmyslu. Důraz je kladen na specifické možnosti rozvoje v České republice a ve Španělsku a jejich národním plánu o obnovitelných zdrojích energií 2011-2020. Velká část je věnována státní podpoře (výkupní tarif a zelený bonus) a slunečnímu záření a FV potencionálu v obou zemích.

V druhé, praktické části, jsem se snažila navrhnout FV systém na plochy zastřešeného parkoviště pro nabíjení elektrických vozidel s použitím veškerých předchozích znalostí a následné vyhodnocení důležitých aspektů.

Klíčová slova

Fotovoltaické systémy, elektrická vozidla, výkupní tarif, sluneční záření, elektrický potenciál, chytré sítě.

Prohlášení

Předkládám tímto k posouzení a obhajobě diplomovou práci, zpracovanou na závěr Magisterského studia na Fakultě Elektrotechnické Západočeské univerzity v Plzni.

Prohlašuji, že jsem tuto diplomovou práci vypracovala samostatně, s použitím odborné literatury a pramenů uvedených v seznamu, který je součástí této práce. Dále prohlašuji, že veškerý software, použitý při řešení této diplomové práce, je legální.

....

podpis

V Plzni dne 1. 5. 2014 Adéla Kuhajdová

Poděkování

Tímto bych ráda poděkovala mému vedoucímu Diplomové práce **Ing. Milanu Bělíkovi Ph.D.** za cenné profesionální rady, připomínky a metodické vedení práce. Také bych ráda zmínila mého profesora ze španělské univerzity Sergio Valero Verdu za možnost zpracování velké části mé práce pod jeho vedením.

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Used abbreviations

AVERE	The European Association for Battery, Hybrid and Fuel Cell Electric Vehicles
BEV	Battery electric vehicle
EGCI	European Green Car Initiative
EPBT	Energy Payback Time
EV	Electric vehicle- powered only by electricity
FIT	Feed-in-tarrif
GB	Green Bonus
GHG	Greenhouse gases
HEV	Hybrid electric vehicle- powered by gasoline plus electricity
NREAP	The National Renewable Energy Action Plan
PGF	Panel generation factor
PHEV	Plug-In hybrid vehicle
PVGIS	Photovoltaic Geographic Information System
RES	Renewable Energy Sources
V2G	vehicle-to-grid

PR [-]…………………….............Performance rate

P_{mp} [kWp]…………………… Peak Power of the Generator

E_p [kWh/day]……………… ... Consumption per day

$P_{cc, fov}$ [W]…………………… Potency of DC power immediately output from the PV panels

1 Introduction

The result of my work should be efficient and accurate assessment parameters for the design PV system for connection to the electric grid and powering electric vehicles and its subsequent application in the project part. Most of the knowledge I have gained during my work placement in Spain, that´s why this thesis is focused on the difference between the possibility of using PV systems in Spain and the Czech Republic.

My goal is to understand electrical vehicles as a normal part of the motor industry and the proper implementation of the solar energy use that the Earth provides for a reduction the energy consume and of course closely related to environmental protection. Everyone should understand the environmental protection as a natural part of his being, and therefore think about this fact when buying a new vehicle. This idea came out because of my interest in solar energy and innovative imaginations about how to use it. I wanted to show that there are no limits in innovative plans for future energies even they are not globally used yet. My intention is to open eyes to everyone who will read my thesis and show the importance of to be aware about energy consuption nowdays and the precaution for the future. We have to be informed to where our world is heading and what can every singel person do with it.

Therefore this thesis in the first part focuses on the basic knowledge of this issue, which I have gained during my studies at the university in Pilsen and Elche and the second (designing) part mastering these skills on my own designing solar charging station for electric vehicles. The plan is to place this station in front of some supermarket and utilize already standing parking area for photovoltaic power plant. For the comparison I decided to use parking area in front of OC Olympia in Pilsen, Czech Republic and Carrefour in Elche, Spain. These both areas are well-oriented with high potencial for PV´s installation.

2 Main features of electric vehicles

2.1 Photovoltaic energy

Photovoltaic energy is produced when sunlight is converted into energy with the use of solar cells or semiconductors. These semiconducting cells are usually made of silicon and do not contain any corrosive materials or moving parts. As long as the solar cells are exposed to light, they will produce photovoltaic energy with a minimum of maintenance. This energy is also environmentally clean, quiet, and safe. In 1839, French physicist Edmond Becquerel discovered the **photovoltaic effect**, the production of a volt by use of a semiconductor. [7] When photons strike a PV cell, they may be reflected or absorbed, or they may pass right through. Only the absorbed photons generate electricity. When this happens, the energy of the photon is transferred to an electron in an atom of the cell .With its newfound energy, the electron is able to escape from its normal position associated with that atom to become part of the current in an electrical circuit. By leaving this position, the electron causes a "hole" to form. Special electrical properties of the PV cell-a built-in electric field-provide the voltage needed to drive the current through an external load (such as a light bulb). [10] This discovery prompted further experimentation with light sources and semiconductors, which led to the invention of solar cells that produce photovoltaic energy.

The amount of power available on cloudy days and at night in a photovoltaic energy system depends on the energy output of the photovoltaic modules and the battery arrangement. Adding additional modules and batteries will increase the available power, but will also increase the cost of the system. For best results, a thorough analysis of needs vs. cost must be conducted in order to create a system design that will balance cost and need with convenience of use. Systems that are well-designed offer the opportunity for expansion or reduction as energy needs increase or decrease. [7]

Fig. 2.1 showes solar radiation reaches the modules, which produce electricity by the photovoltaic effect as direct current (DC), which can be stored or injected into the grid, to benefit directly as DC. Since PV modules are only capable of producing DC electricity, an inverter is required to convert the DC output produced by the PV array into alternating current (AC) power. AC electricity is needed to run almost all appliances and lighting.

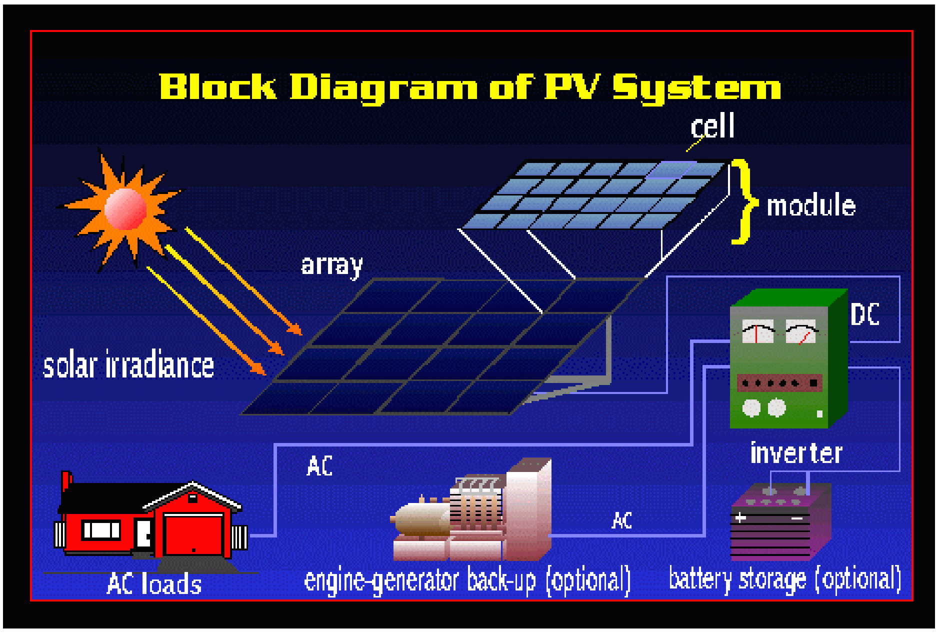

Fig. 2.1 PV Block diagram [11]

Generally is known that solar PV systems have more advantages than disadvantages. One of them is that the only pollution associated to the PV generation is the one produced in the fabrication of the PV system components, most notably by the fabrication of the PV panels, which require high amounts of energy. The other is that some solar panels are made of materials that might be toxic chemicals such as cadmium and arsenic. This impact must be considered, even though it could be largely mitigated through proper recycling and disposal.

Photovoltaic energy as general is emerging as a viable solution to energy problems worldwide. Its current uses include power stations, transportation, rural electricity supplies, and solar roadways. While still a long way from becoming the world's major energy source, ongoing research into photovoltaic energy may bring the promise of hope to the future. [7]

2.2 Electric vehicles

An **electric vehicle** (**EV**), also referred to as an **electric drive vehicle**, uses one or more electric motors or traction motors for propulsion. Three main types of electric vehicles exist:

- directly powered from an external power station,
- powered by stored electricity originally from an external power source,

- powered by an on-board electrical generator, such as an internal combustion engine (a hybrid electric vehicle HEVs) or a hydrogen fuel cell.

Electric vehicles include electric cars, electric trains, electric lorries, electric airplanes, electric boats, electric motorcycles and scooters and electric spacecrafts.

During the last few decades, environmental impact of the petroleum-based transportation infrastructure, along with the peak oil, has led to renewed interest in an electric transportation infrastructure. Electric vehicles differ from fossil fuel-powered vehicles in that the electricity they consume can be generated from a wide range of sources, including fossil fuels, nuclear power, and renewable sources such as tidal power, solar power, and wind power or any combination of those. However it is generated, this energy is then transmitted to the vehicle through use of overhead lines, which necessarily involves transmission loss, wireless energy transfer such as inductive charging, or a direct connection through an electrical cable. The electricity may then be stored on board the vehicle using a battery, flywheel, or super capacitors. [4]

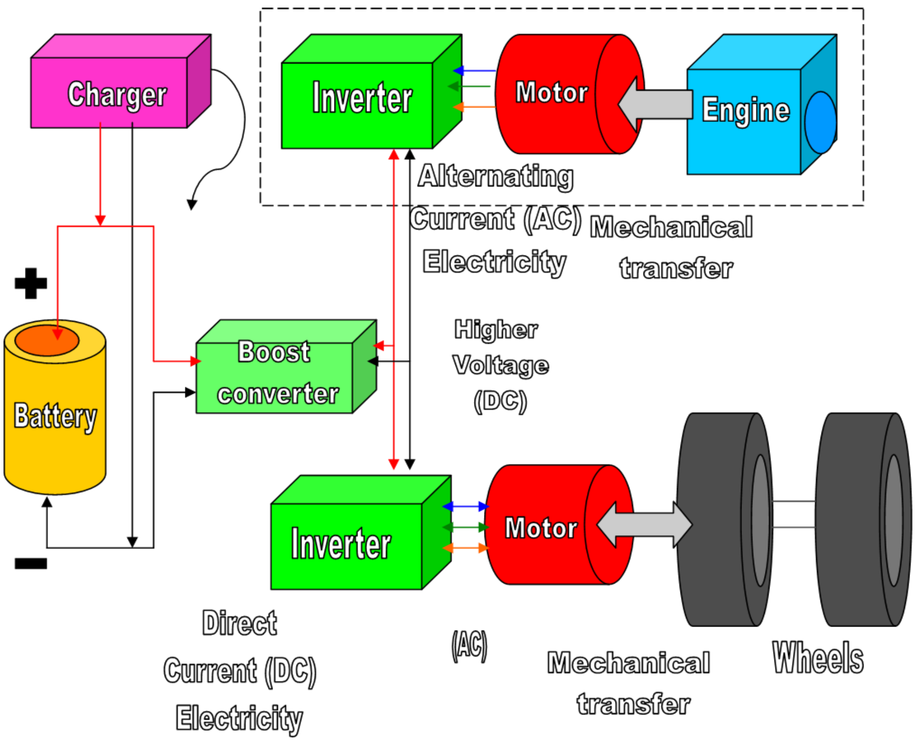

Fig. 2.2 Principe of electric vehicles

Electric motors are mechanically very simple as is shows in the Fig. 2.2. An electric car has an electric motor which draws its energy from a rechargeable battery located in the car. This battery will not only provide the power to drive around but also operates auxiliary items from wipers to lights. It often achieves 90% energy conversion efficiency over the full range of speeds and power output and can be precisely controlled. They can also be combined with regenerative braking systems that have the ability to convert movement energy back into stored electricity.

One of the first electric vehicles manufactured in the Czech Republic was Tatra Beta. Tatra Beta was a two-seat light commercial vehicle with a load capacity of 600 kg, produced in Tatra Kopřivnice in Příbor in years 1996-1999. Unfinished project took over later Škoda Pilsen for its commercial vehicles division Škoda Truck. The first prototypes of electric cars had 140 km range. As you can see in the Fig.2.3 this small car was designed and destined mainly for urban delivery service.

Fig. 2.3 Prototype Škoda/Tatra beta [13]

Modern EV looks little bit different, use smaler and lighter components and have larger km range. I was discusing a new prototype of electric car as showes folowing Fig. 2.4 from company ZF Friedrichshafen AG with local specialists during their open days. ZF technology combines individual mobility and driving pleasure with reduced fuel consumption, preservation of resources, and increased safety. This innovation prototype shows the potential of the combination of electromobility and lightweight approaches. Lightweight chassis components supplement the electric drive system and at the same time increase the range and driving dynamics of the electric vehicle.

Fig. 2.4 Electric car prototype from ZF Friedrichshafen AG

2.3 Advantages and disadvantages of electric vehicles in comparison with internal combustion engine vehicle

2.3.1 Advantages of Electric Cars

- Electricity is everywhere and easy to come by. We do not need to set up electricity stations on the corner to re-charge our cars. It can be done at home.
- Electric vehicles provide quiet and smooth operation and consequently have less noise and vibration.
- Due to efficiency of electric engines as compared to combustion engines, even when the electricity used to charge electric vehicles comes from a CO_2-emitting source, such as a coal- or gas-fired powered plant, the net CO_2 production from an electric car is typically one-half to one-third of that from a comparable internal combustion engine vehicle. As a result they improve air quality in cities, reduce greenhouse gases, dependence on foreign oil and are uniquely able to participate in an interactive energy grid of the future. [6]
- Electric cars are easy to assemble. They have few moving parts so they require less time and effort to put together.
- Electric cars require less maintenance. So not only will the owner save money on gas purchases but there will be less maintenance costs.

- The power plants that produce the electricity for the cars do pollute the environment but pollution from these power plants can be controlled better than gasoline engines.
- Better acceleration.

2.3.2 Disadvantages of Electric Cars

- One charge on a battery can take the car approximately 160km. Therefore if the ower plans on traveling a long distance this is not the car to use.
- It takes 6-8 hours to fully recharge the battery, less with fast charging plug.
- Electric bill will probably increase as the owner has to draw power from home electrical system to charge a car.
- Electric cars cannot compete with gas powered cars in terms of speed. Technology has not yet developed an electrical system as powerful as a gas powered vehicle. [6]
- The problem can be also find in the very quiet engine, especially for pedestrians.
- Accessories such as air conditioning will drain the battery faster.

Electric and hybrid cars can help decrease energy use and pollution, with local no pollution at all being generated by electric vehicles, and may someday use only renewable resources, but the choice that would have the lowest negative environmental impact would be a lifestyle change in favor of walking, biking or use of public transit.

2.4 Battery cost

Energy storage requirements create major hurdles for the success of EVs. It is the biggest problem for progress, which have to be solved. For example, if drivers demand 500 km of range (about the minimum for today’s vehicles), even with very efficient vehicles and battery systems that are capable of repeated deep discharges, the battery capacity will need to be at least 75 kWh. At expected near-term, high-volume battery prices of approximately 385€/kWh, the battery alone would cost 27000 € to 31000 € per vehicle. Thus, to make EVs affordable in the near-term, most recently announced models have shorter driving ranges (50 km to 200 km) that require significantly lower battery capacities.

Table 2.1 shows a general comparison of the specific power and energy of a number of battery technologies. Although there is an inverse relationship between specific energy and specific power (*i.e.*, an increase in specific energy correlates with a decrease in specific power), lithium-ion batteries have a clear edge over other electrochemical approaches when optimized for both energy and power density.

Ultimately, new battery chemistries with increased energy density will facilitate important changes in battery design. Increased energy density means energy storage systems will require less active material, fewer cells, and less cell and module hardware. These improvements, in turn, will result in batteries, and by extension EVs/PHEVs, that are lighter, smaller and less expensive. [14]

Table 2.1 Lithium-ion battery characteristics, by chemistry [14]

	Lithium cobalt oxide($LiCoO_2$)	**Nickel, cobalt and aluminum (NCA)**	**Nickel-manganese-cobalt (NMC)**	**Lithium polymer($LiMn_2O_4$)**	**Lithium iron phosphate($LiFePO_4$)**
Energy Wh/kg or L	Good	Good	Good	Average	Poor
Power	Good	Good	Good	Good	Average (lower V)
Low T	Good	Good	Good	Good	Average
Calendar life	Average	Very Good (if charge at 4.0 V)	Good	Poor	Poor above 30°C
Cycle life	Average	Very good (if charge at 4.0 V)	Good	Average	Average
Safety	Poor	Poor	Poor	Average	Good
Cost/kWh	Higher	High	High	High	High
Maturity	High	High	High	High	Low

2.5 Smart Grids

The “vehicle-to-grid” (V2G) concept could help cut electricity demand during peak periods and prove especially helpful in smoothing variations in power generation introduced to the grid by variable renewable resources such as wind and solar power. The smart grid is a generic concept of modernizing power grids, including activation of demand based on instantaneous, two-way, interactive information and communication technologies which are showen in Fig. 2.5. Features of a smart grid include grid monitoring and management, advanced maintenance, advanced metering infrastructure, demand response, renewable integration, EV integration, and V2G. The most fundamental principle for the power grid is that power supply and demand must be completely balanced at all times. Otherwise, power system frequency is never stabilized. In ordinary electric grids without two-way communication technologies, the supply from power generation plants is measured and operated to balance demand by a centralized electric power company via a bi-directional control system, or by an independent system operator (ISO) using uni-directional information technologies. In contrast, smart grids are automatically and multidirectionally controlled by interactive information technologies.

The main features of a smart grid include:

- grid monitoring and management,
- integrated maintenance,
- advanced metering infrastructures,
- demand response,
- renewables integration,
- electric vehicles,
- energy storage.

The qualitative benefits of smart grids include:

- power reliability and power quality (PQ),
- safety and cyber-security,
- energy efficiency,
- environmental and conservation benefits,
- direct financial benefits.

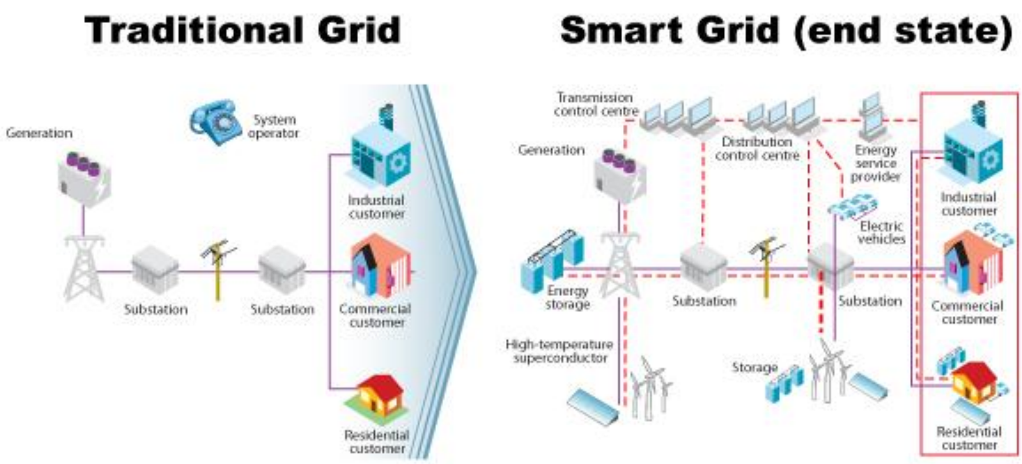

Fig. 2.5 Difference between Traditional and Smart Grid [14]

2.6 EU Electromobility

One of the most important tasks facing the world today is the need to reduce its dependence on oil and other fossil fuels. Nowhere is this felt more keenly than in the transport sector, which alone accounts for some 25% of global greenhouse gas emissions. Although it is widely recognized that electric cars will only make a significant difference if they are accompanied by a move towards smart grids and cleaner electricity generation, global competition for the electric vehicle market will be intense. The speed with which car manufacturers and their suppliers are able to develop these new vehicles and bring them to market is likely to be a decisive factor. **The European Green Cars Initiative** (EGCI), announced by the European Commission in 2008, was an important step in boosting the

European industry's competitiveness in this race. As well as benefiting Europe in terms of the environmental advantages of greener vehicles, the EGCI and **ELECTROMOBILITY+ project** are providing important support to Europe's global competitiveness. By cooperating within Europe as a result of these initiatives, European companies are enabling themselves to compete on the global stage in a way which otherwise would not have been possible.

