CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

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DIPLOMA THESIS

Conventional versus alternative sources of energy and their economy

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Kateřina Jirková

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2. Objectives of thesis and methodology
3. Definition of alternative and conventional energy sources, different options
4. Pros and Cons of alternative energy sources
5. Market with alternative energy, comparison to conventional energy sources
6. Czech and European market with alternative energy
7. Current conditions of alternative energy in the Czech Republic
8. State support and grants
9. Case study
10. Conclusions
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12. Supplements

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Declaration of integrity:

"I declare that I have worked on my diploma thesis titled "Conventional versus alternative sources of energy and their economy" by myself under the management of my supervisor and I have used only the sources mentioned at the end of the thesis. As the author of the diploma thesis I claim that I have not violated any copyright rules and author rights of the third parties."

Prague 3rd April, 2012 …..…………………………

Kateřina Jirková

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Conventional versus alternative sources of energy and their economy

Konvenční versus alternativní zdroje energie a jejich ekonomika

Summary

The aim of the diploma thesis is to deliver a complex and understandable knowledge about the issue of renewable sources of energy and its comparison to conventional sources of energy. For that reason the first part of this work contains theoretical background about renewable energy: definition of alternative sources of energy and conventional sources of energy, different options of alternative energy, pros and cons of alternative energy, analysis of the situation on the market with alternative sources of energy on the European and the Czech level, the European and the Czech energy plan for future and the conditions of governmental support. The practical part is dedicated to the comparison of different renewable energy projects from the point of view of producer and investor. The first case study analyses the situation of the Indian solar photovoltaic panel producer and its possibilities for expansion to foreign countries. The second case study analyses the different options for investment to renewable energy projects in conditions of the Czech Republic. This part compares solar, biogas and wind projects. Finally the renewable energy projects are compared to the nuclear power station.

Keywords

Renewable energy, conventional energy, solar energy, solar photovoltaic panels, biogas power plant, wind power plant, the European market, government support, price level

Souhrn

Cílem diplomové práce je poskytnout komplexní a srozumitelný přehled o problematice obnovitelných zdrojů energie a jejich srovnání s konvenčními zdroji energie. První část práce proto obsahuje teoretické informace o obnovitelných zdrojích energie: definice alternativních zdrojů energie a konvenčních zdrojů energie, různé možnosti alternativní energie, pozitiva a negativa alternativních zdrojů energie, analýza situace na evropském a českém trhu s obnovitelnými zdroji energie, evropský a český energetický plán pro budoucnost a podmínky státní podpory. Praktická část se zabývá srovnáním různých projektů obnovitelných energií z pohledu výrobce a z pohledu investora. První případová studie analyzuje podmínky indického výrobce solárních fotovoltaických panelů a jeho možnosti expanze na zahraniční trhy. Druhá případová studie analyzuje různé možnosti investice do obnovitelných energií v podmínkách České republiky. Tato část porovnává solární, bioplynový a větrný projekt. Nakonec jsou tyto projekty obnovitelných energií porovnány s jadernou elektrárnou.

Klíčová slova

Obnovitelná energie, konvenční energie, solární energie, solární fotovoltaické panely, bioplynová stanice, větrná elektrárna, evropský trh, státní podpora, cenová hladina

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1 Introduction

The topic of “Conventional versus alternative sources of energy and their economy” was chosen, because currently renewable sources of energy are increasing in importance. Problems of global warming and scarcity of fossil fuels are issues generally discussed worldwide. Renewable sources of energy were always present and used by mankind but now the technology improves and harnessing of natural energy is becoming more effective and more important. The European Union member states made the commitment to reduce emissions and to increase percentage of use of renewable energy. The EU member states put great amount of money to research and development of new technologies in renewable energy, there are many EU financial support programs for this purpose.

This work is focused on collecting information about different sources of renewable energy, how it can be used and under what conditions. Different countries can use different renewable sources of energy, it depends on natural conditions, and not all renewable sources of energy are suitable for every region. The framework of the European Union influences the market with renewable energy and its development, the support of each renewable source of energy is further indicating its position on the market and the price of particular technology. In connection to the European market, its framework and policies has significant impact on other markets in Asia and America. The worldwide market is network of mutual dependence. The European Union policies influence significantly also conditions for renewable energy in the Czech Republic as its member state. However, in some cases the governmental policies and support scheme can twist the market in wrong way. Through research of the diploma thesis it will be possible to study the development of prices of conventional sources of energy and how these prices are influencing further expansion of renewable energy. Scientists and professionals in the field of energy envisage that in near future when the prices of oil, coal and natural gas will be too high, people will naturally switch to technologies using renewable energy.

The practical part of this work will be dedicated to different options of renewable energy from the point of view of producer of technology (solar panels) and from the point of view of investor comparing several projects – solar, biogas and wind. Finally, the renewable energy projects will be compared to the nuclear power station.

2 Objectives and Methodology

The major goal of this work is to examine the different forms of alternative energy, to compare their use with conventional energy, to find the reasons why the current society is more and more interested in alternative sources of energy, to find information about the conditions in the Czech Republic, the European subsidies for renewable energy and the global perspective.

The practical part – case study 1 - The first case study is dedicated to analysis of the situation on the market with solar photovoltaic panels and to the comparison of prices and opportunities for this industry from the point of view of the producer. Furthermore, this practical study is focused on the selected company – Indian producer of solar photovoltaic panels. The analysis of the company will be structured according to these research questions: what are the opportunities for solar photovoltaic panels, what are markets the company should focus on and how can be these markets exploited?

The practical part – case study 2 - The second case study is dedicated to different renewable energy projects from the point of view of investor, there will be economic analysis of investment to solar, biogas and wind project in the Czech Republic. The projects will be compared with regard to investment, production of energy and final profit with feed-in tariffs. Finally the renewable energy projects will be compared to the analysis of investment in nuclear power station Temelín.

Methodology of this diploma thesis includes mainly substantial literature study comprising from the majority internet resources because the field of alternative sources of energy is relatively recent emerging area of science and business, so the internet is the most updated source of information for this purpose.

The following analysis of the company – Indian solar photovoltaic panel producer Surana Ventures Ltd. – is important to indicate possible opportunities for the company through the detailed analysis of costs of production, its strategy and further conditions on the global market. The desk market research includes: the price comparison with major competitors on the market, the costs analysis of production of solar panels, the analysis of weather conditions, etc. The second part of the practical part is comparing more different options of renewable energy projects in the Czech Republic from the investor point of view. This part includes: analysis of investment, different socio-economical conditions, opportunities and risks, feed-in tariffs and production possibility. It gives very interesting picture and good comparison of renewable energy options in conditions of the Czech environment.

3 Definition of alternative and conventional energy sources, different options

The term alternative, renewable or sustainable energy is actually quite new, mainly connected to the current time of great debates about global warming and scarcity of natural resources. There are different points of view, some of the voices say that mankind still have enough of natural resources to deplete, on the other hand there are alarming voices telling us to make a change in our consumer behaviour. Of course this issue is largely influenced by politicians, big corporations, media, scientists and ecology activists. Finally, how can a humble citizen know where is the truth? However, there are certain aspects that can tell us more about current situation as: price of oil, price of electricity, price of gas. The threat of prices and threat of scarcity of natural resources push people to find out new ways of energy production.

“Renewable energy is natural energy which does not have a limited supply. Renewable energy can be used again and again, and will never run out.”[1]

“Renewable energy - derived from resources that are naturally regenerative or are practically inexhaustible, such as biomass, heat (geothermal, solar, thermal gradient), moving water (hydro, tidal, and wave power), and wind energy. Municipal solid waste may also be considered a source of renewable (thermal) energy.”[2]

“Renewable is defined by the Canadian government as replenished through natural processes or through sustainable management practices so that a resource is not depleted at current levels of consumption."[3]

Conventional energy is a generally used term for power provided by traditional means such as coal, gas, etc., used in opposition to alternative energy sources such as solar power, tidal power, wind power, etc.

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[1] Clean energy ideas. *Renewable energy definition.* [online]. 2009 [cit. 2010-06-14]. Available at WWW: <http://www.clean-energy-ideas.com/energy_definitions/definition_of_renewable_energy.html>

[2] Business Dictionary. *Renewable energy definition.* [online]. 2010 [cit. 2010-06-14]. Available at WWW: <http://www.businessdictionary.com/definition/renewable-energy.html>

[3] Renewable Energy World. *Canadian Government Releases Definition of Renewable Energy.* [online]. 2001 [cit. 2010-06-14]. Available at WWW: <http://www.renewableenergyworld.com/rea/news/article/2001/12/canadian-government-releases-definition-of-renewable-energy-5791>

There are not that many definitions for conventional energy as for renewable energy; the term is usually used in opposition to renewable or alternative energy. On the other hand, the further meaning of the word conventional is traditional, usual or used for long time.

From the historical point of view, for long time there were other things for generating energy for work or heat as: animal power, man power, wind power, water power, wood, etc. – which are actually defined today as renewable energy. So, the term “conventional” is a bit misleading, however everybody nowadays understand it as “conventional energy = energy from fossil fuels”. Instead of conventional energy, it is better to use non-renewable sources of energy.

There are different sources of renewable energy, the main options are: solar energy, bioenergy, wind energy, hydroelectricity, tidal energy, wave energy, geothermal energy, energy from hydrogen. Recently, there were discovered new inventions as cogeneration engine and nuclear fusion.

3.1 Solar energy

It is the most ancient and also the most modern form of energy used by people. It is divided to solar thermal energy and solar photovoltaic energy. There are different ways of use of solar thermal energy: active solar heating, solar thermal energy and passive solar heating.[4]

Active solar heating

This possibility involves solar collectors, usually placed on the roof of building to use solar radiation. It is actually very simple system and it is used for domestic hot water or swimming pool heating. The most used rooftop solar water heater is composed of a collector panel with water channels, a storage tank and a pumped circulation system.

Solar thermal energy

This is just a special kind of active solar heating, using larger collectors to produce high temperature which drives steam turbines to produce electric power. There is variety of

[4] BOYLE, Godfrey. *Renewable Energy*. Second edition. New York : Oxford University Press, 2004. Page 18

types, e.g. giant solar thermal plant in the Mohave Desert in California - it is actually a big field of mirrors which are centralizing sun radiation and pointing to a tank up on the tower and high temperature is heating a steam boiler and generating energy.

Passive solar heating

It means the absorption of solar energy into a building which reduces the required heating. Passive solar heating system is using the circulation of warm air, the collectors are usually part of the building itself. There are different varieties of passive solar heating systems e.g.: conservatory or greenhouse, Trombe wall or direct gain through windows. Currently, people can choose also from big amount of projects of ecohouses or low energy houses, these buildings include sophisticated system combining insulation, solar collectors, so it minimizes the use of fossil energy and these houses usually have also impressive design.

Solar photovoltaic energy

It is a more direct method of generation electricity from solar radiation, photovoltaics directly convert solar energy into electricity. The photovoltaic effect was discovered in 1839 by the French physicist Edmond Becquerel. The photons from light of suitable wavelength can transfer their energy to some electrons in the material, so the electrons can move into the higher energy level, leaving holes behind causing other moving. This movement is used in silicon photovoltaic cells to generate energy. There are various types of materials used: Monocrystalline silicon cells, Polycrystalline silicon, Gallium arsenide, Amorphous silicon, copper indium diselenide (abbreviated to CIS), copper indium gallium diselenide (CIGS) and cadmium telluride (CdTe). Scientists still work on other innovations as new photovoltaic devices based on nanotechnology. Nanotechnology is promising for every industry and in this case it should make the solar photovoltaic energy generation more efficient, however the impact of nanomaterials on environment and human health is still being examined. In case of CdTe, CIS and CIGS modules, some amount of cadmium is used for its manufacturing and it can be quite harmful for health.[5] So, it raises the problem of safety and recycling of photovoltaic panels after their lifetime. Recently, photovoltaic panels achieved great success in the Czech Republic, more about this issue can be found in following chapters.

[5] BOYLE, Godfrey. *Renewable Energy*. Second edition. New York : Oxford University Press, 2004.

3.2 Bioenergy

This term comprises 3 types of use: energy from biomass, biofuels and biogas.

Biomass is a material from waste (waste from agricultural production, from forestry, organic waste from industry, animal waste, and communal organic waste) or it is a material produced purposely for energy production (wood, grasses, cereals, oil crops and starch or sugar crops). Biomass is actually storage of solar energy then burned and converted to electricity.

Biogas is other form of use of biomass, for production of gas from biomass it is used the process of anaerobic digestion of wastes (this also includes all wastes produced by animals or plants). In the Czech Republic biogas stations are mainly used by agricultural producers. There is a big potential of usage of biogas plants for processing municipal waste (its organic parts and some parts of sewage plant) for production of energy. However, there is a problem of transport of waste from collected area, which can be expensive, and there is also a sociological problem of motivation of inhabitants to sort out garbage precisely.

Biofuels are fuels made from organic material (biomass). For production of liquid fuels there are several crops which are more suitable than others: sugar cane, maize, potatoes, wheat or oilseed rape. In 2007, the European Union decided about the goal of incorporating a minimum 10% biofuel by 2020 in total transport fuel use, also the USA wanted to increase the share of biofuels in total consumption of fuels. However, later it was found out by scientists that the total rating of biofuels in terms of greenhouse gases emissions is not that positive. Taking in account the use of land (normally used for production of food), use of machinery for the biofuel production, all the energy used during the whole process of production the result for biofuels is not that environmentally friendly. Moreover, some economists claimed that it will cause increase of price of food and maybe lack of agricultural land used for food production.[6]

[6] SCHARLEMANN, Jorn P.W.; LAURANCE, William F. *How Green Are Biofuels?* Science Magazine [online]. 2008, volume 319, [cit. 2010-06-14]. Available at WWW: <http://si-pddr.si.edu/dspace/bitstream/10088/8643/1/Scharlemann_and_laurance2008enviro.pdf>

3.3 Wind energy

Wind energy has been used during entire history of humankind, for milling grain, pumping water or for boats. Today, there is big amount of different varieties of windmills or modern wind turbines generating pollution free electricity. The most known is a three-blade horizontal-axis wind turbine.[7] It has to be said that not all regions are suitable for wind turbines. According to the European Wind Atlas, the most suitable areas are: Great Britain, Ireland, the northern coast of France, the coast of Benelux, Denmark, the coast part of Germany, Mediterranean area. The Czech Republic is not among the most suitable countries for wind power, however there are 53 wind turbines, mainly in the north-west region. There is another aspect of wind energy as the problems of public opinion on wind turbines because of noise, threat for birds, electromagnetic interference and visual aspect.

3.4 Energy from water

Energy from water has been also used from ancient times. There are different kinds of usage of water energy: kinetic energy of rivers, gravitation of water. In history there were water mills, now there are more sophisticated systems as various turbines, water dams and reservoirs. Before building dams and hydroelectricity plants, the environmental impact of such a plant have to be considered. The main controversial questions are: sociological impact caused by flooding particular area, impact on ecosystem and wildlife, particularly it is a problem for salmons for their upstream journey to spawning pools, and threat of failure of large dams. On the other hand, energy from hydroelectricity plants is very clean energy, water dam can help river regulation and prevent flooding, it can also be important reservoir of drink water for urban areas. The biggest dam in the world is Three Gorges Dam in China, nearly 200 meters high, the project is expected to have a total hydroelectric capacity 22,000 MW when it will be completed.[8]

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[7] BOYLE, Godfrey. *Renewable Energy*. Second edition. New York : Oxford University Press, 2004.

[8] GLEICK, Peter H. *Three Gorges Dam Project*, Yangtze River, China. The World's Water. 2008–2009, Water Brief 3, p. 139-150. Available at WWW: <http://www.worldwater.org/www/data20082009/WB03.pdf>

Tidal power is way of using gravitational interaction between the earth and the moon for generating energy. There are various possibilities of barrages or turbines. Tidal power is used in a number of countries: Russia, Canada, the USA, Argentina, Korea, Australia, France, China and India.

There are also different devices for using power from waves: energy convertors fixed on the seabed, floating offshore, in intermediate depths or different reservoirs with water turbine. However, tidal energy is considered more promising for future.

