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„Renewable vs. Nuclear Energy: a 21st Century Question about a Sustainable Future“

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Introduction

The rapid growth of the world population is one of the main causes that lead to the fast utilization of the fossil fuels (oil, coal and natural gas) and enhanced the pollution of the worldwide environment. Therefore, a sustainable future for humankind is hard to guarantee. The world had to take some decisions regarding a cleaner and a more sustainable future. Some countries have expanded more towards the production and use of the nuclear energy and some towards renewable energy.[1] The reduction in energy consumption would be another solution (but not a sufficient one) that implies a strong improvement in the efficiency of the existing technologies and at the same time the willingness of people, particularly of those living in developed countries, to change their lifestyle and reduce the unnecessary consumption of electricity.[2]

The first part of the thesis gives a detailed overview of the renewable and nuclear energy sources available currently. The renewable energy sources (solar, wind, geothermal hydropower, and biomass) are characterized individually by presenting the energy production process and the current status of the countries that have operating capacity for each type of energy. Moving forward the nuclear energy sector is being presented. Beginning with the current status of the nuclear current market shares and moving on to a brief presentation of the third and fourth generation of reactors the first part of the thesis ends by summing up a couple of arguments that show how people are afraid of nuclear energy.

The second part of the thesis tries to give a broader view of the techniques that the governments around the world use in order to regulate and sustain the development of the renewable/nuclear sector. The most widely spread tool is the feed-in-tariff.

[1] Hae-Yong Jeong, Young-In Kim, Yong-Bum Lee, Kwi-Seok Ha, Byung-Chool Won, Dong-Uk Lee, Dohee Hahn. A 'must-go path' scenario for sustainable development and the role of nuclear energy in the 21st century. Energy Policy 2010;38:1962-1968

[2] Mariangela Guidolin, Renato Guseo. A nuclear power renaissance? Technological Forecasting & Social Change 2012; 79: 1746-1760

The thesis ends by summing up a couple of proposals that might help to the creation of a more sustainable future.

Renewable energy

Solar energy

The brightest star, which fundamentally symbolizes the sole source of energy for all the organisms living on Earth, is the sun. The power that the sun irradiates on planet Earth is supposed to measure around 175.000 TW. In order to realize the magnitude of the power that the sun produces, it is comparable to think that the power emanated by the sun is four time greater than the amount of power consumed by our modern energy consuming population. The solar activity together with the primordial heat captured inside the planet are assumed to be constant and therefore represent an exclusive source of renewable energy for the human race.[3]

Smith C. describes solar energy as being a source of energy that can be straightforwardly associated to the light of the sun or to the warmth that it irradiates.[4]

The energy coming from different sources like wind, waves or biomass resources needs to be converted into other forms of energy that are usable for the daily life. The conversion of power into electricity is necessary in order to make its distribution possible also to places that are located very far from the point of creation. For example biomass resources, which are caused by solar light through the biological progress, can be incinerated in order to achieve heat.[5]

[3] Athanasios Angelis-Dimakis, Markus Biberacher, Javier Dominguez, Giulia Fiorese,Sabine Gadocha, Edgard Gnansounou, Giorgio Guariso, Avraam Kartalidis, Luis Panichelli,Irene Pinedo, Michela Robba.Methods and tools to evaluate the availability of renewable energy sources. Renewable and Sustainable Energy Reviews 2011; 15:1182-1200

[4] Smith C. Revisiting solar power's past. Technology Review 1995;July: 33-47

[5] Athanasios Angelis-Dimakis, Markus Biberacher, Javier Dominguez, Giulia Fiorese,Sabine Gadocha, Edgard Gnansounou, Giorgio Guariso, Avraam Kartalidis, Luis Panichelli,Irene Pinedo, Michela Robba.Methods and tools to evaluate the availability of renewable energy sources. Renewable and Sustainable Energy Reviews 2011; 15:1182-1200

Types of solar energy technologies

There are three types of solar energy technologies (passive vs. active, thermal vs. photovoltaic and concentrating vs. non-concentrating). The first type comprises the passive and active technology. The only function of the passive solar technology is to collect the energy without changing it into some other form. Passive solar technologies are encountered in buildings, which have a special architecture that permits taking maximum advantage of daylight.[6] On the other hand, the active solar technology has the role of capturing and converting the solar energy into other forms that permit the everyday use of the energy. Active solar technologies are of two types: photovoltaic (PV) and solar thermal. The former PV technology transforms the energy collected from the sunlight into electrical energy; this whole process takes place due to the sunlight that interacts with a semiconductor material producing an excitation of the electrons. The latter offers a direct use of the solar heat in order to produce heating or thermal mechanisms or to generate electricity. The two types of solar thermal technology mainly: solar thermal non-electric (non-concentrated) and solar thermal electric (concentrated) play different roles in the production of the energy.[7]

The first one involves processes that deal with the agricultural domain like agricultural drying, mechanisms that heat the water with solar energy, and heaters that make the air warm using solar energy, also systems for cooling as well as so called solar cookers.[8]

Solar cooking is a very efficient mechanism that in the long run can save tons of firewood and at the same time impede the emission of carbon dioxide into the

[6] Chiras Daniel D. The solar house: passive solar heating and cooling. Chelsea Green Publishing Company 2002
[7] Govinda R. Timilsina*, Lado Kurdgelashvili, Patrick A. Narbel. Solar energy: markets, economics and policies. Renewable and Sustainable Energy Reviews 2012;16:449-465
[8] Manuel J. Blanco, Jose G. Martin, Diego C. Alarcon-Padilla. Theoretical efficiencies of angular-selective non-concentrating solar thermal systems. Solar Energy 2004,76:683-691

atmosphere.[9] The solar cookers cannot be placed anywhere because the area they are installed on should receive more than 2.000kWh of sunlight radiation per m^2 annually. Therefore the best places for the installation of a solar cooker are: South America, North and South Africa, Middle East, Australia or China.[10]

Solar water heaters are the perfect solution for families that consists of an average of four persons and should be the source of warm water in every case where the installation of such a technology is possible. According to an article written by Kumar A. and Kandpal TC., a domestic solar water heater (see Figure 1) with a capacity of 100 l per day could prevent the emission of 1237 kg of CO_2 a year into the atmosphere.[11]

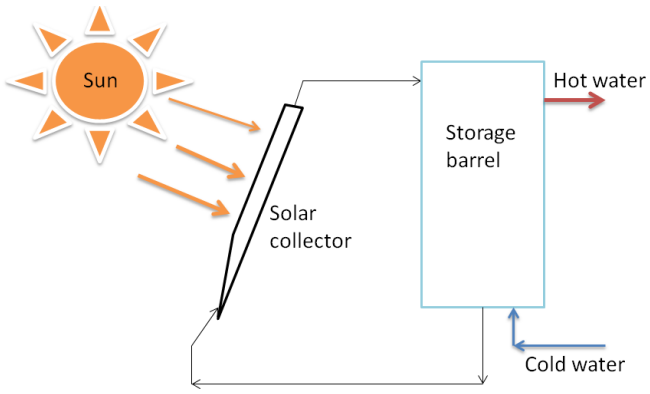

Figure 1 Domestic solar water heater
Source: Xiaowu W, Ben H. Exergy analysis of domestic-scale solar water heaters. Renewable and Sustainable Energy Reviews 2005; 9:638-45

[9] Nandwani SS. Solar cookers cheap technology with high ecological benefits. Ecological Economics 1996;17:73-81
[10] Greenpeace International Homepage (Accessed on 02.02.2013) http://www.greenpeace.org/international/en/press/releases/greenpeace-report-proves-solar/
[11] Kumar A. , Kandpal TC. CO2 emissions mitigation potential of some renewable energy technologies in India. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects 2007;29(13):1203-14

As mentioned above, solar dryers play an important role in the field of agriculture. They offer an alternative that solves many issues. For example the vegetables and the fruits have the possibility of drying in sanitary conditions, occupying a place that is affordable at no energy costs. This key technique contributes to a clean environment without generating any CO_2 emissions.[12]

On the other hand, the non-concentrating is different from the concentrating solar energy technology, because although it operates at lower temperatures it can generate the same quantity of power.[13]

The concentrated solar technology is supposed to play an important role in the future because it has the capacity to convert the highly concentrated solar energy into power of high temperature. This mechanism is able to produce energy without greenhouse gas (GHG) emissions. A further advantage of this technology is that it can develop processes that are able to reduce the production costs of the energy.[14] Nowadays there are a couple of concentrated solar power (CSP) technologies accessible on the market, for example: Parabolic Trough, Power Tower, Fresnel Mirror and Solar Dish Collector.[15]

Current status of the market

Looking at the changes that developed on a gradual basis, the installation of solar energy technologies has evolved drastically over the past few years, enabling the

[12] S. Vijaya Venkata Raman, S. Iniyan, Ranko Goic. A review of solar drying technologies. Renewable and Sustainable Energy Reviews 2012;16(5):2652-2670
[13] Manuel J. Blanco, Jose G. Martin, Diego C. Alarcon-Padilla. Theoretical efficiencies of angular-selective non-concentrating solar thermal systems. Solar Energy 2004,76:683-691
[14] Jun Li. Scaling up concentrating solar thermal technology in China. Renewable and Sustainable Energy Reviews 2009;13:2051-2060
[15] Govinda R. Timilsina∗, Lado Kurdgelashvili, Patrick A. Narbel. Solar energy: markets, economics and policies. Renewable and Sustainable Energy Reviews 2012;16:449-465

expansion of the PV grid and off- grid capacities as well as the installed capacity of the concentrated solar power.[16]

Solar PV

Starting with the examination of the Solar PV markets it can be seen that another 30 GW of new solar PV capacity was added to the global network in 2011. (See Figure 2)

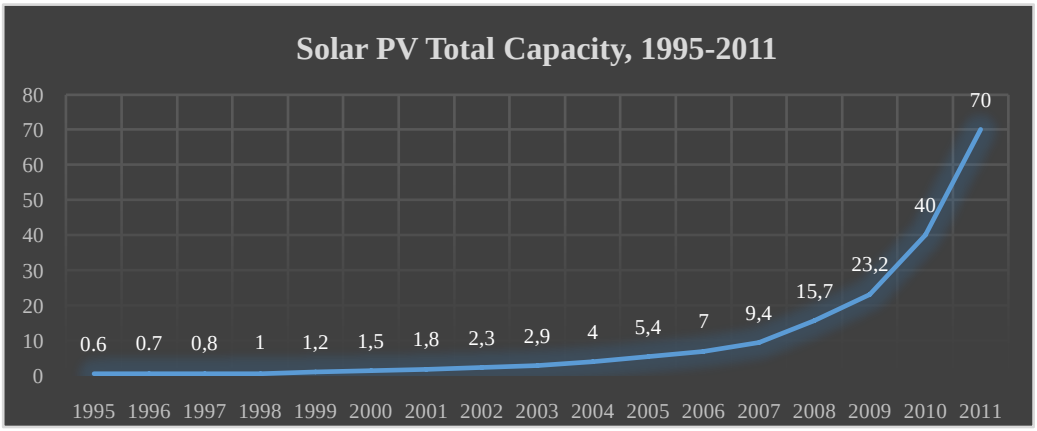

Figure 2 Solar PV Total Capacity, 1995-2011
Source: Global Status Report Renewables 2012 Homepage (Accessed on 03.02.2013)
http://www.ren21.net/REN21Activities/GlobalStatusReport.aspx

The graph above illustrates the evolution of the solar PV total capacity between the years 1995 and 2011. The whole process started slowly and began to exponentially expand around years 2009-2010. As can be depicted from the graph, the year 2011 depicts success because of the massive amount of solar PV capacity (30 GW= 43% of the whole capacity) that has come into operation globally. The expansion of 2011 is almost equal to the cumulative worldwide expansion from the last five years.