Participants : Austria, Belgium, Denmark, Finland, France, Germany, Italy, Norway, Poland, Spain, Sweden, The Netherlands [9]

Spanish government aims to have 1 million electric cars on the roads by 2014 as part of a plan to cut energy consumption and dependence on expensive imports.

“Electric vehicles are the future and the driver of the industrial revolution”

—Miguel Sebastián, Spanish Industry Minister

Electrification of transport (electromobility) figures prominently in the EGCI, included in the European Economic Recovery Plan. The Directorate-General for Mobility and Transport (DG MOVE) is a Directorate-General of the European Commission responsible for transport within the European Union. DG MOVE was created on 17 February 2010 when energy was split from it to form the new DG Ener. Transport and Energy had been merged (as DG TREN) since January 2000 and in June 2002 the EuratomSafeguards Office became part of DG TREN. That is now part of DG Ener.

DG TREN is supporting a large European "electromobility" project on electric vehicles and related infrastructure with a total budget of around €50-million as part of the Green Car Initiative. There are measures to promote efficient vehicles in the Directive 2009/33/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of clean and energy-efficient road transport vehicles and in the Directive 2006/32/EC of the European Parliament and of the Council of 5 April 2006 on energy end-use efficiency and energy services.

The European Association for Battery, Hybrid and Fuel Cell Electric Vehicles (AVERE) has a table summarizing the taxation and incentives for these vehicles in the different European countries, related to state subsidies, reduction of Value added tax (VAT) and other taxes, insurance facilities, parking and charging facilities (including free recharging on street or in the parking areas), EVs imposed by law and banned circulation for petroleum cars, permission to use bus lanes, free road tax, toll free travel on highways, exemption from congestion charging, free or reduced parking rates, and free charging at charge points, amongst other initiatives.

2.6.1 Green eMotion project

The Green eMotion project is part of the EGCI that was launched within the context of the European Recovery Plan. It supports the achievement of the EU's ambitious climate goals, such as the reduction of CO2 emissions by 60 percent by the year 2050. EGCI supports the research and development of road transport solutions that have the potential to achieve sustainable as well as groundbreaking results in the use of renewable and non-polluting energy sources. [8]

2.7 National renewable energy action plan 2011-2020

Directive 2009/28/EC of the European Parliament and the council of 23 April 2009 on the promotion of the use of energy from renewable sources establishes the general targets of 20% share of energy from renewable sources in gross final consumption in the transportation sector by 2020. To achieve that, it sets 2020 targets for each Member State and a minimum indicative trajectory leading up to that year as we can see in the Fig. 2.6.

The National Renewable Energy Action Plan (NREAP) for the Czech Republic beeing presented suggests a target of a 13,5% share of energy from renewable sources in gross final energy consuption and the fulfilment of a target of a 10,8% share of energy from renewable sources in transport in gross final energy consuption. In Spain, the target means that renewable sources must account for at least 20% of final energy consuption by 2020- the same as the EU average- together with contribution of 10% from renewable sources in the field of transport by the year.

NREAP has been drawn up to meet the set targets in the area of the use of energy from renewable sources on the grounds of current and planed realistic projects and the expected realistic prediction of the future.

The main points of measures for achieving the targets*:*

a) Heating and Cooling – geothermal, solar, biomass (biogas, bioliquids, heat pump renewable energy etc.)

b) Electricity production – water, geothermal, solar (photovoltaic, concentrated solar energy), ocean, wind, biomass

c) Transport [9]

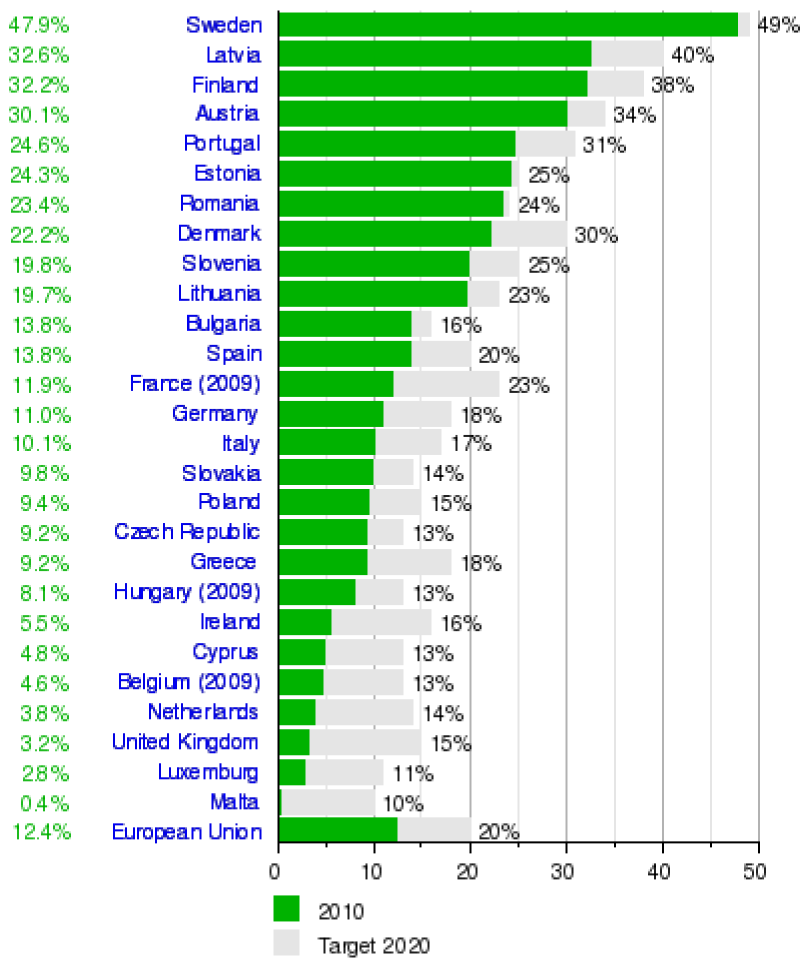

Fig. 2.6 Share of renewable energies in gross final energy consumption in EU-27 countries in 2010 (in %) *[9]*

3 Comparison of situation in Spain and Czech Republic

3.1 Solar radiation and PV electricity potentional

As I found 174 petawatts (PW) of energy comes in form of solar radiation (or insolation) hits our atmosphere. Almost one third of this is reflected back into space. The rest, 3 850 000 exajoules (EJ) every year, is absorbed by the atmosphere, clouds, oceans and land – one hour of insolation is the equivalent to more than the world's energy consumption for an entire year. Solar energy is by far the largest energy resource on the Earth.

Here are some other interesting comparisons to realize how big the massive potential of solar energy is:

One year's worth of solar energy reaching the surface of the Earth would be twice the amount of all non-renewable resources, including fossil fuels and nuclear uranium. The solar energy that hits the Earth every second is equivalent to 4 trillion 100-watt light bulbs. The solar energy that hits one square mile in a year is equivalent to 4 million barrels of oil. [12]

The following map in Fig. 3.1 represents yearly sum of global irradiation on horizontal and optimally inclined surface. Over most of the region, the data represent the average of the period 1998-2011, however, north of 58° N, the data represent the 10-years average of the period 1981-1990. All data values are given as kWh/m^2. 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 0.75. [3]

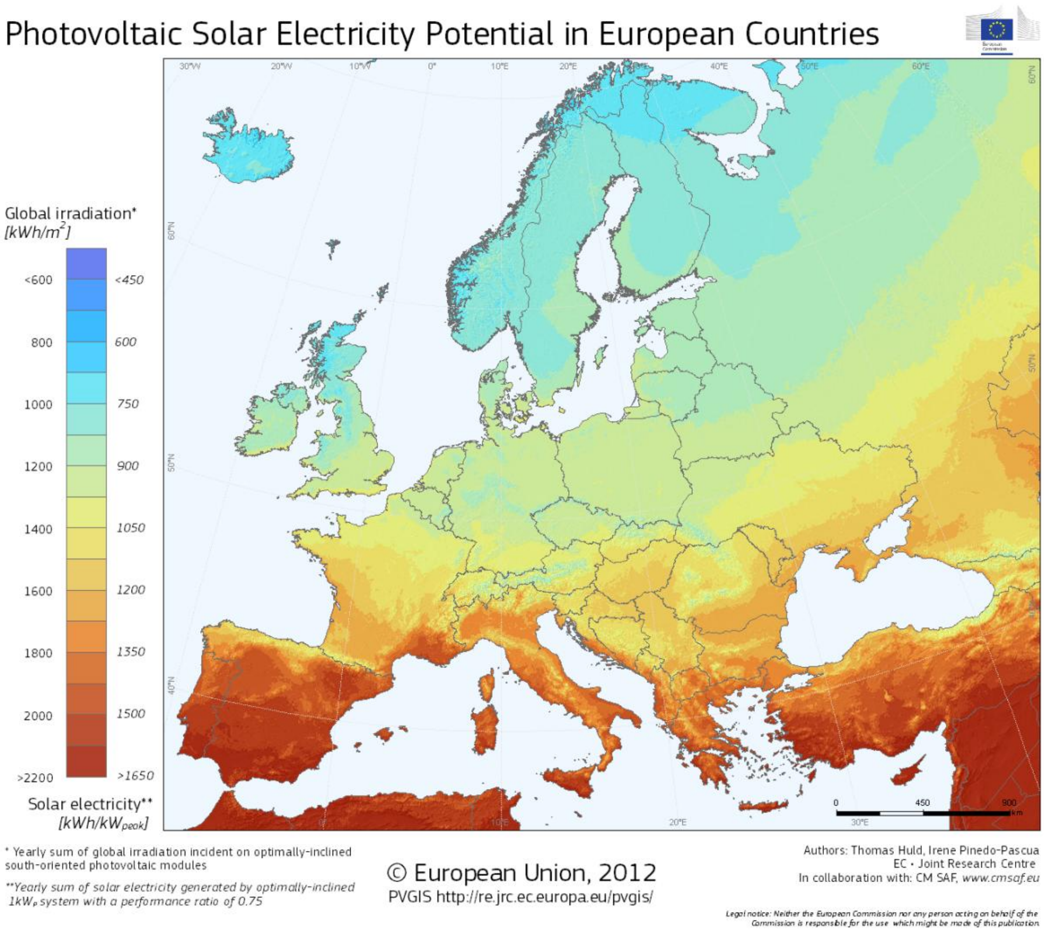

Fig. 3.1 PV solar electricity potential in EU [3]

The generation of solar electricity from photovoltaics (PV) is beginning to penetrate the energy market in those countries, where clear and stable policy commitments have been made determining the economic performance of the PV system is the solar energy arriving at the surface of the Earth. There are 4 factors determining the economic performance of the PV system: the solar energy arriving at the surface of the Earth, the cost per unit or installed peak power (€/kWp), the lifetime, and the operational cost including capital cost. This has led to the development of the Photovoltaic Geographic Information System (PVGIS) at the Joint Research Centre of the European Commission since the year 2001. PVGIS combines the long-term expertise from laboratory research, monitoring and testing with geographical knowledge. It is used as a research tool for the performance assessment of PV technology in geographical regions, and as a support system for policy-making in the European Union. The web interface was developed to provide interactive access to the data, maps and tools to other research and education institutes, decision-makers, PV professionals and system owners as well as to the general public. The PVGIS solar radiation database was used for an assessment of the potential solar electricity generation by PV modules mounted at horizontal, vertical and optimal inclination.

The annual total of electricity generated from a PV system was calculated using the following equation:

$$\mathbf{E = P_K\ PRG\ \ [kWh]} \qquad (1)$$

Where P_k is the unit peak power (assumed to be 1 kW_p in our calculation), PR is the system performance ratio, and G is the yearly sum of global irradiation on a horizontal, vertical or inclined plane of the PV module (kWh/m_2).

The size of PV systems (installed peak power, P_k) is typically measured in watt-peak (W_p) and it characterizes the nominal power output of the PV modules at Standard Test Conditions (STC; see IEC/TS 61836, 1997), i.e. when the irradiance in the plane of the PV modules is 1000 W/m_2 and the temperature of the modules is 25°C. In practice, the output of a PV system is lower than the peak power, even at an irradiance of 1000 W/m_2. One reason is the operating temperature that is typically higher than 25 °C and which tends to lower the PV efficiency. The other factors are losses due to angular and spectral variation, and system losses in inverters and cables. The ratio between the actual output and the nominal output is therefore expressed by a gross measure, the performance ratio PR (see IEC 61724, 1998). A typical value for a roof-mounted system with modules from mono- or polycrystalline silicon is around 0.75 and this value is assumed in their further considerations. Inclining the PV modules southwards to an optimum angle maximizes yearly energy yields and this is the most typical way how PV modules are installed. On the other hand, PV is also used as a building integrated material (cladding) on facades of buildings. Therefore we have compared the energy gains and losses for PV modules inclined at the optimum angle and vertically. It is obvious that the higher potential for solar electricity generation with a typical crystalline silicon PV system is in Spain than Czech Republic. In Spain generates annual electricity is between 1100 and 1330 kWh per installed kWp. Czech Republic has less favorable conditions in the interval from 700 to 800 kWh/ kWp. [3]

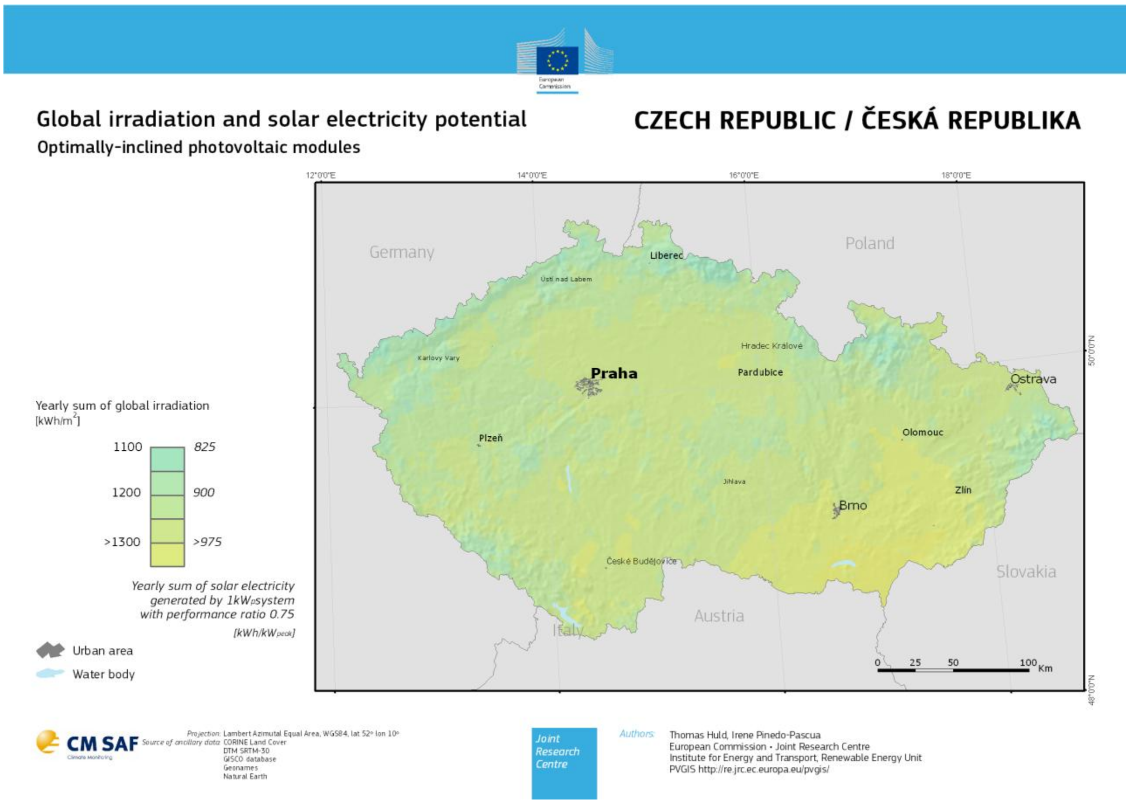

Fig. 3.2 Global irradiation and solar electricity potential in CZE [3]

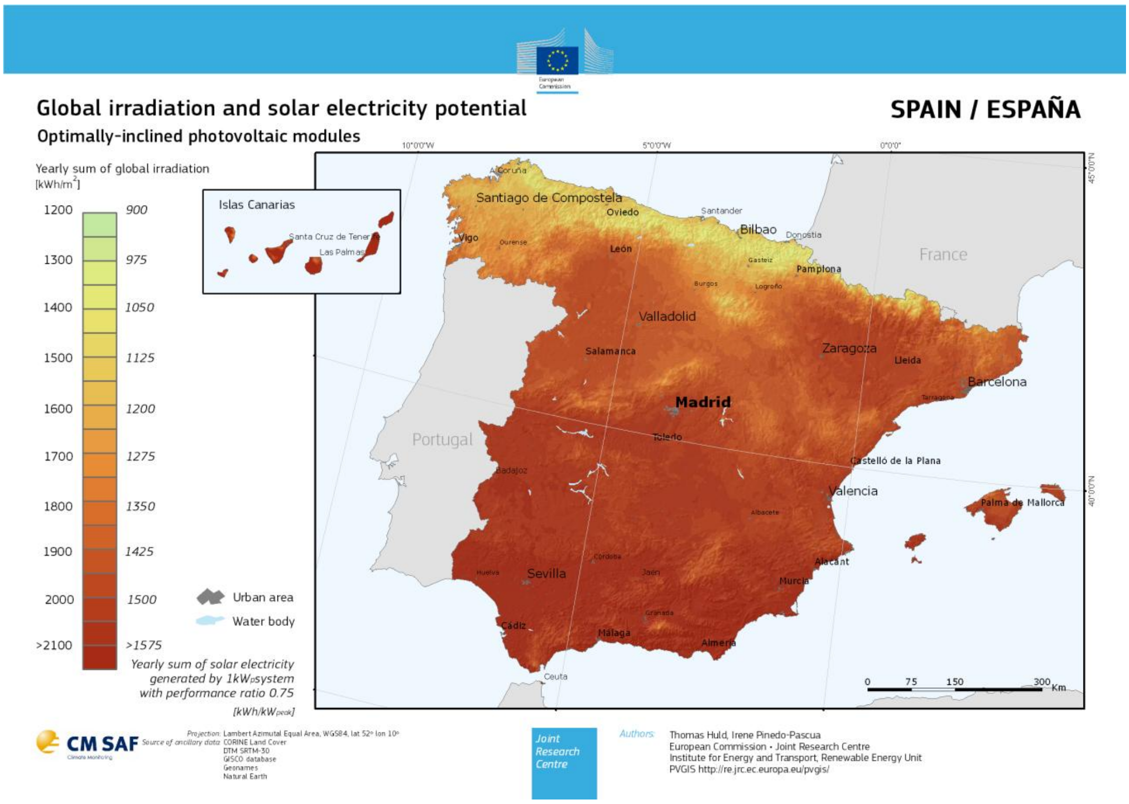

Fig. 3.3 Global irradiation and solar electricity potential in Spain [3]

3.2 Energy consumption

The energy consumption in countries EU 27 and all around of world is totally different. Every country use different source of energy as major one. The Czech Republic is an important producer of hard coal. The Czech Republic has one of the lowest energy import dependencies in the European Union, mainly due to its domestically produced solid fuels. More details are provided in Attachment {1}. Imports are limited to natural gas and oil from Russia. The share of renewable energy sources has also been increasing, although still below EU average. Coal is the main energy source for electricity production. The second most important source is nuclear power. [9] But as we realized from previous paragraphs, using renewable energies is getting more and more common source of energy and Czech Republic is one of the top 10 countries, which use RES. We can realize these changes in following Fig.3.4, which shows energy production from the past to present. I hope that finally we realize that there is no other option than use sources, which our planet offer to us, to avoid global war.