3.5 Geothermal energy

Geothermal energy is one of the resources of energy which does not contribute to global warming nor threaten citizens security. It is not dependent on the sun, it is using the widespread heat within the earth. However, there are doubts about calling it "renewable" resource of energy, for sure it is not the same case as store of energy like fossil or nuclear fuels, it is more likely natural flow of energy, but it can be depleted. Declining temperature was observed in some producing steam fields. Geothermal energy is used for generating electricity or for direct use of steam or hot water for space heating, agriculture, aquaculture or industrial purposes. From ancient times hot springs are also used for bathing, washing and healing. Major geothermal energy producing areas are located on the borders of lithospheric plates. Countries with the highest geothermal power generation are: the USA, Philippines, New Zealand, Mexico, Japan, Italy, Iceland, Indonesia, Costa Rica, and El Salvador.[9]

3.6 Hydrogen

Hydrogen is currently regarded as the energy of the future, very clean and the material for its production is abundant. It can be used as storage of renewable energy from season to season, it can be very good transport fuel not depending on oil and the only by-products of its combustion are water and little amount of nitrogen oxides (can be decreased almost to zero when using fuel cells). Hydrogen can be produced by the electrolysis of water using electricity, by the gasification of biomass or by the thermal dissociation of water

[9] BOYLE, Godfrey. *Renewable Energy*. Second edition. New York : Oxford University Press, 2004.

into hydrogen and oxygen using solar collectors. Hydrogen can be the possibility to store seasonal peaks of the renewable energy – water, wind and solar. Those peaks were very harmful in the past causing blackouts in several countries due to insufficient power grid. Now, this seasonal energy peak can be used to production of hydrogen and stored for seasons with lack of energy or for transportation.[10] There is also new research done for production of hydrogen from various macro-algae (seaweeds) through anaerobic fermentation. This should be very promising possibility of production of hydrogen just using biomass and sunlight.[11]

3.7 Cogeneration

Cogeneration is simultaneous production of electricity and thermal energy from a single plant. It can be used for various sources of production of electricity, it can just reduce the energy loss during the electricity production. For example, cogeneration used for biomass plants can be very profitable, making both energy efficient and environmentally beneficial; it has been successfully piloted in several African countries. Cogeneration can be used for remote located settlements without the need to be connected to the utility grid, transmission and distribution losses of energy are minimized.[12]

3.8 Nuclear fusion

Nuclear fusion is the same process that powers the Sun and other stars. It can be carbon-free source of energy generated without the radioactive waste as related to the nuclear fission (currently used process in nuclear power plants).[13] The research of this method has

[10] BOYLE, Godfrey. *Renewable Energy*. Second edition. New York : Oxford University Press, 2004. Page 406

[11] Jae-Il Park; Jinwon Lee; Sang Jun Sim; Jae-Hwa Lee. *Production of Hydrogen from Marine Macro-algae Biomass Using Anaerobic Sewage Sludge Microflora*. Biotechnology and Bioprocess Engineering. 2009, 14, p. 307-315. Available at WWW: <http://www.springerlink.com/content/hw3852k350w10w3u/fulltext.pdf>

[12] KAREKEZI, Stephen; KITHYOMA, Waeni; ONGURU, Oscar. *Evaluating Anaerobic Digester Energy Generation: Opportunities and Barriers*. Global Bioenergy Partnership. 2009, p. 171-178. Available at WWW: <http://www.globalbioenergy.org/uploads/media/0908_UNDP_-_Bio-carbon_in_Africa_-_harnessing_carbon_finance_for_forestry_and_bio-energy.pdf#page=190>

[13] KER THAN. *National Geographic News* [online]. 2010 [cit. 2010-06-14]. Fusion Power a Step Closer After Giant Laser Blast. Available at: http://news.nationalgeographic.com/news/2010/01/100128-nuclear-fusion-power-lasers-science/

already started during the Cold War linked to development of atomic weapons. Hydrogen atoms fuse together to form helium, and this matter is converted into energy. In the Sun, the massive gravitational power creates right conditions for fusion, however on the Earth those conditions are much harder to achieve. With current technology, it is possible to use two heavy forms (isotopes) of hydrogen, Deuterium and Tritium. Isotopes of hydrogen must be heated to extreme temperatures of 100 million degrees Celsius to allow nuclei to fuse. Deuterium naturally occurs in seawater which means that it is very abundant. Tritium does not occur naturally and is radioactive, but it can be made from Lithium which can be found in the Earth's crust and it is weakly concentrated also in the sea. Nuclear fusion does not produce long-term radioactive waste as nuclear fission, however it produces some short-term radioactive waste which is much less problematic than in the case of nuclear fission. There are numerous fusion research centres worldwide, so maybe if the research will be successful and the cost of production will be lowered, nuclear fusion can be a quite good, reliable and sufficient source of energy which can be regarded as very clean energy. On the other hand, it cannot be (with currently known technology) taken for a real renewable source of energy.[14]

4 Pros and Cons of alternative energy sources

The major advantage of alternative sources of energy is that they are clean, it was also the basic reason of massive development of alternative sources of energy. Actually the fear from global warming is so big that it can be expressed in money put to the research of development of renewable energy technologies. The other major advantage is that alternative energy resources are renewable – not possible to deplete, kind of "perpetuum mobile". The fossil fuels are said to be depleted soon, maybe in several decades. Most of the scientists doubt about the exact time of depletion, the period also depends on the level of technology used and the possibilities of mining of fossil fuels. Some locations for mining can be too expensive now, however when the fuels will reach certain price, the location for mining can become profitable.

[14] World Nuclear Association. *Nuclear Fusion Power* [online]. 2010 [cit. 2010-06-14]. Available at WWW: http://www.world-nuclear.org/info/inf66.html

The major disadvantages of alternative sources of energy are cost and efficiency. Nowadays, the costs of alternative energy are still too high, so people tend to prefer fossil fuels. When the price of alternative energy sources and their technology will reach the same level as the one of fossil fuels, people will naturally switch. Nobody knows when this "great switch" will come. Efficiency is also big issue, the technology still has its space for development, it has to become common, widespread and cheap. Another disadvantage of alternative energy is public opinion, installation of large solar plants, wind plants or huge dams can be controversial and obviously difficult for local people.

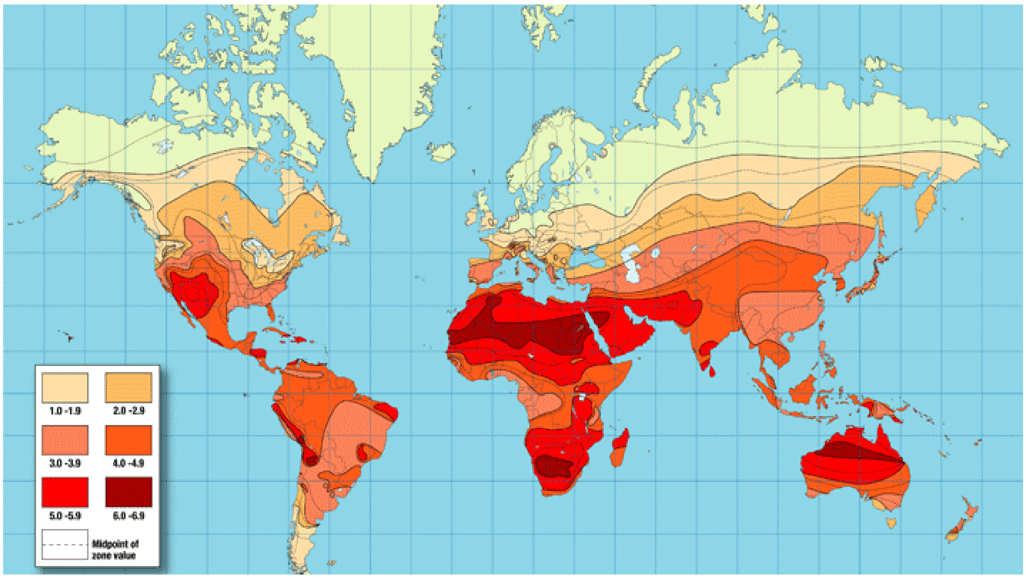
4.1 Solar energy worldwide – social, economical and weather conditions overview

Currently the biggest markets of solar photovoltaic modules are the European countries, the USA, China, Japan and India. Basically, these countries are also known as big developed economies where the social-economical situation is generally much better than in the rest of the world. In case of China and India, the situation is different, these large countries are raising markets and they become more and more powerful in global scale. However, the majority of the population is still living in poverty. In Europe or in the USA, solar energy is the way to more ecological future, the way how to fight with global warming and decrease CO_2 emissions. On the other hand, in the developing countries the solar energy can be more helpful to solve vital problems of the population. In 2009, the estimation of the number of people without electricity was 1.4 billion people, mainly in Sub-Saharan Africa, South-East Asia, Latin America and Middle East. [15] Most of these people are living in rural areas, electrification in those areas means important development of human life – lighting, running basic home appliances, food conservation, education improvement, communication, etc.[16]

[15] International Energy Agency. *World energy outlook-access to electricity* [online]. 2011 [cit. 2011-10-16]. Available at WWW: http://www.iea.org/weo/electricity.asp

[16] AlterStore. *World solar insolation values* [online]. 2011 [cit. 2011-10-16]. Available at WWW: http://www.altestore.com/howto/Solar-Electric-Power/Reference-Materials/Solar-Insolation-Map-World/a43/

1) Picture – World solar insolation values



Source: AlterStore [online] 2011

The upper map shows the amount of solar energy in hours, received every day on an optimally tilted surface during the worst month of the year (insolation). The most dark-red areas are the areas with the highest amount of insolation hours per day. It is obvious from the map that the most insolated countries are in Africa, Middle East, South Asia, Latin America, South of the USA and Australia. It is interesting that actually the bigger part of these most insolated areas is matching with areas without electrification or with very poor electrification.

The solar energy business is still very expensive and highly specialised business. Under current conditions the poorest countries in the world cannot afford to install large photovoltaic parks. However, the research is continuing and market with photovoltaic modules is changing very fast. If the new development and scientific research could make the photovoltaic modules less costly and easier for installation, then it can mean enormous development in developing countries during upcoming decades.

4.2 Annual Fuel Utilization Efficiency

When considering different sources of energy, it has to be taken in account the actual annual performance of each energy source in comparison to the installed capacity. It is indicated by the Coefficient of annual fuel utilization efficiency k_r which is calculated from the comparison of the actual produced energy with the theoretical, maximal capacity of energy produced during one year with concrete performance. [17]

$$k_r = \frac{W_r}{P_i * h}$$

W_r is annual amount of energy produced (kWh/year), P_i is installed capacity (kW), h is number of hours a year (8760 hours).

If k_r is known, then the average annual capacity P_r can be estimated:

$$P_r = k_r * P_i$$

In case of alternative sources of energy, empirical knowledge of this Coefficient of annual utilization efficiency can be used for approximate estimation of the annual production of concrete installed capacity. The availability of wind and sun has random character, it can cause technical problems and the Coefficient of annual utilization efficiency cannot be really high.

4.3 Trade theory and energy market

Countries participate in international trade for two simple reasons, both of them contributes to their gains from trade. Firstly, countries trade because they are different from each other. Countries, as individuals, can benefit from their differences by reaching an agreement in which each does the things it does relatively well. Secondly, countries want to trade to be able to achieve economies of scale in their production. So, each country produces just

[17] NOSKIEVIČ, Pavel. *Renewable Energy Sources in the Czech Republic. The Potential of Biomass Sources* [online]. 2005, p. 91-101, [cit. 2010-06-15]. Available at WWW: <http://www.biomasa-info.cz/cs/doc/moznosti.pdf#page=91>

a limited range of goods which can be produced in large scale and more efficiently than if it would have to produce everything, at the end both trading countries benefit from the trade. In reality, patterns of international trade reflect both these motives. The essential concept of international trade is the comparative advantage. There is a trade-off of resources used for production of one good instead of other good. Economists use the term opportunity cost to describe these trade-offs: the opportunity cost of good 1 in terms of good 2 is the number of good 2 that could have been produced with the resources used to produce a given number of good 1. Trade between two countries can be beneficial for both countries if each of them exports the goods in which it has a comparative advantage. Under such conditions the world as whole is producing more, so it is possible in principle to raise everyone's standard of living. [18]

This trade principle implies also in the market of energy. However, in this case there are many specifics, as each country has different kind of natural resources which can be used for energy production: coal, oil, gas, uranium, rivers which can be used for hydro power, etc. Each country is trading their resources of energy in which it is rich, or already produced energy from these resources. The Middle East countries are using their position on the market with oil, the price is slowly increasing year by year. Other countries without own resources of oil are simply just price takers. This situation and the situation of scarce resources of fossil fuels motivate many countries to make more effort in the field of renewable energies.

However, information asymmetry means a significant problem for renewable energy use. Firstly, the competitiveness of renewable energy sources is always determined in comparison to conventional energy sources. As from the past several years, it is obvious that prices of fossil fuels fluctuate greatly. The uncertainty concerning both market developments for conventional fossil fuels and the future generation costs of renewable sources decrease the willingness to invest in renewable energy technologies. More information on the characteristics of renewable energy helps to increase the transparency

[18] KRUGMAN, OBSTFELD, MELITZ. *International Economics*: *Theory & Policy*. USA: Pearson, 2012. Ninth edition. ISBN-13: 978-0-13-214665-4.

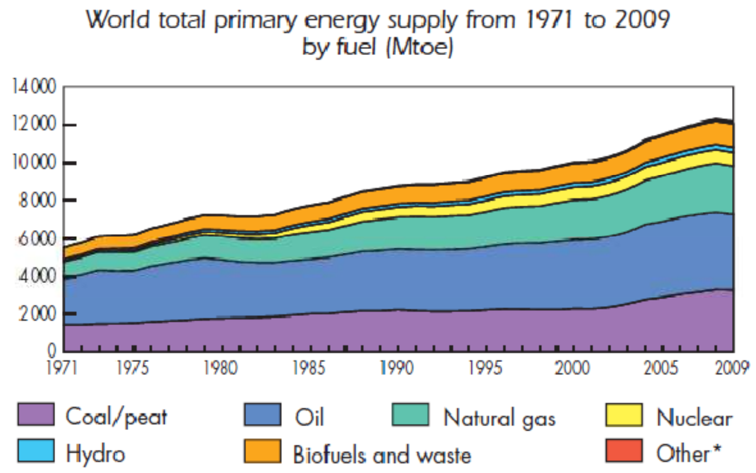
of the renewable energy markets and helps to decrease the risk for investment in renewable energy technologies. [19]

This kind of situation calls for government intervention, it can reduce the information asymmetry and help the market with initial development. On the other hand, there is a risk of government failure and it can harm the market for longer period. This actually happened in case of support of solar energy in the Czech Republic, this case will be discussed later in this work.

[19] JORDAN-KORTE, Katrin. *Government Promotion of Renewable Energy Technologies* [online]. [cit. 2012-02-01]. Available at: http://books.google.cz/books?id=KeIr5mmFPuEC&pg=PA37&lpg=PA37&dq=energy+trade+theory&source=bl&ots=F3BLZ6l4f5&sig=SUfAtnRJX3eFPgZAB0UKWjK9rGQ&hl=cs&sa=X&ei=wbAmT97fBYTf4QSW_tnrCw&ved=0CGoQ6AEwBg#v=onepage&q=energy%20trade%20theory&f=false

5 Market with alternative energy, comparison to conventional energy sources

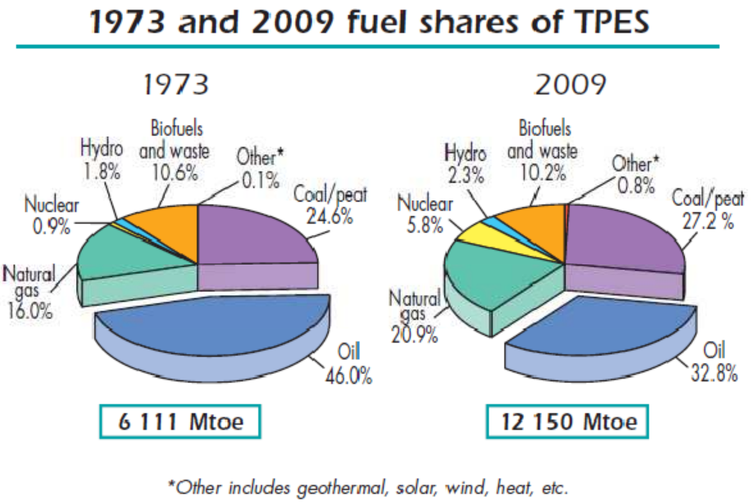
1) Graph – World total primary energy supply



Source: IEA [online] 2011

This graph indicates the development of world total primary energy supply[20] from 1971 to 2009. It is obvious that renewable energy (comprising blue, orange and red line – hydro, biofuels and waste, geothermal, wind, solar and heat) still plays minor role, however its role is rising together with the nuclear energy.