The next pie chart presents the top countries based on operating capacity used.

[16] Govinda R. Timilsina*, Lado Kurdgelashvili, Patrick A. Narbel. Solar energy: markets, economics and policies. Renewable and Sustainable Energy Reviews 2012;16:449-465

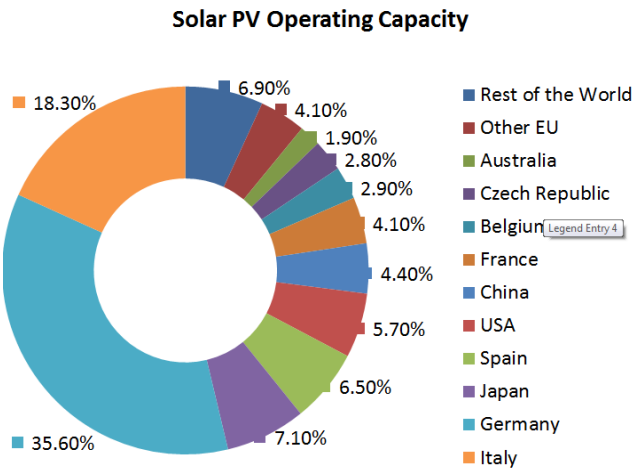

Figure 3 Top 10 countries, Solar PV Operating Capacity
Source: Global Status Report Renewables 2012 Homepage (Accessed on 03.02.2013)
http://www.ren21.net/REN21Activities/GlobalStatusReport.aspx

The figure above (See Figure 3) shows Europe as being the leader in solar PV operating capacity where only Germany and Italy together account for 54%. Approximately 17 GW were installed by the EU and 22 GW were also connected to the grid. Because of the 51 GW installed, EU accounted for nearly three-quarters of the globally installed solar PV operating capacity. Through the total amount of GW installed, the EU had the possibility to meet the energy demand for over 15 million European households. From the solar PV point of view, the year 2011 was very successful because it symbolized nearly a half (47%) of all the European electric capacity that entered the network that year.[17]

Germany added a significant amount of 7.5 GW to the network just at the end of the year 2011. Some of the reasons were the lower feed-in-tariff (FIT) rate and on the other hand the presumption of an ongoing reduction in price.[18]

Italy however, had a very good year in 2011. By the end of the year it added 9.3 GW of solar PV to the network. Italy's solar power production was five times higher than

[17] Global Status Report Renewables 2012 Homepage (Accessed on 03.02.2013)
http://www.ren21.net/REN21Activities/GlobalStatusReport.aspx
[18] Global Status Report Renewables 2012 Homepage (Accessed on 03.02.2013)
http://www.ren21.net/REN21Activities/GlobalStatusReport.aspx

the level of production achieved during 2010. With this, the solar power output exceeded the wind power production. Among the top countries in Europe that brought new GW online during 2011, it can be mentioned: Belgium (almost 1 GW), UK (0.9 GW) and Spain (approximately 0.4 GW). Among countries that faced a decline in bringing GW online, it can be mentioned that France (little capacity due to fewer FIT support) or the Czech Republic faced a decline because of reduced support and a retroactive tax on plants that already existed and suspension on grid connection. Examining the other continents, it is to be noted that China (with 2.1 new GW brought online) is ahead of United States with 1.9 GW and Japan with 1.3 GW brought online.[19]

Because of the economic downturn and the declining support from the governments, the construction of new solar PV operating capacity has slowed down. Although the economic situation plays a very important role in the development of a country, some markets have shown some progress with respect to solar PV. For example Tibet introduced the highest network connected power generating unit in the world, a 10 MW installation as did Kenya with its 0.5 MW solar PV.[20]

Concentrating Solar Thermal Power (CSP)

The total capacity of concentrating solar thermal power (CSP) amounted to 1,760 MW at the end of 2011 with an average 37% annual growth rate over the past five years. The most used technology of CSP is the Parabolic Through, accounting for 90% of nearly all new plats built.[21]

Spain, the country where most of the CSP capacity was brought online, finished 2011 with 1,150 MW of capacity in execution. This was possible due to the acceptable

[19] Global Status Report Renewables 2012 Homepage (Accessed on 03.02.2013) http://www.ren21.net/REN21Activities/GlobalStatusReport.aspx
[20] EurObserv'ER, The State of Renewable Energies in Europe. December 2011: 101-105
[21] Fred Morse and Florian Klein, Abengoa Solar, Washington, DC and Madrid, personal communication with REN21, March 2012

feed-in-tariff (FIT) and the legal structure set up by the Spanish government. Interesting enough, Spain is the only country that is equipped with a functional utility-scale solar tower powers. Gemasolar was the first plant that achieved the performance of having a 24 hours operation schedule having a storage capacity of 15 hours. This process involved a couple of conditions that needed to be fulfilled in order to work at full capacity. The Gemasolar works with a rated electrical power of 19.9 MW and has an annual net electrical output of 110 GWh. This plant ensures 6500 hours of electricity per year. More than 25000 households will benefit from the electricity produced by this plant.[22] In the city of Barcelona in Spain, a solar project has been finished which uses not only CSP but also combines biomass with it in order to improve the outcome.[23]

The CSP technology is not only considered for Europe, but rather other markets like Morocco, Algeria, Thailand and India started to use their CSP capacities during 2011. At the moment there are other international markets that seem to speed up their CSP growth: Australia (with a promising capacity of 250 MW), China and India followed by Turkey.[24]

New projects in the United States hope to increase the energy production toward 250 MW. The argument is that, increased production will benefit from economies of scale and therefore reduce costs. Other production plans that were unable to expand decided to profit from the bad economic environment by building joint ventures with other companies. Good examples are the joint ventures built between Spanish and Japanese companies in order to finance new CSP projects.[25]

[22] Torresol Energy Homepage (Accessed on 10.02.2013)
http: //www.torresolenergy.com/TORRESOL/gemasolar-plant/en
[23] Global Status Report Renewables 2012 Homepage (Accessed on 07.02.2013)
http://www.ren21.net/REN21Activities/GlobalStatusReport.aspx
[24] Global Status Report Renewables 2012 Homepage (Accessed on 03.02.2013)
http://www.ren21.net/REN21Activities/GlobalStatusReport.aspx
[25] Global Solar Thermal Energy Council Homepage (Accessed on 10.02.2013)
http://www.solarthermalworld.org/content/intersolar-speakers-present-latest-figures-key-solar-thermal-markets

Solar Thermal Heating and Cooling

Out of 44.3 GW_{th} of solar thermal heat capacity that was brought online in 2010, 42.4 GW_{th} represent the glazed solar capacity and the rest of 1.9 GW_{th} unglazed capacity. The latter is used especially for heating the swimming pools. The capacity of the unglazed pool heating volume is divided as follows 60% in the U.S.A., 17 % in Australia followed by other markets among which the most important one is Brazil.[26]

The worldwide total solar heating gazed capacity amounted to 232 GW_{th} in 2011. The Chinese market is ranking at glazed systems. By adding 18 GW_{th} to its glazed installations, the total capacity amounted to 135.5 GW_{th} at the end of 2011.This amount represents 58% of the entire capacity globally.[27]

The development of solar thermal heating and cooling capacity is struggling to find its footing because of the European economic crisis. Being the largest European installer, Germany has succeeded in retaining its position during 2011, recovering after the powerful drop in 2010. Greece's market dropped significantly in 2011 but the solar thermal sector did not face the same consequence as other sectors did. The Austrian market dropped approximately by 10%-12% as a result of the incentive cuts and the new program that promulgated the heating oil industry.[28]

Turkey's position regarding the solar thermal heating remained stable during the economic crisis and even experienced an expansion of the natural gas grid. Its solar thermal capacity increased during 2011 by 1.3 $GW_{th.}$.[29] Being a country that enjoys more sun than many other countries in the region, more than 70% of the hotels that are placed in the south of Turkey are equipped with solar thermal installations. At the

[26] Global Solar Thermal Energy Council Homepage (Accessed on 10.02.2013) http://solarthermalworld.org/content/intersolar-speakers-present-latest-figures-key-solar-thermal-markets
[27] Global Solar Thermal Energy Council Homepage (Accessed on 11.02.2013) http://www.solarthermalworld.org/content/china-industry-increased-export-business-12-fold
[28] Global Solar Thermal Energy Council Homepage (Accessed on 11.02.2013) http://www.solarthermalworld.org/content/austria-solar-thermal-market-verge-collapse-one-province
[29] Global Solar Thermal Energy Council Homepage (Accessed on 11.02.2013) http://www.solarthermalworld.org/content/turkey-vacuum-tubes-rise

same time more than 100 hospitals around the country benefit from this type of water heaters.[30]

Moving on to other continents, Brazil encountered a total capacity of 5 GW_{th} by the end of 2011. One of the factors that lead to this expansion was the program that tried to help low-income households by promoting solar thermal solutions. The Unites States dropped from the 10^{th} to 12^{th} place regarding solar thermal capacity on a global scale. Examining the Middle East, there is a clear willingness to promote the installation of solar thermal heaters. For example round 72% of the Palestinian houses rely on solar heaters. This type of installation is a very good solution for low-income families and is widely spread among areas with low economic growth.[31]

The new trend is to implement large-scale systems that provide warm water and space heat for as many places as possible. The trend tries to replace the individual solar heaters with immense systems that can cover more households at once. In Riyadh, Saudi Arabia, the development of the world's largest solar plant (25 MW_{th}) that is supposed to supply an entire campus with more than 40,000 students and 13 faculties, with hot water and space heat took place.[32]

On the other hand, the world's largest solar cooling plant (3 MW_{th}) is located at Singapore's United World College. This installation is supposed to provide 100% of the school's warm water and at the same time assist with a significant part of the air-conditioning system.[33]

[30] Global Solar Thermal Energy Council Homepage (Accessed on 11.02.2013) http://www.solarthermalworld.org/content/turkey-solar-hot-water-systems-supply-20000-low-income-family-flat

[31] Slide Share Homepage (Accessed on 11.02.2013) http://www.slideshare.net/rcreee/rcreee-newsletter-issue4

[32] Global Solar Thermal Energy Council Homepage (Accessed on 17.02.2013) http://www.solarthermalworld.org/content/saudi-arabia-largest-solar-thermal-plant-world-36305-m2

[33] Renewable Energy Focus Homepage (Accessed on 17. 02. 2013) http://www.renewableenergyfocus.com/view/22688/large-solar-cooling-system-unveiled-at-uwcsea-singapore/

Wind energy

Wind energy is not a new discovery. Evidence points to early civilizations which have used it to propel and sail boats, to granulate grain with windmills, or to extract and distribute water. The first documented wind turbine that was operated automatically was developed and built in 1888 by C.F. Brush in Cleveland, Ohio. The wind turbine was 18 m tall and was equipped with a 12kW turbine.[34]

The key components of wind technology are the wind turbines, which have the capacity to capture the energy produced by the wind through aerodynamically designed blades and convert it into electricity or mechanical power.[35]

Wind power is a source of energy that can be implemented in countries where the wind reaches a specific level of activity. The electricity can be transported rapidly even to remote areas that are inaccessible because of the geographical architecture. The electricity generated by the wind is an inexhaustible source that will never suffer an increase in price. This type of renewable energy has the potential to mitigate the use of several billion barrels of oil and at the same time impede the spread of million tons of CO_2 into the atmosphere.[36]