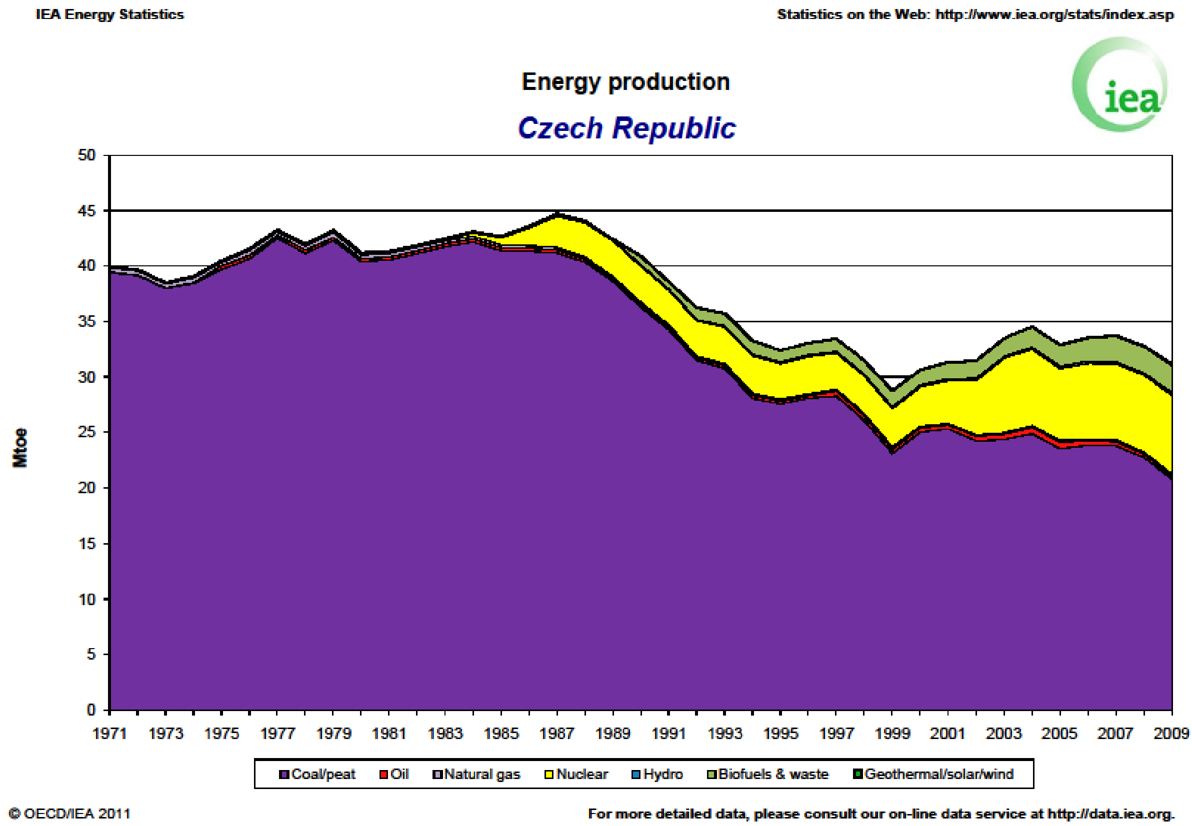

Fig. 3.4 Energy production between years 1971-2009 [14]

As evidence I would like to mention how we started use renewable sources of energy in Table 3.1 to produce electricity and heat. All details are described in The National Renewable Energy Action Plan to the year 2020.

Table 3.1 Production of electricity and heat from renewable sources and waste [20]

2005	**2008**	**2009**	**2010**	**2011**	***Indicator***
Electricity (GWh)					
3 027	2 376	2 983	3 381	2 835	*Hydroelectric power plants*
21	245	288	335	397	*Wind power plants*
2	13	89	616	2 118	*Solar power plants*
560	1 171	1 396	1 492	1 683	*Solid biomass*
0	2	2	2	5	*Industrial wastes*
18	21	18	60	150	*Municipal wastes*
161	267	441	635	933	*Biogas*
Heat (TJ)					
40 892	43 400	43 007	46 736	47 750	*Solid biomass*
5 196	5 983	6 283	5 929	5 920	*Industrial wastes*
3 420	3 146	2 743	2 973	3 460	*Municipal wastes*
1 010	1 065	1 211	1 610	2 379	*Biogas*
510	1 160	1 445	1 776	2 200	*Heat pump*
103	204	266	366	455	*Solar thermal collector*

As I have learned in KEE/SOES subject the annual incident energy in Czech is 800-1250 kWh/m2 and total sunshine hours 1400-1800 hours / year contrary to Spain, which is about 2400-2800 hours/year. The Spanish economy is characterized by relatively higher energy intensity than the rest of Europe, by a high dependence on energy imports, but also by rapid changes of the energy system in the last few years. Indeed, security and diversity of energy sources remain the major driving forces for the growth of Spain renewable energy industry. A stable legal framework based on feed-in tariffs with premium price recognizing the environmental benefits promotes the development of renewable. The success in the development of wind power in Spain has been accompanied by the creation of competitive companies now active in the international technology markets. The photovoltaic energy is characterized by a similar industrial development. Regarding biofuels, Spain is the second producer of bioethanol in Europe (behind Germany) and remains behind the big European biodiesel producers such as Germany, France, although its installed capacity is increasing. [9]

To have a real data for energy consumption in 2010, the Czech Republic consumed 63,736 GWh (ENTSO-E 2011, Eurostat 2011), i.e. circa 6.1 MWh per inhabitant and Spain consumed 267 TWh according to the EU average of 6.2 MWh. In terms of electricity intensity of the economy Czech consumed 438.6 MWh/M€ and Spain 255 MWh/M€ against the EU average 257.7 MWh/M€ (ENTSO-E 2011, Eurostat 2011). According to the Czech NREAP, gross final electricity consumption is forecasted to grow from 71,536 GWh to 87,957 GWh between 2010 and 2020. RES-E production, in the same period, should grow from 5,072 GWh to 11,679 GWh. The share of RES-E generation over gross final electricity consumption should grow from 7.09% in 2010 to 13.28% in 2020; this means that the Czech Republic, according to its plan, will be able to satisfy 7.09% and 13.28% of its internal electricity consumption through its internal production of RES-E in 2010 and 2020. In comparison, historical data indicate that the share of RES-E generation over consumption went from 1.9% in 1990 to 3.2% in 1998, to 2.8% in 2003, to 5.2% in 2008 (Eurostat 2011). On the other hand, according to the reference scenario of the Spanish NREAP, gross final electricity consumption is forecast to grow by 43%, from 291 TWh in 2010 to 417 TWh in 2020. This assumes more or less a prosecution of the very high growth rates registered during the last two decades. According to the NREAP, RES-E production, in the same period, should grow from 87.9 TWh in 2010 to 158 GWh in 2020 (80% growth). Given the high growth in consumption, in absolute terms this would nevertheless result in an increase of non-renewable generation from 203.7 to 258.5 TWh/year. Hydropower generation is planned to grow from 34.6 TWh in 2010 to 39.6 in 2020 (+14%). Wind from 41 to 78,3 TWh (+91%), most of it onshore, PV from 6.4 to 14.3 TWh (+223%) and CSP from 1.1 to 15.4 TWh. Other renewables, mainly biomass and geothermal are planned to grow from 4.5 TWh in 2010 to 10.5 TWh in 2020 (+14%). These goals are for both countries very ambitious. In the following pie chart we can see energy balance in Spain for the year 2012 as half-fulfilled resolutions.

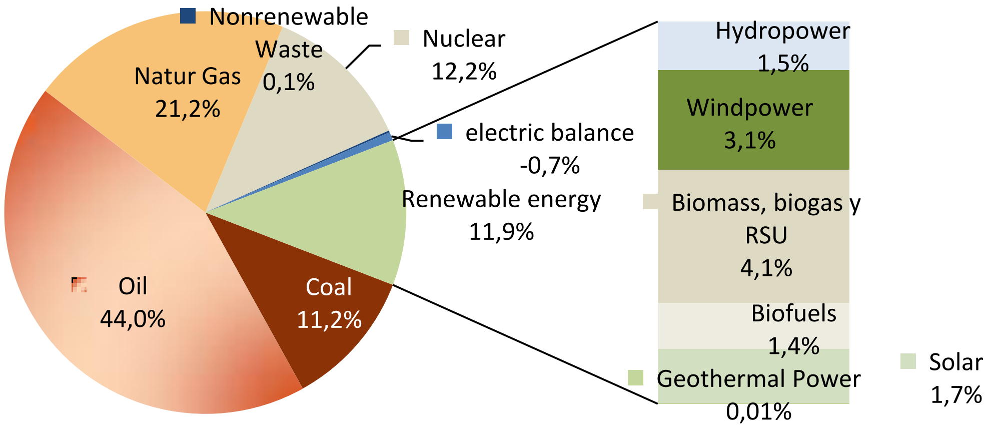

Fig. 3.5 Primary energy consumption in Spain 2012 [15]

3.3 Feed-in tariffs

A **feed-in tariff** (**FIT**) is a policy mechanism designed to accelerate investment in renewable energy technologies. The FIT should adequately motivate investors to prepare and to run RES-E projects. It achieves this by offering long-term contracts to renewable energy producers, typically based on the cost of generation of each technology. Technologies such as wind power, for instance, are awarded a lower per-kWh price, while technologies such as solar PV and tidal power are offered a higher price, reflecting higher costs. In addition, feed-in tariffs often include "tariff degression", a mechanism according to which the price (or tariff) ratchets down over time. The goal of feed-in tariffs is to offer cost-based compensation to renewable energy producers, providing the price certainty and long-term contracts that help finance renewable energy investments. Under a feed-in tariff, eligible renewable electricity generators (which can include homeowners, business owners, farmers, as well as private investors) are paid a cost-based price for the renewable electricity they produce. This enables a diversity of technologies (wind, solar, biogas, etc.) to be developed, providing investors a reasonable return on their investments.

In case you decide to direct sale, sell all the electricity to distributor, who is required to remove it from you at a price that is valid at the time of PVP connection to the network.

FITs typically include three key provisions:

- guaranteed grid access ;
- long-term contracts for the electricity produced;
- purchase prices based on the cost of generation . [21]

3.4 Green bonus

In contrast to FIT, Green bonus (GB) is based on difference between FIT and predicted market price of conventional electricity; payback time or profit is not guaranteed. Green bonus is more profitable in case the operator of a photovoltaic plant is trading the electricity at better-than-usual market price or in case a significant part of electricity produced is self-consumed. GB is for short a premium to the market price of electricity. If the manufacturer sells electricity to a distributor of electricity as an agreed market price or generated electricity consumed alone, has also right to encash from regional transmission or distribution system based on the submitted statement of GB. The amount of GB for each species of RES is reviewed annually and published in the pricing decisions of the regulatory authority. In terms of cost effectiveness of this method is advantageous. The GB you must add to amount you would pay for energy, if you have to remove it from your supplier. So the most effective system is when you use as much electricity you produced as you can and get to consume price higher, compared to when the unused surplus electricity produced deliver to a network. A disadvantage of the GB is higher level of risk because the manufacturer does not guarantee 100% of electricity sales in the market or the market price. There is possibility to switch between the GB and FIT and vice versa once a year, so we can try what is profitable for us.

3.4.1 Can be feed-in tariff or green bonus reduced?

Thanks to state regulation may not be a significant increase, but a significant reduction neither in the FIT or GB. Both components are tied to the market price of electricity. If the market price of electricity rises (which can be certainly presumed), even raises amount of GB and FIT. The maximum increase is 104% of the volume for the previous year. If the market price for electricity falls (which does not expect even the biggest optimist), even drops amount of GB and FIT. The minimum amount of decrease is 95% of the volume for the previous year.

3.5 PV history in Czech Republic

Photovoltaics as separate branch started in the Czech Republic in the early 1990s. The first version FIT for Renewable Energy Sources was introduced in 2002 by Notice of Ministry of Industry and Trade (No. 252/2001 Coll.) about purchasing of electricity from renewable energy sources and combined heat and power generation. Priority connection, transmission and distribution of electricity from renewable sources were done by Energy Act (No. 458/2000 Coll.). From this time there was a really quick progress. State Environmental found from 2000 to 2004 about 600 FV projects. In 2005, Parliament accepted and passed the law for subsidy of renewable energy sources decrease of FIT was restricted at 5% and purchase time of energy from FV was set for 15 years (other RES 20 years, small water plant 30 years). In the year 2006, FIT increased lead to „solar boom". In 2007, were put into operation first 4 photovoltaic power plants each with instaled capacity at least 0,5 MWp as one of largest PV plants in Central and Eastern Europe ant the time. Despite Czech Republic weather conditions are not the best suitable for PV installations, installed capacity per citizen ratio is one of the highest in the world.

The main reason for such a huge development in this sector:

- very high FIT;
- guarantee of the prices for 15 (later 20) years;
- duty of energetic companies to buy-out energy from renewable energy sources;
- producer´s guaratntees of lifetime period of the PV panels up to 30 years;
- time of the economic return on investments 7 years or less;

Until 2008, the feed-in tariff and green bonus had been the same for all categories of PV systems disregarding installed power or location. In 2009, PV installations were split into two categories--up to 30 kWp and above 30 kWp and rapid reduction of cost of PV panels caused by restrictions of the market in Spain, price pressure from Chinese producers and massive increase in production of solar silicon. Also in this year Ministry of Industry and Trade announced amendment draft of the law for subsidy of renewable energy sources as lower purchase prices of electricity. Impact had no effect on the installed capacity in 2010 and the purchase prices were still the highest in the EU. But in comparison with year 2006 the cost of PV system in CZ fell down by half. In the same year government approved NREAP to meet

EU target. [22] In table 3.2 is showed all process of „solar boom" and price dicreasing in CZ (05-13).

Table 3.2 FIT and Green bonus tariffs for CZ [4]

Supported resource	**Date of a generating plant**		**Installed capacity[kW]**		**One tariff zone operating**	
	From (including)	**To (including)**	**From**	**To (incl.)**	**FIT [€/MWh]**	**G.bonus [€/MWh]**
Production of electricity using solar radiation	-	31.12.2005	-	-	279,73	243,96
	1.1.2006	31.12.2007	-	-	586,92	551,15
	1.1.2008	31.12.2008	-	-	572,42	536,62
	1.1.2009	31.12.2009	0	30	537,08	515,92
	1.1.2009	31.12.2009	30	-	533,15	497,38
	1.1.2010	31.12.2010	0	30	500,19	479,04
	1.1.2010	31.12.2010	30	-	496,27	460,50
	1.1.2011	31.12.2011	0	30	300,12	278,96
	1.1.2011	31.12.2011	30	100	236,19	200,42
	1.1.2011	31.12.2011	100	-	220,12	184,35
	1.1.2012	31.12.2012	0	30	241,69	220,54
	1.1.2013	30.6.2013	0	5	131,15	110,00
	1.1.2013	30.6.2013	5	30	108,84	87,69

	1.7.2013	31.12.2013	0	5	115,00	93,85
	1.7.2013	31.12.2013	5	30	93,46	72,31

3.5.1 Main developing mistakes of PV in CZ:

- unresponsive to the development and legislation changes in neighbouring countries (Germany);
- insufficient possibility of regulation of purchase prices (FIT);
- similarity of purchase prices for all PV installationes regardless of location and installed capacity;
- the possibility of almost free booking of capacity in the transmission grid for connecting the PV installationes;
- mistaken prediction of growth of installed capacity;
- delayed reaction on the situation.

3.6 PV history in Spain

In Spain, as in most other countries, the competition in the PV electricity market is heavy. In spite of this theoretically challenging environment, comparatively expensive photovoltaic power generation has experienced tremendous growth in Spain in the years 2007 and 2008. As in Czech the beginning of state support was very favorable for the construction of photovoltaic power plants.

3.6.1 Royal Decree 436/2004, from March 12th

This Decree allowed generation facilities based on renewable energies to sell their energy surplus to distributors in the Spanish energy market. In order to do that, the owner of the generation facility could be between two alternatives. The first one was to sell it at a regulated tariff, which would be defined as a percentage of the reference average tariff (RAT). The second option was to sell the surplus directly in the market at market prices, but receiving an additional incentive and a bonus, also defined as a percentage of the RAT. In both cases, the result is a non-constant FIT, which would remain directly tied to the production market price. The percentages were defined for two different periods:

- The first one would be valid during the first 25 years after installation of the power plant.
- The second would start after this first 25 years.

3.6.2 Royal Decree 661/2007, from May 25th

This decree replaced the Royal Decree 436/2004. In terms of the photovoltaic power generation plants, it was decided that owners could only sell their energy under the modality of fixed price (no incentive or bonus was defined for this type of technology). Also, now the FIT would be defined not as a percentage of the RAT, but as a fixed value. In addition, all producers of electric energy from renewable resources were allowed to sell not only their energy surplus, but the totality of their net electric energy production. It also created a differentiation between the photovoltaic installations in three groups. The following table shows the FIT values defined in this royal decree. There was a massive increase in the effective feed-in-tariff for installations with an installed power greater than 100kW, coupled with a complete elimination of market risk due to electricity price fluctuations.

Table 3.3 Royal Decree 661/2007

Type of PV Installation	FIT (first 25 years after installation)	FIT (after first 25 years)
Installations with less than 100kW of installed power	44,0381 c€/kWh	35,2305 c€/kWh
Installations with more than 100kW and less than 10MW of installed power	41,7500 c€/kWh	33,4000 c€/kWh
Installations with more than 10MW and less than 50MW of installed power	22,9764 c€/kWh	18,3811 c€/kWh

3.6.3 Royal Decree 1578/2008, from September 26th

The law entered into force on January 1st, 2009. A maximum power capacity to be installed for the year 2009 was defined. This quota would be distributed amongst two types of installation:

1) **Type I installations**: Installations on roofs or facades of buildings dedicated for residential, services, commercial, or industrial, or installations located on fixed structures whose purpose is parking or shadowing. They must all be located in urban areas.

Type I.1 installation of type I with less or the same potency than 20kWp.

Regulated Tariff 34, 00 c€/kWh.

Type I.2 installation of type I with more potency than 20kWp.

Regulated Tariff 32, 00 c€/kWh.

2) **Type II installations**: All those not included in type 1, like ground installations (in general, large PV generation plants). Regulated Tariff 32, 00 c€/kWh.