2) Graph – World total primary energy supply (TPES)



Source: IEA [online] 2011

[20] World total primary energy supply = production + imports – exports

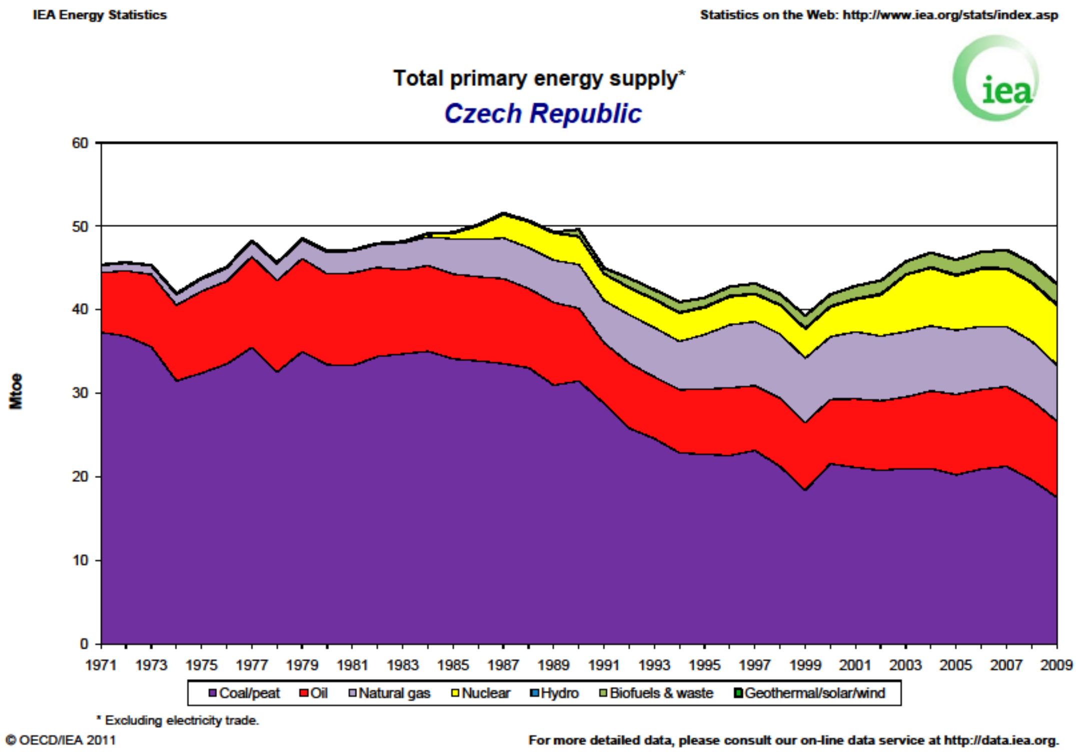
This second graph indicates the exact shares of world total primary energy supply and the difference between 1973 and 2009. The total world primary energy supplied almost doubled, from the total primary energy supply in 1973 when it was 6111 Mtoe (measured in million tonnes in oil equivalent) to the total primary energy supply in 2009 when it was 12150 Mtoe, it is enormous change.

In 1973, the total consumption of energy was 4674 Mtoe and in 2009 it was 8353 Mtoe. In comparison to the supply of energy, it means immense loss of energy. In 1973, the OECD countries consumed the majority of the energy 60.3%. With the development of other parts of the world came also difference of this proportion of energy in the worldwide energy consumption and the OECD countries in 2009 consumed just 42.8 % from the total amount. The developing countries will play a big role in upcoming years, the world's most populated countries as China and India are becoming economically very strong and demand more and more energy. The future challenge for energetic industry is also building such an electricity grid, which can resist seasonal peaks of renewable energy sources and which will be able to prevent regional blackouts. This electricity grid should be also able to transport electricity from one house to another, so balancing the energy demands and prevent huge energy losses. Currently, there are several projects in the European Commission for research and development of such a grid, one of them is the project Integral – Integrated ICT platform based Distributed Control (IIDC) in electricity grids with a large share of Distributed Energy Resources and Renewable Energy Sources.[21]

[21] European Commission. *Renewable Energy: Grid Demonstration Project*. [online]. 2006 [cit. 2010-06-14]. Available at WWW: <http://ec.europa.eu/energy/renewables/grid/projects_en.htm>

5.1 Energy market in the Czech Republic

3) Graph – Czech total primary energy supply



Source: IEA [online] 2011

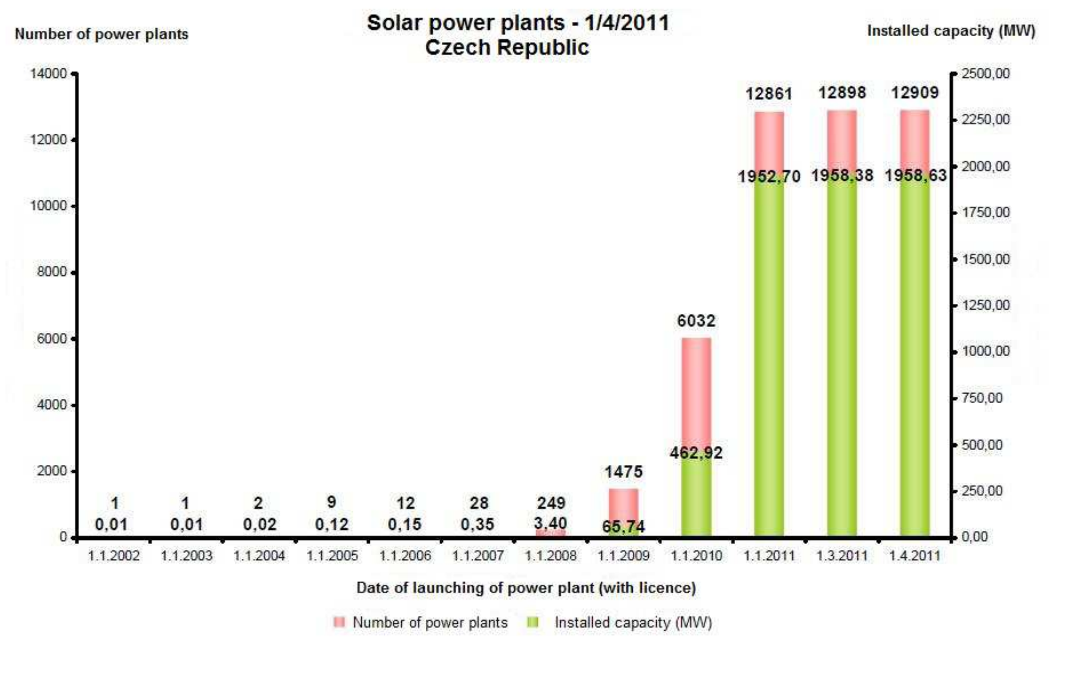
This graph above indicates the development of the total primary energy supply of the Czech Republic from 1971 till 2009. Coal still plays the major role, however from the development it is visible that its role is declining. In 2009, the total primary energy supply of the Czech Republic was 42 Mtoe, 40.7 % covered by coal/peat, 21.1 % covered by oil, 15.6 % covered by gas, 16.5 % covered by nuclear energy, 5.5 % covered by combustion of renewable sources and waste, 0.5 % covered by hydro energy and 0.1 % covered by geothermal, solar and wind energy.[22]

In 2010, the total gross consumption of electricity in the Czech Republic was 70 961.7 GWh and the share of renewable energy in the total consumption was 5 850.7 GWh which is 8.24%. The share of the renewable energy is increasing every year, the Czech Republic is committed to reach the goal of 20% share of renewable energy of the total energy

[22] International Energy Agency. *Share of total primary energy supply in 2009, Czech Republic*. [online]. 2011 [cit. 2012-02-17]. Available at WWW: <http://www.iea.org/stats/pdf_graphs/CZTPESPI.pdf>

consumption in 2020 and the predictions to reach this goal are positive. During the years 2009, 2010 and 2011 there was a big boom of solar photovoltaic power plants in the Czech Republic, new solar power plants were built everywhere and the numbers had risen enormously. This big boom of solar power plants was due to the great increase of government support for this type of energy source, it motivated a lot of foreign investors to come to the Czech Republic and invest in these solar projects. The Czech government support for the solar power plants and big solar boom will be analyzed more in details in following part of this work.

4) Graph – Solar power plants – Czech Republic



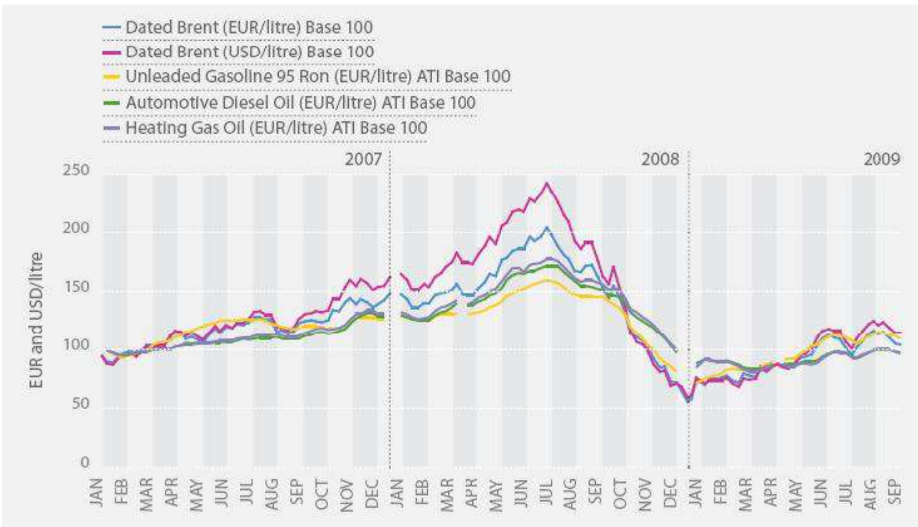
Source: Nazeleno[online] 2011

The graph above shows the enormous increase of installed solar power plants in the Czech Republic during years 2009, 2010 and 2011. At the beginning of the year 2009, the installed capacity of solar power plants was only 65.74 MW. The biggest boom was during the year 2010 when new 1025 MW of solar power plants were connected to the grid. During the year 2010, the solar power plants in the Czech Republic produced 615.7 GWh which is 0.86 % of the total gross consumption of electricity in the Czech Republic. The share of solar power on renewable energy during the year 2010 was 10.5 %, hydro power stations 47.7 %, biomass 25.8 %, biogas 8.7 %, wind 5.7 % and waste dump gas 1.5 %. According to the graph above, on 1st April 2011 the installed solar power plant capacity in the Czech Republic was 1959 MW and the total number of solar power plants was 12 909 MW. In comparison, the nuclear power plant Temelín has installed capacity of 2000 MW.[23]

6 Czech and European market with alternative energy

In recent years, the EU energy market was influenced by different crises and different aspects; oil price spike in July 2008, cut of gas supply from Russia via Ukraine in January 2009, etc. However, the biggest challenge was the global financial crisis. There is also the important change of transition towards low-carbon energy systems, comprising alternative energy sources. In year 2009, the consumption of electricity of the EU 27 decreased generally by 10% and the overall consumption of gas of the EU 27 also decreased significantly. Consequently, the emissions of greenhouse gases have been decreasing since the year 2008.

5) Graph – the EU market – prices of energy



Source: European Commission [online] 2010

[23] ERU. *Energie - statistika 2010*. [online]. 2011[cit. 2012-02-17]. Available at WWW: http://www.eru.cz/user_data/files/statistika_elektro/rocni_zprava/2010/pdf/energie.pdf

There were dramatic changes of prices of energy, the crude oil price fell from USD 140 per barrel in July 2008 to around USD 70 per barrel in June 2009. At the beginning of the year 2009, the monthly average reached the level of USD 43 per barrel. Between June 2008 and January 2009, the price of gas decreased by 57 % from EUR 24.54 to EUR 10.54 per MWh and the electricity price decreased by 45 % from EUR 66.78 to EUR 36.54 per MWh.[24]

6.1 State Energy Conception of the Czech Republic

Available, safe and reasonable price of energy is one of the basic conditions of existence of the democratic society. The functioning energy sector is necessary for the security of the Czech Republic.[25] The State Energy Conception is the key responsibility of the state for reliable and long term supply of energy and its economical usage with regard to sustainable development. The State Energy Conception of the Czech Republic is the document about managing energy of the state, it proclaims the strategic goals of energy sector with long-term plan for 30 years. The last State Energy Conception of the Czech Republic was approved in 2004, however during the period 2004-2009 there were a lot of major changes not just only in the Czech economy but also in the international environment. The State Energy Conception was actualized in 2010 and the new proposals are in preparation. The international situation showed that access to some of the energy resources in several producing countries is becoming the key factor for their offensive politics and the consuming countries have to react with very well prepared, coordinated and long-term energy policy. The international relations are very important for energy policy and they have major impact on conditions of standard functioning of energy markets and for ensuring of functioning of society in critical situations.

One of the basic frames for creation of energy policy is the strategic goal and the development of energy policy of the European Union. From the long-term trends it is obvious that the energy policy of the EU will be harmonized and the new common energy

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[24] European Commission, Energy. *Europe's Energy Position, markets and supply*. [online]. Annual report 2009 [cit. 2010-06-15]. Available at WWW: <http://ec.europa.eu/energy/observatory/annual_reports/doc/2009_annual_report.pdf>

[25] MPO. *Státní energetická koncepce ČR* [online]. 2010 [cit. 2012-01-18]. Available at WWW: http://www.mpo.cz/dokument5903.html

policy of the EU will be created. The Czech Republic has to formulate its energy conception with regard to all already declared goals and strategies of the EU.

Actualization of the State Energy Conception of the CR is based on broad energy mix with the stress on using domestic energy resources and it is corresponding to the traditions and competitive advantage of the Czech Republic. The proposed energy scenario is preferentially using the Czech own energy resources – brown coal, black coal and renewable energy but also increasing support of mining uranium to ensure stability for nuclear energy production. This energy mix together with import of gas and oil should place the Czech energy dependency on acceptable level. The current level of import energy dependency (balance of imports and exports of energy) is positive under 50 % which is less than average of the EU (around 60 %). In the vision for years 2030 and 2050, the use of coal will be decreasing and the use of renewable resources of energy and nuclear energy will be increasing. The Czech resources of coal are supposed to be exhausted around the year 2050 but it also depends on available technology. [26]

The goals for the renewable energy resources are at least 13 % of the total energy consumption in the Czech Republic in 2013, 17 % in 2020 and 23 % in 2050, under condition of reaching competitiveness of renewable energy with other resources of energy and under maintaining stability of transfer grid.

Among the strategic tools to support renewable resources of energy there are:

- At the level of primary and secondary legislation guarantee equal conditions to support variable renewable energy resources. Develop new law amendments for support of renewable energy and ensure economically effective market tools for this subvention which will be corresponding to safe functioning of energy system.
- Developing support of renewable energy with regard to the balance between accomplishment of international commitments of the CR and the costs of this kind of support and its impact on final consumers. Ensuring interest of investors to renewable energy and its protection with regard to the final consumers and tax

[26] MPO. *Státní energetická koncepce ČR* [online]. 2010 [cit. 2012-01-18]. Available at WWW: http://www.mpo.cz/dokument5903.html

payers. The tools of renewable energy support should be more oriented to financing outside of the state budget.

- At the stage of regulation, the purchasing price of renewable energy should be determined for stimulation of building new projects with correspondence to real possibilities of producing energy efficiently, under the European standards and under the geographic conditions of the CR.

To ensure usage of the domestic primary resources there should be a change in view of extending of mining of brown coal and uranium. The mining of uranium will be assessed at the basis of detailed research and economical analysis, the mining will be extended just under conditions of acceptable ecological technology and consent of the local community.