Between 2005 and 2009, the price of the wind power rose as a result of the increasing price of steel. Nowadays, due to increased competition, the high number of manufacturers and the development of the technology that lead to a decline in the prices of turbines, the recent prices of the electricity derived from the wind power have declined. Although the decrease in turbine prices is a negative side effect for the manufacturer, this may lead to competitiveness between wind power and fossil-fueled power.[37]

[34] Balat M. Usage of energy sources and environmental problems. Energy Exploration and Exploitation 2005; 23:141-68
[35] Thomas BG, Urquhart J. Wind Energy for the 1990s and beyond. Journal of Energy Conversion and Management 1996;37:1741-52
[36] Meyer NI. Danish Wind Power Development. Energy for Sustainable Development 1995; 2: 18-25
[37] World Wind Energy Homepage (Accessed on 18.02.2013) http://en.86wind.com/?p=2615

Current status of the wind energy market

The wind power market faced a blooming year 2011. During this year a capacity of 40 GW was brought to the network. This means a 20% growth of the worldwide wind capacity arriving at a total capacity of 238 GW. (See Figure 4)

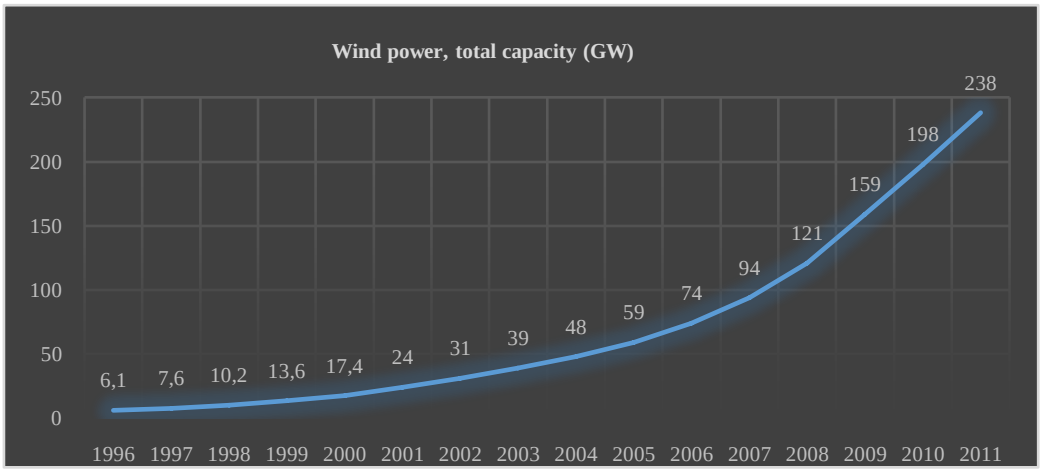

Figure 4 Wind power, total capacity (GW)
Source: Global Status Report Renewables 2012 Homepage (Accessed on 07.02.2013)
http://www.ren21.net/REN21Activities/GlobalStatusReport.aspx

In comparison with the solar PV capacity, wind power had a much higher starting capacity. In 1996 the starting capacity of wind power was 6.1 GW in comparison to solar PV, where the capacity amounted to 0.7 GW. Total wind power in 2011 was more than three times higher than the total solar PV capacity. In this comparison the total capacity of the concentrating solar thermal power can be left out of the equation because it is negligible amounting for just 1,760 Megawatts. Over the last five years the increase in the capacity of the wind power represents 70% from the today's total operating capacity.

What can be derived from the next graph is that a lot of countries added GW to their wind power capacities. The top countries are China, the United States, India, Germany and Spain followed by the United Kingdom, Canada, Italy, France and Portugal.

According to the literature, despite the fact that China added 17. 6 GW to its network in 2011, it was the first year when China brought less capacity into operation than it did the year before. This was the result of a slowdown period that consisted in a larger timeframe of strict analysis and approvals because of some irregularities and faults discovered at some important wind plants. China's total wind capacity by the end of 2011 reached 62.4 GW.[38]

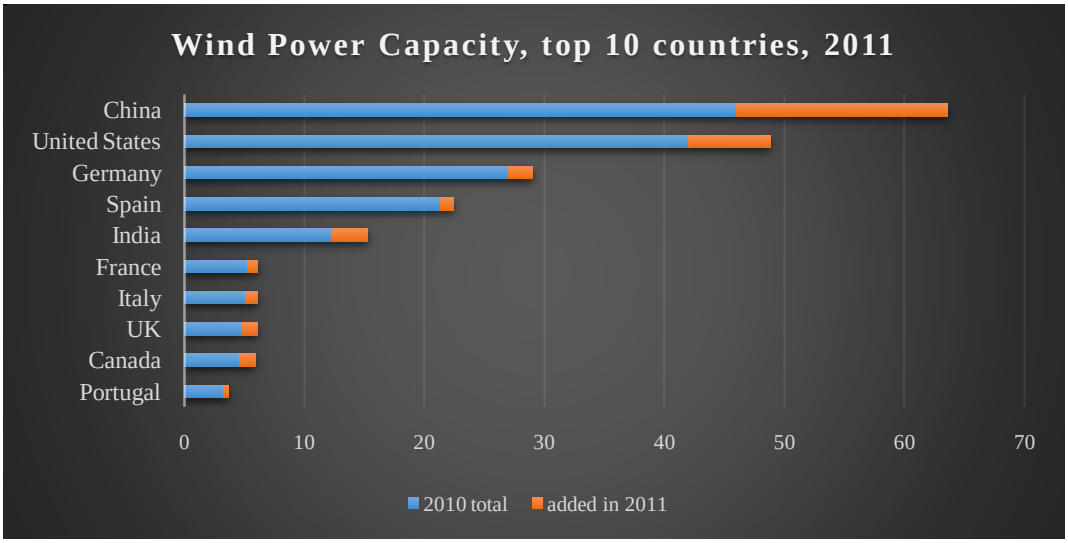

Figure 5 Wind Power Capacity, top 10 countries, 2011
Source: Global Status Report Renewables 2012 Homepage (Accessed on 07.02.2013) http://www.ren21.net/REN21Activities/GlobalStatusReport.aspx

The United States occupies the second place in the top 10 countries that added capacity to their wind power network in 2011. Adding 6.8 GW and possessing a total capacity of 47 GW wind power, the United States was able to supply nearly 2 million households with this type of electricity. The capacity of wind power brought into operation since 2007 was twice the combined amount of coal and nuclear power.[39]

According to Figure 5 Europe has a strong position regarding the increasing capacity for wind power. In 2011, Germany was the European market leader with 2 GW in operation, summing up a total of 29.1 GW capacity of wind power. The United

[38] World Wind Energy Homepage (Accessed on 18.02.2013) http://en.86wind.com/?p=2615
[39] Global Status Report Renewables 2012 Homepage (Accessed on 07.02.2013) http://www.ren21.net/REN21Activities/GlobalStatusReport.aspx

Kingdom added another 1.3 GW, having by the end of the year a total capacity of 6.5 GW.

Although some countries experienced a drawback or have stagnated during 2011, others have experienced significant steps forward, like Romania where wind power capacity has more than doubled. Significant expansion of wind power capacity has occurred also in Latin America. In countries like Brazil for example, the presence of the wind power sources have begun to grow from the moment it was clear that its prices are lower than the prices of electricity derived from natural gas. Other regions from that part of the world that have increased their wind power capacity or have built new capacity are Argentina, Chile, Honduras, Mexico, Dominican Republic and last but not least Honduras. On the other hand, the situation in the Middle East does not look as bright as in other places. Little investments have been made in enlarging the capacity of wind power. Only one country from the Middle East is involved in large projects regarding the development and growth of wind energy, mainly Iran, which added 3 MW for a total of 91 MW.[40]

Even though the capacity of wind power is significantly smaller than that of the solar power, its share increases every year pointing out the fact that people become more and more aware of the environment and the benefits that come from using renewable energy.

An interesting fact is that nearly 6.7% of the US wind capacity is owned by the community. On the other hand, things are clearer in the case of Germany, where 50% of its total wind capacity is owned either by individuals or by the community.[41]

Because a representative number of people live in remote rural areas, the utilization and need for small-scale turbines is continuingly growing, influenced by the expansions of lower-cost inverters that are connected to the grid and government incentives. Small-scale turbines are defined as turbines that produce not more than 100 kW, enough to sustain a household, a farm or even a tiny business. The number

[40] Global Status Report Renewables 2012 Homepage (Accessed on 07.02.2013) http://www.ren21.net/REN21Activities/GlobalStatusReport.aspx
[41] Wind Works Homepage (Accessed on 20.02.2013) http://www.wind-works.org/cms/

of people that are using small-scale turbines has increased on average 35% annually.[42]

In 2011, the total existing capacity of wind power was sufficient for supplying approximately 2-3% of the entire energy consumption. Some European countries were able to meet a higher share of their electricity consumption. For example Denmark succeeded through supplying approximately 26% of the country's electricity demand; similar examples are Spain (16%) and Portugal with 15.6%.[43]

Geothermal Heat and Power

Geothermal energy is that thermal energy that is captured in the interior of the Earth and can be extracted at any hour of the day in all seasons. This temperature is the one that drives the temperature of matter. There are two primary sources of the geothermal energy. The first source is the slow discomposure of radioactive isotopes with a long life. The second energy source is that deriving directly from planetary growth. The year of 2000 has led to the discovery of more than 80 countries that enjoy geothermal resources. Until 2011, another 20 were added to the list. The advantage of the geothermal energy is that it can be used directly (at high or low temperature) by end consumers such as the heating and cooling industry, fish farms, health resorts and spas. Nevertheless, the production of electricity deriving from geothermal energy is far more complicated. First of all, the geothermal resources should have a temperature between 100 ºC and 150ºC. Furthermore, the whole process involves drilling at high depth followed by pumping the water to the surface. Therefore, the direct use of the geothermal resources is far more productive and time saving than the electricity production.[44]

[42] Global Status Report Renewables 2012 Homepage (Accessed on 07.02.2013) http://www.ren21.net/REN21Activities/GlobalStatusReport.aspx
[43] Global Wind Energy Council. Global Wind Report: Annual Market Update 2011 (Brussels: March 2012)
[44] Fridleifsson IB. Geothermal energy for the benefit of the people. Renewable and Sustainable Energy Reviews 2001;5(3):299-312

The exploration program of the geothermal resources consists of a step by step procedure. The most important step is the identification of the geothermal field. However, once the geothermal area has been labeled, a lot of techniques are used in order to determine the most valuable spot for resources. This leads to results that in approximate temperature, estimated volume of the resource and its purpose; either for direct use or electricity production.[45]

Current status of the geothermal heat and power sector

From a total of 205 TWh of geothermal energy delivered during 2011, two-thirds was directly used as heat and the remaining was converted into electricity.