3.6.4 Royal Decree 1565/2010

The values of the PV rates for the first call for registration in the pre-allocation of the deadline for filing starts after the entry into force of this Royal Decree is calculated from the values resulting from the application of the methodology set out in Article 11.2 of Royal Decree 1578/2008 of 26th September, multiplying by the following factors:

Type I.1 installation: 0, 95

Type I.2 installation: 0, 75

Type II installation: 0, 55

In 28 of January 2012 the new Spanish government, under Prime Minister Mariano Rajoy, has suspended all incentives for photovoltaic systems in response to the current financial situation. They have not made clear when, if ever, any incentives will be reinstated. They did make clear that this will not retroactively affect installations which previously secured feed-in tariffs. In place of the FIT, there is legislation in place that allows small generators of up to 100 kW to connect to the grid and receive the market price for any electricity they feed in. Prior to suspension, the planned tariffs were as follows:

Table 3.4 Royal Decree 1565/2010

Rooftop/BIPV		***Ground-mounted***	
Size	**Incentive**	**Size**	**Incentive**
<20kW	0.283€/kWh	Any size	0.121716€/kWh
>20kW	0.15675€/kWh		

The Spanish tariff is also limited in how many hours per year it will be paid until 31.December 2013, the number will be fixed across the country, but from 2014, the country was divided into five climactic zones (shown in table 3.5 and fig. 3.6) with corresponding limits of hours of solar radiation as follows:

Table 3.5 Royal Decree 1565/2010

Until 31 Dec, 2013	**Fixed Installation**	**Installation with 1-axis tracking**	**Installation with 2-axis tracking**
	1250	1644	1707
From 2014 onward			
Zone I	1232	1602	1664
Zone II	1362	1770	1838
Zone III	1492	1940	2015
Zone IV	1632	2122	2204
Zone V	1753	2279	2367

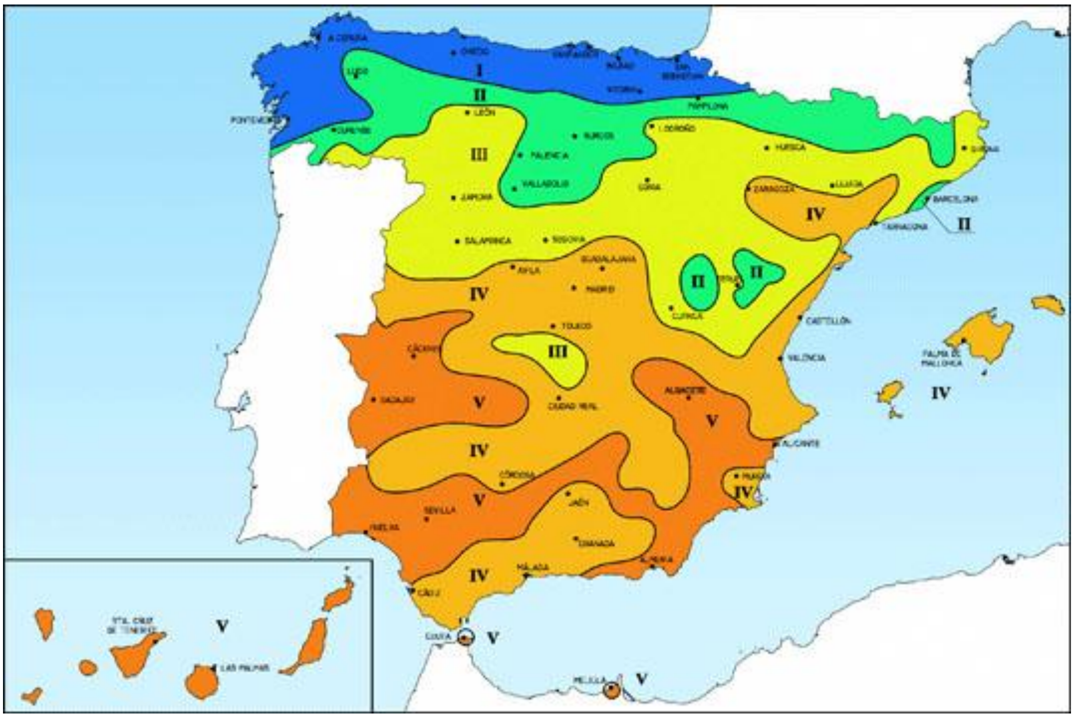

Fig. 3.6 Spanish five climactic zones in Royal Decree 1565/2010

3.6.5 Royal Decree-Law 1/2012, of January 27

This law proceeds to the suspension of pre-allocation procedures and the removal of economic incentives for new energy production facilities electricity from cogeneration, renewables and waste.

In conclusion, nowadays in Spain is not as much profitable built PV plant as before, but for energy consumption in the household is still one of the best options.

3.7 Electric and Hybrid Electric Vehicles progress

HEV and **EV** show very encouraging progress. HEV sales broke the one million mark in 2012, and reached 1.2 million, up 43% from 2011. Japan and the United States continue to lead the market, accounting for 62% and 29% of global sales in 2012 (740 000 and 355 000 vehicles sold). In order to hit 2020 targets, sales need to increase by 50% each year. EV sales more than doubled from 2011 to 2012, passing 100 000 units. This rate of sales growth puts EV deployment on track to meet 2020 targets, which require a 80% annual growth rate. This will require longer-term policies, more infrastructure and lower battery development costs. Sales of non-plug-in hybrid-electric vehicles (HEVs) also grew strongly in 2011 and 2012. To build on this moment, governments must continue and expand policies such as vehicle price incentives.

Progress in Czech Republic

Because of massive foreign direct investments in the last two decades, the Czech Republic has become one of the major car manufacturers in Europe. Production of new passenger cars rose to an all-time record high of 979,085 units in 2009, which represents around 93 cars per 1,000 people, the second highest car production per capita in Europe. The leading Czech automotive companies are SKODA AUTO/Volkswagen, Toyota-Peugeot- Citroen (TPCA), Hyundai, Tatra and Avia Ashok Leyland (trucks), Iveco and SOR (buses), and Zetor (tractors). There are also 270 car-part suppliers represented in the Czech market (50% of the top 100 European automotive component suppliers and 40% of the top 100 world automotive component suppliers). CEZ Group, a Czech energy company, bought electric vehicles for non-profit organizations and built the needed infrastructure and battery recharging points as showes Fig.3.7. There are also big progresses in trams and trolley buses, hybrid and electric buses and electric bikes, which can be found in almost every city. [17]

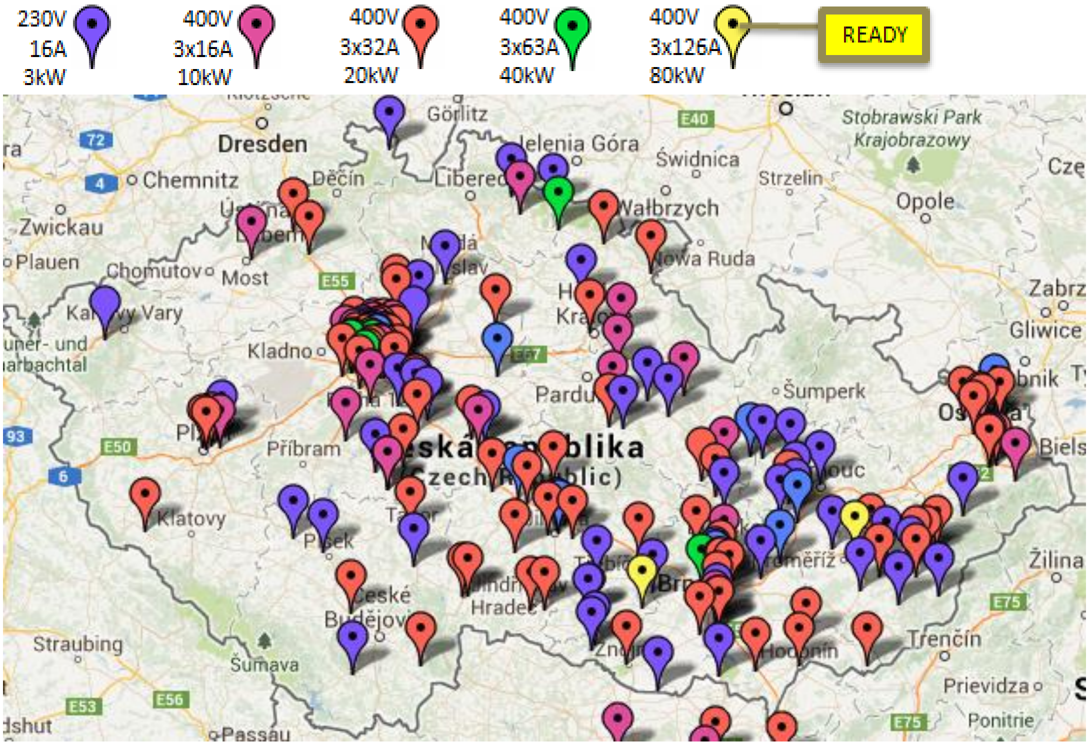

Fig. 3.7 Plug-in map in Czech Republic [17]

4 Design of PV system for charging station

In the practical part I would like to use knowledge from theoretical part and apply them for the design of charging station, which will be situated at the supermarket parking lot. To make more real my project I have decided to install 100kW, which will be enough wattage to recharge several vehicles but don´t need such a big space for installing. My idea is to compare conditions in Spain and Czech Republic. Ideal conditions in Pilsen I had found in parking lot in front of OC Olympia as you can see in Fig. 4.1 and 4.2. For the comparison I propose parking area in front of shopping area in Elche. Both areas have a big space potencial in case of needful increasing, great orientation and high visite rate. Difference between installations could be in case of covered and uncovered style of both parkings. In Czech Republic is not usual to build coverd parkings for higher comfort for cars owners and should be necessary to build construction for PV installation. On the other hand, in Spain these parkings are already covered but in milder inclination than the one which would be ideal for PV installation (Fig.4.3,4.4)

Fig.4.1 Proposed section of OC Olympia´s parking lot

Fig.4.2 Uncovered parking place in OC Olympia

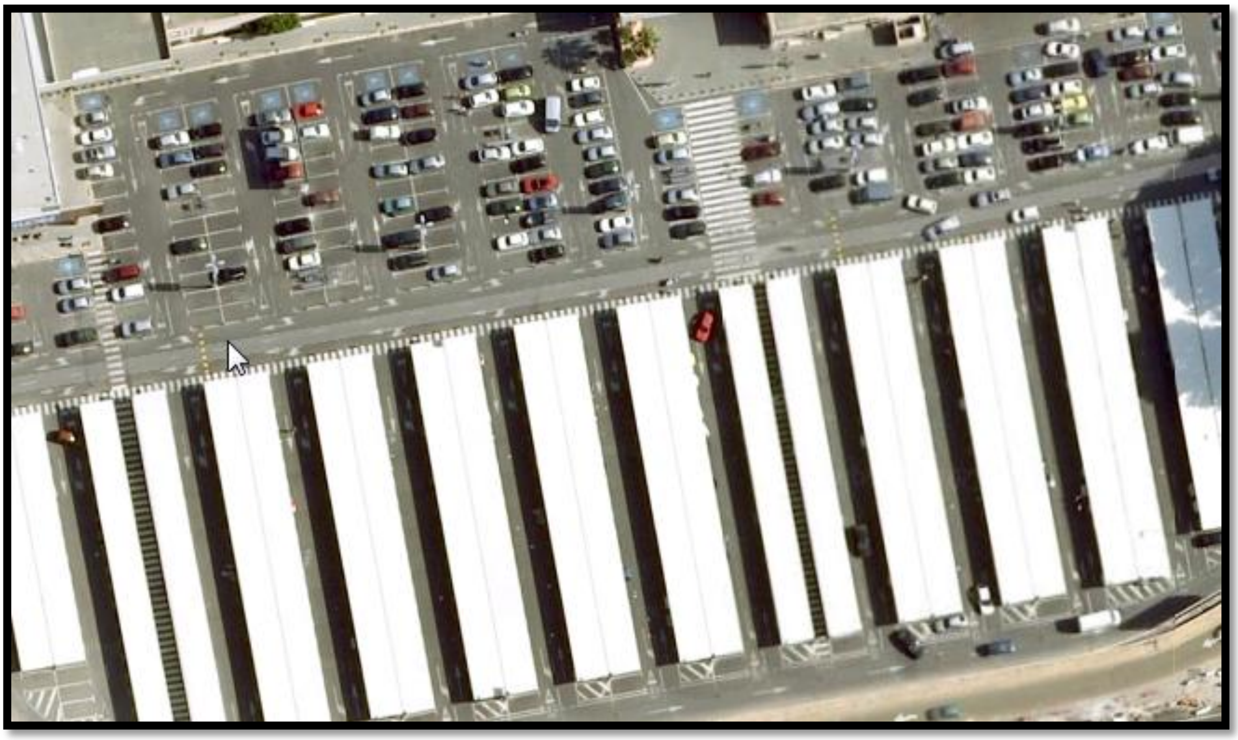

Fig. 4.3 Proposed section of Carrefour´s parking lot

Fig.4.4 Covered parking place in Elche

Not only this idea makes useful of unused space of covered and uncovered parking, but also reduce the time spent at the charging station. Many households around the world already have parking locations with access to electricity plugs. For many others, such access will require new investments and modifications of electrical systems. For daytime recharging, public recharging infrastructure such as office locations, shopping centres and street parking will be needed. Currently, public recharging infrastructure for EVs is very limited or non-existent in most cities, though a few cities have already installed significant infrastructure as part of pilot projects and other programmes. I would like to make this idea of recharging infrastructure as a real future project and obviousness for all cities.

4.1 Calculation of expected annual production

4.1.1 Dimensioning of the generator

Annual Report is included in the monthly productions based theoretical maximum irradiance, the installed power and performance of the installation. The input data to be supplied by the installer are:

- G(0) Average value of monthly and annual daily irradiation on a horizontal surface,

  in kWh /(m^2 .day)

- G_{dm} (α, β) Monthly and annual average value of daily irradiation on the plane of the generator in kWh / (m^2 · day), obtained from above, which have been deducted shading losses if they exceeding 10% year.

- Energy performance of the installation or "performance rate", PR.

  Efficiency of the system working in real conditions accounted of:

  - The dependence of the efficiency with temperature.

  - The efficiency of wiring.

  - Scattering losses and soil parameters.

  - Losses due to errors in tracking the maximum power point.

  - Energy efficiency of the inverter.

  - Other.

  Typical values for systems with inverter is PR = 0.7 and with inverter and battery is PR = 0.6.

- The injection estimate of the energy will be made according to the following equation:

$$E_p = \frac{G_{dm}(\alpha,\beta)\ P_{mp}\ PR}{G_{CEM}} \tag{2}$$

Where: P_{mp} = Peak Power of the Generator [kWp]

G_{CEM} = 1 kW/m^2

E_p= Consumption expressed in kWh/day

- Period of design

The period of design the generater is very important. We have to know in advance for what period of year we want the instalation.

- For constant consumption in scenes of along the year, the "worst month" criterion corresponds to the least radiation.
- Pump installations, depending on the location and availability of water, the "worst month" corresponds with the summer often.
- To maximize annual production, the design period is whole year. [15]

Table 4.1 Period of design dependent on location latitude [15]

Period of design	$\boldsymbol{\beta_{opt}}$
Decembre	ϕ +10
July	ϕ - 20
Annual	ϕ - 10

4.1.2 Measurement of installed photovoltaic power plant connected to the grid

Is described below the minimum equipment required to calculate the installed power:

- 1 solar cell calibrated of equivalent technology;

- 1 thermometer of temperature;

- 1 meter of direct current (DC) and alternating current (AC);

- 1 clamp meter DC and AC.

$$P_{\text{cc, inv}} = P_{\text{cc, fov}}(1 - L_{\text{cab}}) \tag{3}$$

$$P_{\text{cc, fov}} = P_{\text{o}} R_{\text{to, var}} [1 - g(T_{\text{c}} - 25)] E / 1000 \tag{4}$$

$$T_{\text{c}} = T_{\text{amb}} + (TONC - 20) E / 800 \tag{5}$$

Where: $P_{cc,\ fov}$ –Potency of DC power immediately output from the PV panels, in W.

L_{cab} - Power loss at DC wiring between the PV panels and inverter input, including further losses in fuses, switches, interconnections, if antiparallel diodes, etc..

E - Solar irradiance in W/m^2

g - Temperature coefficient the potency, in 1 / ° C.

T_c - Solar cell temperature in ° C.

T_{amb} - Ambient temperature in the shade, in ° C, measured with the thermometer.

TONC - Nominal operating temperature of the module.

P_o - Nominal generator power in W.

$R_{to,\ var}$ - Performance, which includes loss percentages due to the photovoltaic modules operate under different conditions

L_{tem} - Annual averages temperature losses. In equation (4) can be substituted by the term [1 – g (T_c – 25)] por (1 – L_{tem}).

$$R_{\text{to, var}} = (1 - L_{\text{pol}})(1 - L_{\text{dis}})(1 - L_{\text{ref}}) \tag{6}$$

L_{pol} - Power loss due to dust on the PV modules.

L_{dis} - Power losses by dispersing parameters between modules.

L_{ref} - Power losses angular spectral reflectance, when using a as a reference radiometer measurement.

If there is no other information more precisely can be used the values listed in Table 4.2.

Table 4.2 Values for formulas (3), (4), (5), (6) [15]

Parametr	**Estimated value, annual average**	**Estimated value, clear day (*)**	**Check observation**
L_{cab}	0,02	0,02	(3)
g (1/ °C)	-	0,0035 (**)	-
TONC (°C)	-	45	-
L_{tem}	0,08	-	(4)
L_{pol}	0,03	-	(5)
L_{dis}	0,02	0,02	-
L_{ref}	0,03	0,01	(6)

(*) At solar noon ± 2 hours a cloudless day. (**) Valid for crystalline silicon.

Observations:

(3) Cabling major losses can be calculated if the cable section and length are known, by the equation:

$$L_{cab} = RI^2 \tag{7}$$

$$R = 0{,}000002\ L/S \tag{8}$$

Where: R- the electrical resistance value of all wires, in ohms.

L- the length of all cables (adding the flow and return) in cm.

S- the section of each wire, in cm^2.

Normally, losses in switches, fuses and diodes are very small and do not need to be considered. Falls in the wiring can be very important when are long and operate at low voltage DC. Cabling losses in % are usually lower in large power plants than in small power plants. In our case, according to specifications, the maximum permissible value for the CC is 1.5% and it is recommended not to exceed 0.5%.

(4) Temperature losses depend on the temperature difference in the modules and 25 °C, the cell type and encapsulated and wind. If the modules are conveniently ventilated from behind, this difference is about 30 °C above ambient temperature, for an irradiance of 1000 W/m^2. For building integration case where modules are not separated from the walls or roof, this difference may increase between 5 °C and 15 °C.

(5) Dust losses in a one day can be 0% and the day after (rainy day) reach to 8%, when modules have "very dirty look." These losses are dependent on the inclination of the modules, distance from the road etc. A major cause of loss occurs when the PV modules which are having solar cell frame very close to the frame located at the bottom of the module. Sometimes they are projecting support structures of the modules and act as dust detents.

(6) Losses angular and spectral reflectance can be neglected when you measure the PV array at solar noon (± 2 h) and also when solar radiation is measured with a calibrated cell technology equivalent (CTE) to the PV module. Annual losses are higher in cells with cell layers antirreflexed than textured. They are higher in winter than in summer. They are also higher in higher latitude locations. The losses may also oscillate over a day between 2% and 6%. [15]

4.1.3 Losses for orientation and inclination of the generator other than the optimal

The purpose of this annex is to determine the limits of the orientation and inclination of the modules according to the maximum allowable losses.

- Angle of inclination β, defined as the angle between the surfaces of the modules with the horizontal plane (profile of module in Fig. 4.5). Its value is 0° for horizontal modules and 90° for vertical.
- Azimuth angle α, defined as the angle between the projection onto the horizontal plane normal to the surface of the module and the meridian of the place (*Fig. 4.6*). Its value is 0° for South-oriented modules, -90° for modules oriented to East and +90° for West-oriented modules.