Another important priority of the State Energy Conception is the orientation towards innovation and education. After the year 2030, the possibility of development of the local resources, smart grids, special managing systems and the development of electro-mobility will be the major factor of fulfillment of the state strategic goals. The new transportation systems based on electricity or hydrogen power are one of the major ways how to cut off the dependency on imported oil used for transportation. [27]

The new amendment of the State Energy Conception goes even further, however it is still just a proposal made in November 2011 and it was not approved yet. The international scenarios show that the population growth and increasing standard of living mainly in India and China will continue. It will also increase the international demand for the primary energy resources, oil and gas will be scarcer. The countries will be under pressure, the energy self-sufficiency will become very important. In this new amendment there is a big stress on increasing importance of nuclear energy which is relatively clean and efficient resource of energy. This proposal made nuclear energy as preference number one in the long-term future of the Czech Republic. However, mainly Germany and Austria, our close neighbors are against further development of the nuclear energy, so it is a question of international relations. [28]

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[27] MPO. *Státní energetická koncepce ČR* [online]. 2010 [cit. 2012-01-18]. Available at WWW: http://www.mpo.cz/dokument5903.html

[28] ASOCR. *Státní energetická koncepce ČR 2011-2060* [online]. 2011 [cit. 2012-01-18]. Available at WWW: http://asocr.cz/dokumenty/2011/111213statni.pdf

6.2 The European Commission – Energy Roadmap 2050

The Energy Roadmap 2050 is a plan to ensure safe, secure, sustainable and affordable energy, it was introduced in December 2011. The EU is committed to reduce greenhouse gas emissions to 80-95% below 1990 levels by 2050, this goal should be delivered by the developed countries as a group. The Commission explores the challenges connected to delivering the EU's decarbonisation objective and at the same time ensuring security of energy supply and competitiveness. This document together with the document Energy 2020 (introduced in 2010 by the European Commission) are forming major goals and strategy for the EU energy plan in following decades.

In the long-term decarbonisation scenario 2050, the major factors are:

- High energy efficiency – the commitment of EU countries should lead to very high energy savings for energy appliances and new buildings.
- Diversified supply technologies – no technology will be preferred, all energy sources and technologies should compete on a market. Decarbonisation will be introduced mainly by carbon pricing and nuclear and Carbon Capture & Storage (CCS).
- High renewable energy sources – there will strong support leading to high share of renewable energy sources in gross final energy consumption 75% in 2050 (positive scenario).
- Delayed Carbon Capture & Storage (CCS)
- Low nuclear energy

The scenario assumes also that the average capital costs of the energy system will increase, it will demand high investments in special equipment and technology. However, in long-term the more efficient technology will bring benefits and savings. The plan shows that electricity will play a much greater role than currently, it will replace energy demand for powering majority of vehicles 65%. The scenario suggests that electricity prices will rise till 2030 and drop thereafter, it is due to the high capital costs investing to renewable energy technologies and storage and grid investments. The share of renewable energy will rise substantially, the goal is to achieve at least 55% in gross final energy consumption in 2050 when today's average EU level is around 10%.

There will be prime focus on energy efficiency, it will be a priority for decarbonisation. Energy efficient buildings will become a norm, buildings could produce more energy than they use. All household products and appliances should have the highest efficiency standard. Consumers with smart technologies and smart grid will be able to control more their energy consumption themselves.

Renewable energy will move to the center of European energy mix, the cost of renewable energy should decrease through improved research, more efficient support scheme and policies. There will be more pressure on development of renewable technologies, improvement of efficiency of solar modules, ocean energy, wind energy and biofuels. Technologies of storages systems for energy harnessed from renewable resources still remains as a crucial question. The development of smart grids will be also important, it will enable to redirect electricity from a producing source to an appliance and back and regulate energy according to customer needs. It will require technology shifts, information and communication technologies (ICT) will increase in importance in transport and in different urban applications. [29]

Nuclear energy will have significant contribution on transformation in the EU Member States, it is still a major source of low carbon electricity production. However, some of the countries are against development of nuclear energy and others as the Czech Republic still takes nuclear energy in account as the major energy generating way of production for the future. After the accident in Fukushima (Japan), some Member States of the EU changed their public policy on nuclear energy and made stricter safety rules. Nevertheless, nuclear energy lowers system costs and electricity prices. The EU wants to ensure the highest safety and security standards. Till 2050, nuclear energy can become even clearer when nuclear fusion will be used.

The European Union needs to develop international partnerships on broader level to achieve the goals of the Energy Roadmap 2050. The international relations have to ensure reliable suppliers, new strategies and technologies for the low-carbon plan. The EU has to manage partnerships with its neighbours: Norway, Russia, Ukraine, Azerbaijan,

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[29] European Commission. *Energy Roadmap 2050* [online]. 2011[cit. 2012-02-02]. Available at WWW: http://ec.europa.eu/energy/energy2020/roadmap/doc/com_2011_8852_en.pdf

Turkmenistan, the Maghreb and the Gulf countries. It should expand connections also to the North Africa, there is a great potential for solar project in Sahara.

7 Current conditions of alternative energy in the Czech Republic

State support and grants

In 2007, there was a start of big boom with renewable sources of energy in the Czech Republic. This situation was concerning mainly solar energy. The Czech government decided about high support for solar energy which motivated a lot of entrepreneurs, investors and even natural persons to invest in solar projects. Firstly, the technology for solar photovoltaic projects was very expensive, so the government support was important and needed to start these photovoltaic projects. However, the planners from government did not assume that the market situation will shift so quickly. With more and more solar projects and higher investments, the price of the solar technology was decreasing and the projects of building solar power plants in the Czech Republic became very lucrative business.

1) Table – solar energy

Solar energy[30]

Date of launching the project	**Purchasing price of electricity supplied to the grid CZK/1 KWh**	**Green bonuses CZK/ 1 KWh**
Production of electricity from solar energy – power plant with installed capacity up to 30 kW launched 1/1/2012 – 31/12/2012	6.160	5.080
Production of electricity from solar energy – power plant with installed capacity up to 30 kW launched 1/1/2011 – 31/12/2011	7.650	6.570
Production of electricity from solar energy – power plant with installed capacity over 30 kW to 100 kW launched 1/1/2011 – 31/12/2011	6.020	4.940

[30] ERU. *Cenové rozhodnutí Energetického regulačního úřadu č. 7/2011* [online]. 2011 [cit. 2012-01-25]. Available at WWW: http://www.eru.cz/user_data/files/cenova%20rozhodnuti/CR%20elektro/2011/ER%20CR%207_2011OZEKVETDZ.pdf

Production of electricity from solar energy – power plant with installed capacity over 100 kW launched 1/1/2011 – 31/12/2011	5.610	4.530
Production of electricity from solar energy – power plant with installed capacity up to 30 kW launched 1/1/2010 – 31/12/2010	12.750	11.670
Production of electricity from solar energy – power plant with installed capacity over 30 kW launched 1/1/2010 – 31/12/2010	12.650	11.570
Production of electricity from solar energy – power plant with installed capacity up to 30 kW launched 1/1/2009 – 31/12/2009	13.690	12.610
Production of electricity from solar energy – power plant with installed capacity over 30 kW launched 1/1/2009 – 31/12/2009	13.590	12.510
Production of electricity from solar energy – power plant launched 1/1/2008 – 31/12/2008	14.590	13.510
Production of electricity from solar energy – power plant launched 1/1/2007 – 31/12/2007	14.960	13.880
Production of electricity from solar energy – power plant launched 1/1/2006 – 31/12/2006	7.130	6.050

The above table shows the purchasing of electricity supplied to the grid produced from solar energy. The left column shows the period and capacity of solar projects for which the prices are used. The middle column price is meant for the projects which just produce the electricity for commercial use and supply it directly to the grid. The green bonus prices in the right column are for the companies or natural persons who can produce electricity from their solar power plant, supply the electricity to the grid but at the same time consume part of the electricity produced by their solar power plant, so it is meant for solar projects built in connection to some factory or for the house roof projects when the household consume some of the electricity produced.

The biggest boom of solar energy projects in the Czech Republic was between 2009 and 2010. Already in 2007, there were very high purchasing prices but still not many investors were aware of this big opportunity and solar energy was still very new phenomenon. However, many investors came to the market in 2009, even investors from abroad.

2) Table – consumer prices

Consumer prices[31]

Year	Price of electricity for consumers – entrepreneurs CZK/ 1 kWh	Price of electricity for consumers – households CZK/ 1 kWh
2009	4.487	4.128
2008	3.945	3.613
2007	3.628	3.225
2006	3.321	2.951

This table above shows the development of average consumer prices, the prices for buying 1 kWh from the grid. In comparison of those two tables, it indicates that for example in 2009, there was a big difference between the prices of producer of solar energy who had production capacity higher than 30 kW, in that case the price was 13.590 CZK per kW and for the normal consumer household which could buy electricity for 4.128 CZK per kW, the difference was 9.462 CZK per kW. This was a great motivation for investors, if the solar power plant was connected to the grid on time, it was a sure investment with guaranteed prices for 20 years, such an investment was better than any funds or stocks. The investment was usually repaid in 10 years and then it was just beneficial for the investor. This opportunity was also very interesting for natural persons willing to build solar system on their roofs, however the big field solar power projects were investments with great benefits.

[31] ERU. *Ceny elektřiny: statistika* [online]. 2011 [cit. 2012-01-25]. Available at WWW: http://www.eru.cz/user_data/files/statistika_elektro/rocni_zprava/2010/pdf/elektrina.pdf

Wind energy

3) Table – wind energy

Date of launching the project	Purchasing price of electricity supplied to the grid CZK/1 KWh	Green bonuses CZK/ 1 KWh
Wind power plant launched 1/1/2012 – 31/12/2012	2.230	1.790
Wind power plant launched 1/1/2011 – 31/12/2011	2.280	1.840
Wind power plant launched 1/1/2010 – 31/12/2010	2.330	1.890
Wind power plant launched 1/1/2009 – 31/12/2009	2.490	2.050
Wind power plant launched 1/1/2008 – 31/12/2008	2.730	2.290
Wind power plant launched 1/1/2007 – 31/12/2007	2.800	2.360
Wind power plant launched 1/1/2006 – 31/12/2006	2.850	2.410

This table indicates the support purchasing price of electricity produced by wind power plant. Just for illustration:

- **Biomass energy** - in case of electricity produced from combustion of biomass, the support purchasing price of electricity was 2.530 – 3.900 CZK per 1kWh in 2008, 2.630 - 4.580 CZK per 1kWh from 2008 till 2012 (depending on category of biomass power plant), green bonuses are always a bit lower price.
- **Water energy** - in case of electricity produced from small water power plants, the support purchasing price of electricity was 2.240 – 3.800 CZK per 1kWh from 2007 till 2012 (depending on category of water power plant), green bonuses are always a bit lower price.

From the above mentioned information it is obvious that the support for solar energy was the highest from all renewable sources of energy. The enormous boom in solar energy caused a lot of investors to come to the Czech market and invest in large solar power plants. Formerly, the Czech government counted the support for solar energy with return on investment in 15 years, however in 2008 the solar technology reduced the price dramatically, so the return on investment became shorter and made solar energy in the Czech Republic very lucrative business. This became a big problem for Czech citizens, the high support for solar energy was financed by tax payers and made electricity more expensive. The situation created negative environment for solar business in the Czech Republic, investors in solar energy were publicly blamed for the situation and for the increase in consumer prices by around 5%, however, it was caused by unbalanced planning of the Czech government at the beginning.

In 2010, the Czech government decided to impose solar energy tax of 26% for large solar power plants over 30 kW of installed capacity, so it would not harm smaller solar systems e.g. built on houses roof tops. The new solar energy tax was concerning just solar power plants launched in 2009 and 2010, as it should balance the high support. Nevertheless, it had big impact on many solar power projects, some of the companies could even bankrupt because of this tax, it caused big differences in computation of revenues and problems with bank loans. It is still discussed if it was not against the law to impose such a tax ex post, because most of the contracts about the purchasing electricity price and support were already signed for the period of guaranteed 20 years and this tax caused major change. Some of the investors appealed to law courts because of this imposed solar tax and there will be probably even international arbitrations. Foreign investors can be very discouraged for next investments in the Czech business environment, this case can fundamentally harm the Czech business for future, foreign investors can judge the Czech Republic to be an unstable environment. [32]

[32] IDNES. *Solární elektrárny se zdaní 26 procenty* [online]. 2010 [cit. 2012-01-27]. Available at WWW: http://ekonomika.idnes.cz/solarni-elektrarny-se-zdani-26-procenty-d91-/ekonomika.aspx?c=A101019_113251_ekonomika_fih

8 Case study number 1

This part of work is dedicated to the analysis of the real situation of the market with solar energy. The information used in the case study was collected during my traineeship in the Indian company Surana Ventures Ltd. producing solar modules and other solar utilities. This part is focused on detailed analysis of the solar photovoltaic module price of the given company, followed by the market study and comparison of the prices of cells and modules with other companies. All the gathered information is used for the further market forecast and final conclusion.

8.1 Company presentation and solar modules certification

Surana Ventures Limited manufactures solar energy systems, mainly solar photovoltaic modules. The flexible manufacturing facility is enabling the company to adjust the production to the customer's need. The company keeps very good position among the Indian producers and can compete with the reasonable price. Surana Ventures Ltd. is part of the Surana Group located in Hyderabad, India. The group was founded in 1978, currently it is one of the country's powerful industrial manufacturers and a strong diversified conglomerate covering following areas: solar and wind power, telecommunication, metal processing and infrastructure. The Surana Group workforce comprises of about 1200 employees. Surana Ventures provides also other solar products: solar home lightning, street lighting and solar lanterns. The company's products are certified by ISO 9001, IEC 61215 by Euro Test and TUV. Surana Ventures manufacturing plant was set up in Cherlapally, Hyderabad with an installed capacity 12 MW, presently the production capacity is 40 MW/ annum. There is the solar cell factory of 35 MW going to be finished this year. [33]

For the solar modules producer, the world's recognized certification of quality is very important. For Asian modules producers it is a basic condition for penetrating to the European market. Generally, the image of Asian products in Europe is mostly represented by low quality and low durability. This is the main reason why certification of

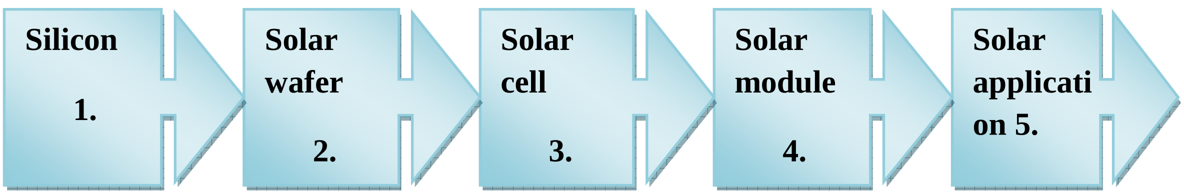
[33] Surana Ventures Ltd. *Company presentation* [online]. 2011 [cit. 2011-07-06]. Available at WWW: http://www.suranaventures.com

solar modules is of high importance. One of the most globally recognized certification organizations is Underwriters Laboratories (UL), it offers compliance in accordance to the standards of the International Electrotechnical Commission (IEC). These certifications add value to the products and enables entry in the most demanded markets. Surana Ventures is currently waiting to be certified by the UL.

8.2 Solar photovoltaic modules production cycle

For the purpose of economies of scale, most of the companies regardless the sector will benefit if they are able to cover all stages of the production cycle, starting with the raw material, going through all stages of production cycle and ending with the final product. Companies generally start just with operation in one of the stages and then they develop their business to cover more stages to be able to finally cover all stages of the production cycle. The largest companies in the sector save money and resources by covering all the stages and not being dependant on suppliers.

2) Picture - scheme



Source: SolarWorld [online] 2011

1. Silicon is starting point of the solar production cycle, it is a material extracted from sand, very common element on the earth, so there is almost endless supply.

2. Solar wafer is developed during the second production process step, highly pure silicon is melted into blocks at very high temperature and then it hardens. The blocks are formed into square columns. These columns are cut in very thin slices, or wafers, using special cutting technology.

3. Solar cell is processed from solar wafer. Solar cells are basic elements of the solar modules. The cells already have all of the technical attributes to be able to generate

electricity from sunlight. Positive and negative charge carriers are released in the cells through light radiation causing electrical current to flow. The quality and efficiency of the solar cell is determining the quality of the final solar module.

4. Solar modules are made by assembling solar cells together to large units. They are framed and weather proofed. The solar energy modules are the final products of the production process and they can directly produce electricity from sunlight. The current produced this way is converted to alternating current by the inverted, so it can be send to the grid or it can be directly used in the house.

5. Solar applications are complete solar systems which can directly generate solar energy and feed it in the grid. There are different solutions for different purposes off grid systems providing electricity for single house, grid connected systems providing electricity for commercial purposes (large solar power plants) or other solutions as solar street and home lighting, solar powered water pumps and other customized solutions.[34]

Surana Ventures Ltd. currently covers solar module assembling stage and very soon the company will finish also the solar cell production factory. Surana solar module assembling line is operated by human work and as the workforce in India is very cheap, it can compete very well on the market with reasonably lower price. The most of the European solar modules assembling lines are operated by robotic work which is generally more precise, faster and makes less mistakes, on the other hand in comparison with the human workforce, the robotic machinery is very costly and crashes and any problems with the machinery stop the whole production, the reparation is costly and complicated, so the production is less flexible and cannot be adjusted to the customer needs as in case of human workforce. The main problem is that the human workforce is more expensive than in Asia, so the machinery is a better option for the producers.