The next figure illustrates the evolution of geothermal power capacity from 1975 to 2010 and the predictions of installed capacity by 2015. (See Figure 6)

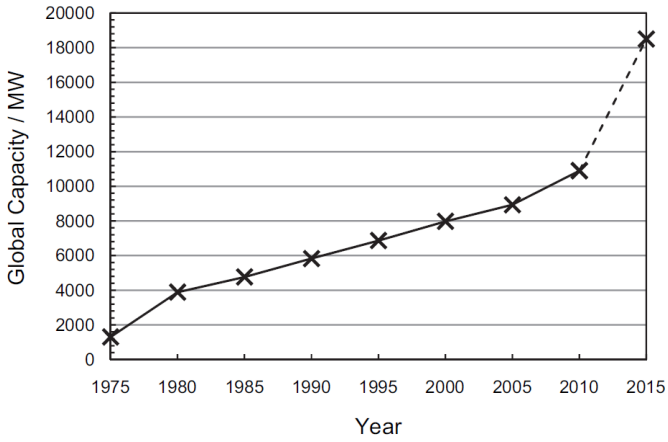

Figure 6 Evolution of the geothermal power capacity from 1975 to 2010 and planned capacity for 2015 Source: Cesar R Chamorro, Maria E. Mondejar, Roberto Ramos. World geothermal power production status: Energy, environmental and economic study of high enthalpy technologies. Energy 2012; 42:10-18

Among the top countries in 2010 that have geothermal energy and used it directly as heat include: the United States, China, Sweden, Germany and Japan. Northern European countries like: Iceland, Sweden, Norway, and Denmark were recognized as

[45] Barbier E. Geothermal energy technology and current status: an overview. Renewable & Sustainable Energy Reviews 2002;6:3-65

the countries with the highest annual energy consumption per person. Interesting to notice is that in 2011 nearly 90% of Iceland's heating demand was supplied from geothermal resources.[46]

According to the literature, the geothermal electricity generation has hit the 69 TWh verge in 2011. Therefore, the situation of the geothermal electricity generation does not look as well as the wind or solar power one; some of the countries that added geothermal power capacity during 2011 are the following: Nicaragua (36MW), the United States (10 MW), Iceland (90 MW).[47]

The situation is more or less under control as more and more countries get interested in this type of electricity. Therefore countries like: Kenya, Tanzania, Uganda as well as Latin America among others Chile and Peru are at different stages of the geothermal energy development. For example Kenya's plans regarding the geothermal energy are to cover nearly half of its energy demand with this source.[48],[49]

Hydropower

Hydropower, among all the renewable sources is considered to be the biggest source.

According to Ibrahim Yüksel, the use of hydropower has its advantages and its disadvantages. The following table was taken directly from his paper entitled "Hydropower for sustainable water and energy development".[50]

Advantages
Economic aspects
Provides low operating and maintenance costs

[46] Energy Statistics in Iceland 2011. http://www.os.is/gogn/os-onnur-rit/orkutolur_2011-enska.pdf
[47] Geothermal Power Generation in the World, 2005–2010 Update Report," Geothermics, vol. 41 (2012), pp. 1–29
[48] Sunday Nation Homepage (Accessed on 27.02.2013) http://www.nation.co.ke/business/news/Geothermal+expected+to+meet+half+of+Kenyas+energy+needs+/-/1006/1278722/-/qq8lw2/-/index.html
[49] Sinclair Knight Merz Homepage (Accessed on 27.02.2013) http://www.globalskm.com/Insights/achieve-magazine/issue3-2011/article5.aspx
[50] Ibrahim Yüksel. Hydropower for sustainable water and energy development. Renewable and Sustainable Energy Reviews 2010;14(1):462-469

Provides long life span (50-100 years and more)
Provides reliable service
Includes proven technology
Instigates and fosters regional development
Provides highest energy efficiency rate
Creates employment opportunities and saves fuel
Social aspects
Leaves water available for other uses
Often provides flood protection
May enhance navigation conditions
Often enhances recreation
Enhances accessibility of the territory and its resources
Improves living conditions
Sustains livelihoods (fresh water, food supply)
Environmental aspects
Produces no pollutants but only very few GHG emissions.
Enhances air quality
Produces no waste
Avoids depleting non-renewable fuel resources
Often creates new freshwater ecosystems with increased productivity
Enhances knowledge and improves management of valued species due to study results
Helps to slow down climate change
Neither consumes nor pollutes the water it uses for electricity generation purposes
Disadvantages
Economic aspects
High upfront investment
Precipitation
Requires long-term planning
Requires long-term agreements
Requires multidisciplinary involvement
Often requires foreign contractors and funding
Social aspects
May involve resettlement
May restrict navigation
Local land use patterns will be modified
Waterborne disease vectors may need to be checked
Requires management of competing water uses
Environmental aspects
Inundation of terrestrial habitat

Modification of hydrological regimes
Modification of aquatic habitats
Water quality needs to be managed
Temporary introduction of methyl-mercury into the food chain needs to be monitored/managed
Species activities and populations need to be monitored
Barriers for fish migration, fish entrainment
Sediment composition and transport may need to be monitored/managed

Table 1 Advantages and disadvantages of the hydropower alternative
Source: Ibrahim Yüksel. Hydropower for sustainable water and energy development. Renewable and Sustainable Energy Reviews 2010; 14(1):462-469

One of the advantages of using hydropower as an energy source option according to Varun Ik, Bhat R. and Prakash (also seen in the table above from Mr. Yüksel), is the fact that it expects a longer timeframe up to 100 years and at the same time requires less maintenance costs than other renewable energy sources. This implies also disadvantages, as seen in the table. Risks include natural causes like river floods, barrier for fish migration and modification of aquatic habitat. The uncertainty of the hydropower is as high as the world's biggest challenge; climate change due to the global warming.[51]

To be noted is that almost every advantage has a correspondent disadvantage. That means that while trying to improve one part one may cause damage to other parts on account of the side effects. For example on the one hand the implementation of the hydropower energy produces no waste but on the other hand it modifies the aquatic habitat. At the same time it may provide a barrier against flood but this may cause restrictions in the navigation system. Another good example is that it possesses on the long run lower operating and maintenance cost but it implies high upfront investments.

[51] Varun IK, Bhat R, Prakash. LCA of renewable energy for electricity generation-a review. Renew Sustain Energy Rev 2009; 13:1067-73

Current status of the hydropower market

In 2011 a new batch of hydropower capacity namely 25 GW were brought to the market. The entire capacity was estimated to be 970 GW at the end of 2011, representing an increase of approximately 2.7% in the global capacity with respect to the previous year. The countries that have the most operating hydropower capacity as follows: China (22%), Brazil (8%), the United States (8%), Canada (8%) and Russia (5%). Their entire hydropower volume amounts for 51% of the operating global capacity. Looking at the year of 2011, the electricity that was generated by the hydropower resources was estimated by 3,400 TWh.[52]

Analyzing the next figure (See Figure7) it can be easily noticed that China was one of the countries that have brought the most hydropower capacity on line, accounting for nearly 49% of the entire added capacity during the whole year.

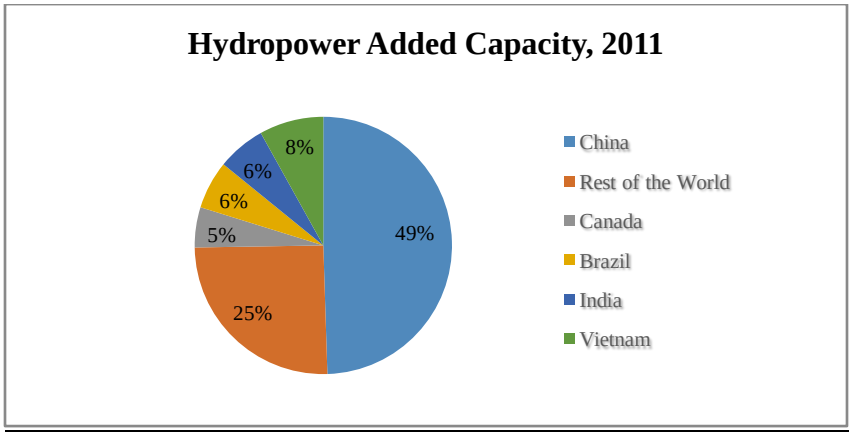

Figure 7 Hydropower added capacity, top five countries, 2011
Source: Global Status Report Renewables 2012 Homepage (Accessed on 07.02.2013)
http://www.ren21.net/REN21Activities/GlobalStatusReport.aspx

Analyzing the top countries that added hydropower capacity to the system, China lands in first place, followed by Vietnam, India, Brazil and last but not least Canada. Comparing the top countries that have hydropower capacity with the top countries that added capacity during 2011, there can be mentioned that Russia, although

[52] Global Status Report Renewables 2012 Homepage (Accessed on 01.03.2013)
http://www.ren21.net/REN21Activities/GlobalStatusReport.aspx

measuring 5% of the global capacity, it did not brought any significant capacity during 2011 on line. One thing worth mentioning regarding Russia is that, even if it does not have significant solar PV and Wind power capacity, it is placed among the top five countries that have hydropower capacity. Russia does not have that many renewable energy sources because their main sources of energy are the nuclear generators. This case will be better explained in the next chapter of the paper that deals with the nuclear energy.

Countries like Burundi, Rwanda and Tanzania all located in Africa decided during 2011 to open their markets for the hydropower energy systems. All the projects that have started are supposed to be financed by the World Bank. The same year, the hydropower project entitled 16 MW Kikagati-Murongo began to take root along the Kagera River.[53]

On the one hand, countries that experience economic growth like the ones located in Africa tend to establish (or in some cases even increase their pumped storage capacity for) hydropower in order to be able to generate more power and satisfy, as well as meet the actual electricity demand. On the other hand, markets like the ones located in Europe North America or Russia tend to modernize and improve their plants rather than building new facilities. A good example is Russia, where RusHydro's purpose is to replace all the old infrastructure and equipment with high-tech one by 2025. RusHydro is considered to be the highest hydropower generator in Russia.[54]

The idea of the pump water storage system gives the impression of being simple but implies a lot of costs particularly if the whole process is developed in such a way that it does not damage the environment. This whole process takes place at two different stages of the day. During the off-peak time (night), the water is pulled out from a spring consisting from a lower lake to a higher lake in order to prepare its use for the day. Consequently during the peak time (day), when everyone needs electricity in

[53] East African Community Homepage (Accessed 01.03.2013)
http://www.eac.int/index.php?option=com_content&view=article&id=771:tz-uganda-deal-for-hydropower-project&catid=146:press-releases&Itemid=194
[54] Hydro World Homepage (Accessed on 01.03.2013)
http://www.hydroworld.com/articles/2011/03/energy-minister-power.html

order to run their businesses, the water that is now located in the higher lake is set free downwards in order to have high speed when reaching the turbines that transform the power of the water into electricity. The whole process is circular. It always starts by bringing the water from the lower lake to the higher lake, and then when electricity is needed, water is released and finally resurfaces again in the lower lake. During the night the whole process start again and so on.[55]

During 2011 a capacity of nearly 3 GW of pumped storage was brought on line, amounting for a total of approximately 140 GW by the end of the year. Projects have started and it is estimated that about another 27 GW will be brought on the market by 2020 in the European countries, especially in Austria, Germany Switzerland and Spain. The biggest advantage of the pumped storage facilities is that they can store electricity. This kind of electricity source is perfect for cases where the use and demand of electricity is intermittent because it can respond instantly if changes in the grid settings appear. According to the literature, the hydropower plants have a much longer life of up to 90 years if maintained appropriately; in comparison with other renewable sources, like wind power (on average up to 25 years) or thermal plants (on average up to 40 years), which do not have such a long operating life.[56]

[55] Techno Student Homepage (Accessed on 01.03.2013)
http://www.technologystudent.com/energy1/pstr1.htm
[56] Hydro World Homepage (Accessed on 02.03.2013)
http://www.hydroworld.com/articles/print/volume-19/issue-3/articles/new-development/renaissance-for-pumped-storage-in-europe.html

Biomass Energy

The whole process of bioenergy can be depicted from the figure on the next page (See Figure 8). The first thing that should be known about the anaerobic digestion is that it offers representative advantages among all the other forms of bioenergy production. The process of the bioenergy production is considered to have the highest energy efficiency and represents one of the environmentally valuable technologies.