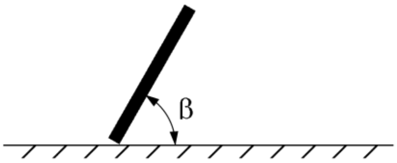

Fig. 4.5 Source:[15]

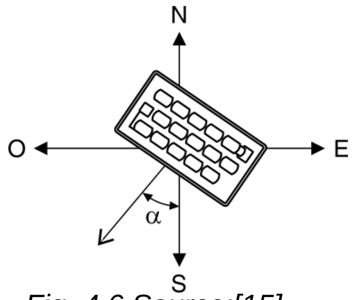

Fig. 4.6 Source:[15]

Having determined the azimuth angle, the generator limits are calculated according to inclination acceptable maximum losses. This will be shown in Fig. 4.7, valid for one latitude of 41°. For the general case, the maximum loss for this concept is 10%, for superposition is 20%, and 40% for architectural integration. The points of intersection of the limit losses straight to azimuth values provide maximum and minimum inclination. We will correct limits acceptable in terms of the difference between the latitude of the place (Elche $\phi = 38°$ and Pilsen $\phi = 49°$) and 41°, if azimut is 0° according to the following formulas:

Maximum inclination = inclination 80° - (41° - latitude) (9)

Minimum inclination = inclination 5° - (41° - latitude), where 0° its min. value. (10)

Maximum inclination: Pilsen = 88°, Elche = 77°

Minimum inclination: Pilsen = 13°, Elche = 3°

In cases close to the limit, and as an instrument of verification, use the following formulas:

Losses (%) = $100 \times [1.2 \times 10^{-4} (\beta - \phi + 10)^2 + 3.5 \times 10^{-5} \alpha^2]$ for $15° < \beta < 90°$ (11)

Losses (%) = $100 \times [1.2 \times 10^{-4} (\beta - \phi + 10)^2]$ for $\beta \leq 15°$ (12)

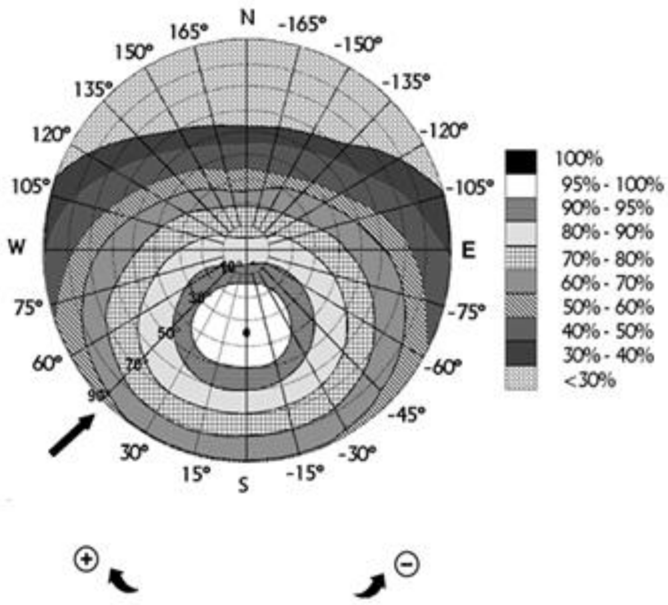

Fig. 4.7 Azimut and inclination verification scheme [15]

4.1.4 Solar radiation losses by shadows

These losses are expressed as percentage of total solar radiation which operates with surface in the absence of any shade. We can localize the main barriers which affect the surface in terms of its position of azimuth and elevation. Barriers profile is represented in the diagram of Fig.4.8, which shows the stripes of sun trajectories over the whole year. Each strip is divided into portions, bounded by solar hours (negative before solar noon and positive after east) and identified by a letter and a number (A1, A2, ..., D14). The tables in references [15] page 41-42 refer to different surfaces characterized by their inclination and orientation angles. There should be chosen one that is most similar to the study area. The numbers in each box correspond to the percentage of annual solar irradiation, which would be lost if the corresponding portion is intercepted by an obstacle. [15]

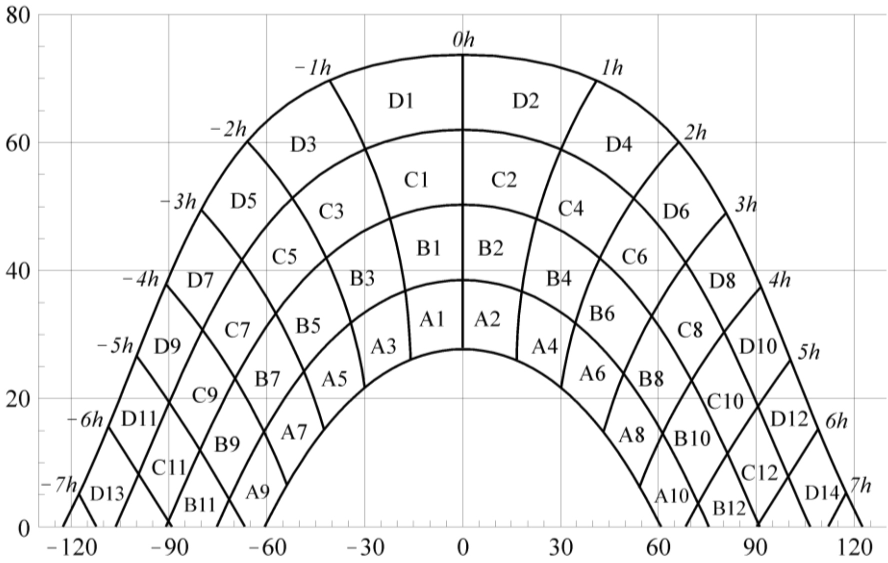

Fig. 4.8 Sun diagram trajectories [15]

4.1.5 Panel generation factor

Panel generation factor (PGF) is used while calculating the size of solar photovoltaic cells. It is a varying factor depending upon the climate of the site location (depending upon global geographic location). In EU countries it is 2.93. This factor is used in calculation of "Total Watt-Peak Rating" while designing the size of solar photovoltaic cells. Therefore, "Total Watt-Peak Rating" = "Total Watt-hours per day needed/generated from the PV modules" divided by "PGF". "Total Watt-Hours per Day" = "Total Watt-hours per day needed by appliances" Multiplied by "1.3 times" (the energy lost in the system). Now, to calculate "size of PV cells" OR "number of PV cells" just divide the above obtained "Total Watt-Peak Rating" by "Watt-Peak of each cell OR Watt-Peak of each square meter size", which ever is convenient. [4]

4.1.6 Few steps of Designing Solar PV System

The main idea of this project is use energy, which is given to us for free from sun, and transforms it to electricity, which can charge electrical vehicles. Usually, full charge of the battery takes around 5 hours. This charging station is situated in front of supermarket and has three main advanteges:

- Use of already built-up areas and save of nature,
- Use the time for charging for other activities,

- Unused energy can be utilized for running the supermarket.

Major system components

Solar PV system includes different components that should be selected according to your system type, site location and applications. The major components for solar PV system are solar charge controller, inverter, battery bank, auxiliary energy sources and loads (appliances).

- PV module – converts sunlight into DC electricity.
- Solar charge controller – regulates the voltage and current coming from the PV panels going to battery and prevents battery overcharging and prolongs the battery life.
- Inverter – converts DC output of PV panels or wind turbine into a clean AC current for AC appliances or fed back into grid line.
- Battery – stores energy for supplying to electrical appliances when there is a demand.
- Load – is electrical appliance that is connected to solar PV system such as lights, radio, TV, computer, refrigerator, etc.
- Auxiliary energy source - is diesel generator or other renewable energy source.

Solar PV system sizing

1) **Determine power consumption demands**

The first step in designing a solar PV system is to find out the total power and energy consumption of all loads that need to be supplied by the solar PV system as follows:

1.1. Calculate total Watt-hours per day for each appliance used. Add the Watt-hours needed for all appliances together to get the total Watt-hours per day which must be delivered to the appliances.

1.2. Calculate total Watt-hours per day needed from the PV modules. Multiply the total appliances Watt-hours per day times 1.3 (the energy lost in the system) to get the total Watt-hours per day which must be provided by the panels.

We skip these two steps and decide to install total power of **100kW/day**

2) **Size the PV modules**

Different size of PV modules will produce different amount of power. To find out the sizing of PV module, the total peak watt produced needs. The peak watt (Wp) produced depends on size of the PV module and climate of site location. We have to consider "panel generation factor" which is different in each site location. To determine the sizing of PV modules, calculate as follows:

2.1. Calculate the total Watt-peak rating needed for PV modules. Divide the total Watt-hours per day needed from the PV modules (from item 1.2) to get the total Watt-peak rating needed for the PV panels needed to operate the appliances.

2.2. Calculate the number of PV panels for the system. Divide the answer obtained in item by the rated output Watt-peak of the PV modules available to you. Increase any fractional part of result to the next highest full number and that will be the number of PV modules required. [1]

3) **Inverter sizing**

An inverter is used in the system where AC power output is needed. The input rating of the inverter should never be lower than the total watt of appliances. The inverter must have the same nominal voltage as your battery. For stand-alone systems, the inverter must be large enough to handle the total amount of Watts you will be using at one time. The inverter size should be 25-30% bigger than total Watts of appliances. In case of appliance type is motor or compressor then inverter size should be minimum 3 times the capacity of those appliances and must be added to the inverter capacity to handle surge current during starting. For grid tie systems or grid connected systems, the input rating of the inverter should be same as PV array rating to allow for safe and efficient operation. [1]

Total Wp of PV panel capacity needed (2):

$$E_{\mathrm{p}} = \frac{G_{\mathrm{dm}}(\alpha,\beta)\ P_{\mathrm{mp}}\ PR}{G_{\mathrm{CEM}}}$$

G_{CEM} = 1kWh/day

PR= 0,6 (with inversor and battery)

E_p = 100 kWh/day

G_{dm}(0, 30/35)

P_{mp}= ?Wp (to calculate)

Monthly Solar Irradiation

PVGIS Estimates of long-term monthly averages

Location: 38°15'57" North, 0°41'0" West, Elevation: 78 m a.s.l., ELCHE

Solar radiation database used: PVGIS-CMSAF

Annual irradiation deficit due to shadowing (horizontal): 0.0 %

Table 4.3 Monthly radiation in Elche

Month	***H_h***	***H_{opt}***	***H(30)***	***I_{opt}***	***T_{24h}***	***N_{DD}***
Jan	2540	4390	4190	63	11.3	172
Feb	3430	5130	4970	55	12.1	134
Mar	4700	5890	5820	42	14.4	66
Apr	5950	6380	6440	26	16.4	18
May	6940	6620	6780	13	19.7	0
Jun	7870	7090	7320	5	23.9	0
Jul	7810	7230	7440	8	26.3	0
Aug	6770	6940	7040	20	26.7	0
Sep	5240	6210	6180	36	23.7	2
Oct	3890	5440	5310	51	20.1	14
Nov	2720	4480	4310	61	14.9	127
Dec	2480	4320	4120	64	12.0	172
Year	**5040**	**5850**	**5830**	**35**	**18.5**	**705**

Location: 49°44'18" North, 13°22'25" East, Elevation: 337 m a.s.l., PILSEN

Solar radiation database used: PVGIS-CMSAF

Annual irradiation deficit due to shadowing (horizontal): 0.0 %

Table 4.4 Monthly radiation in Pilsen

Month	H_h	H_{opt}	***H(35)***	I_{opt}	T_{24h}	N_{DD}
Jan	763	1130	1140	62	-1.5	569
Feb	1500	2160	2170	57	0.9	462
Mar	2660	3360	3370	46	4.0	383
Apr	4400	5020	5020	34	8.9	192
May	5100	5210	5190	20	14.0	84
Jun	5560	5440	5420	14	16.8	38
Jul	5140	5100	5080	16	18.6	10
Aug	4430	4810	4800	28	18.5	42
Sep	3140	3800	3810	42	14.2	174
Oct	1770	2410	2420	53	9.8	341
Nov	893	1320	1330	61	3.7	508
Dec	752	1090	1090	61	-0.2	601
Year	**3020**	**3410**	**3410**	**34**	**9.0**	**3404**

H_h: Irradiation on horizontal plane ($Wh/m^2/day$)

H_{opt}: Irradiation on optimally inclined plane ($Wh/m^2/day$)

H(30): Irradiation on plane at angle: 30deg. ($Wh/m^2/day$)

I_{opt}: Optimal inclination (deg.)

T_{24h}: 24 hour average of temperature (°C)

N_{DD}: Number of heating degree-days (-)

In scenarios of constant consumption along the year, the criterion of "worst month" corresponds to less radiation. For calculation purposes we have to choose the month with the lowest radiation received to calculate the minimum electrical power supplied by the set of photovoltaic panels. The months of lowest radiation are January and December. Any of them would be worth because the value consulted daily average radiation is very similar.

Elche

$P_{mp,min}$= (100000 x 1)/(4,12 x 0,6) = 40453,1 $W_{peak\ min}$

P_{mp}= 40453,1 x 1,2 = 48543,7 W_{peak}

Technical parametres of used modules are spesifized in Attachments {3}. I used module ATERSA A-290P with I_{cc} = 8,67 A

Number of PV panels needed : 48543,7 /290= 168 modules *MAX*

40453,1 /290=140 modules *MIN*

Pilsen

$P_{mp,min}$= (100000 x 1)/(1,09 x 0,6) = 152905,2 $W_{peak\ min}$

P_{mp}= 152905,2 x 1,2 = 183486,2 W_{peak}

Number of PV panels needed : 183486,2 /290= 633 modules *MAX*

152905,2 /290= 527 modules *MIN*

Result of the calculation is the minimum and maximum number of PV panels. If more PV modules are installed, the system will perform better and battery life will be improved. If fewer PV modules are used, the system may not work at all during cloudy periods and battery life will be shortened. [1]

Elche

V_{max} = 35,93 x 4= 143,72 V-----120V 4 modules series

40 modules parallel Icc =8,67x 40= 346,8 A

Pilsen

V_{max} = 35,93 x 6= 215,6 V-----220V 6 modules series

100 modules parallel Icc =8,67x 100= 867 A

4) **Battery sizing**

The battery type recommended for using in solar PV system is deep cycle battery. Deep cycle battery is specifically designed for to be discharged to low energy level and rapid recharged or cycle charged and discharged day after day for years. The battery should be large enough to store sufficient energy to operate the appliances at night and cloudy days.

Elche

L_D= 100000/120= 833 A (Average daily consumption of the charge in Ah)

$$C_{20} = \frac{A\ x\ L_d}{PD\ _{MAX}} \mu\ _{inv}\ \mu_{rb} \tag{13}$$

A- Days of autonomy = 3 days

PD_{max}- Maximum discharge depth

μ_{inv} - Energy efficiency of the inverter

μ_{rd} - Energy efficiency tank + regulator

C_{20}= (3 x 833)/(0,6 x 0,9 x 0,85)= 5447Ah

C_{20}/ I_{cc}< 25

5447 / 346,8 <25

15,7 <25 condition is met

Pilsen

L_D= 100000/220= 455 A (Average daily consumption of the charge in Ah)

$$C_{20} = \frac{A\ x\ L_d}{PD\ _{MAX}} \mu\ _{inv}\ \mu_{rb}$$

A: Days of autonomy = 3 days

PD_{max}: Maximum discharge depth

μ_{inv} : Energy efficiency of the inverter

μ_{rd} : Energy efficiency tank + regulator

C_{20}= (3 x 455)/(0,6 x 0,9 x 0,85)= 2973,9 Ah

C_{20}/ I_{cc}< 25

2973,9 / 867 <25

3, 43 <25 condition is met

In market we can find many types and producers of batteries and also regulators. Design of proper system would depend on many aspects as voltage, price and related costs. As I know from [1] in design of batteries we have to follow these ruls, which are descried in Fig.4.9. Furthure calculation would be done in case of investor´s interests.

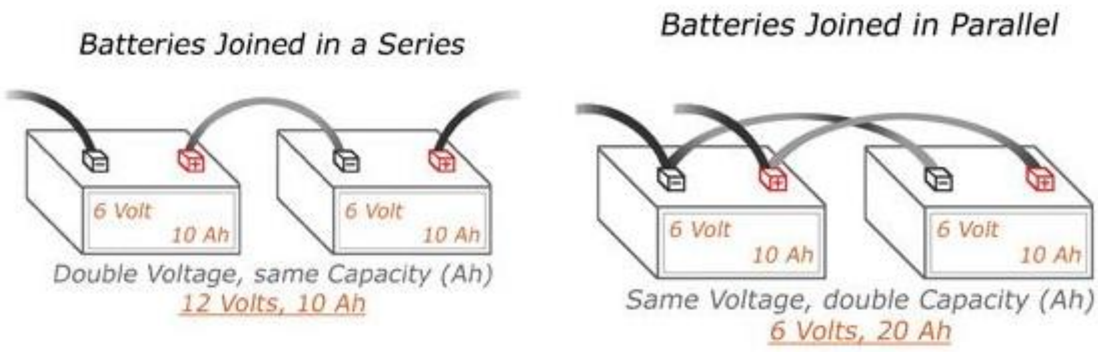

Fig. 4.9 Battery connection [1]

Average daily production

Elche 100 (kWh) x 5, 83 = 5 830 kWh

Pilsen 100 (kWh) x 3,41 = 3 410 kWh

Normal electromobile needs for driving 100 km about 12 to 16 kWh of electricity. Today is the length of rapid recharge from capacity 0% to 80% from 30 minutes to 45 min by special rechargeable "stands" with 400 V/32 A/7 pols, of power consumption about 50 kW according to many sources comparison. Considering that, every hour could be charged one car, the total energy consumption is:

50 kW x 24hours= 1200 kWh per day

The last thing to count is how many rechargeable "stands" it could be installed for parking area:

Elche 5830 kWh / 1200 kWh = 4,8 - 4 plugs

It means that per day would be possible to recharge max **96 cars.**

Pilsen 3 410 kWh / 1200 kWh = 2,8 - 2 plugs

It means that per day would be possible to recharge max **48 cars**.

The results are of course only theoretical, but very important for investor's decisions. Calculations can be affected by many factors for example of selection a manufacturer, type of photovoltaic panels, inclination and rotation angle, etc. The real usability would show up after 1 year of useage but also these calculations can show what a great step forward would be the construction of these charging station.

5 Assessment of my proposal and its efficiency

In the following Fig.5.1 is my proper design of fotovoltaic charging station in Pilsen. The project has been done in AutoCAD program and it shows how this parking lot could be use for powering electrical vehicles in real. My final task is to evaluate my project in terms of economy, environment and efficiency.

Fig. 5.1 Fotovoltaic parking lot from south-west view

5.1 Solar Irradiance evaluation

My project and all this calculation depend on **Average Daily Solar Irradiance**, which is transformed to electrical energy. Folowing tables and graphs are result of my work of calculation solar irradiance performance to electrical energy. These datas are consulted by PVGIS © European Communities, 2001-2012 and reproduced formulas (3), (4), (5), (6).

Table 5.1 Used data of module ATERSA A-290P

Inverter performance [%]	0,04
$P_{cc,inv}$ [W]	6903,430551
$P_{cc,fov}$ [W]	7044,316889
Po [W]	**100000**
$R_{to, var}$[W]	0,922082
T_c [°C]	32,66625
T_{amb} [°C]	30
TONC	47
g (coefficient of variation of the power with temp.)	0,0043

My task was to compare situation In Czech Republic and Spain. I chose Pilsen, which is city where I live and also part of Czech, which is suitable for construction of PV power plants. In Spain I chose Elche, which was epicenter of my Erasmus Internschip and is situated in Zone V with the highest solar irradiation. The main factor that we are interested in is **P_{AC} inversor**, which represents Potency of DC power immediately output from the inversor in W. Specific data can be found in the Table 5.1 and demonstrated in following Charts.