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[34] SolarWorld. *From sand to the module* [online]. 2011 [cit. 2011-07-06]. Available at WWW: http://www.solarworld.de/en/solar-power/from-sand-to-module

8.3 Jawaharlal Nehru National Solar Mission, Towards Building Solar India

The National Solar Mission is a great initiative of the government of India to promote renewable energy and addressing India's energy security challenge. It is also focused on contribution to the global effort to combat with the climate change. This project includes both solar photovoltaic energy and solar collectors. India has very good location for using solar energy, it is a tropical country where sunshine is available for longer hours, so solar energy has a great potential as future energy source. India is also a country where electricity is still not available for the whole population, the grid is not connecting all remote areas and even in the big cities people have to face often power cuts. These are the reasons why solar energy development can improve the development of the country largely.

Under current conditions, solar energy is still very costly in comparison to other sources of energy such as coal. The objective of the National Solar Mission is to establish conditions which will help rapid technological innovation lowering the energy production costs. The Mission envisages achieving the grid parity with coal by the year 2022. There are already some off-grid applications ready mainly for meeting rural energy needs. They are available, cost-effective and rapid for direct expansion. The Indian government has set up target of 20 000 MW of solar power by 2022.

The large national investment support will be given to this Mission through different ways to create really long term sustainable project. The support will be given to research and development of innovative technology, to industrial companies producing silicon, wafers, cells and modules, to education to be able to bring up young engineers for solar sector and to direct development in the States to help rural regions and remote areas which are not connected to the grid. Solar lanterns and solar home lighting systems will be also used and develop to be able to help households during power cuts.[35]

Generally, this Nation Solar Mission could have similar development impact as the IT development boom in India in 1990's which massively changed the business in India and

[35] Government of India. *National Solar Mission* [online]. 2011 [cit. 2011-07-15]. Available at WWW: http://india.gov.in/allimpfrms/alldocs/15657.pdf

its connection to foreign companies. Moreover, this Mission will have more impact on poor people and rural areas development.

8.4 Price comparison

The table in Supplement 1 – Price comparison[36] is an example of online retailers of solar panels. This table shows the price list of different solar panel brands, with panel's power, minimum quantity which can be purchased for given price, cost of given panel in USD, indication if the given panel has the UL certification or not (indicator of quality), the most important – price in USD per watt and the name of the online vendor (online sales of solar panels) from where the information was taken.

The table in Supplement 1 – Price comparison contains big amount of data about different solar panels, the data are not really the representative sample of information about solar panels, it is just an example from one the US website where online vendors can register to announce their offers. There are major solar panels brands, from Germany: Conergy, Centro Solar, Schott Solar; from the USA: Sun, DmSolar, Lumos, Ecolargy; from Japan: Sharp, Kyocera; from the South Korea: LG, Samsung; and very well known brand REC from Norway. Among the brands there are a lot of US brands because the origin of the website is the USA. The various online vendors are offering different prices often for the same brands, it always depends on the profit margin which the company takes from the sales.

The actual price of the solar panels is changing very quickly, some companies change their prices every month. In last several years, the price of the solar photovoltaic panels dropped. The solar panels business became a large scale business, more producers entered the market and naturally the price decreased.

In case of unknown brands of solar panels, the price is usually lower. However, the quality is also questionable. There are many new brands of solar panels from Asia, the basic problem is that most of these solar panel companies do not have their products certified by

[36] Ecobusiness Links. *Solar panels - best prices* [online]. 2011 [cit. 2011-10-18]. Available at WWW: http://www.ecobusinesslinks.com/solar_panels.htm

the international certification bodies and it is difficult for them to penetrate to international solar markets.

4) Table – prices of solar panels, USD per watt

Solar modules	mono 10-50W	mono 190W	mono 200W	mono 300W	poly 100W	poly 230W	Incoterms
Sungold Solar			1.38-1.65				FOB
Zhejiang Xiongtai Photovoltaic Technology		1.243		1.269		1.224	FOB
Foshan Oyad Electronic	1.9	1.9	1.9	1.9		1.9	FOB
Felicity Solar	1.65						FOB
Sunny International Power Corp					1.65		EXW
Wenzhou Dingwen New Energy Science & Technology Co., Ltd		1.25				1.25	FOB
Tangshan Shaiyang Solar Technology Co., Ltd.	1.3	1.3	1.3	1.3	1.3	1.3	FOB
Zhejiang SC Solar Technology Co.,LTD	1.20	1.20	1.20	1.20	1.20	1.20	FOB
Faro Group	1.4-1.8	1.4-1.8	1.4-1.8				FOB
Ningbo zhonghong photovoltaic technology co.,ltd.			1.03-1.15	1.03-1.15	1.03-1.15		FOB
Macro-Solar Technology Co., Ltd	1.34						FOB
Cixi Henghe Chuanhong Appliance Factory	1.35	1.35	1.35	1.35	1.30	1.30	CIF
Xiamen Jiaguang Imp&Exp Corp.	1.68-1.75	1.68-1.75	1.68-1.75	1.68-1.75	1.68-1.75	1.68-1.75	FOB

Explanation: prices of solar panels, units: USD per watt, source: own research, information given by the Chinese companies in July 2011

The data in the upper table were given by the different Chinese solar companies. In general, the prices of solar panels in USD per watt are lower than in the table of very well known brands. The prices are also given for different wattage of solar panels, the price per watt decreases with higher wattage of the panel. Most of the companies give just price per watt for any wattage of the panel because the differences in price are not crucial. In the last column of the table are written Incoterms.

Incoterm (International Commercial Terms) are rules for domestic and trade terms. These rules describe the tasks, costs and risks involved in the delivery of goods between sellers and buyers. Ex Works (EXW) - the biggest part of the responsibilities on the buyer and minimum on the seller, the seller prepares goods at the named place of delivery and the rest is up to the buyer. Free on Board (FOB) - divide the responsibilities among buyer and seller, the seller has to load the goods on a boat and from there the rest of responsibilities are up to the buyer. Cost, Insurance and Freight (CIF) – divide the responsibilities among buyer and seller, the seller has to transport the goods till the named port of delivery and also pay the insurance till that point, the buyer takes the rest of the responsibilities from the port of delivery.[37]

The actual information about the price of solar panels has to indicate also the other conditions, the currency of the price, if it is the price per watt, how much it will cost with the rest of the material for the complete photovoltaic system and Incoterms. Nevertheless, the producers of the solar panels usually give exact pricing just with regard to the demanded quantity. The seller usually offer lower price with the higher demanded quantity by the customer, so the actual pricing is given exactly according to the customer's demanded quantity. This is also the reason why most of the well known solar modules producers do not announce their prices directly on their website, they even provide the pricing information just if the customer gives them detailed information about himself and his solar project, it provides them the opportunity for negotiation with their customer.

8.5 Surana Ventures ltd. – solar panel costs

As it was mentioned above in Surana Ventures ltd. introduction and in the part of solar photovoltaic modules production cycle, the solar panels assembling line in the company Surana Ventures ltd. is operated by human work. This is specific for Asian solar companies, human workforce in Asia is very cheap in comparison to the machinery, and most of the work which is in Europe already operated by machines is done in Asia by humans. The big German solar brands use very expensive machinery for solar panels assembling which is precise and fast. On the other hand, human workforce is very flexible and does not need expensive reparation as in case of machinery. The assembly line operated by humans can produce solar panels of various wattages, the workers can work in several work shifts and the company can adjust their production according to the demand of the client. Moreover, the assembly line of solar panels and other factories provide

[37] REGNEROVÁ. Trade and Commerce : *Delivery Terms – lecture notes.* 2007. Lectures

opportunity to work for many local people without need of special education, just short training is needed.

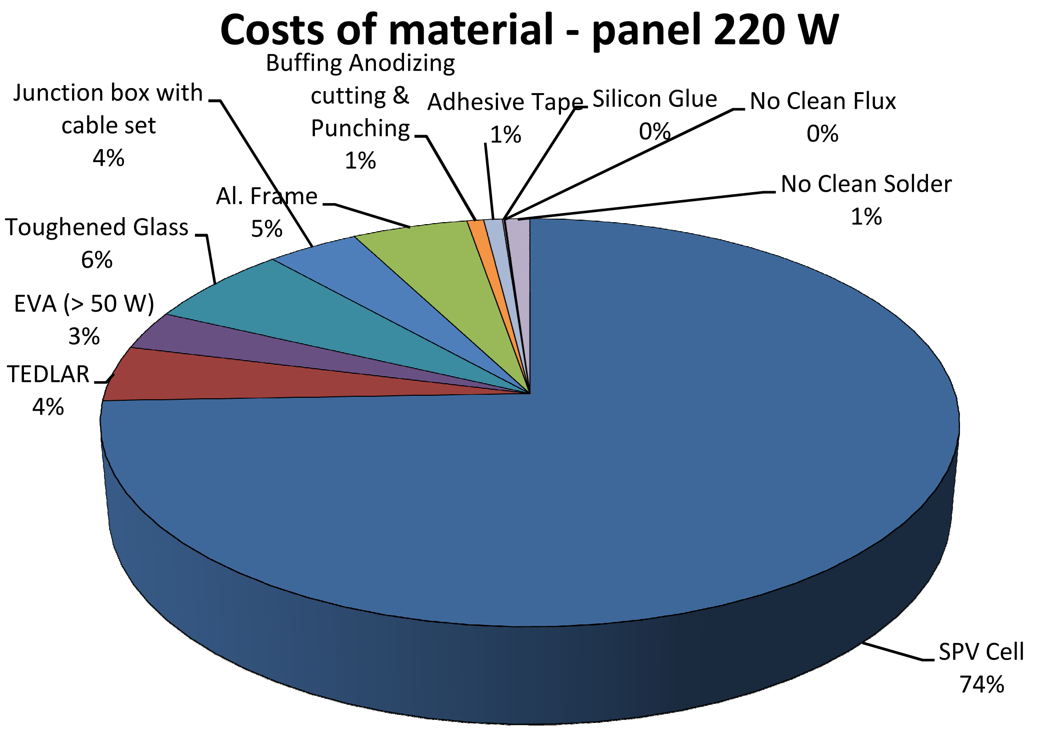
3) Picture – Human workforce in solar panels production

Source: own photo taken in the factory of the company Surana Ventures ltd., Cherlapally, Hyderabad, Andhra Pradesh, India, July 2011

Human workforce is a big comparative advantage for Asian countries, mainly in the most populated countries as China and India. All the products, which can be produced by hands, are generally produced cheaper in Asia than in Europe or in America. Human workforce is abundant production factor in Asia.

Surana Ventures ltd. is producing different sizes of solar panels from very small used for powering solar lanterns to very large used for large field solar power plants. The following computation of costs was done with solar panels of 5W, 10W, 20W, 30W, 40W, 50W, 80W, 110W, 135W, 175W, 210W and 220W. The material used for production of solar panels is following: solar photovoltaic cells, Tedlar – polymer material used as photovoltaic panel backsheet, EVA – ethylene vinyl acetate, used for protecting photovoltaic cells against water and breakage, toughened glass – used as a top protection, Junction box with cable set – used for outdoor solar wiring, aluminium frame, adhesive tape, no clean flux and no clean solder – used for soldering. More detailed information about the panels in the Supplement 2 – Solar PV modules.

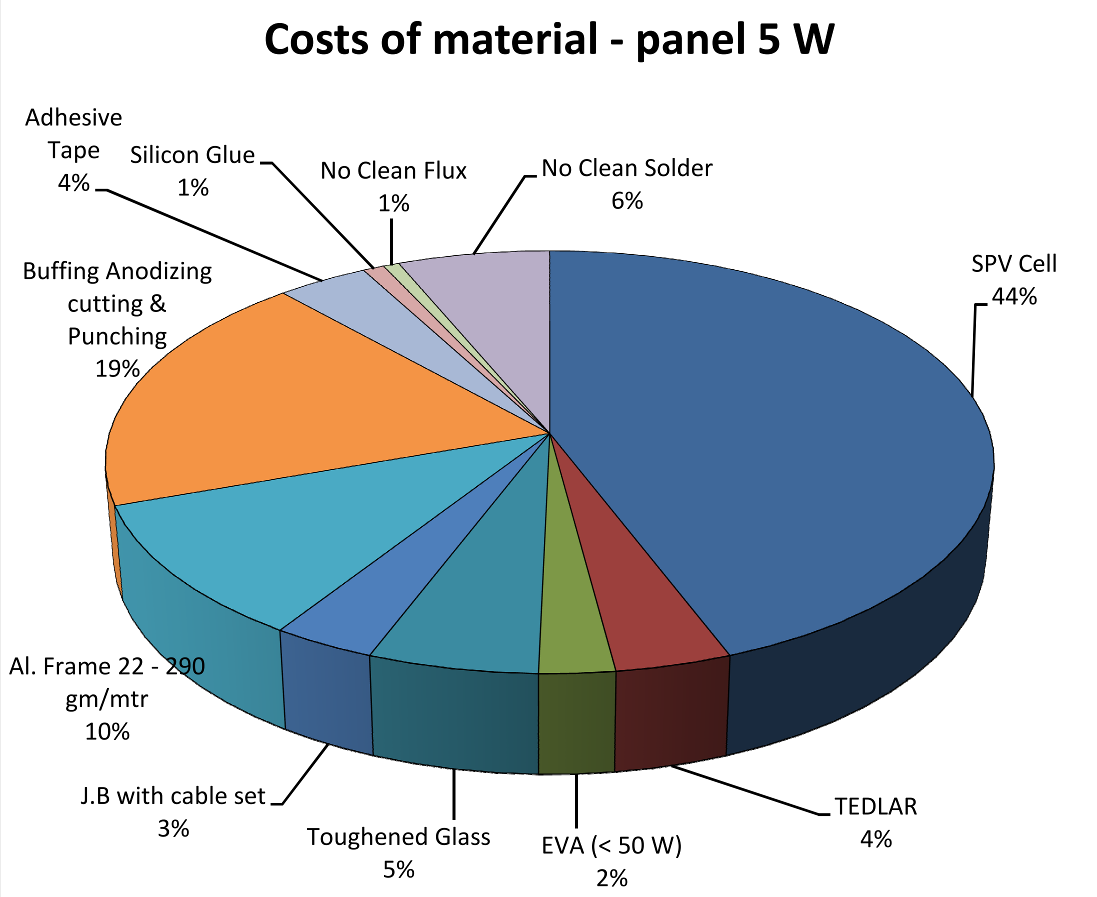
6) Graph – costs of material – panel 220 W



Source: own computation from data from Surana Ventures ltd.

The upper graph "Costs of material – solar panel 220 W" indicates percentage of costs of material used for production of the panel of power 220 watts. The computation includes just data available for production material costs concerning solar photovoltaic panels assembling line of the company Surana Ventures ltd., the data comes from the period of May 2011, labour costs and capital are not considered in this computation. The graph shows that in case of the solar panel of 220 W the biggest part of the costs are the solar photovoltaic cells, they form 74 % of the total cost of the material used for this panel. The other significant materials are: toughened glass 6%, aluminium frame 5%, junction box with cable set 4%, tedlar 4%, Eva 3%. From this computation it is obvious that the cost of solar photovoltaic cells is the most significant for the total costs of the production of solar panels, mainly in case of high wattage solar panels used for large projects of solar power plants.