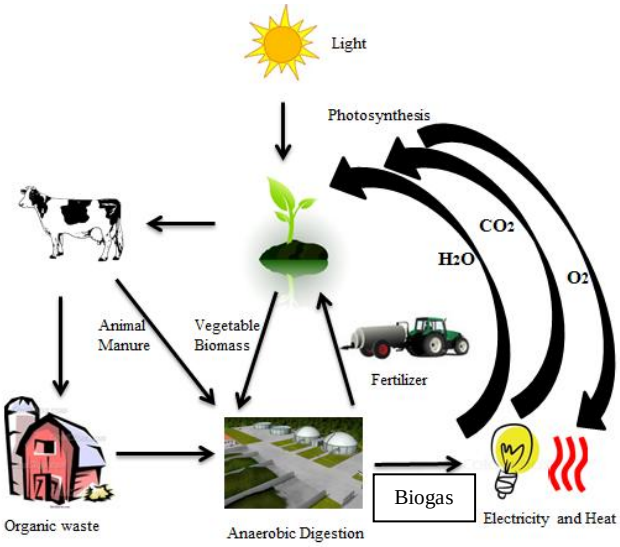

Figure 8 Representation of the sustainable cycle of anaerobic co-digestion of animal manure and organic waste
Source: IEA Bioenergy, Task- Energy from Biological Conversion of Organic Waste, January 2002 (Accessed on 01.03.2013) www.iea-biogas.net

Biomass can be classified into two categories: dry biomass (humidity percentage below 30%) and the wet biomass. Under the former type of biomass, the following categories can be classified: woody biomass, agricultural biomass, energy crops and industrial residuals. The latter consists of the anaerobic digestion, cycle presented in Figure 7. This type of biomass has gained significant market share in the last few years, especially in northern Europe. All the biological feedstock types represent resources for the production of biogas. Under feedstock resources that are being classified in three categories (solid, liquid and gaseous instances) the following can be mentioned: animal manure, slurries, crop residuals, slurries or organic waste

streams. These resources can be transformed, using various technologies in order to provide heat, electricity and even fuels for transportation.[57]

Large amount of animal waste and wet organic waste that are not optimally recycled can damage the environment. Therefore, the whole cycle (presented in figure 7) should be done properly in order to block the emission of greenhouse gasses (GHG), mitigation of global warming and the unwanted escape of organic waste into the environment. All this can be achieved through substituting the burning of firewood needed for cooking, kerosene for lightening or chemical fertilizers for agriculture.[58]

Biogas consists of a mixture substantially built of CH_4 (in proportion of 40 to 75%), CO_2 (25 to 55%) and the rest of 1 to 7% representing other gases.[59]

One of the most important advantages and benefits of biogas (beside the fact that it can be produced when needed and even stored) is that it does not need a special infrastructure in order to be distributed. It can use the same infrastructure as natural gas. Biogas can be used directly, hence it does not need to go through any other processes before using it for cooking for example.[60]

Representing 10% of the worldwide primary energy supply, the biomass energy finds itself on the fourth place after oil, natural gas and the coal. From the nearly 53 EJ of the global demand for biomass that is used for energy purposes, 86 % is accounted in production of heating and cooling that is directly used by the end consumers. From the remaining 14%, 75% is used to generate electricity and combined heat and power (CHP). The rest of 25% is used for the production of biofuels for land transport. The most important fuels that have been traded around the world for the past years are: wood pellets, biodiesel and last but not least ethanol. Analysing the numbers achieved

[57] Athanasios Angelis- Dimakis, Markus Biberacher, Javier Dominiguez, Giulia Fiorese, Sabine Gadocha, Edgard Gnansounou, Giorgio Guariso, Avraam Kartalidis. Methods and tools to evaluate the availability of renewable energy sources. Renewable and Sustainable Energy Reviews 2011; 15: 1182-1200

[58] Borjesson P, Berglund M. Environmental systems analysis of biogas systems. Biomass and Bioenergy 2006; 30:469-85

[59] Renewable Energy Concepts Homepage (Accessed on 10.03.2013) http://www.renewable-energy-concepts.com/biomass-bioenergy/biogas-basics/gas-composition.html

[60] Nielson JBH, Seadi TA, Popiel PO. The future of anaerobic digestion and biogas utilization. Bio resource Technology 2009; 100: 5478-84

during 2010, it can be mentioned that nearly 18 million tonnes of solid biomass fuels have been traded globally. Approximately 90% of these solid biomass fuels were pellets, wood waste and fuel wood. Although the wood pellets did not constitute such a great share of the whole, its relevance is growing due to its simple and affordable shipment methods; even over long distances. Out of all pellets produced worldwide, Europe consumes nearly 85%, where Sweden alone accounts for one fifth of the consumption.[61]

Current status of the biomass energy market

A significant part of the increment in the production of primary energy derived from biogas has arisen in Germany. In 2010, Germany produced 6.7 Mtoe of primary energy. This represents 61% of the entire production of the European Union.[62]

Biomass heating (and cooling) markets

In 2011 approximately 10 GW_{th} of biomass heating capacity were brought online, amounting for a total of 290 GW_{th} by the end of the year. The importance of the modern biomass is noticed in the building sector, where in 2008 heat production amounted for 3.4 EJ. This number does not say much but it actually represents nearly 3.5 times the sum of geothermal and solar heat together.[63]

According to the data provided for 2010, solid biomass fuels have produced about 2.8 EJ of heat throughout Europe. This result is considered taking into account that the

[61] Global Status Report Renewables 2012 Homepage (Accessed on 01.03.2013) http://www.ren21.net/REN21Activities/GlobalStatusReport.aspx
[62] Observ'er. The State of Renewable Energies in Europe. 11th EurObser'er Report http://www.eurobserv-er.org/pdf/barobilan11.pdf
[63] Global Status Report Renewables 2012 Homepage (Accessed on 01.03.2013) http://www.ren21.net/REN21Activities/GlobalStatusReport.aspx

renewable municipal solid waste like paper, wood, leather and other are excluded. Around half of the total heat produced was used in France, Germany and Sweden.[64]

The use of biogas for heating purposes has also increased. In Europe (2010) the usage of biogas for heating consumption amounted for 63 PJ. In the United States for example the use of biogas in 2011 has met the demanded electricity for almost 750000 households.[65]

Domestic digesters are used mostly in developing countries where the biogas produced through this mechanism is consumed for cooking and in rare cases also for lightening and water heating. Nowadays the countries with the highest rates of domestic digesters consumption are China and India. In 2011, China was considered to have 43 million and India 4.4 million operating domestic biogas digesters.[66]

In 2011 the increase in the price of the heating oil has led to a higher consumption of pure or blended biodiesel. Statistics show that the use of liquid biofuels has risen up, particularly in the European countries including Germany, Portugal and Sweden.[67]

In developed countries, the use of biomass-fired boilers and stoves is increasing continuously because of their efficiency and affordability. In order to be able to imagine how the whole process has extended and developed, one only needs to look at Germany. In 2000, Germany had 3,000 installed wood pellets combustion units. By the end of 2011, there were up to 155,000 units installed.[68]

The same year, the use of stoves increased in Italy by 14% and in the United States by 34%. (13)

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[64] Observ'er. The State of Renewable Energies in Europe. 11th EurObser'er Report http://www.eurobserv-er.org/pdf/barobilan11.pdf

[65] Tom Frankiewicz.U.S. EPA Landfill Methane Outreach Program.15th Annual LMOP Conference & Project Expo (Accessed on 10.03.2013) http://www.epa.gov/lmop/documents/pdfs/ conf/15th/01Ganguli.pdf

[66] Hu Runqing. Energy Research Institute of the National Development and Reform Commission. (Accessed on 15.03.2013) http:// mnre.gov.in/mission-and-vision-2/achievements/

[67] European Biomass Association, Annual Statistical Report 2011 (Accessed on 19.03.2013) http://www. springboardbiodiesel.com/biodiesel-big-mandates-Initiatives-global

[68] Development of renewable energy sources in Germany (Accessed on 20.03.2013) http://www.erneuerbare-energien.de/fileadmin/ee-import/files/english/pdf/application/pdf/ee_in_deutschland_graf_tab_en.pdf

The use of absorption refrigeration chillers that produce a cooling effect using heat are not that spread worldwide. One of the countries that established an absorption refrigeration chiller until now, is Spain. The plant, built up by Geolit, supplies cold as well as warm water for approximately 35,000 square meters of buildings that are acclimatised.[69]

Biomass Power Markets

The global capacity of biomass power generation has increased from 66 GW in 2010 to 72 GW by the end of 2011. The process implies the generation of electricity that is produced through direct firing or co-firing of solid biomass, renewable municipal solid waste or liquid biofuels; among which 88.3% the power is generated using solid biomass fuels.[70]

The total operating capacity of bioenergy power plants in the United States taking into account the renewable municipal waste has reached 13.7 GW by the end of 2011. This represents an increase by 3% over the previous year.[71]

Europe's total installed capacity of biomass, by the end of 2011 amounted for 26.2 GW. The largest biomass power plant in the world is located in the UK. The plant has a capacity of 750 MW and is powered primarily with wood pellets that are mainly imported.[72]

By the end of 2010 China had a total capacity for generating biogas power of 800MW, while India only 91MW. The main sector where the liquid biofuel is used is the transport sector; but it has also great importance for the stationary power and

[69] Alliance for Green Heat. Residential Wood Heat Report Card. 15 February 2011. (Accessed on 20.03.2013) http://www.forgreenheat.org/resources/
[70] Global Status Report Renewables 2012 Homepage (Accessed on 01.03.2013) http://www.ren21.net/REN21Activities/GlobalStatusReport.aspx
[71] U.S. Federal Energy Regulatory Commission. Energy Infrastructure Update. December 2010 (Accessed on 20.03.2013) http://www.ferc.gov/legal/staff-reports/12-10-energy-infrastructure.pdf
[72] International Forest Industries Homepage. World's biggest plant plan approved (Accessed on 21.03.2013) http://www.internationalforestindustries.com/2011/04/01/worlds-biggest-biomass-plant-plan-approved/

combined heat and power generation application. Italy possesses the largest palm oil power station in the world and has a capacity of 100 MW.[73]

Transport Biofuel Markets

The most frequently used biofuels nowadays are ethanol (which is generated from corn and sugar cane) and biodiesel (which is produced from virgin plant oils, animal fats or even fish oil). The marine transport sector uses a significant part of biofuel resources. According to the literature, there is high incentive to use biofuel also for the aviation sector. The global production of ethanol declined slightly during 2011, amounting at the end of the year 86.1 billion litres in comparison to 2010 when the total production was of 86.5 billion litres. (See Figure 9)[74]