Table 5.2 Comparison of Annual Potency [W]in Pilsen and Elche

Month	January		February		March	
Time(h)	***P_{AC} inversor Pilsen***	***P_{AC} inversor Elche***	***P_{AC} inversor Pilsen***	***P_{AC} inversor Elche***	***P_{AC} inversor Pilsen***	***P_{AC} inversor Elche***
0:00	0	0	0	0	0	0
1:00	0	0	0	0	0	0
2:00	0	0	0	0	0	0
3:00	0	0	0	0	0	0
4:00	0	0	0	0	0	0
5:00	0	0	0	0	0	0
6:00	0	0	0	0	1975,63398	3895,174622

7:00	0	4783,62893	3183,41232	11806,94255	11425,8199	19343,61221
8:00	4975,839036	23435,26241	12707,2119	29180,72357	21630,5094	35333,75509
9:00	11145,24449	37613,34591	20704,4952	43113,96795	30244,7028	48043,52494
10:00	15527,7294	47278,47473	26475,4487	52663,57217	36411,0364	56647,03399
11:00	17965,41386	52423,73328	29650,0200	57769,55627	39789,5849	61277,91031
12:00	18442,12052	53234,58466	30224,4621	58575,07052	40340,8204	61973,53427
13:00	16933,1654	49801,61628	28224,1202	55121,61188	38180,862	58933,79948
14:00	13511,76588	42164,9528	23667,0415	47510,19054	33245,6830	52042,52119
15:00	8168,19995	30301,10833	16708,2979	35787,2259	25777,31	41344,6014
16:00	1387,812184	14087,73232	7897,33571	20292,13055	16306,7824	27008,03109
17:00	0	0	402,9703698	3487,065983	6258,85532	10696,88639
18:00	0	0	0	0	0	471,6720716
19:00	0	0	0	0	0	0
20:00	0	0	0	0	0	0
21:00	0	0	0	0	0	0
22:00	0	0	0	0	0	0
23:00	0	0	0	0	0	0
Month	April		May		June	
Time(h)	***P_{AC} inversor Pilsen***	***P_{AC} inversor Elche***	***P_{AC} inversor Pilsen***	***P_{AC} inversor Elche***	***P_{AC} inversor Pilsen***	***P_{AC} inversor Elche***
0:00	0	0	0	0	0	0
1:00	0	0	0	0	0	0
2:00	0	0	0	0	0	0
3:00	0	0	0	0	0	0
4:00	0	0	556,7322764	0	2224,108997	0
5:00	1441,868837	571,6908976	5357,345398	2832,402756	7015,704066	3733,899986
6:00	8757,351587	8173,494336	12522,17278	11171,05002	14214,91017	11474,02099

7:00	20306,9184	23379,40368	22648,82133	25933,51185	23844,35354	26843,94698
8:00	31802,93388	38618,92245	32121,28688	40157,88964	32800,36098	41780,97384
9:00	41263,22782	50905,33369	39802,06619	51474,67671	39999,69252	53895,78895
10:00	47870,00517	59317,70175	45143,64906	59294,32437	45016,0355	62304,40241
11:00	51520,49463	63869,14673	48056,29179	63517,93288	47754,41663	66888,91665
12:00	52111,19602	64630,19923	48503,09288	64268,30147	48207,69526	67666,44679
13:00	49709,99835	61685,87945	46589,5365	61578,7876	46357,12203	64738,51295
14:00	44362,82318	55011,6058	42242,20439	55372,51401	42298,86717	58055,43977
15:00	36227,23874	44545,0701	35634,94194	45678,51719	36059,93194	47629,40455
16:00	25672,15172	30689,5143	26972,12508	32806,91786	27889,33481	33981,39064
17:00	13974,4499	15035,9991	17104,49477	18031,9318	18555,6037	18571,43832
18:00	4381,341891	2969,550406	8091,760101	5971,15991	9688,550552	6258,177446
19:00	0	0	2557,704364	0	4616,68167	860,596384
20:00	0	0	0	0	0	0
21:00	0	0	0	0	0	0
22:00	0	0	0	0	0	0
23:00	0	0	0	0	0	0
Month	July		August		September	
Time(h)	***P_{AC} inversor Pilsen***	***P_{AC} inversor Elche***	***P_{AC} inversor Pilsen***	***P_{AC} inversor Elche***	***P_{AC} inversor Pilsen***	***P_{AC} inversor Elche***
0:00	0	0	0	0	0	0
1:00	0	0	0	0	0	0
2:00	0	0	0	0	0	0
3:00	0	0	0	0	0	0
4:00	1370,152708	0	0	0	0	0
5:00	6312,271379	3025,344822	2453,617839	1139,442095	0	0
6:00	13261,6048	10719,11425	9307,814539	8627,377617	4099,689013	4659,514711

7:00	22401,69418	26351,90969	19309,29268	23920,76452	13492,71239	18977,03107
8:00	30818,81091	41782,46182	29216,4493	39585,18519	23531,80742	34938,4628
9:00	37527,36461	54355,38126	37406,06973	52342,7717	31954,22258	48186,6445
10:00	42183,42518	63070,65081	43184,21677	61209,34423	37989,30931	57409,77856
11:00	44717,74351	67821,76828	46344,33832	65974,73693	41270,39864	62376,88394
12:00	45115,98303	68631,34335	46857,47609	66758,19854	41803,53893	63218,59865
13:00	43436,71789	65576,80161	44732,35757	63676,73016	39651,95306	59992,2617
14:00	39636,7096	58610,88548	40055,38185	56652,3356	34804,80909	52700,09394
15:00	33852,5945	47822,03244	32948,18775	45690,10002	27486,01721	41361,32
16:00	26216,40407	33670,07775	23806,53427	31360,30388	18200,80372	26627,99522
17:00	17398,8143	17868,23802	13771,97003	15519,62636	8226,953634	10864,80174
18:00	8943,147093	5540,610052	5266,581982	3711,515249	1077,400714	973,0813454
19:00	3845,472145	670,0577561	507,8689188	0	0	0
20:00	0	0	0	0	0	0
21:00	0	0	0	0	0	0
22:00	0	0	0	0	0	0
23:00	0	0	0	0	0	0
Month	October		November		December	
Time(h)	***P_{AC} inversor Pilsen***	***P_{AC} inversor Elche***	***P_{AC} inversor Pilsen***	***P_{AC} inversor Elche***	***P_{AC} inversor Pilsen***	***P_{AC} inversor Elche***
0:00	0	0	0	0	0	0
1:00	0	0	0	0	0	0
2:00	0	0	0	0	0	0
3:00	0	0	0	0	0	0
4:00	0	0	0	0	0	0
5:00	0	0	0	0	0	0
6:00	0	958,8173027	0	0	0	0

7:00	5725,474625	13890,08278	355,7963959	5815,124885	0	3217,720172
8:00	14420,9484	30332,05672	6694,262701	23532,03538	3727,748648	22569,67445
9:00	21906,50175	43659,85291	12833,00068	37532,38061	10636,55795	37201,31686
10:00	27276,69974	52823,06165	17109,9194	47186,99218	15026,52821	46869,79799
11:00	30233,74784	57773,90957	19494,27018	52405,62128	17464,06066	51953,17812
12:00	30772,25621	58573,25221	19935,57027	53269,46142	17923,73726	52798,91273
13:00	28862,60144	55386,02619	18490,07069	49901,18124	16453,12206	49442,86875
14:00	24607,24272	48117,27991	15121,61278	42283,66909	13024,10501	41876,2066
15:00	18130,10085	36824,63104	9926,875692	30462,01079	7531,428298	29944,11062
16:00	9948,734727	21938,20545	2784,646219	14811,57543	501,6351233	12033,47224
17:00	1732,597244	5622,514303	0	1069,104688	0	0
18:00	0	0	0	0	0	0
19:00	0	0	0	0	0	0
20:00	0	0	0	0	0	0
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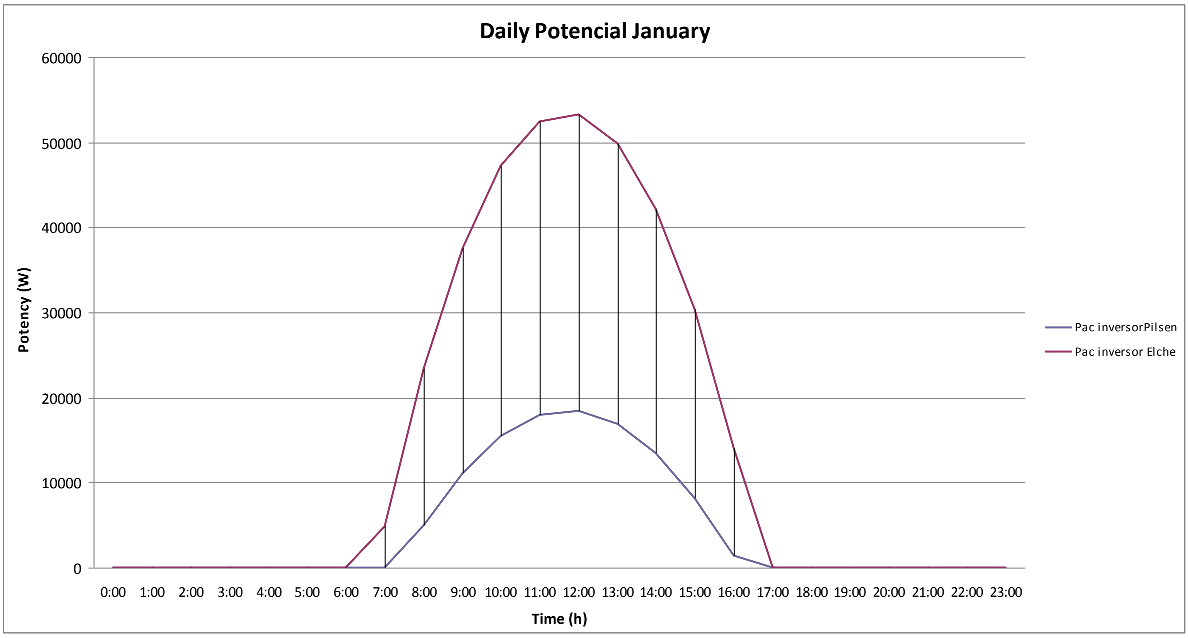