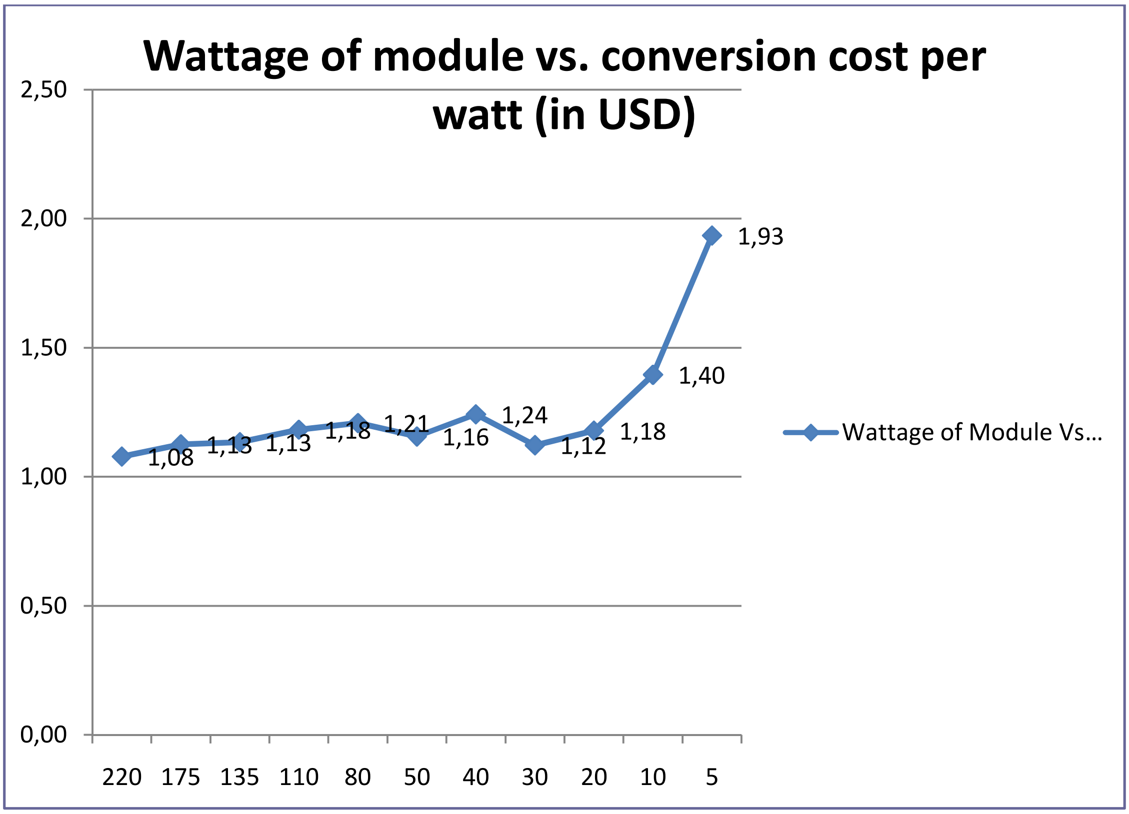
7) Graph – costs of material – panel 5 W



Source: own computation from data from Surana Ventures ltd.

The upper graph "Costs of material – solar panel 5 W" indicates percentage of costs of material used for production of the panel of power 5 watts. In comparison to the graph of the panel 220W, the material used for production of this small solar panel consists still mainly from solar photovoltaic cells 44%, however in this case the other materials have more significant percentage proportion than in the case of the big panel of 220 watts. With regard to this comparison of production of the small and big panel it is obvious that the small panel production use relatively more construction material than the material which makes the solar panel efficient – solar cells, so it makes the small solar panels relatively more costly.

8) Graph – wattage of module vs. conversion cost per watt



Source: own computation from data from Surana Ventures ltd.

This last graph "Wattage of module vs. conversion cost per watt (in USD)" shows how much is the cost, computed for different size of solar modules. Finally, it is obvious that the smaller the size of the modules, the higher is the price per watt. The cost of production of smaller modules is relatively higher than the cost of production of the larger modules.

The company Surana Ventures ltd. will benefit more if it produces mainly solar modules of large size, solar modules of wattage around 200 W are used for large solar power energy plants, in case of sale of these large size modules, there is also a higher possibility that the buyer will demand higher volume and the final profit for the producer will be bigger. On the other hand, in conditions of a country as India the smaller solar modules are also very useful because the company can sell them together with solar lightening systems for use in rural areas and these projects can receive regional government support.

8.6 Sales and marketing potential – solar panels Surana Ventures ltd.

Many countries in the European Union decreased significantly the government support for solar energy, recently including the Czech Republic. This situation can be only temporary problem, however in year 2012 the European Union will not be very potential market for the solar panels of the company Surana Ventures ltd. Nevertheless, according to the document of the European Commission – Energy Roadmap 2050, renewable energy should be very much in focus for future, the plan is to reach over 50% of final energy consumption from renewable sources of energy which is a very ambitious goal. The future potential in this market is great but the Indian company has to keep the pace with the technology improvements in the solar energy sector. From own experience from work in Surana Ventures ltd., the companies in Europe generally judge the Indian products as low quality products and these prejudgments have significant impact on possible trade. Indian companies have to get all the international certificates on their products to be able to prove their quality standards and to be able to export to foreign markets.

Under current conditions, the best option for Surana Ventures ltd. would be to expand to African market. As mentioned already in the previous part of this work, in 2009 the estimation of the number of people without electricity was 1.4 billion people, most of them were located in Sub-Saharan Africa. These people are mainly living in rural areas and electricity is a basic condition for development in these areas. Most African electricity supplies are government owned and operated. The priority for grid supplies and the allocation of generating capacity have been cities and towns, providing electricity grid to dispersed rural areas is expensive, inefficient and with low return on investment. This is a great problem in Sub-Saharan countries, till today none of these countries has managed to provide electricity to significant majority of the rural population. In cities, there is a problem with increasing demand for air conditioning, mainly for uninsulated and unshaded buildings, and this is weakening the electricity supply in general and causing often blackouts in cities.

Access to reliable, safe and mostly environmentally-friendly energy is among the basic conditions for human development, providing energy access is among the needs to achieve the United Nations Millennium Development Goals. Access to energy can improve not just basic living conditions but it also helps to increase economic development, enhancing value-added activities, prolonging daylight hours and creating additional working opportunities.

Energy is among main focus of the Millennium Development Goals:

- Access to energy decreases hunger and improves access to safe drinking water
- Access to energy decreases threat of diseases and reduces child mortality
- Energy helps to achieve universal primary education and the empowerment of women
- Efficient use of energy promotes environmental sustainability
- Access to energy enables urban mobility which helps wider employment and economic opportunities in the city

The African countries have to change their policies to encourage further development. The OECD and the EU countries contrast with energy policy in Africa. The OECD and the EU put great effort on enhancing renewable energy and regulation of energy supplies. These policies focus on great energy security, protection from fossil fuels price increase and reduction in fossil carbon emissions. However, some of the African countries have already taken preliminary actions in energy field. There are several examples of integrated liberalization and initiatives of renewable energy in Africa: Ghana – Energy Foundation (from 1997) - information and promotion, Ghana – Electricity Commission (Act 1997) – Grants for renewable energy, especially rural electrification, Kenya – Electricity Act (1997) – Geothermal power, Mauritius – Sugar Industry Efficiency Act (1991) – Exported electricity from sugar mills, Uganda - Republic of Uganda Act 1999, sect 66 – grants and subsidies for renewable energy from a “rural electrification fund”, Zambia – Energy Regulation Board (from 1997). In Kenya, government supports solar panels for heating water at all new housing projects from the year 2012. These are significant examples that African countries support renewable energy.[38]

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[38] UNITED NATIONS. *Energy for Sustainable Development: Policy Options for Africa.* [online]. 2008[cit. 2012-02-08]. Available at WWW: http://www.uneca.org/eca_resources/publications/unea-publication-tocsd15.pdf

There are major changes and reforms in energy sector taking place in African countries. New structural changes are mainly encouraging private sector in generation, transmission and distribution of energy. Private investments should be the key ones for further development of energy situation. These reforms can bring foreign investors to Africa and enhance commerce with other continents. The development of energy sector and new reforms are supported strongly by the United Nations.

According to the given information, Sub-Saharan Africa can be very likely potential market for solar panels and solar lightening products of the company Surana Ventures ltd.

Currently, the company Surana Ventures ltd. should follow these proposed recommendations to be able to exploit African market:

- contact different companies – solar products installers of retailers
- follow up governmental support and regional projects in different countries
- get local contacts – people who understand local conditions and trends
- in future – build new factory for assembling solar panels in selected African country, it will decrease transportation costs and they will be able to employ local workers at low cost

These proposed recommendations could significantly increase the company's sales. The probably most important aspect is to have local contact persons who could help with orientation on the market. Currently, the access to internet connected with accessibility to electricity is still big issue in most of the African countries, so the local retailer and installing companies cannot be reached easily by e-mail. Local contact person can ensure the analysis of the solar panels market in the given country and he/she can ensure the committed and responsible communication with potential customers.

8.7 Recycling of photovoltaic panels

Recycling of solar panels became a great issue with wider spreading of the solar energy technology around the world. A challenge in recycling of solar photovoltaic panels is that their lifetime is estimated to 25 years and technical lifetime is as long as 30 to 40 years. So under current conditions in the year 2012, the recycling of solar panels is not economically viable, this problem will become relevant in 2025 and in following years.

There are three basic types of solar panels:

1. Crystalline Silicon – Monocrystalline and Multicrystalline – mostly used, made from silicon
2. Thin film – one or more thin layers made from photovoltaic material – Amorphous silicon, Cadmium telluride (high toxic material), Copper indium gallium selenide
3. New and emerging technologies, still under research – Concentrator photovoltaics, Organic solar cells, Hybrid cells

The European Commission in 2008 proposed to recast Directive 2002/96/EC on waste electrical and electronic equipment (WEEE)[39]. According to this Directive, all electrical and electronic equipment produced in the European Union should be recycled or reused. The producers of this equipment should design their products already in advance to be able to recycle them after usage by consumer and consumer should be able to return the product to its producer or retailer after the lifetime of this product. The objective of the Directive is to encourage recycling of materials used for production of electric and electronic devices and to preserve environment. In the Article 2 of this Directive there are defined different categories of products according to their use, solar photovoltaic panels are not specifically mentioned in the categories, however it would probably be part of the category number 1 – Large household appliances – as freezer, electric radiator, etc. According to these categories of WEEE, there is an indication of how many percent of the weight of the electrical or electronic equipment should be reused or recycled and mainly for larger WEEE the percentage is 80% or 70%. As the Directive is old (from 2002) and it does not

[39] European Commission. *Study on Photovoltaic Panels* [online]. 2011[cit. 2012-02-08]. Available at WWW: http://ec.europa.eu/environment/waste/weee/pdf/Study%20on%20PVs%20Bio%20final.pdf

include new devices it should be renewed and include also solar photovoltaic panels. Nevertheless, this Directive or the Directive which will follow is a big issue for producers of solar photovoltaic panels, they have to take into account recycling of their panels after their lifetime and they have to directly implement it in the cost of their solar photovoltaic panels.[40]

The most widespread technology which is currently used is the solar photovoltaic panels made from Crystalline Silicon – Monocrystalline and Multicrystalline. For the recycling purpose, these photovoltaic panels contain a lot of glass, aluminium and of course silicon photovoltaic cells.

This is also the case for Surana Ventures ltd., if the company wants to increase sales of its solar photovoltaic panels – Monocrystalline or Multicrystalline, it has to obey rules of the European Union and it has to have recycling policy.

[40] European Commission. *Directive 2002/96/EC* [online]. [cit. 2012-02-08] Available at WWW: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:037:0024:0038:en:PDF

9 Case study number 2

This part of work is dedicated to the analysis and comparison of different energy projects, comparing conventional sources of energy with alternative sources of energy. The selected examples are real and should help to illustrate differences of investments and costs of different options of energy production. During the research conducted for this diploma thesis in several cases it was not desirable for the companies to publish certain information for obvious reasons.

9.1 Company X – solar photovoltaic power plant in the Czech Republic

5) Table – Company X

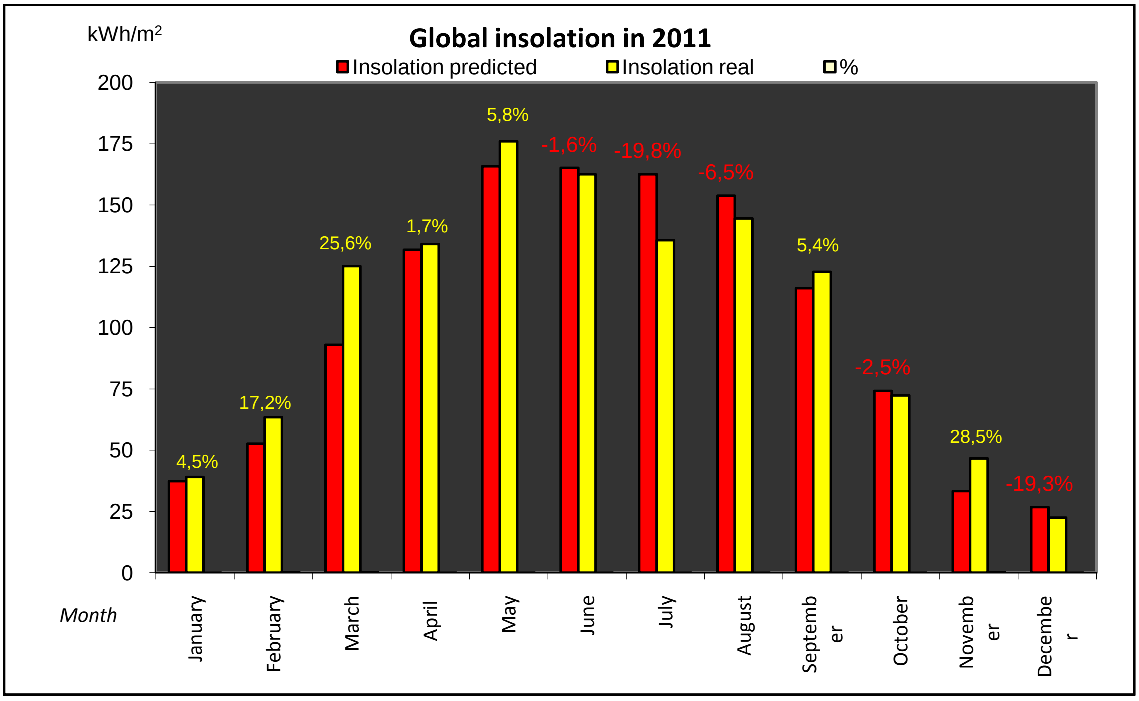
Total investment for installed capacity of 1 MW	77 000 000 CZK
Investment for installed capacity of 1 kW	77 000 CZK
Estimated lifetime	30 to 40 years (20 years guaranteed purchasing prices by regulatory directives ERU)
Credit provided by the bank	80%
Own sources (land + investment)	20%
Each year payment for credit is	73% from annual profit, including tax of 26% (for 3 years) which was imposed ex post
Cost of solar photovoltaic panel	1.62 EUR per Wp = 39.74 CZK (counted with currency rates of November 2010 when the project was built)
Total costs for solar PV panels per 1 MW	39 740 000 CZK

The solar photovoltaic project was built in 2010 in the Czech Republic. The installed photovoltaic panels are 190 W panels. As other solar power projects, the Company X was under big pressure in 2010 because there was a threat that if the project would not be finished by the end of the year 2010 and connected to the grid, it could not get the contract with the energy distribution company for electricity supplied to the grid. Finally, the project was connected in time, before the end of the year 2010 which was necessary for success of the project.

The purchasing price of electricity supplied to the grid was 12.40 CZK per Watt in 2011 and according to the law, each year this contracted price will increase by 2%, the contract with the energy distribution company is for 20 years guaranteed for the supply of the electricity to the grid, regulated by the directives of Energy Regulatory Office (ERÚ). However, the Czech government imposed in the same time tax of 26% for the period of 3 years, the investors did not count with such a surprise and the profit of the projects decreased significantly, some companies building solar projects went bankrupt because of this tax. Fortunately, the project of the Company X was well covered by the contract with the bank and with the investor, anyway the Company X had to add some personal loans.

The Company X counts with slightly decreasing efficiency of 1% per year of the capacity of the solar panels. The contract with the energy distribution company is for 20 years, however the estimated lifetime of the solar photovoltaic power plant is even 30 to 40 years, it is depending on different factors, the efficiency will decrease significantly after 20 years of production but it can still have around 80% of efficiency. The solar project of the Company X is secured by a special high fence, a security system with cameras and security guard. It has also a special insurance against stealing, breakage, different natural causes and calamities.

9) Graph – Global insolation in 2011



Source: computations given by the Company X

The upper graph indicates the Global insolation during the first year of production 2011 of the project Company X, it is indicated in kWh per m^2, simply said how much the Sun was shining. The graph shows the predicted insolation with red colour of the columns and the real insolation with yellow colour. Generally, till May the results were very positive and the insolation of the solar panels was higher than predicted, March and November were extraordinary good months, on the other hand, July and December were very disappointing. As a result the overall insolation during the year 2011 was higher by 4.7 % than it was predicted.