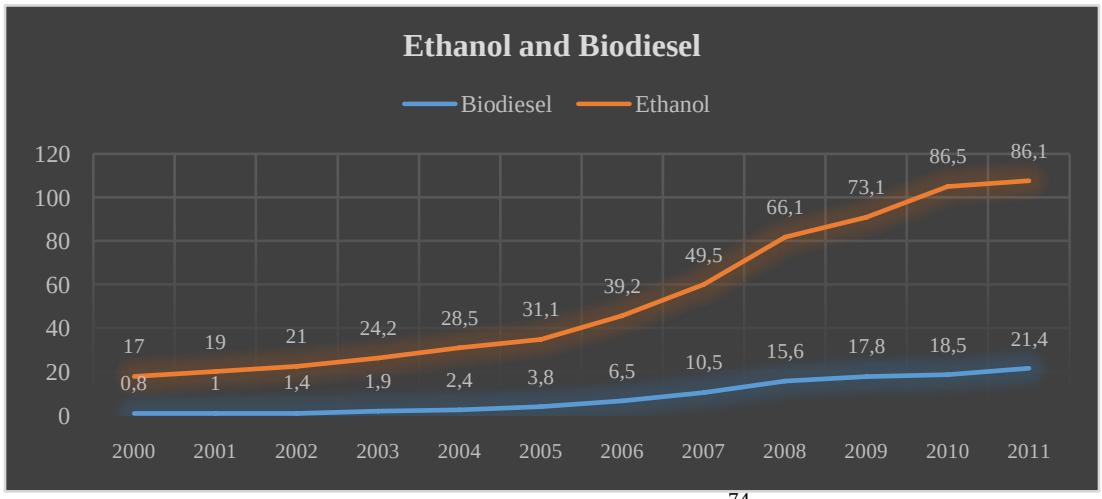

Figure 9 Production of ethanol and biodiesel between 2000 and 2011
Source: Global Status Report Renewables 2012 Homepage (Accessed on 01.03.2013) http://www.ren21.net/REN21Activities/GlobalStatusReport.aspx

Although during 2011, the worldwide production of ethanol (produced out of corn) was slightly down, the Unites States has experienced an increase in ethanol

[73] Global Status Report Renewables 2012 Homepage (Accessed on 01.03.2013) http://www.ren21.net/REN21Activities/GlobalStatusReport.aspx
[74] National Renewable Energy Laboratory. Biodiesel Handling and Use Guide (Accessed on 21.03.2013) http://www.nrel.gov/vehiclesandfuels/pdfs/43672.pdf

production that led to a new high record of 54 billion litres. The interesting part is that until 2010, the United States was an important biofuel importer. This radical change in 2011 came about because its exports have tripled from 1.5 billion litres to nearly 4.5 billion litres.[75]

Brazil, despite the fact that it was for many years the leader on the market for the production and export of ethanol, starting with 2008 it experienced some unfavourable economic and climate conditions. In 2008 the start of the economic crises affected Brazil just as it affected many other countries. Like every other situation almost every bad thing brings along a couple of other bad things. For example, in this case, despite the financial crisis, the prices of sugar have increased drastically and at the same time Brazil experienced poor sugarcane harvests caused by the hostile weather conditions.[76]

After the United States and Brazil, China ranks as the third in capacity of ethanol production with 2.1 billion litres in 2011, followed by Canada (production of 1.8 billion litres), France (1.1 billion) and Germany on the last place with only 0.8 billion litres ethanol.[77]

On the other hand, the production of biodiesel in 2011 faced another fate compared to ethanol production. Its production increased by approximately 16% with respect to the previous year. Therefore, the global biodiesel production amounted to 21.4 by the end of 2011. The country that made a huge progress in 2011 was the United States. Its production skyrocketed experiencing an increase of 159%, in absolute terms, up to 3.2 billion litres of biodiesel. The United State was able to overtake the biodiesel market leaders Germany, Brazil, Argentina and France in just one year becoming the

[75] Renewable Fuels Association Homepage (Accessed on 21.03.2013) http://www.ethanolrfa.org/exchange/entry/2011-ethanol-exports-total-1.19-billion-gallons-brazil-accounts-for-one-thi/

[76] OECD Observer Homepage (Accessed on 21.03.2013) http://www.oecdobserver.org/m/fullstory.php/aid/3748/Brazil_92s_biofuel_sector:_What_future_.html

[77] Bioenergy in Germany: Facts and Figures (Accessed on 30.03.2013) http://www.biodeutschland.org/tl_files/content/dokumente/biothek/Bioenergy_in-Germany_2012_fnr.pdf

first. This entire jump made by the United States was due to government tax credits and usage mandates.[78]

Although remaining the biggest regional biodiesel producer, Europe experienced a decline in the production of biodiesel in 2011. Even Germany and France that are top producers in Europe experienced drops in their productions.[79]

The use of purified biogas known as biomethane started to gain importance and therefore more market share. Mostly in the European countries, biomethane plays an important role in the transport sector because it is being inserted into the natural gas network. Looking at the statistics in 2010 out of 70,000 buses that were operated with natural gas in Europe, 13% were functioning on biomethane. A particular example is Sweden where a significant number of buses (39,000) are operated on a mix of nearly 60% biogas and 40% natural gas.[80]

Worldwide a couple of important airline companies have started to be more environmentally aware of the GHG emissions impact their business is having on the environment, hence their interest in the use of biofuels is increasing. Therefore, airlines like Finnair, KLM Royal Dutch Airlines, Lufthansa, Thai Airways, United Airlines or Alaska Airlines have started in 2011 to acquire airplanes that run on biofuels.[81]

Not only airline companies show interest in the purchase and use of the biofuels, but also the US Navy who intends to build a "Green Strike Force". The Navy intends to replace approximately 50% of its fossil fuel demand with alternative fuels and therefore signed some contracts that certify the purchase of 1.7 million litres of

[78] Reuters Homepage (Accessed on 30.03.2013) http://www.reuters.com/article/2011/02/04/us-usa-bi0diesel-idUSTRE7130H920110204
[79] OECD Observer Homepage (Accessed on 21.03.2013) http://www.oecdobserver.org/m/fullstory.php/aid/3748/Brazil_92s_biofuel_sector:_What_future_.html
[80] Global Status Report Renewables 2012 Homepage (Accessed on 01.03.2013) http://www.ren21.net/REN21Activities/GlobalStatusReport.aspx
[81] The Seattle Times. Alaska Air starts test of fuel-powered flights (Accessed on 01.04.2013) http://seattletimes.com/html/businesstechnology/2016719598_alaska09.html, http://www.renewableenergyworld.com/rea/news/article/2011/11/advanced-biofuels-taking-off-use-of-non-food-bio-based-jet-fuel-climbing

biofuels. The biofuel is supposed to be used on jets and vessels. This change in fuel has been mostly encouraged by the drop of the biofuels price.[82]

Nuclear energy

Abu-Khader states in his paper entitled "Recent advances in nuclear power: A review" that" *Nuclear power alone won't get us to where we need to be, but we won't get there without it*".[83] His statement reveals a truth that is probably well known by other scientist but hard to argue with parties that fight against the development of the nuclear energy.

The birth of the first commercial nuclear power station was in 1950. The basic principle of nuclear technology is that it splits the atoms contained in specific elements. The beginning of nuclear technology took place in the 1940s and the greatest developments were reached during the Second World War. Back then, researchers were tasked with producing bombs by pulling apart the atoms of isotopes like uranium or plutonium. Once the War finished, the purpose of the nuclear technology was power generation. The interesting part is that nowadays the nuclear generated energy is equal to the entire amount generated in 1960 from all sources combined.[84]

According to the International Atomic Energy Agency (IAEA) by 2009 the number of the countries that begun to show interest in the building and development of their first nuclear power plant has reached 52. Out of the nuclear plants that have been built up to now, the patterns show that such plants were constructed especially in

[82] Renewable Energy World Homepage (Accessed on 01.04.2013) http://www.renewableenergyworld.com/rea/news/article/2011/12/u-s-navy-fuels-green-strike-force-with-12-million-biofuels-contract
[83] Mazen M. Abu-Khader. Recent advances in nuclear power: A review. Progress in Nuclear Energy 2009;51: 225-235
[84] World Nuclear Association. Nuclear Power in the World Today (Accessed on 04.04.2013) http://www.world-nuclear.org/info/Current-and-Future-Generation/Nuclear-Power-in-the-World-Today/#.UX4s8rX-GHg

areas where the nuclear facility had the possibility to be privately owned. There also exists a positive correlation between the existence of the nuclear power plant and the dimension, wealth, political stability of the economy and the efficiency of government. Among other characteristics that determine in some way the construction of a nuclear plant are the size of the national grid, the fuel supply security that is required for the production of the electricity and the existence and possibility of international grid connections.[85]

In comparison to renewable energy, which is highly promoted and supported by most of the population, nuclear energy has supporters like International Atomic Energy Agency (IAEA) and Environmentalists for Nuclear Energy (EFN) on one hand and opponents such as Greenpeace or the Nuclear Information and Resource Service (NIRS) on the other hand. Every party has its own arguments either for or against the development of the nuclear energy. The arguments that both parties rely on will be presented further in this paper.

People that are supportive of renewable sources of energy try to give a simple solution to the current situation by saying that saving energy will help cover the upcoming demand in energy. This is a narrow solution because looking at the daily growth of population and life expectancy energy consumption reduction is clearly not the right choice, if even possible.

Looking only at China's and India's population, which in 2012 accounted for 1.36 billion (expected to increase to 1.45 billion by 2040) respective 1.22 billion (expected to increase to 1.52 billion by 2040) it is obvious that the current resources of energy are not sufficient to sustain the upcoming generations.[86]

Nuclear power is considered to be efficient, reliable, economically feasible and supplies nearly one fifth of the global demand for electricity. Studies reveal that nuclear energy is clean because its emissions are infinitely smaller than the pollution

[85] Jessica Jewell. Ready for nuclear energy? : An assessment of capacities and motivations for launching new national nuclear power programs. Energy Policy 2011; 39: 1041- 1055
[86] India Online Pages Homepage. India and China Population (Accessed on 02.04.2013) http://www.indiaonlinepages.com/population/compare-india-china-population.html

derived from their fossil fuel cousins. One key part of the nuclear power process that still needs to be developed, is waste management, including storing and disposal methods. Waste management is classified in five categories depending on the level of uranium that is being wasted. The time frame of the waste management also plays a role in the classification as there are different methods used in case of a short- term nuclear waste or long-term nuclear waste. Of course, every type of waste management includes its risks because it is dealing with highly radioactive material that can harm the environment badly for many generations if not managed properly.[87]

Current status of the nuclear power markets

In recent years nuclear fission reactors supplied nearly one sixth of the global energy demand. This represents approximately 6% of the global primary energy requirements.[88]

At a global scale, more than 400 power nuclear fission reactors are presently running. The existing reactors deliver a total power amounting for 270 GWe. This reactors are categorized as second generation systems because they were built in the seventies and eighties after the first generation systems that were developed in the early sixties even fifties.[89]

One of the most important criteria regarding the nuclear fission reactors is their safety. Fermi built the first reactor in 1942. His model of reactor included basic applications of redundancy and diversity. Even since the fifties the defense-in depth safety strategy was known and applied. This type of strategy operates using multiple, redundant and independent layers of safety methods for the core of the reactor. The three main functions that are fulfilled by using the safety strategies are: control of the

[87] Mazen M. Abu-Khader. Recent advances in nuclear power: A review. Progress in Nuclear Energy 2009;51: 225-235
[88] J.G.Marques.Evolution of nuclear fission reactors: Third generation and beyond. Energy Conversion and Management 2010; 51: 1774-1780
[89] World Nuclear Association. Safety of nuclear power reactors. Information paper no. 6. WNA 2008 (Accessed on 05.04.2013) http://www.world-nuclear.org/

power and of the reactivity, cooling the fuel and last but not least the limitation of the radioactive material. [90]

The two accidents that took place at Three Mile Island (Pennsylvania, US) in 1979 and Chernobyl (Ukraine) in 1986 have affected the progress of the nuclear power development. In both cases the incident occurred because the core of the reactor melted. The former accident is a living proof of the effectiveness of the defense-in-depth strategy because the greatest part of the fission products were deposited by the Three Miles Island concept.[91] More details to both accidents will be described in a further section that deals with the supporters and opponents of the nuclear power.