Chart 5.1 January daily potential in Pilsen and Elche

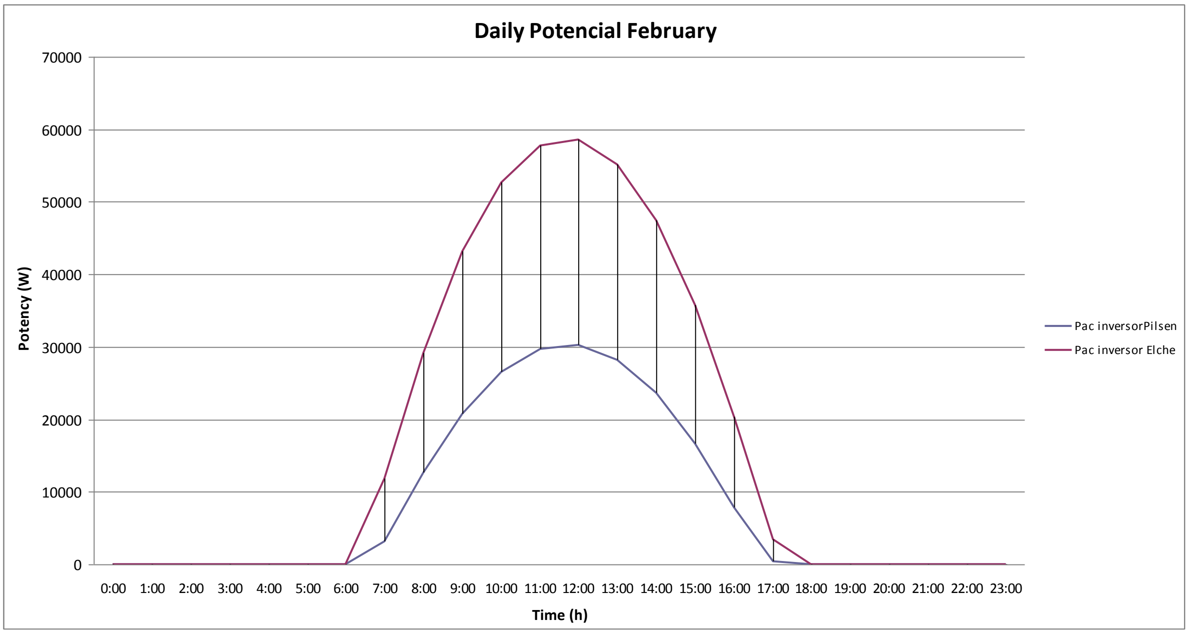

Chart 5.2 February daily potential in Pilsen and Elche

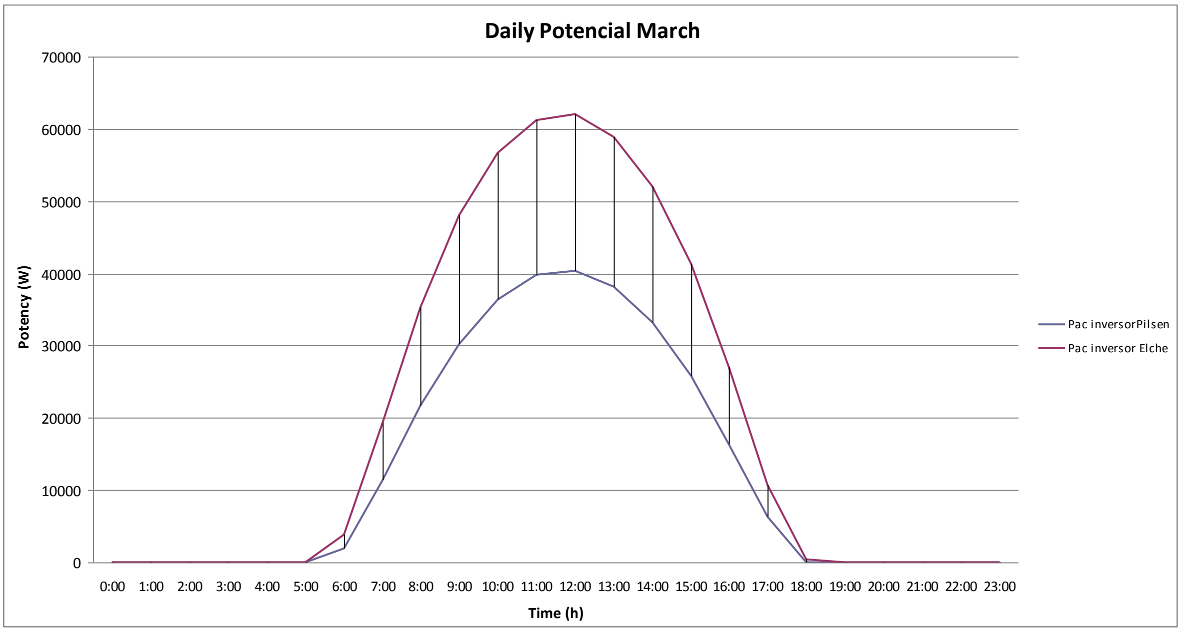

Chart 5.3 March daily potential in Pilsen and Elche

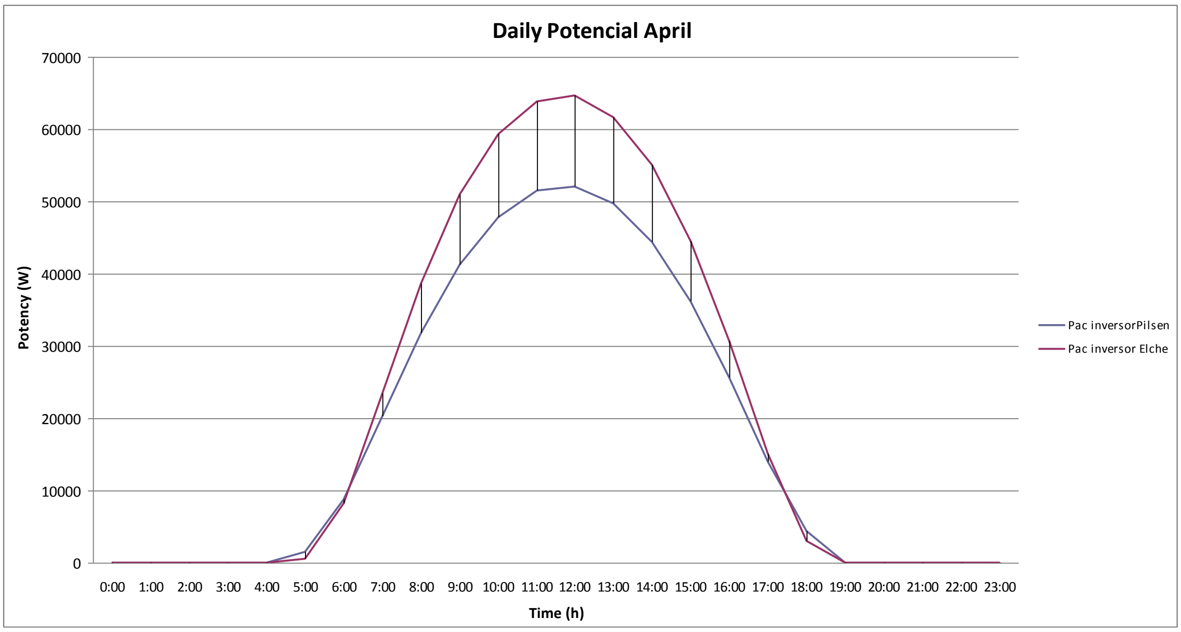

Chart 5.4 April daily potential in Pilsen and Elche

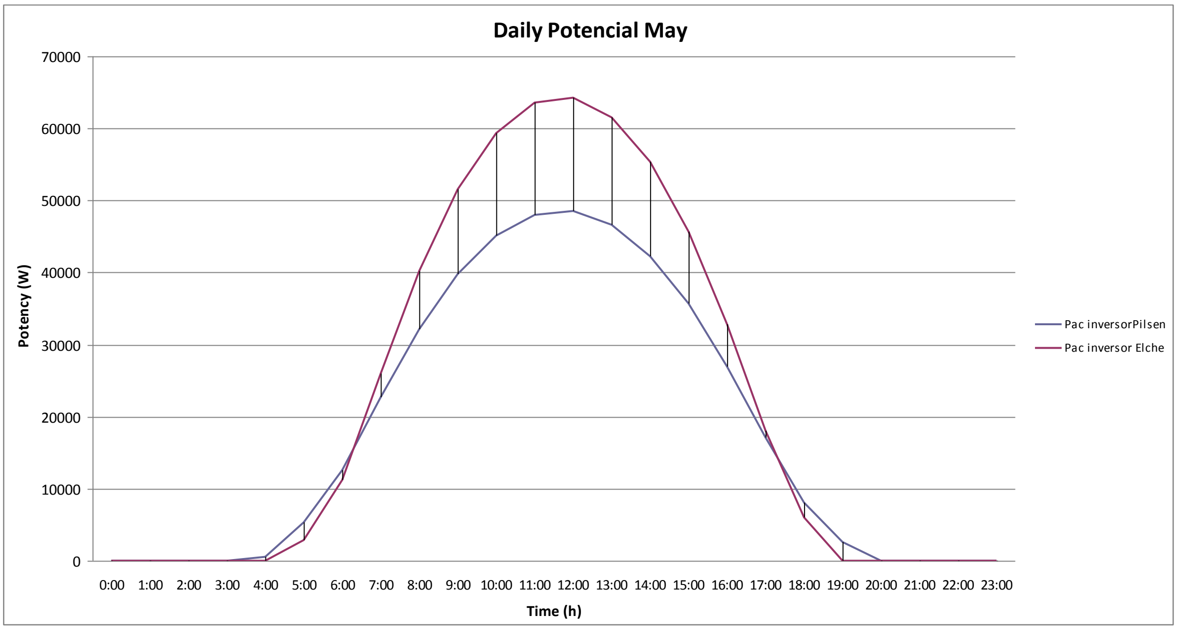

Chart 5.5 May daily potential in Pilsen and Elche

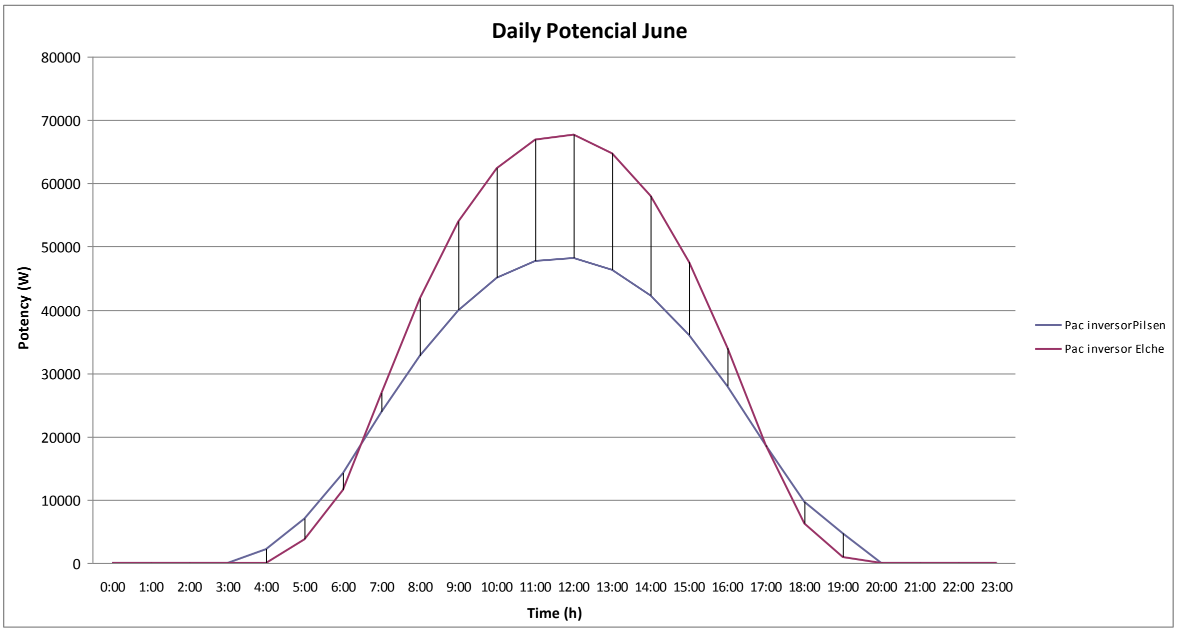

Chart 5.6 June daily potential in Pilsen and Elche

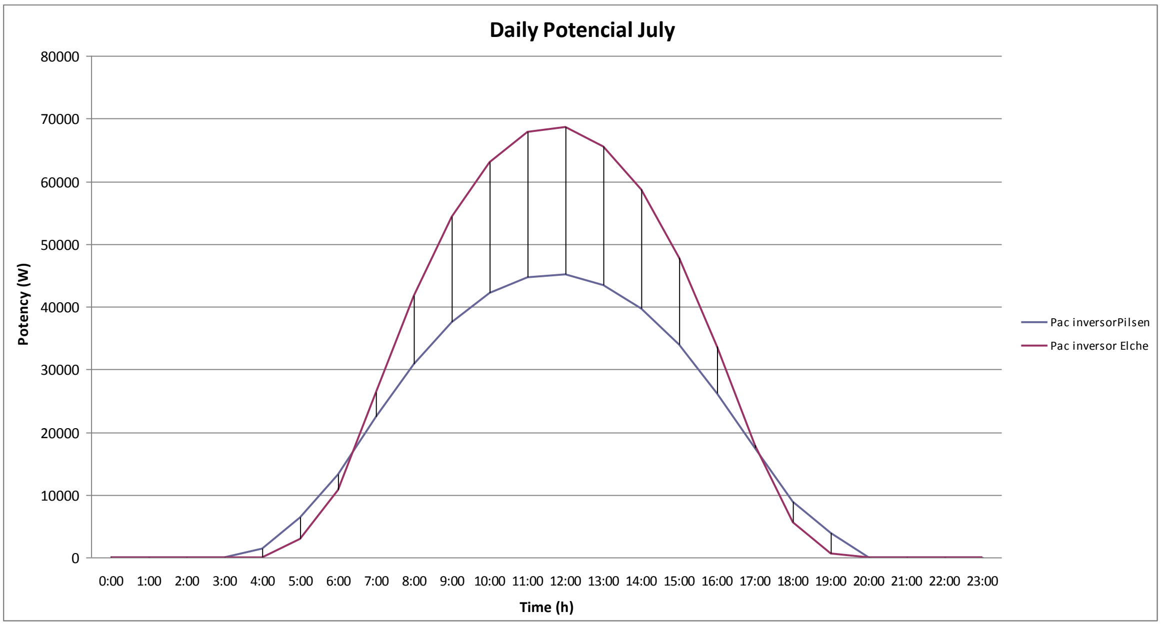

Chart 5.7 July daily potential in Pilsen and Elche

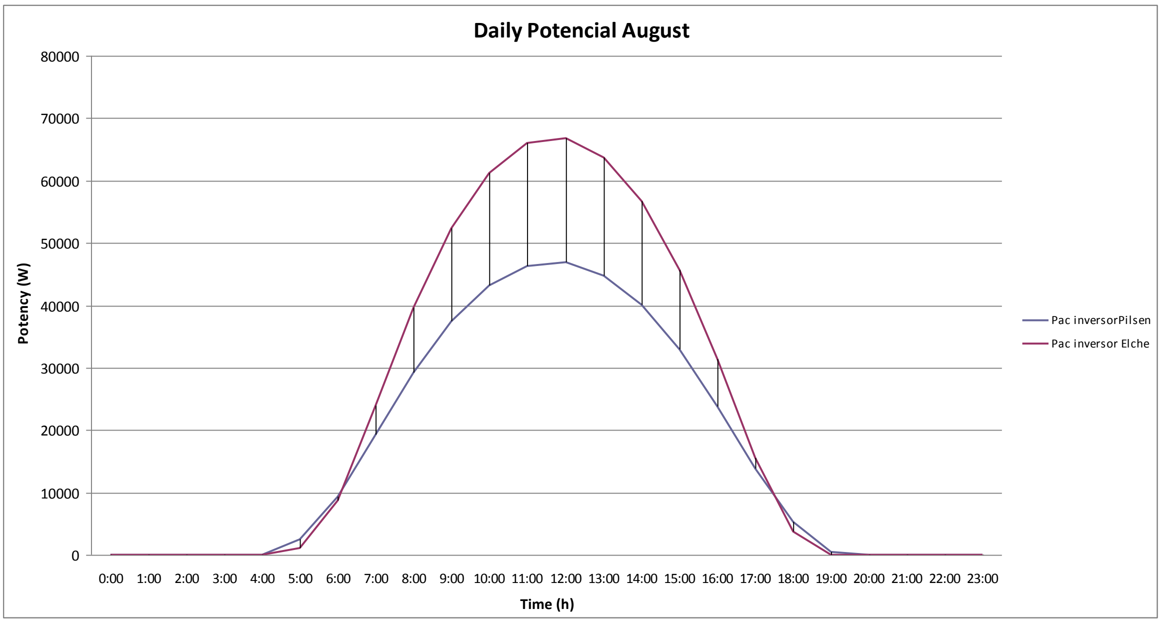

Chart 5.8 August daily potential in Pilsen and Elche

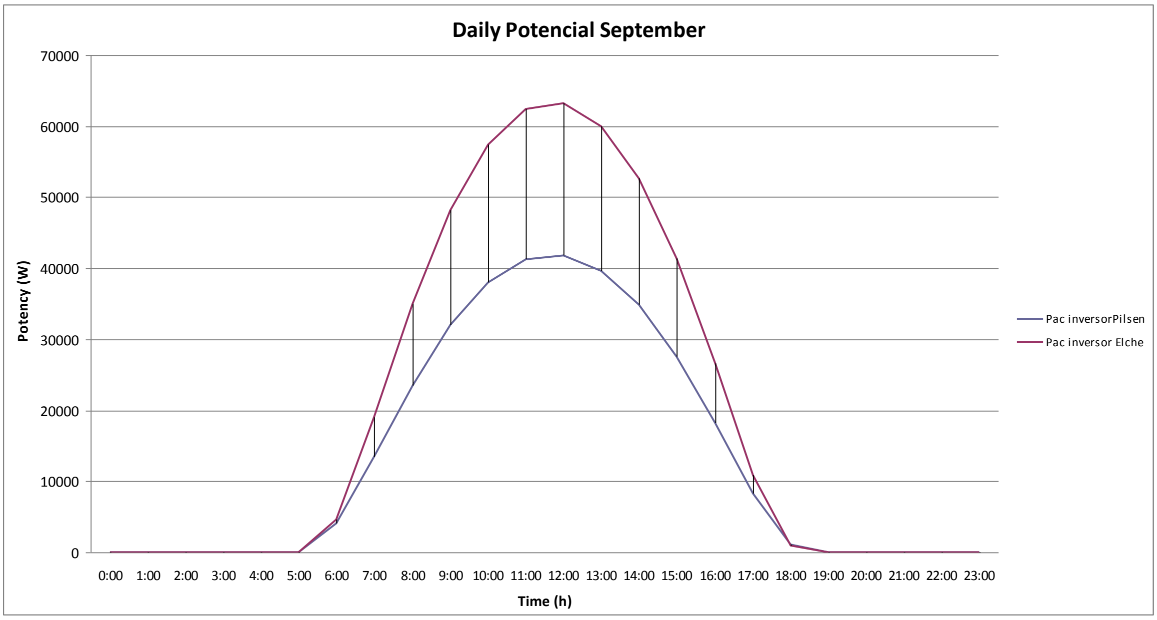

Chart 5.9 September daily potential in Pilsen and Elche

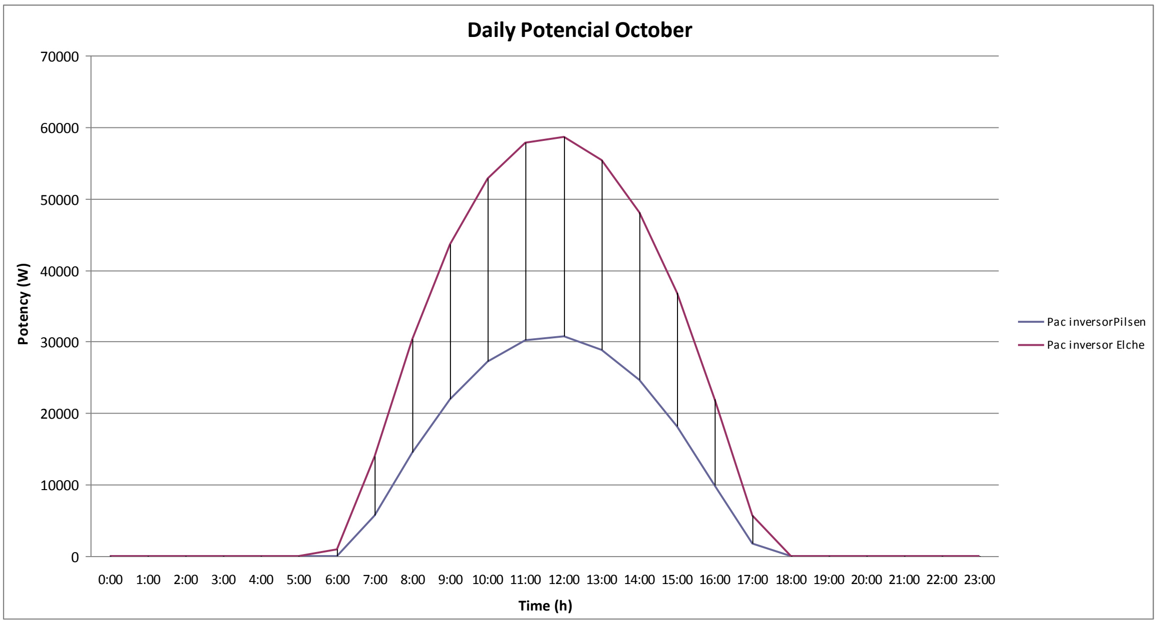

Chart 5.10 October daily potential in Pilsen and Elche

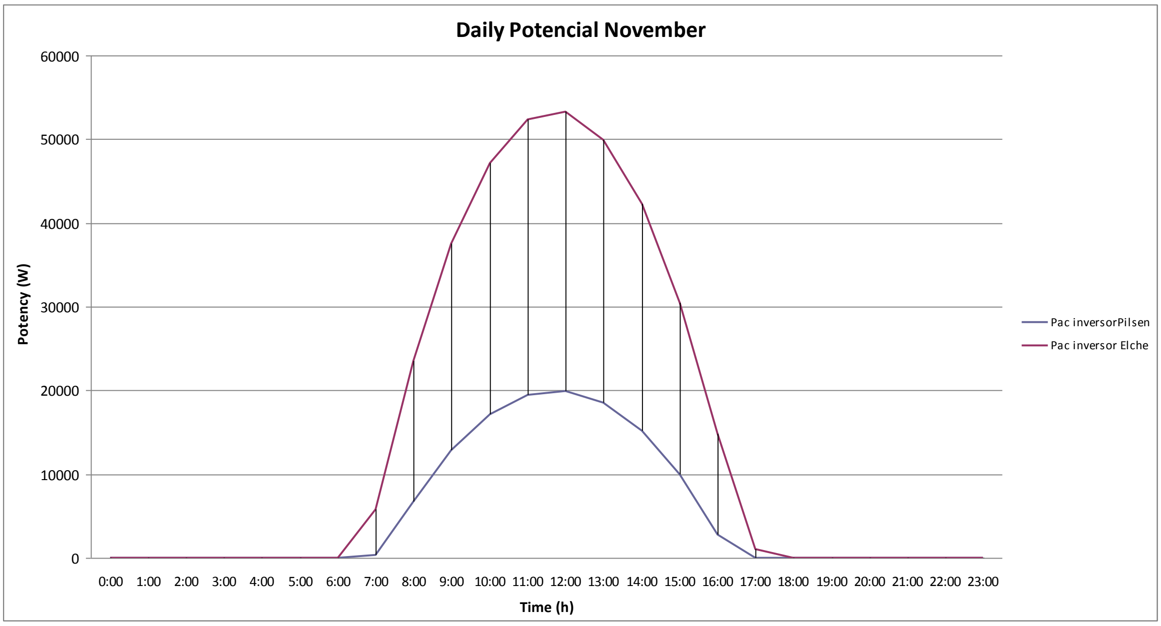

Chart 5.11 November daily potential in Pilsen and Elche

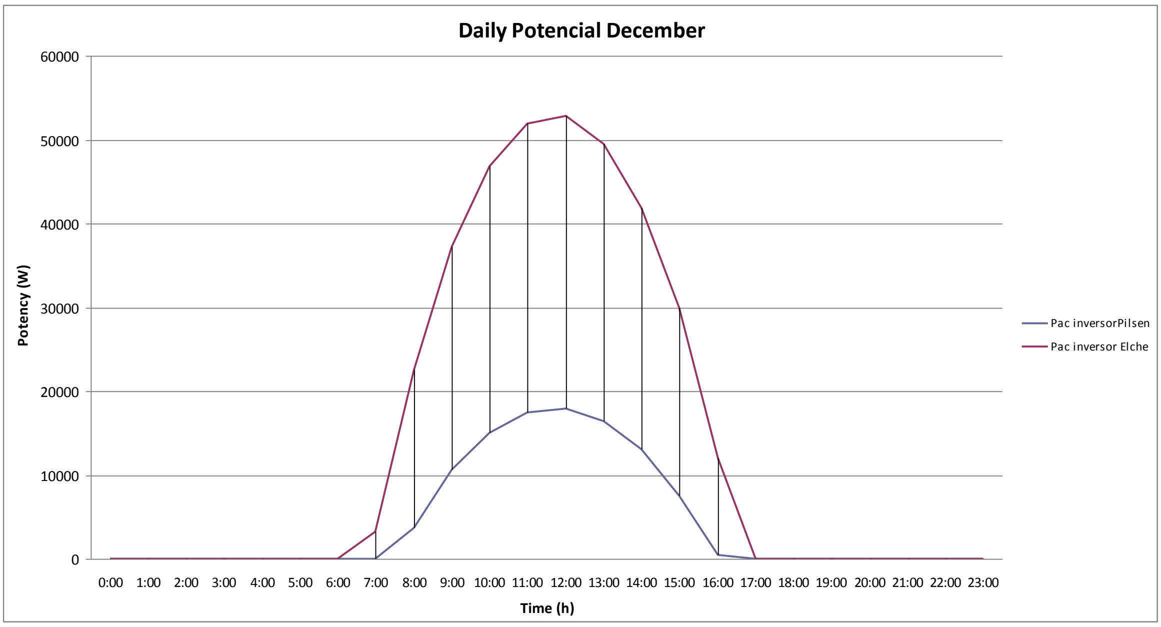

Chart 5.12 December daily potential in Pilsen and Elche

These results show notable differance between these both countries. During summer months red (Elche) and blue (Pilsen) lines are going to approximate, even in Pilsen the sun rises are earlier and sunsets later but the production is not even comparable.

5.2 Economy evaluation

This is the most interesting part for investors. In this paragraph Czech Rebublic has considerable advantages. In Spain Royal Decree-Law 1/2012, of January 27 cutted all dotation for instaling photovoltais systems and the market price is about 5 c€. In Czech Republic is still support from the state. From 1.7.2013 to 31.12.2013 and installed power from 5-30 kW FIT is 9,346 kWh/c€ and GB tarrif is 7,231c€. The problem in my project is that installed power is going to be 100kW, which is beyond subsidies. That is why I decided that unused energy would serve to fill energy needs for the supermarket.

There is another question about price of photovoltaic system. Average price of 1Wp of installed capacity is 2 € in EU. I can very simply calculate cost of fotovoltaic system installed in Elche and Pilsen. It is necessary to say that prices of cells are rapidly decreasing every year and almost all producers indicate an 80% performance after 20 years.

Elche: 48 543,7 x 2 = **97 087 €**

Pilsen: 152905,2 x 2= **305 810 €**

From this perspective, installation in Elche is worth it 3times by the initial costs in comparison to Pilsen and the associated return on investment.

5.2.1 Savings of electric vehicles

Economical view for vehicle owners is a way more interesting. Acquisition costs of electric vehicles are still little bit higher but total operating costs are lower compared to combustion, because it is not necessary to change the oil, clutch, exhaust, plugs, wiring, engine repair. Moreover, it is without emission fees. For furthure information for electric vehicle´s investors I highly recommend following webpage with program DrRange5.xls, which describes in detail all car specifications: http://www.elektromobily.org/wiki/Vypocty_a_simulace

In folowing Table 5.3 I would like to show how much more economic electric vehicles are. The prices are actual for year 2013.

Table 5.3 Comparison of electricity prices and gasoline [19]

	Electric vehicle	**Combustion vehicles**
Consumption per 100 km	16 kWh (el.energy)	8 litres (Natural 95)
Price per unit in Czech Republic	0,149 €/kWh	1,46 €/l
Price per 100 km	**2,384 €**	**11,68 €**
Price per unit in Spain	0,195 €/kWh	1,44 €/l
Price per 100 km	**3,13 €**	**11,52 €**

5.3 Environmental evaluation

In any magazine there is always written that use of solar energy releases no CO^2, SO^2, or NO^2 gases and don't contribute to global warming. Actually PV plant with an output of 100 kW per year will save an average of 90 000 kg of CO^2 emissions. Photovoltaic is now a proven technology, which is inherently safe as opposed to some dangerous electricity generating technologies. Photovoltaic systems make no noise and cause no pollution in operation. Solar energy is clean, silent, and freely available. But the answer if is really so environmentally friendly, is a bit longer.