6) Table – Company X computation

years	capacity decreasing by	annual production in kW	purchasing price in CZK	production* purchasing price	Profit - after tax 26% (3years)
2011	1%	930 000	12,40	11 532 000	8 533 680
2012	1%	920 700	12,65	11 645 014	8 617 310
2013	1%	911 493	12,90	11 759 135	8 701 760
2014	1%	902 378	13,16	11 874 374	11 874 374
2015	1%	893 354	13,42	11 990 743	11 990 743
2016	1%	884 421	13,69	12 108 252	12 108 252
2017	1%	875 577	13,96	12 226 913	12 226 913
2018	1%	866 821	14,24	12 346 737	12 346 737
2019	1%	858 153	14,53	12 467 735	12 467 735
2020	1%	849 571	14,82	12 589 919	12 589 919
2021	1%	841 075	15,12	12 713 300	12 713 300
2022	1%	832 665	15,42	12 837 890	12 837 890
2023	1%	824 338	15,73	12 963 702	12 963 702
2024	1%	816 095	16,04	13 090 746	13 090 746
2025	1%	807 934	16,36	13 219 035	13 219 035
2026	1%	799 854	16,69	13 348 582	13 348 582
2027	1%	791 856	17,02	13 479 398	13 479 398
2028	1%	783 937	17,36	13 611 496	13 611 496
2029	1%	776 098	17,71	13 744 889	13 744 889
2030	1%	768 337	18,06	13 879 589	13 879 589

Source: own computation from the data given by the Company X

The upper table indicates computation of the production of the Company X during 20 years. This computation includes also decreasing efficiency of the production capacity by 1% each year. The installed capacity of the project is 1 MW and the counted insolation is 930 hours per year (counted according to the location and predicted insolation). The table shows annual production in kW, the changing purchasing price by 2% every year contracted with the energy distribution company (regulated by the directive from ERÚ), then it shows the annual production of the solar power plant multiplied by the purchasing price of the year and finally it shows the revenue after tax of 26% (just for 3 years at the beginning). The total predicted production of electricity in 20 years is 16 934 655 kW. However, this computation of profits in the upper table does not include repayment of the credit from bank and it does not include the operational annual expenses of the solar power plant.

The returnability of the solar power project of the Company X was around 10 years before the tax was imposed. The returnability of the project of the Company X after the tax of 26% was imposed (tax for 3 years) is counted as 13 years.

9.2 Company Y - Biogas power station plant in the Czech Republic

This case study was used from the diploma thesis with title “Production, modification and usage of biogas in energetics and transportation” of Ms. Tereza Vyšteinová. It is a very good example of economic analysis of building biogas power station, it is providing a perfect opportunity to compare this renewable resource of energy with others.

These calculations were made with regard to the conditions in year 2011. The biogas station is in the category AF1 which means that it is processing crops planted on purpose of energy production. In the category AF2 there are materials which are the side products from production in agriculture. According to these categories there are also different purchasing prices of electricity given by the Czech government. This case study is considering two different options of processing biogas in the biogas power station. The first option considers investment for building biogas power station and processing biogas to produce electricity and to produce heat as a side effect in cogeneration unit. The second option considers investment for building biogas power station and additional investment for cleaning and processing biogas to be able to sell it in gas form as biomethane.

7) Table – Company Y

Total investment for installed capacity of 1MW	83 663 000 CZK
Total investment with cleaning technology of biogas	92 000 000 CZK
Investment for installed capacity of 1 kW	92 000 CZK
Estimated lifetime	30 to 40 years

The calculation of investment does not include arrangement of the land, connection to the grid, heat pipe-line, sewerage, water pipe-line and in case of biomethane other arrangements for distribution. The investment for the cleaning technology of biogas was estimated roughly as additional 10 % investment as the technology is still under research and development. The total investment depends on the total installed capacity. With increasing installed capacity, the total investment needed is decreasing. [41]

Option 1

The produced biogas will be transformed into electricity and heat in the cogeneration unit of 1MW and it is assumed that the own consumption of the biogas power station will be 5 % of the total electricity capacity and 30 % of the total heat produced. The produced electricity will be sold to the distributing energy company for the purchasing prices set for the year 2011. The production of heat at the biogas power station should not be considered as part of the profit because most of the biogas stations are usually located far away from some residential area, so the distribution of the heat will be problematic. However, if the location of the project will be suitable, then selling of the heat can be profitable and will not be wasted.

Utilization time of the capacity of cogeneration unit…………………8000 hours /year (21.9 hours per day)

Purchasing price of electricity from biogas stations (AF1) in 2011………4.12 CZK/ kWh

The total electric capacity of the biogas station…………………………. …. 1000 kW

The total heat capacity of the biogas station………………………………… 1040 kW

8) Table – Company Y, option 1

	power capacity in kW	**annual production in kWh**	**Real annual production in kWh - 90%**	**Profit - purchasing price 4.12 CZK/kWh**
Total el. capacity of biogas st.	1 000	8 000 000	-	-
El. capacity - own consumption	50	400 000	-	-
El. capacity - sold to grid	950	7 600 000	6 840 000	28 180 800
	power capacity in kW	**annual production in kWh**	**Real annual production in kWh - 60%**	**Profit - purchasing price 300 CZK/GJ**
Total heat capacity of biogas st.	1 040	8 320 000	-	-
Heat capacity - own consumption	312	2 496 000	-	-
Heat capacity - sold	728	5 824 000	3 494 400	3 774 000

[41] VYŠTEINOVÁ, Tereza. *DP: Výroba, úprava a využití bioplynu v energetice a dopravě* [online]. ZČU v Plzni, 2011 [cit. 2012-02-18]. Available at WWW: http://www.czba.cz/aktuality/dp-vyroba-uprava-a-vyuziti-bioplynu-v-energetice-a-doprave.html

Total profit	31 954 800

Source: VYŠTEINOVÁ, Tereza. *DP: Výroba, úprava a využití bioplynu v energetice a dopravě* [online]. 2011

The annual profit from the electricity produced and sold to the grid will be 28 million CZK and if the produced heat will be also possible to sell, then the total profit will increase by 3.7 million to the total 32 million CZK.

Option 2

In this case, there will be installed smaller cogeneration unit of production electric capacity of 255 kWh and heat capacity of 419 kWh. This cogeneration unit will produce 82 m^3 of gas every hour. This gas will be produced by the station from biogas (biomethane) after cleaning process and it will be equivalent to natural gas that is distributed in the pipe-line. All data related to the biogas cleaning technology and numbers in this option are rough assumptions because the exact numbers are secret of the production companies and still under research.

Utilization time of the capacity of cogeneration unit………………… …8000 hours /year

Purchasing price of electricity from biogas stations (AF1) in 2011……… 4.12 CZK/ kWh

Purchasing price of natural gas in 2011……………………………………13 CZK/ Nm^3

The total electric capacity of the biogas station………………………… …. 255 kW

The total heat capacity of the biogas station………………………………… 419 kW

9) Table – Company Y, option 2

	power capacity in kW	**annual production in kWh**	**Real annual production in kWh - 90%**	**Profit - purchasing price 4.12 CZK/kWh**
Total el. capacity of biogas st.	255	2 040 000	-	-
El. capacity - own consumption	100	800 000	-	-
El. capacity - sold to grid	155	1 240 000	1 116 000	4 597 920
	power capacity in kW	**annual production in kWh**		
Total heat capacity of biogas st.	419	3 352 000		
Heat capacity = own consumption + cleaning	419	3 352 000		

Production of biomethane	2 000 000	m^3 / year
Own consumption of biomethane	656 000	m^3 / year
Biomethane sold	1 344 000	m^3 / year
Profit from selling biomethane	17 472 000	CZK / year
Total profit	**22 069 920**	

Source: VYŠTEINOVÁ, Tereza. *DP: Výroba, úprava a využití bioplynu v energetice a dopravě* [online]. 2011

The calculation of the Option 2 shows the cogeneration unit will produce more electricity than it can be consumed by the biogas station, so the rest can be sold to the grid with a profit of 4.6 million CZK. The major profit will be from the production of biomethane, with the price of 13 CZK for m^3, and the annual profit will be 17.5 million CZK. The total profit from Option 2 will be 22 million CZK per year.

In conclusion, the Option 1 is more profitable under current conditions even without selling the additional heat produced, it is more profitable to produce electricity and heat from the biogas power station than use the cleaning technology and transform produced biogas into biomethane and sell it to the gas pipe-line.

It is assumed that the repayment period for the biogas power station will be 4-6 years, depending on the fact if the investor uses additional government support or not.

9.3 Company Z – wind power station in the Czech Republic

The company Z built the wind power station in 2007. There is just limited information about this project.

10) Table – Company Z

Total investment for installed capacity of 1 MW	93 000 000 CZK
Investment for installed capacity of 1 kW	93 000 CZK
Estimated lifetime	30 years

The highest cost of the total investment was the power generation machine (wind turbine) which made about 39%, the rest was: concrete foundation of the wind power station, switching station, transformer station, cables, storage room, construction of road and snow scooter. In year 2007, the purchasing price was 2.8 CZK per kWh. The guaranteed period of purchasing electricity generated by the wind power station connected to the grid is 20 years.

11) Table – Company Z computation

	power capacity in kW	**annual production in kWh**	**Profit - purchasing price 2.8 CZK/kWh**
Total el. capacity of wind station	1 000	4 500 000	-
El. capacity - own consumption	?	?	-
El. capacity - sold to grid	1 000	4 500 000	12 600 000

Source: own computation from the data given by the Company Z

The information about the own consumption of electricity is not available. The annual production of the wind station is 4.5 GWh per year, with the purchasing price in 2007 of 2.8 CZK per kWh the wind station generates 12.6 million CZK of profit. The information about the operational costs is not available, it is not possible to indicate the annual revenue.

The construction of wind power station includes several specific issues, the wind turbine has to be built at very windy location which is part of its limits of success. The investor has to consult a professional to be sure that some piece of land is appropriate for building a wind power station. There is another problem of noise which the wind turbine makes, people in surrounding areas may protest against it. So, generally it will be better if the wind power station is located in some isolated area far from residential buildings. Another issue is that environmental activists claim that a wind power station can hurt population of local birds. This does not help the overall image of wind power station but in reality, it was not even confirmed that it makes some significant problems to local birds.

9.4 Nuclear energy power plant Temelín

The first project and investment proposal was created in 1979, this proposal included 4 blocks of nuclear power station of the total capacity 4000 MW. After the Velvet Revolution in 1989 under new economic and political conditions, the project was re-evaluated, the main question was if the Czech Republic really needs the nuclear power station of the capacity 4000 MW. Finally, it was decided to realize the project just with 2 blocks and in year 2000 the first production of electricity in the power plant started. The nuclear power station Temelín is under management of the energy company ČEZ, however as the strategic sources of energy it has to be partly managed also by the Czech government.

12) Table – Temelín

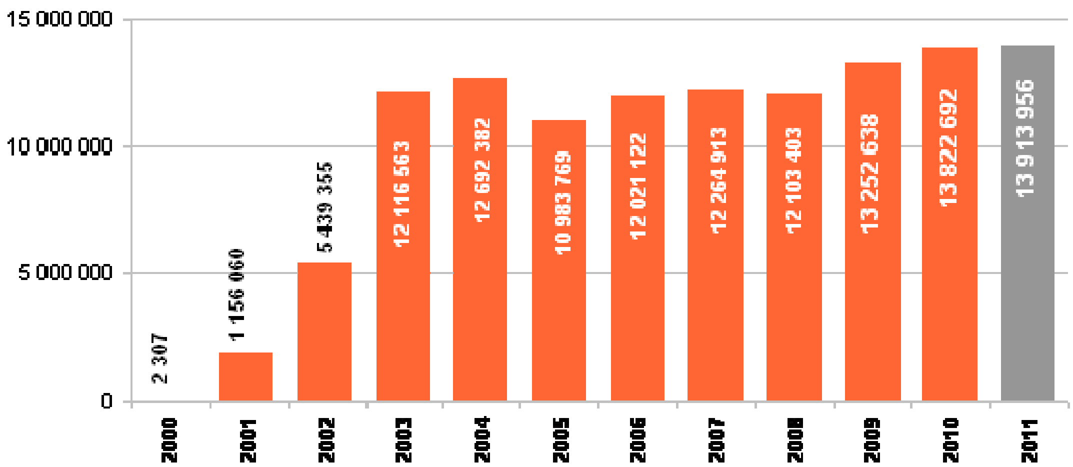
Total investment for installed capacity of 2000 MW	98 600 000 000 CZK
Investment for installed capacity of 1 MW	49 300 000 CZK
Investment for installed capacity of 1 kW	49 300 CZK
Estimated lifetime	40 to 60 years

The final price of the nuclear power station Temelín of 2000 MW was 98.6 milliards CZK, however the predicted price from the former budget from 1980s was about half of the actual price. The final price increased because of the increasing prices of materials in 1990s and mainly also because of the raising need of security of the nuclear blocks and the use of modern technology and materials.

From the point of view of investment, building of nuclear power station is a very demanding project and it can be handled just by very financially stable company. Nevertheless, the primary investment is then balanced by relatively cheap operational cost. The operational costs of nuclear power station are quite cheap and it is said to be the cheapest from all sources of energy followed by power station from coal and then followed by power station from gas. The lower operational costs of the production of electricity from nuclear power station are balancing the increasing final prices for the customer. The main operational costs are the cost of the material used for powering the nuclear power station – Uranium 235, the security systems and the cost of working staff. Obviously, the company ČEZ does not want to publish the operational costs of the nuclear power station as it would reveal their profit margin from the produced energy.[42]

10) Graph - Temelín

The energy production during years 2000 – 2011 in the nuclear power station Temelín (values given in MW)



Source: Press department of the nuclear power station Temelín

The graph shows that the production of the nuclear power station Temelín in the last three years reached the value over 13 TW, in 2011 the production was close to 14 TW which is enormous amount of energy. For example in 2010, the total production of electricity in the Czech Republic was 85.91 TW and the production of electricity in the Czech Republic from the nuclear power stations (Temelín and Dukovany) was 27.99 TW which is

[42] ČEZ. *Nuclear power station Temelín*. 2011. Information given by the press department.

about 32.6 % of the total production. The total gross consumption of energy in the Czech Republic in year 2010 was 70.9 TW, the production even enables us to trade the electricity with the neighbouring countries. So, the nuclear power stations are very important source of energy in the Czech Republic.[43]

The projected lifetime of the nuclear power station Temelín is 30 years. The lifetime is mainly given by the state of the pressure vessel of the reactor which is regularly controlled. Currently, it is already obvious that the nuclear power station will be used for at least 40 years. The managing company ČEZ supposes that the nuclear power station Temelín can securely produce electricity for 60 years. Every ten years, the company ČEZ testifies to the State Office for Nuclear Energy that the nuclear power station Temelín is producing safely and it will be safely producing for at least next 10 years, after these periodical controls the State Office of Nuclear Energy issues licence for the company ČEZ for the next 10 years of production. The first block has licence valid until the year 2020 and the second block will be controlled this year 2012 and the company ČEZ will apply for the licence for the next 10 years of production.

The nuclear energy is relatively clean, it does not produce greenhouse gases. However, it produces waste from processing uranium and generally people are scared about their safety as they heard about the cases as Chernobyl and Fukushima. As it was discussed in previous parts of this work, nuclear energy is not very popular nowadays between our neighbours as Germany and Austria. However, according to the State Conception of Energy in the Czech Republic for the upcoming future, the use of nuclear energy will be probably increasing in future in the Czech Republic. There is a great discussion, in generally public but also between politics, if to complete the former Temelín project of 4 blocks or not and it seems that the most probably the project of Temelín will be finished in the near future and the remaining two blocks will be built.

[43] ERU. *Energie 2010, statistika* [online]. [cit. 2012-02-11]. Available at WWW: http://www.eru.cz/user_data/files/statistika_elektro/rocni_zprava/2010/pdf/energie.pdf

9.5 Comparison of different energy projects in Case study number 2

It is not easy to compare these different energy projects because each of them has some specific issues and includes different risks, conditions of the environment and need of specific maintenance during the production. However, even simple comparison of initial investment, annual production of electricity and profit per year, is very interesting.

13) Table - comparison

Source	investment for 1MW, CZK	annual production in kW	profit per year
Company X – solar	77 000 000	930 000	8 534 000
Company Y – biogas	83 663 000	8 000 000	28 181 000
Company Z – wind	93 000 000	4 500 000	12 600 000
Temelín – nuclear	49 300 000	6 950 000	?

Table – own computation

The upper table shows comparison of the Companies X, Y, Z and the nuclear power station Temelín from the previous parts. The computation is made for the installed capacity of 1 MW for each source of energy. The first column indicates investment, the lowest initial investment is needed for construction of 1 MW of nuclear power station, the second lowest is needed for solar power plant, the highest is needed in case of wind power station.