Nowadays there are 31 countries that accommodate around 434 commercial nuclear power reactors, summing up a total installed capacity of 372 GWe. Analyzing this amount on a larger scale it represents three times more total capacity than France and Germany have considering all sources. As a future perspective, 60 nuclear power reactors are currently being constructed, with more than 150 planned.[92]

Around the world there are at least sixteen countries that rely on nuclear power for at least 25% of their electricity. France for example supplies nearly 75% of its power from nuclear sources. Furthermore Belgium, Bulgaria, Czech Republic, Hungary, Slovakia, South Korea, Sweden, Switzerland, Slovenia and Ukraine rely on nuclear power for satisfying 33% of the electricity demand. Descending, Japan and Finland supply around 25% of the demanded energy from nuclear sources while the USA only 20%. There are also countries that do not have nuclear power plants but still consume energy from nuclear. Two good examples are Italy with around 10% and with Denmark 8% of their energy demanded coming from imported nuclear energy.[93]

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[90] Frisch W, Gros G. Improving the safety of future nuclear fission power plants.Fusion Eng Des 2001;56–57:83–93

[91] Cooper JR, Randle K, Sokhi RS. Radioactive releases in the environment: impact and assessment. Chichester: Wiley; 2003. p. 62-149. ISBN 0-471-89924-0

[92] World Nuclear Association. Nuclear Power in the World Today (Accessed on 04.04.2013) http://www.world-nuclear.org/info/Current-and-Future-Generation/Nuclear-Power-in-the-World-Today/#.UX4s8rX-GHg

[93] World Nuclear Association. Nuclear Power in the World Today (Accessed on 04.04.2013) http://www.world-nuclear.org/info/Current-and-Future-Generation/Nuclear-Power-in-the-World-Today/#.UX4s8rX-GHg

Third generation of systems

The development of the third generation of reactors has brought significant improvements that deal with the reduction of the radioactive releases that may also occur in case of a core melting accident. These types of reactors were created in the nineties. Researchers argue that they be used predominantly in the next decade and will help with the creation of the fourth generation of reactors that will be equipped with an improved method of using uranium resources and will have a more sustainable way of managing radioactive waste.[94]

The characteristics of the third generation of reactors are standardized, have a more rugged design, reduced capital expenses, reduced creation time, passive safety is improved significantly because features do not request active control, very low probabilities that a core will melt and in case it does, because of the new measures the impact on population and environment will be reduced, construction resistant to an aircraft impact, longer operative lifetime (60 years), longer gap between two fueling processes and last but not least a higher burn-up process that enable a reduction in the fuel used and amount of waste. A couple of reactors that belong to the third generation are: ABWR (developed by General Electric and Hitachi, power generation of 1.37 GWe), AES-92 (developed by Gidropress, power generation of 1.00 GWe), EPR (Areva, 1.60 GWe). The construction of the next three reactors will finish by the end of 2012: AP600, AP1000 (developed by Westinghouse, power generation of 0.65 respectively 1.12 GWe) and APR-1400 (developed by KHNP, Westinghouse, power generation of 1.30 GWe). There are also other reactors that are still waiting to receive their licenses.[95]

Most of the fission reactors that run today are operating in an open fuel cycle that requires the mining of uranium. Through this process the uranium is enriched in a specific isotope being partially fissioned in the reactor stocked in the end. Looking at

[94] Frisch W, Gros G. Improving the safety of future nuclear fission power plants.Fusion Eng Des 2001;56–57:83–93

[95] J.G.Marques.Evolution of nuclear fission reactors: Third generation and beyond. Energy Conversion and Management 2010; 51: 1774-1780

the percentage of the uranium that is actually used by a 1.0 GWe Light Water Reactor (LWR) that produces 6.6 TWh per year it is important to be mentioned that from the 150 tons of natural uranium that are being converted into approximately 27 tons of enriched uranium nearly 1 tone will be actually fissioned.[96]

Regarding the discharge of burn-up rate it is important to be noticed that it has witnessed an increased in the last few years and is supposed to increase once again with the introduction of the new designs. The economic gain that should or should not arise from the increasing discharge burn-up above 60 GWd/tHM is not clearly demonstrated in the literature. With the current reactors, the discharge burn-up rate is estimated to be around 55 GWd/tHM. This represents nearly twice as much discharge burn-up amount than in the eighties. Therefore the open fuel cycle is considered to have its limitation regarding the waste of valuable resources.[97]

Considering that 5.5 Mt of uranium resources were identified and some considerable amounts are still to be added to this amount, a total of 38 Mt represents the total uranium resources. All things considered it is estimated that if the consumption of uranium would stay at the same level as it is today of 60-70 kt per year it would have enough identified resources to last up to 80 years (considering a PWR or BWR reactors). If the entire amount of uranium is considered then the resources would last up to 500 years.[98]

Fourth generation systems

As mentioned in the beginning of the nuclear chapter the fourth generation systems are strongly believed to demonstrate meaningful advancement in the fields of economy, safety, environmental awareness and proliferation resistance. In 2001 The Generation IV International Forum (GIF) was established in order to support and

[96] Petrunik K. ACR-1000 ready to deliver: evolutionary technology experienced team and proven track record. In: Nuclear technology international 2008. London: Sovereign Publications; 2008.
[97] Sengler G, Forêt F, Schlosser G, Lisdat R, Stelletta S. EPR core design. Nuclear Engineering and Design. Elsevier 1999;187:79–119
[98] Nuclear Energy Agency. Uranium 2007: resources, production and demand. Paris: NEA; 2008. ISBN 978-92-64-04766-2

develop the things that are essential for those types of nuclear power plants. The three main categories of design that represent a development from the third generation of system are the following: first of all, a considerable change is that a large number of designs had a closed fuel cycle, second of all, out of six designs, three of them are fast reactors and last but not least four of them are high temperature designs. Therefore these type of reactors are able to produce hydrogen or synthetic fuels hence have a positive influence on the transport systems.[99]

The accident that was reported at the Fukushima Daiichi nuclear power plant directly influenced the development of the nuclear energy, which dropped after the incident from a capacity of 375 GWe in 2010 to a capacity of 368 GWe in 2011. During the timeframe 2010 until 2011 projects of building new reactors have started; the number reached 16 and after the incident in 2011 dropped to 4. The forecast that has been made predicts that the global nuclear power capacity will increase until 2030 from 370 GWe in 2010 to 501 GWe. (80)

According to IAEA a couple of countries that showed strong interest in the development of nuclear power plants revised their position after the Fukushima Daiichi and remained in a stand-by-position in order to see in what direction the public opinion on the subject matter of nuclear energy will head.[100]

Even though nuclear energy has been at the forefront of technology since 1954, when it was first widely distributed, fossil fuels still surprisingly power the majority of energy needs. As of 2011 only 12,3% of the energy used worldwide directly derives from nuclear energy. This is achieved through a sophisticated network of 435 active nuclear reactors operating in 30 countries with an additional 60 plus units due online in the near future. Cumulative, the total experience of the industry since the late 60s and 70s totals more than 14.700 reactor years of experience. An interesting development in reactor technology is linked to economics of scale as reactors grow more in both efficiency as well as physical size. Most of the late 60s designs are not

[99] J.G.Marques.Evolution of nuclear fission reactors: Third generation and beyond. Energy Conversion and Management 2010; 51: 1774-1780

[100] IAEA. International Status and Prospects for nuclear power 2012 (Accessed on 08.04.2013) http://www.iaea.org/About/Policy/GC/GC56/GC56InfDocuments/English/gc56inf-6_en.pdf

available anymore for rebuilding today. A more concrete example of this phenomenon is the half point of the 20th century, commercial reactors were not bigger than 50 MW(e), while current reactors range between 1000 to 1500MW(e) with a mean of 851 MW(e) when looking at all of the reactors online as of summer 2012. These figures however do not indicate that the industry is only absolutely moving in one direction, mainly bigger. The production of smaller reactors is still bustling with reactors in the small end of the scale meaning under 300MW (e). These are designed for remote communities in remote areas where the possibility of linking the main grid to the community are vastly reduced. The whole life cycle of nuclear fuel is made up of two parts. The first half of the cycle is called "front-end activities" which include the entire process from the mining phase to fuel fabrication in preparation for use in the available reactors. The latter part of the cycle is appropriately named "back-end activities" which basically includes everything from the moment the fuel rod leaves the reactor, meaning everything from storage of the toxic material to waste disposal.[101]

Life cycle of a nuclear reactor

Front end

With a spot price hovering around $130/kg of uranium at the end of July 2012, it is no wonder that the mining capacity is increasing. The incentive to find new deposits and extract the uranium is quite high and therefore year over year absolute amounts of uranium extracted worldwide have increased by 55 tonnes in 2010 over 2009. Coincidentally, economies of scale and industry clusters can easily form in this industry. The distribution of countries with known extractable deposits is extremely small. In total 15 countries account for 92% of known deposits worldwide with the

[101] IAEA. International Status and Prospects for nuclear power 2012 (Accessed on 08.04.2013) http://www.iaea.org/About/Policy/GC/GC56/GC56InfDocuments/English/gc56inf-6_en.pdf

leading three producers (Australia, Canada and Kazakhstan) accounting for more than 62% of total production for 2011.[102]

Most of the countries with known deposits all have the classical fuel types available: phosphates, nonferrousores, carbonatite, black shale and lignite. In total about 10 Mt of known Uranium resources of these types is estimated worldwide. Only a few countries have unconventional thorium deposits. The magnitude of deposits here is about 6 Mt.[103]

These resources once extracted and processed can be used in Light water reactors (LWRs), pressurized heavy water reactors (PHWRs). The LWRs can use enriched uranium of which 13,000 t U per year can be produced of which 7,000 t U is currently demanded. Capacity of producing natural uranium for the PHWRs is at 4,000 t U per year of which 3,000 t U is currently demanded. The last type of fuel is recycled fuel also called MOX fuel. The capacity for this type is only 250 t U.[104]

Back end

When the fuel rods are spent, depending on the country, it can be either classified as high level waste (HLW) or seen as a product ready for reprocessing and reuse. Unfortunately, for the countries that want to store and dispose and not reuse and process, they need to rely on their own ability as a market does not exist for buying such services. With this said, the deposits of spent flue rods of HLW facilities keeps on growing worldwide. This is an interesting prospect as the rods will have to be carefully stored for more than 100 years in order to ensure non contamination. In total about 350k t HM of fuel discharge was released in 2011 of which 240k t HM were stored with the rest being reprocessed. The countries that can do such reprocessing

[102] IAEA. International Status and Prospects for nuclear power 2012 (Accessed on 08.04.2013) http://www.iaea.org/About/Policy/GC/GC56/GC56InfDocuments/English/gc56inf-6_en.pdf
[103] IAEA. International Status and Prospects for nuclear power 2012 (Accessed on 09.04.2013) http://www.iaea.org/About/Policy/GC/GC56/GC56InfDocuments/English/gc56inf-6_en.pdf
[104] IAEA. International Status and Prospects for nuclear power 2012 (Accessed on 09.04.2013) http://www.iaea.org/About/Policy/GC/GC56/GC56InfDocuments/English/gc56inf-6_en.pdf

are few and in between; France, India, Russia and the UK make up the whole market for this. Japan almost joined this league in 2011 but after the Fukushima incident plans to bring the build facility were put on hold. Other countries such as Finland and Sweden but also France are advancing their technology in underground rock characterization facilities. This means that the countries can safely deposit the material in remote deep underground facilities. France has just signed a contract at the beginning of 2012 for such a facility, due to be open in eastern France at the beginning of 2025. In the European Union, a harmonisation of standards is also taking place to ensure that as of August 2015 all national programmes EU wide will be on the same level of quality and safety.[105]