We are interested in environmental impact of the technology, all impacts from inception to retirement must be taken into account. Life Cycle Assessment (LCA) methodology considers three distinct phases in the life cycle of CPV: (1) fabrication of PV modules and deployment in the field on two-axis tracking systems (2) energy production (3) recycling and disposal at end of life. Here, four LCA environmental impact metrics are discussed in the context of PV: energy, emissions, water use and land use. Generally, a 1 kWp of installed capacity use land of about 8 to 10 m^2. In our case in Elche is about 485 m^2 and Pilsen 1840 m^2. We negate land use by installing PV plant on the roof of parking lot. A dominant LCA energy metric is the Energy Payback Time (EPBT), which denotes the time in years it takes for a technology to produce as much energy (net) as it takes to create and dispose of the device. EPBT is a measure of energy efficacy - for an energy technology to be a worthwhile investment from an energy production perspective; the EPBT should be much less than the lifetime of the device. EPBTs are calculated (eq. 14) by adding up all energy used in fabrication and installation of an electric power device, as well as disposal/recycling at the end of life, and then dividing this Cumulative Energy Demand (CED) by the yearly net energy during operation. The yearly net energy during operation is expressed in units of primary energy per year, thereby giving the EPBT in years. The conversion from yearly net electricity generated by the device $P_{GeneratedNet}$ to primary energy terms is accomplished by dividing $P_{GeneratedNet}$ by the efficiency of electric power grid at converting primary energy into electricity at the site of deployment of the device. This conversion represents the input energy that would have been used to create a unit of electricity from other electric power generators, had the device in question not been installed. The primary energy used in operations and maintenance $P_{O\&M}$ is subtracted from the denominator to obtain the yearly operational net energy. [1]

$$EPBT = \frac{CED}{Yearly\,Operational\,Net\,\mathrm{Energy}} = \frac{E_{Fabrication} + E_{Installation} + E_{EndOfLife}}{\frac{P_{GeneratedNet}}{GridEfficency} - P_{O\&M}} \tag{14}$$

Recent EPBT values are for a range of solar technologies, all of which are less than or equal to two years. Considering this fact, drive EVs or HEVS contributes to naturally sustainable development.

5.4 Problems of real mass development of electric vehicles

One could say that technology has advanced so much that the production and introduction of electric vehicles into practice almost nothing stays in the way. But I have few doubts. These vehicles from the user's perspective view look like their combustion colleagues, which have power over 40 kW, maximum speed over 130 km / h, range over 100 km and don´t look like "experimental monsters". It is already a great promise for the future. Something else is of course the purchase price of the car. The biggest problem for the practical application of electric cars I do not see in still significantly less range per charge but in providing of charging. One possibility is to charge overnight but not everybody has this option and moreover it takes approximately 8 hours. Over time I hope that each resident will have their own house charger and new houses with connecting electric vehicles will already be counted, but still is not done and investments of the transformation of our cities can be quite high. Therefore I see markedly solution in my project. Inventers are working on new practically feasible solution in the form of exchanges of standardized batteries. All electric cars would use the same standardized battery type, which would be built into the car, but it would be easily removed / ejected. But this is question of the future. Electric vehicles, besides the above mentioned problems of practical operation, can be by their massive use in the future to face challenges related to greatly increased electricity consumption. While today's household electrical appliance has a total power of only a few kW-day consumption in the order of tens or maximum kWh, the acquisition by its electric consumption practically more than doubled if the car is used every day, which is quite likely. I see the positive that electric vehicles could help solve a constant problem with the balance of electic grid with massive use of solar and wind power. However, significantly higher electricity consumption would certainly set in motion electricity prices.

Personally, I believe that time fully electric cars will just have to come in the future if mankind does not develop some kind of a synthetic liquid or gaseous fuel suitable for replacing oil with combustion engines. Oil or gases that will not be forever and currently it seems that electricity along with hydrogen in fuel cells are still the only proven viable alternatives for transport.

6 Conclusion

Energy is a term that follows us every step of our life. Energy is mainly a question of the future, because the future will show how people can deal with the increasing energy consumption. Limit the right of the energy needed for operation is possible resource that gives us nature such as solar energy, wind energy, hydro energy and the use ground heat and biogas from waste.

Firstly, I dicussed main features of electric vehicles and their more advantages than disadvantages. In the coparison between Spain and Czech Republic was confirmed that PV electricity potential in Spain is much higher. Unfortunately, Spanish govermant in 2012 cutted bonuses for sell produced energy to the grid. Secondly, my thesis shows up EV´s and HEV´s progress and step by step how to design PV system. In this part I came up with a proposal of PV charging stations and its own design. To reach total power 100 kW/day in Elche should be installed between 140 and 168 modules, which have **Average daily production of 5 830 kWh**. This special rechargeable "stands" with 400 V/32 A/7 pols would contain 4 plugs and recharge max **96 cars** a day. In Pilsen the amount of modules needed is between 527 and 633, which have **Average daily production of 3 410 kWh**. In this case is capacity of plugs two times less and has the possibility of recharging **48 cars** a day. These data are also proven from 2 sources ([11] and Attachment {3}). Both results are comparable. The last part is dedicated to evaluate my project in terms of economy, environment and efficiency. Calculated cost of photovoltaic system installed in Elche would be **97 087 €** and Pilsen **305 810 €.** Morover, I wanted to show economic aspects of EV´s and HEV´s and also possible problems of real mass development.

If we change our approach to transport and respect the call for gentle treatment of nature, electric vehicles can very significantly affect ecological consequences of our behavior towards nature. No matter how accurate the estimates of ecosystem changes are, melting glaciers and limits of energy supply make needs to develop new transport options. The more strict emission reduction requirements lead automotive industry to the introduction of many new technologies and responsible approach to the problem and reduce oil demand. To be totally honest the lowest negative environmental impact would be a lifestyle change in favor of walking, biking or use of public transit.

RES + EVs and HEVs = energy saving = environmental protection.

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9 Attachments

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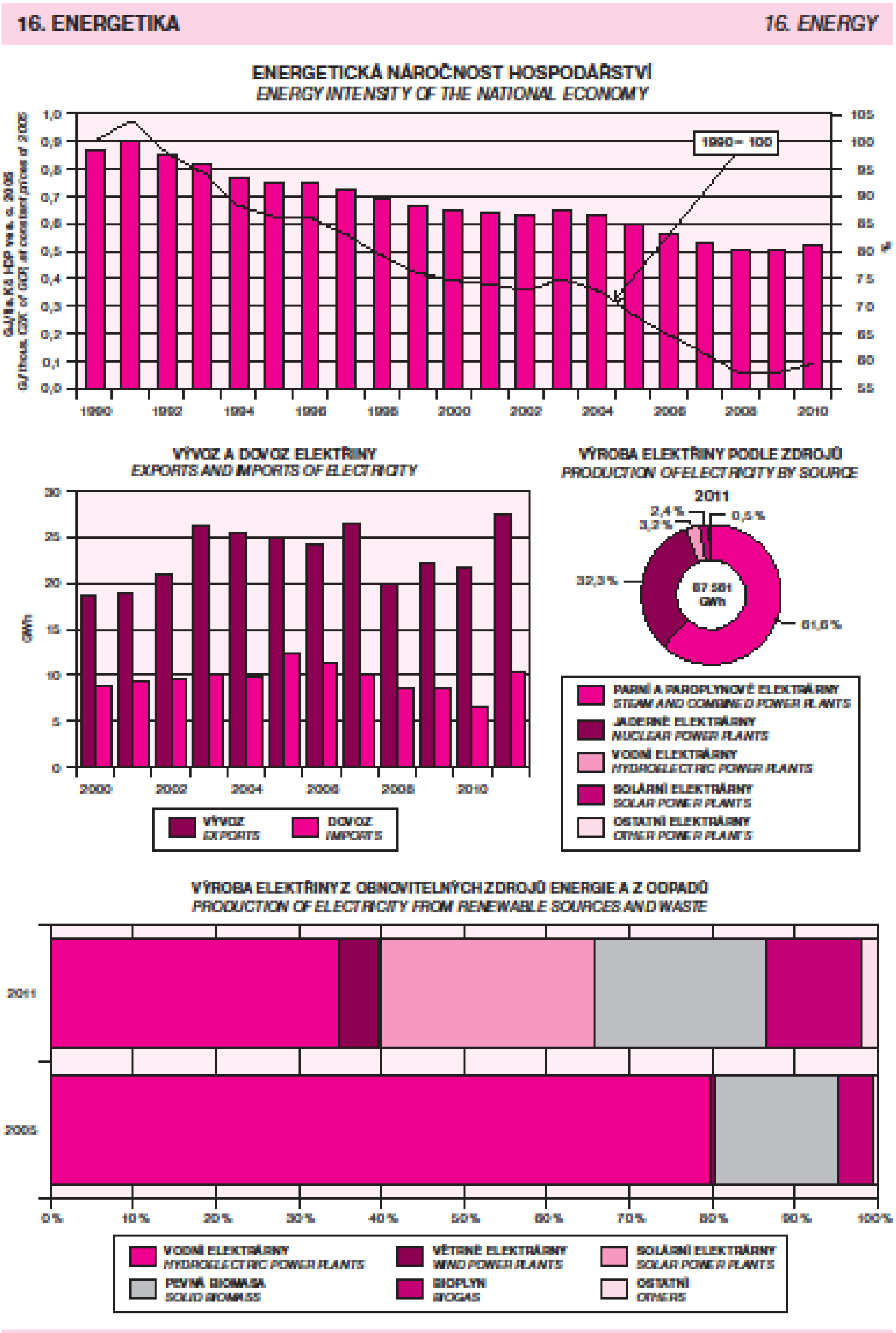
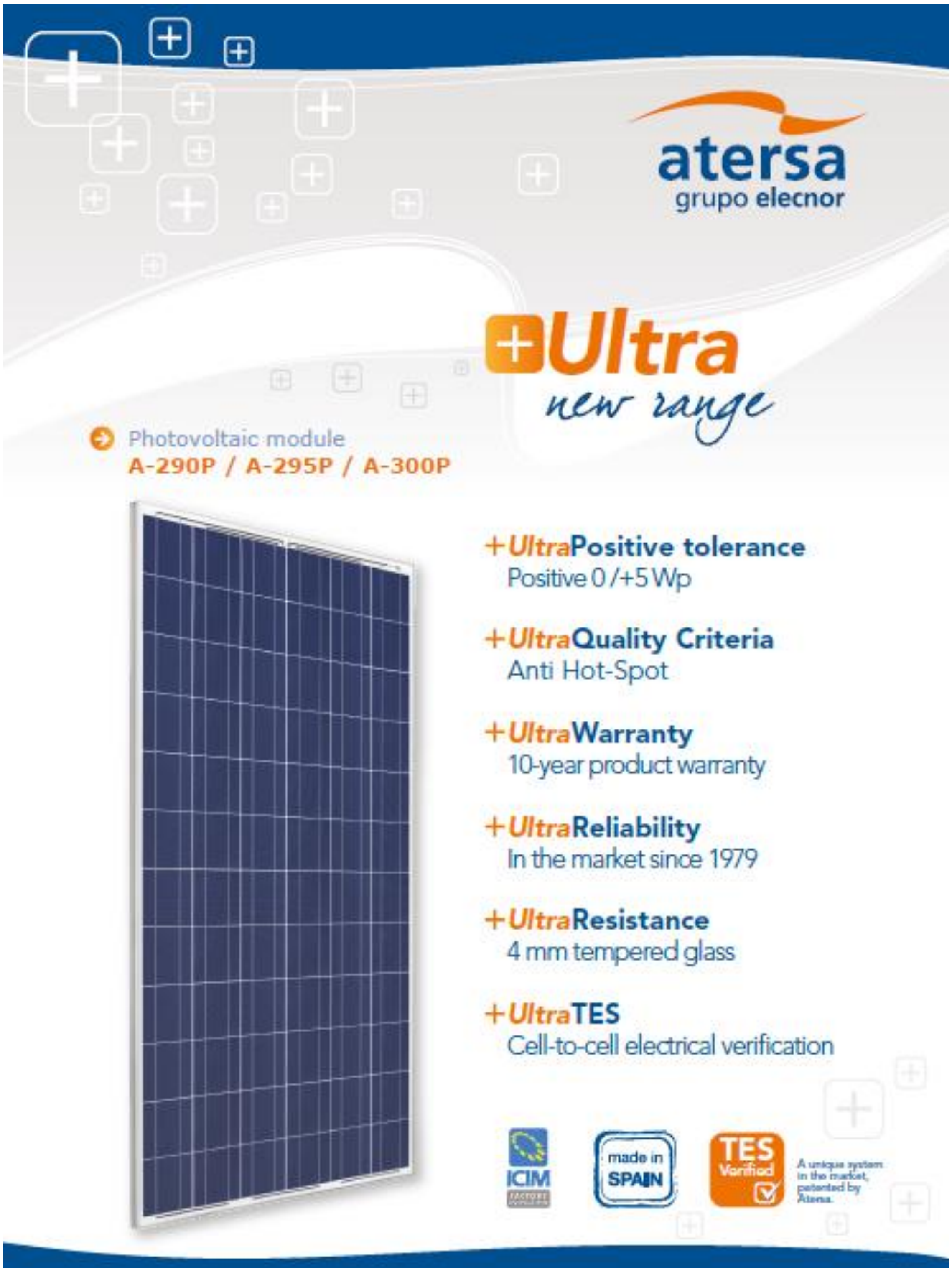


Attachment {2}



Electrical characteristics (STC: 1kW/m², 25°C±2°C and AM 1,5)*	A-290P	A-295P	A-300P
Rated Power (0/+5 W)	290 W	295 W	300 W
Module efficiency	14,91%	15,16%	15,42%
Peak-Point Current of Maximum Power (Imp)	8,07 A	8,14 A	8,21 A
Peak-Point Voltage of Maximum Power (Vmp)	35,93 V	36,23 V	36,52 V
Short-circuit Current (Isc)	8,67 A	8,78 A	8,89 A
Open Current Voltage (Voc)	44,67 V	44,82 V	44,97 V

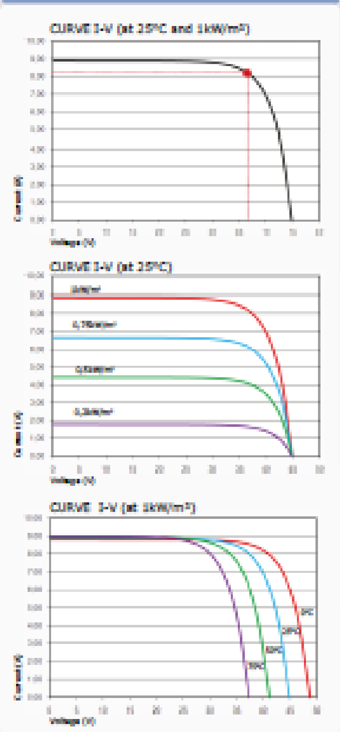
Thermal parameters	
Isc (α) Temperature Coefficient	0,04% /°C
Voc (β) Temperature Coefficient	-0,32% /°C
P (γ) Temperature Coefficient	-0,43% /°C

Physical characteristics	
Dimensions (mm ± 2 mm)	1965x990x40
Weight (kg)	24
Surface area (m²)	1,95
Cell type	Polycrystalline 156x156 mm (6 inches)
Cells in series	72 (6x12)
Front glass	Ultra-clear 4 mm tempered glass
Frame	Polyester-coated aluminium alloy
Connection box / Optional	QUAD IP54 / QUAD IP65
Cables	Solar Cable 4 mm² 1250 mm
Connectors	MC4 or combinable MC4

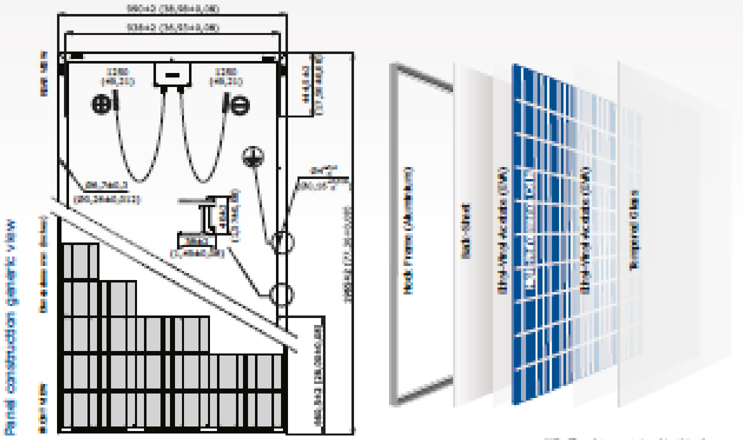
Operating range	
Temperature	-40°C to +85°C
Maximum System Voltage / Protection	1000 V / CLASS II
Maximum Wind Load / Snow Load	2400 Pa (130 km/h) / 5400 Pa (551 kg/m²)
Max. Reverse Current (IR)	15,1 A

*Electrical specifications measured in STC. NOCT: 47±2°C.
Tolerance measures STC: ±3% (Pmp); ±10% (Isc, Voc, Imp, Vmp).

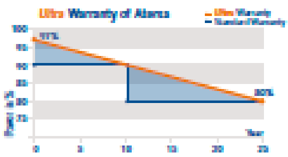
A-300P curves model



Panel construction generic view



- Modules per box: **25 units**
- Weight per pallet: **680 kg**
- A 40-foot container can hold 21 boxes: **525 panels**
- A 40-foot HC container can hold 22 boxes: **550 panels**
- A 20-foot container can hold 9 boxes: **225 panels**
- A TAUTLINER truck can hold 26 boxes: **650 panels**



NB: The data contained in this documentation are subject to modification without prior notification.

www.atersa.com • atersa@elecnor.com
Madrid +34 915 178 452 • Valencia +34 961 038 430 • Italy +39 039 226 24 82 • Germany +49 151 153 988 44

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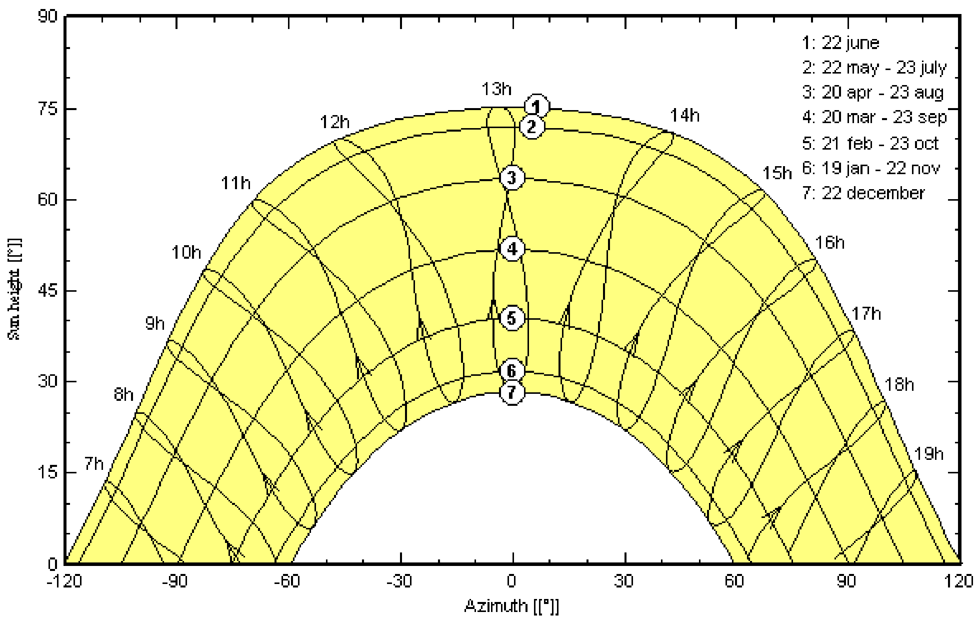
Ref.: E-MU-6P (1) 6x12-F

Attachment {3}

PVsyst V6.22	**Elche (Spain)**		**Pilsen (Czech Rep.)**	
Month	**Global irradiance [kWh/m^2.day]**	**Temperature [°C]**	**Global irradiance [kWh/m^2.day]**	**Temperature [°C]**
January	2.49	11.6	0.72	-1.6
February	3.39	12.0	1.39	0.4
March	4.61	14.2	2.35	3.5
April	5.72	16.5	3.84	8.3
May	6.56	19.6	4.90	13.7
June	7.13	24.1	5.01	16.4
July	7.26	26.1	4.87	17.5
August	6.28	26.7	4.46	18.2
September	5.05	23.8	2.93	13.3
October	3.71	19.9	1.80	8.7
November	2.55	14.8	0.83	3.1
December	2.17	12.0	0.51	-0.8
Year	4.75	18.4	2.81	8.4

Solar paths at Elche, (Lat. 38.3°N, long. 0.7°W, alt. 97 m)



Solar paths at Plzen, (Lat. 49.7°N, long. 13.4°E, alt. 353 m)