The second column of the table is very interesting, it indicates annual production of energy of different projects with the same installed capacity of 1 MW. The highest production is reached in case of the biogas power station with 8 000 000 kW production per year, it is even higher than in case of the nuclear power station (counted from the latest production capacity of Temelín in 2011). The solar power station produces more than 8 times less energy per year than the biogas power station in total. The major cause of this result is basically the production time per day of different power stations, solar station is depending on insolation hours per day and on seasonal changes, wind station is depending on wind flows and also on seasonal changes, nuclear station has to be put out of operation very often and it has to be regulated for security reasons, however biogas station can run almost nonstop. It is obvious just even from comparison of the time of production in solar power plant and biogas power plants, it is 930 hours per year in case of solar plant and 8000 hours per year in case of biogas plant (from the analysed cases).

The third column is actually the most interesting for the comparison, it shows the profit of different energy power plants per year. The highest profit is the profit of biogas power station with 28 million (does not include profit from heat), then the second highest profit is the profit of 12.6 million of the wind energy power station, almost twice smaller than the profit of biogas power station, and the lowest profit is the profit of solar power station with 8.5 million. The profit of nuclear power station is unknown, as the purchasing price is not applicable in this case.

Nevertheless, the comparison of profit between solar, biogas and wind energy power station is little biased. This comparison is not counting with operational costs, there is not much maintenance needed in case of solar and wind stations, just security and controlling systems, staff needed for example in case of snow on solar panels or in case of needed reparations. The biogas power station cannot function without daily operations, the biogas station needs to be fed with inputs on daily basis. The investor has to consider appropriate choice of biomass for feeding of biogas power station, the Company Y was considering special production of energy rich crops which is also significant cost, including necessary work. On the other hand, biomass waste can be also used and then it depends on the source of the biodegradable waste but in case of the waste collected from restaurants or other, the restaurants even have to pay for disposal of the waste. Different types of biomass have different efficiency. These factors have to be considered in primary business plan.

Natural conditions and conditions of the environment are substantial premises of renewable resources. To be able to build solar power station, the investor needs land with good orientation, not surrounded by trees or rocks, ideally located at well insolated region. For the water power station, the investor needs to buy piece of land on river. In case of wind power station, the project has to be built in very windy area. Otherwise all these projects will not work. On the other hand, biogas power station does not have to be built at special location with specific natural conditions but it has to have access to sufficient biomass feeding, either from agricultural activity or from biodegradable waste of other activities.

Social conditions and risks are also very important aspects of business plan of energy power plants. General public has to understand the planned project and has to approve it or the project will not be successful. People often hear or read about some incorrectly built projects of wind power stations which make noise, biogas station which produces smell in surrounding areas or solar power plant which is built on wrong place and does not fit to local landscape. These are cases that do not help the image of renewable energies. However, well constructed renewable energy project should not harm its surroundings.

When considering different energy options as investor, various factors and risks have to be taken into account. There are safety risks connected to any manipulation with energy, safety risks connected with wind turbines falling down (in extreme cases), in case of solar power plant there are no real safety risks, but there could be safety risks related to biogas power station as manipulation with natural gas. These factors could also threaten people when building power station close to their houses. However, people are still more scared of nuclear power stations because the impact of any problem in nuclear station could be devastating. After disasters in Chernobyl and Fukushima, all nuclear power station strengthened their safety systems but some countries restricted use of nuclear energy totally.

Economic conditions and feed-in tariffs are basic factors of decision making for investors. Feed-in tariffs of each renewable energy (purchasing prices) are determining the profit of the project, the level of feed-in tariffs is decided by government and predestines the level and pace of development of renewable energy. Undoubtedly, without high feed-in tariffs for solar energy in the Czech Republic there would never has been such a big boom with solar power plants. However, in the same time the level of feed-in tariffs gives better opportunity to grow for certain renewable energy, privileging some from others.

All these factors have to be taken into account when comparing renewable energy projects. It is not possible to simply evaluate the profitability of these projects because there are more aspects of renewable energy production. If the projects should be successful, sustainability and all influencing conditions have to be part of the evaluation.

10 Conclusion

Renewable energy technology had been improving every year during the last decade, however it is still marginal way of production of energy. The real pace of the development of renewable energy is indicated by its cost and by social-economic conditions. Generally, renewable energy is still very expensive in comparison to conventional energy but it is probably just a matter of time.

The case study number 1 about the solar producer company Surana Ventures ltd. showed the material costs in production of solar panels in India. This case brought very interesting example and inside view of solar photovoltaic panel producer in economically rising conditions of quickly developing India. The profitability of the company is ensured by low cost of its production and by the opportunities of the market. Currently, solar projects in India are successful due to Jawaharlal Nehru National Solar Mission – national support program. The detailed analysis of Surana’s production material cost showed that more profitable is to produce larger solar panels than smaller panels. Larger solar panels can be sold for larger solar field projects. The smaller panels are also good products in case of connection of solar panels with solar lanterns and they could be well distributed in rural areas of India. However, the export of Surana’s solar panels to Europe is limited due to need of certain certificates and also due to prejudgments related to Indian products. Anyway, the European market with solar panels is declining in years 2011-2012 and governmental support is also low. As the result of analysis of overall conditions, the best recommended market for export of Surana’s solar panels is the African market, mainly countries with increasing governmental support for solar panels such as Kenya.

The case study number 2 provided very interesting comparison of three renewable energy projects with one nuclear energy project from the point of view of investor in the Czech Republic. There was the solar power plant project of Company X, the biogas power station of Company Y, the wind power station of Company Z and the nuclear power plant Temelín. It was not very easy to compare so various projects, however different aspects had to be taken in account: investment, annual production, but also risks and limits of production and social-economic conditions of the location. The analysis was done for 1 MW of installed capacity to be able to compare all projects. The lowest investment needed for 1 MW was in nuclear power station. However, the highest annual production of energy was found out in case of biogas power station, and also its profit per year was the highest of all studied renewable energy projects. This result is caused mainly by the production hours per year which is the highest in biogas power station. On the other hand, biogas power station is depending on its inputs, solar and wind power plants are depending just on weather conditions. Biogas power station needs daily maintenance and service so the project can create employment for local people. Solar and wind power plants do not need daily service and they are not source of local employment (just for few people). Clearly from the point of view of investor, the best opportunity is the biogas power station but it is very much dependent on inputs and it is limited by the cost of its inputs, it cannot be built just anywhere (too far from its source of biomass) and it needs maintenance. The solar power plant was very profitable just in years with high feed-in tariffs.

All renewable energy options depend on governmental support and feed-in tariffs. The profitability of the renewable energy projects is simply given by the feed-in tariffs. Under current conditions, the renewable energy cannot compete on energy market with prices of conventional energy. However, the price of renewable energy technology is decreasing due to governmental support and expanding use of this technology. Renewable energy could reach grid parity in near future.

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12 Supplements

Supplement 1 - price comparison

Solar panel brand	Power	Min. quantity	Cost of panel $	UL listed?	price $ per watt	Vendor
Conergy	225	60	$263.97	UL	**$1.17**	The Solar BiZ
Conergy	225	40	$266.97	UL	**$1.19**	The Solar BiZ
DMSolar	250	22	$320.00	-	**$1.28**	DmSolar
Sun	190	1	$254.60	-	**$1.34**	Sun Electronics
Sun	195	1	$261.30	-	**$1.34**	Sun Electronics
Canadian Solar	230	1	$308.20	UL	**$1.34**	Sun Electronics
Conergy	235	60	$319.97	UL	**$1.36**	The Solar BiZ
Canadian Solar	225	1	$312.75	UL	**$1.39**	Affordable Solar
Canadian Solar	235	1	$329.57	UL	**$1.40**	Affordable Solar
Conergy	235	40	$329.97	UL	**$1.40**	The Solar BiZ
REC	215	1	$303.21	UL	**$1.41**	CivicSolar
Centro Solar	230	54	$325.97	UL	**$1.42**	The Solar BiZ
Canadian Solar	215	1	$309.60	UL	**$1.44**	Sun Electronics
Canadian Solar	230	1	$331.20	UL	**$1.44**	Affordable Solar
Canadian Solar	220	2	$316.80	UL	**$1.44**	Sun Electronics
Conergy	235	20	$337.97	UL	**$1.44**	The Solar BiZ
LG	230	30	$331.12	UL	**$1.44**	Beyond Oil Solar
LG	230	1	$340.40	UL	**$1.48**	Beyond Oil Solar
Canadian Solar	230	1	$340.40	UL	**$1.48**	DmSolar
Canadian Solar	245	1	$362.60	UL	**$1.48**	DmSolar
Canadian Solar	295	1	$436.60	UL	**$1.48**	DmSolar
Micromorph	130	1	$195.00	-	**$1.50**	DmSolar
Sharp	240	17	$360.00	UL	**$1.50**	Solar Wholesale Products
Sharp	240	34	$360.00	UL	**$1.50**	Solar Wholesale Products
Canadian Solar	225	1	$348.75	UL	**$1.55**	CivicSolar
Sharp	240	1	$372.00	UL	**$1.55**	Solar Wholesale Products
Canadian Solar	230	1	$356.50	UL	**$1.55**	CivicSolar
Sharp	240	2	$372.00	UL	**$1.55**	Beyond Oil Solar
Canadian Solar	230	20	$356.50	UL	**$1.55**	SolarSyz
Canadian Solar	235	20	$364.25	UL	**$1.55**	SolarSyz
EcoSolargy	230	23	$356.50	-	**$1.55**	SolarSyz
Canadian Solar	230	2	$358.80	UL	**$1.56**	Beyond Oil Solar
Canadian Solar	230	24	$359.00	UL	**$1.56**	SolarPanelsOnline
LG	235	30	$366.60	UL	**$1.56**	Beyond Oil Solar
Kyocera	185	20	$292.20	UL	**$1.58**	ECO Distributing
Conergy	225	23	$357.75	UL	**$1.59**	SolarSyz
EcoSolargy	185	26	$294.15	-	**$1.59**	SolarSyz
Canadian Solar	295	26	$472.00	UL	**$1.60**	CivicSolar

Sharp	235	1	$378.94	UL	**$1.61**	CivicSolar
Schott Solar	230	1	$374.56	UL	**$1.63**	Affordable Solar
Lumos	250	24	$412.50	UL	**$1.65**	Solar Panel Store
Canadian Solar	220	24	$369.00	UL	**$1.68**	SolarPanelsOnline
Canadian Solar	230	1	$388.00	UL	**$1.69**	Solar Wholesale Products
Schott Solar	235	1	$398.21	UL	**$1.69**	Affordable Solar
Canadian Solar	250	20	$422.50	UL	**$1.69**	Solar Panel Store
REC	240	40	$405.60	UL	**$1.69**	Aten Solar
Canadian Solar	205	1	$349.00	UL	**$1.70**	Discount PV
Lumos	285	21	$485.86	UL	**$1.70**	Aten Solar
Kyocera	235	20	$406.55	UL	**$1.73**	ECO Distributing
Canadian Solar	200	1	$349.00	UL	**$1.75**	Discount PV
Kyocera	240	20	$420.65	UL	**$1.75**	ECO Distributing
Kyocera	240	1	$422.00	UL	**$1.76**	AltE
Samsung	244	1	$433.70	UL	**$1.78**	Infinigi
Lumos	240	20	$420.65	UL	**$1.79**	Aten Solar
Lumos	245	20	$438.55	UL	**$1.79**	Aten Solar
Lumos	300	21	$537.00	UL	**$1.79**	Aten Solar
Sharp	240	34	$430.00	UL	**$1.79**	Wholesale Solar
Kyocera	235	20	$423.00	UL	**$1.80**	Solar Panel Store
Hyundai	227	1	$411.68	UL	**$1.81**	Infinigi
Samsung	235	1	$425.16	UL	**$1.81**	Infinigi
Kyocera	210	20	$384.20	UL	**$1.83**	ECO Distributing
Kyocera	235	20	$430.00	UL	**$1.83**	Wholesale Solar
Sharp	240	1	$450.00	UL	**$1.88**	Wholesale Solar
Samsung	247	1	$463.69	UL	**$1.88**	Infinigi
Sharp	235	26	$445.00	UL	**$1.89**	SolarPanelsOnline
Kyocera	205	1	$399.00	UL	**$1.95**	AltE
Samsung	241	1	$469.88	UL	**$1.95**	Infinigi
Samsung	244	20	$479.00	UL	**$1.96**	SolarPanelsOnline
Kyocera	215	20	$424.95	UL	**$1.98**	ECO Distributing
Kyocera	210	1	$417.90	UL	**$1.99**	AltE
Kyocera	210	20	$417.90	UL	**$1.99**	AltE
Kyocera	235	1	$470.00	UL	**$2.00**	Wholesale Solar
Sharp	230	1	$470.00	UL	**$2.04**	Wholesale Solar
Kyocera	215	1	$469.00	UL	**$2.18**	AltE
Conergy	180	20	$400.00	UL	**$2.22**	Solar Panel Store
SolarWorld	250	30	$565.00	-	**$2.26**	Solar Panel Store
SolarWorld	240	30	$576.00	-	**$2.40**	GreenEcoSavers
Solon	230	25	$559.00	UL	**$2.43**	SolarPanelsOnline
SolarWorld	240	1	$585.00	-	**$2.44**	GreenEcoSavers
Sharp	235	34	$581.62	UL	**$2.47**	GreenEcoSavers
Sharp	235	34	$590.44	UL	**$2.51**	GreenEcoSavers
Sharp	235	1	$596.00	UL	**$2.54**	GreenEcoSavers

Source : Ecobusiness Links. *Solar panels - best prices* [online]. 2011 [cit. 2011-10-18]. Available at WWW: http://www.ecobusinesslinks.com/solar_panels.htm

Supplement 2 – Solar PV modules

Surana Ventures Limited

Inspiring Excellence

SOLAR PV MODULES

SURANA offers high-quality silicon Photo Photovoltaic Modules: a clean, reliable and economical source of energy. Our Solar PV Modules range from **3 Wp to 230 Wp** and feature:

- **High-quality, Mono- or Polycrystalline cells** from our European Suppliers
- ISO 9001 Manufacturing and IEC 61215 (TUV) **Module Certification**
- Strong **Durability** with aluminum alloy frame, tempered glass and waterproof lamination
- Quality Check of each cell and **Testing of every Module**, at all production stages

SURANA takes great pride in continuously developing innovative, top-quality products for its costumers. In addition, SURANA provides a **5-year product guarantee** on each Solar PV Module detailed below, plus a **power warranty of 90% of the first 10 years and 80% for 25 years.**

150 - 195 FAMILY

200 - 230 FAMILY

Technical Specifications:			150 - 195 Family			200 - 230 Family		
Module	SVL-075	SVL-125	SVL-150	SVL-175	SVL-195	SVL-200	SVL-220	SVL-230
Nominal Peak Power (W_p)	75	125	150	175	195	200	220	230
Voltage at max. Power - V_{mp} (Volts)	17.3	18.2	25.5	26.7	27.2	28.9	29.9	30.0
Current at max. Power - I_{mp} (Amps)	4.6	6.9	6.4	6.6	7.3	7.1	7.4	7.8
Open Circuit Voltage - V_{oc} (Volts)	21.2	22.1	32.4	32.8	33.2	36.6	37.0	37.2
Short Circuit Current - I_{sc} (Amps)	4.7	7.9	5.7	7.6	8.1	8.3	8.4	8.4
Module Efficiency	13.1%	13.1%	12.2%	12.5%	13.2%	12.6%	13.3%	13.6%
Number of Cells	36(9x4 Matrix)	36(9x4 Matrix)	54 (9x6 Matrix)			60 (10x6 Matrix)		
Dimensions (L x W x T) - mm	890x655x34	1490x655x42	1490 x 990 x 42			1660 x 990 x 42		
Mounting Holes Pitch (Y) - mm	510	920	1100			1100		
Mounting Holes Pitch (X) - mm	610	610	950			950		
Weight - Kgs	6.6	10.5	17.5			19.1		
Junction Box Dimensions - mm	105 x 80 x 25		130 x 105 x 30			130 x 105 x 30		
Junction Box Cables (ø x L)	no cables included		4mm x 1m			4mm x 1m		
Power Tolerance	All modules are provided with a positive power tolerance.							

Note: Measurement tolerance on electrical parameters +/- 5%
All specified parameters are at STC: 25°C Cell Temperature, 1000 W / m2 Irradiance and AM 1.5.

Temperature Coefficients:
- Voc - 0.034 %/°C
- Isc + 0.03 %/°C
- Pmax - 0.45 %/°C

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