Decommissioning

At the end of the life cycle of a power reactor three options exist for decommissioning: immediate dismantling, long term safe enclosure after which dismantling, and entombment of the reactor for good. Of course the option chosen depends on a variety of factors, including reactivation requirements, job preservation, and availability of funds, costs, regulation and waste management strategies. At the end of 2011 there were 124 reactors worldwide fully shut down according to the various strategies mentioned above.[106]

From nuclear to sustainability

One might think that fusion and fission are based on the same principle when it comes to the production of energy, but the two are quite different. Both rely on the energy that is being released out of high order atomic bonds placed in-between the particles inside the nucleus. The central difference among these two procedures is that

[105] IAEA. International Status and Prospects for nuclear power 2012 (Accessed on 09.04.2013) http://www.iaea.org/About/Policy/GC/GC56/GC56InfDocuments/English/gc56inf-6_en.pdf
[106] IAEA. International Status and Prospects for nuclear power 2012 (Accessed on 10.04.2013) http://www.iaea.org/About/Policy/GC/GC56/GC56InfDocuments/English/gc56inf-6_en.pdf

fission represents the division of an atom into many smaller atoms while fusion is based on the merging of smaller atoms into a single large one. Another difference is that the former one does not take place in nature while the latter one arises in stars (sun). The part that is considered to be of great value to opponents of nuclear energy is that the fusion reaction produces few radioactive particles.[107]

According to most of the literature, the fuels that are being used in the fusion process are categorized as being "limitless". The two major fuels used in the nuclear fusion process are: lithium and deuterium. These two resources are considered to be endless because of their worldwide spread. Hence lithium can be found in seawater while deuterium in all kind of water.[108]

Fusion is also described as being "sustainable". The term sustainability can be related in many ways but the most important aspect is that it improves or at least maintains the wellbeing of the human life. The way the population and the environment live together is not sustainable at all because over three quarter of the energy supplied derives from fossil fuels. Nuclear fusion is seen by many scientist as an alternative to nuclear fission which still needs to be developed in order to become the new revolutionary source of energy.[109]

The potential and benefits of the nuclear fusion are impressive. Burning 100 tonnes of coal delivers the same quantity of energy as nuclear fusion which requires only few litters of water and the amount of lithium that is incorporated in a normal laptop battery and no CO2 emissions at all. (99)

Iter is a fusion reactor which is being constructed in France and should be finished until 2020. The main purpose of this reactor is to measure the viability of fusion on a larger scale. It is supposed to present a great success story and therefore a complete power plant is planned to start in the 2030s. The biggest challenge that the fusion

[107] Nuclear Fission vs. Nuclear Fusion (Accessed on 10.04.2013) http://www.diffen.com/difference/Nuclear_Fission_vs_Nuclear_Fusion
[108] Nuclear Fission vs. Nuclear Fusion (Accessed on 10.04.2013) http://www.diffen.com/difference/Nuclear_Fission_vs_Nuclear_Fusion
[109] A. M. Bradshaw, T. Hamacher, U. Fischer. Is nuclear fusion a sustainable energy form? Fusion Engineering and Design 2011; 86:2770-2773

reactor will face will be the amount of money that will be invested in it in order to make it reliable and competitive. This is directly proportional with the energy that will be supplied to the people at a price which they will be prepared to pay.[110]

Why are people against or afraid of nuclear power?

Most of the time people that are against the nuclear energy are against two words: "nuclear" and" radiation".

Among others reason, the biggest argument of the parties that fight against the development of the nuclear energy is based on two accidents that happened in more than half a century since the operation of the first nuclear reactor.

One incident took place in 1979 at The Three Mile Island (TMI) in Pennsylvania, USA. What caused the accident was the failure of the cooling circuit that lead to a fraction of the core located in the second reactor to melt. All the radioactivity that was released because of this malfunctioning was released in the reactors housing. No one died during this accident, which demonstrated the safety and reliability of nuclear power plant. The biggest issue back then remained the possible irradiation of the people who lived in that area. The Department of Health of Pennsylvania, showed concerns about the possible health problems of the inhabitants and started a program that kept track in the next 18 years of all people that were living within 8 kilometers from the Three Mile Island. The results were very satisfying because out of more than 30,000 of people registered in the program, none of them showed health problems that could indicate a possible correlation between the disease and the nuclear accident.[111]

[110] The Guardian Homepage (Accessed on 11.04.2013) http://www.guardian.co.uk/science/2012/sep/16/nuclear-fusion-iter-jet-forshaw
[111] World Nuclear Association Homepage (Accessed on 12.04.2013) http://www.world-nuclear.org/info/inf36.html

The accident at Chernobyl is the second worst disaster and biggest environmental one in the world. In 1986 at the nuclear plant Chernobyl located near the town Prypjat in Ukraine, the 4th unit of the reactor melted and caused an incident without precedent. According to proof found, the accident was caused and triggered by deficiencies in the construction of the nuclear reactor and the errors of the operating system. In practical terms, the accident happened due to insufficient security techniques and the will of people to experiment the performance of the reactors. What happened at Chernobyl could have been easily prevented. Through the explosion, large amounts of radioactive material were spread into the atmosphere and were distributed mainly over the northeastern area of Chernobyl but were also carried by the wind to come other parts of Europe. The number of people who died because of that accident was never precisely published. The radiation that was emanated by the explosion was also seen as a possible cause for diseases like cancer that affected a lot of people in the years that followed.[112]

But looking at another side of this perspective: How many people die yearly in the fossil fuel industry, mining coal or during the construction of the wind power and hydropower plants?

In America, statistically speaking around 20,000 people day every year because of the effects caused by the fossil fuel industry.[113] Apart from that more than 3000 American soldiers died between 2003 and 2007 during the fuel supply convoys in Iraq and Afghanistan.[114] Also it is estimated that around 2,900 Americans die yearly because of their exposure to the intense pollution of the coal mining regions like Appalachian, not to mention the rest of them who get serious diseases.[115]

[112] Atomkraftwerk Homepage (Accessed on 11.04.2013) http://www.atomkraftwerk.biz/tschernobyl.html
[113] Econ Media Library Homepage (Accessed on 11.04.2013) http://econ4.org/media-library/20000-people-a-year-die-from-effects-of-fossil-fuel-generation
[114] Lopez, T. Saving energy saves lives says new Army exec. U.S. Army. 2010 (Accessed on 15.04.2013)
[115] Better Future Project Homepage (Accessed on 15.04.2013) http://www.betterfutureproject.org/wp-content/uploads/2012/02/Energy-Casualties.pdf

If it were to sum up at a global scale more than 800,000 people die every year because of the effects that air pollution has on their health. This is mainly the case in developing countries where the air pollution is very high.[116]

Looking at the next graph there can be easily noticed that the number of accidents that have occurred during the construction of wind turbines has massively increased from 1996 until 2012 which actually describes a trend because the construction of wind turbines has gone up in the recent years and therefore also the number of accidents. (See Fig. 10).[117]

The next table represents increase of the numbers of accidents that occurred from 1970 until 2012. (See Table 2)

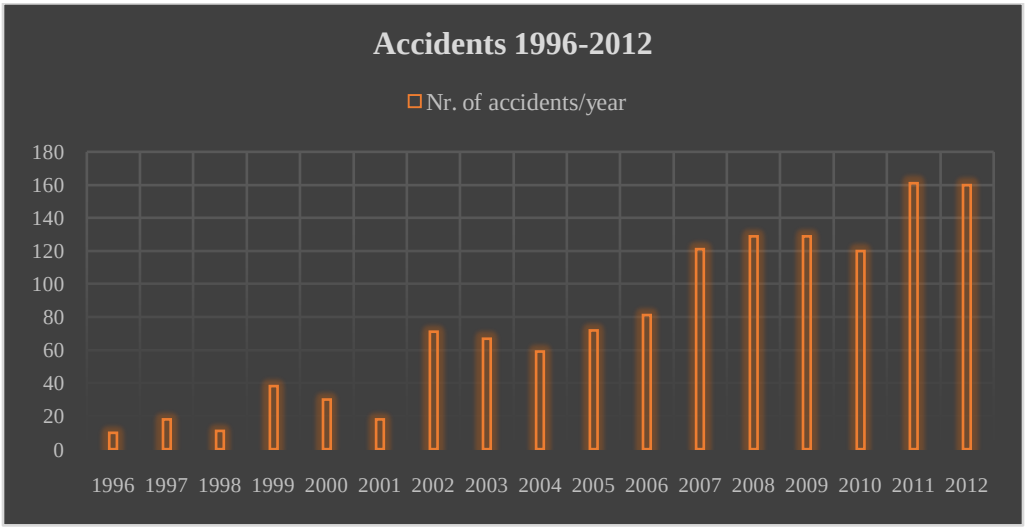

Figure 10 Upward trend in the number of wind turbine accidents
Source: Caithness Windfarm Information Homepage (Accessed on 16.04.2013) http://www.caithnesswindfarms.co.uk/page4.htm

[116] OGC Network Homepage (Accessed on 15.04.2013) http://www.ogcnetwork.net/node/349
[117] Caithness Windfarm Information Homepage (Accessed on 16.04.2013) http://www.caithnesswindfarms.co.uk/page4.htm

Year	‘70	‘80	‘90	‘00	‘01	‘02	‘03	‘04
Number	1	9	98	30	17	70	66	59
Year	‘05	‘06	‘07	‘08	‘90	‘10	‘11	‘12
Number	71	82	124	130	130	119	162	160
Total	**1328**							

Table 2 Total number of accidents ’70-‘12
Source: Caithness Windfarm Information Homepage (Accessed on 16.04.2013)
http://www.caithnesswindfarms.co.uk/page4.htm

Table 3 gives a brief preview on the documented accidents that included human injuries.

Year	‘70	‘80	‘90	‘00	‘01	‘02	‘03	‘04
Number			5	4	1	2	2	2
Year	‘05	‘06	‘07	‘08	‘90	‘10	‘11	‘12
Number	6	10	16	16	9	14	12	15
Total	**114**							

Table 3 Human injuries
Source: Caithness Windfarm Information Homepage (Accessed on 16.04.2013)
http://www.caithnesswindfarms.co.uk/page4.htm

Most of the accidents were caused by blade failures. This implies that either the whole blade or only pieces of it were launched from the turbines and injured the

people located near the wind turbine. Along the years over 251 accidents were reported because of the blade failures.[118]

In 1998 Paul Scherrer Institute in Switzerland published a 400 page report which examined the external costs from another angle; meaning other consequences that might incur from the production of energy besides health and environment expenses. The reported considers according to the existing data that out of 4290 accidents that were related to the energy sector, 1943 were categorized as severe and were caused by different energy sources. If it were to sum up, the number of fatalities were estimated at about seven times the victims that were considered in the World Trade Center catastrophe: 15.000 deaths in the oil sector, more than 8000 in the coal and 5000 in the hydro sector. Another thing that should be considered is that a lot of energy chains often have to place their parts in different countries. If it were to consider the number of deaths that have taken place on a per Terawatt/year basis the following would come out: 342 in the coal industry, 883 in hydro, 85 in gas and only 8 in the nuclear power sector. Taking into consideration the whole amount of power 2500 TWh that has been delivered over 3.5 years (representing 14% of the global electricity demand) the number of people who die in the coal industry is much higher (342 deaths, every 1.5 years, 30% of the global energy demand). (See Table 4)[119]

[118] Source: Caithness Windfarm Information Homepage (Accessed on 16.04.2013) http://www.caithnesswindfarms.co.uk/page4.htm

[119] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 17.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg

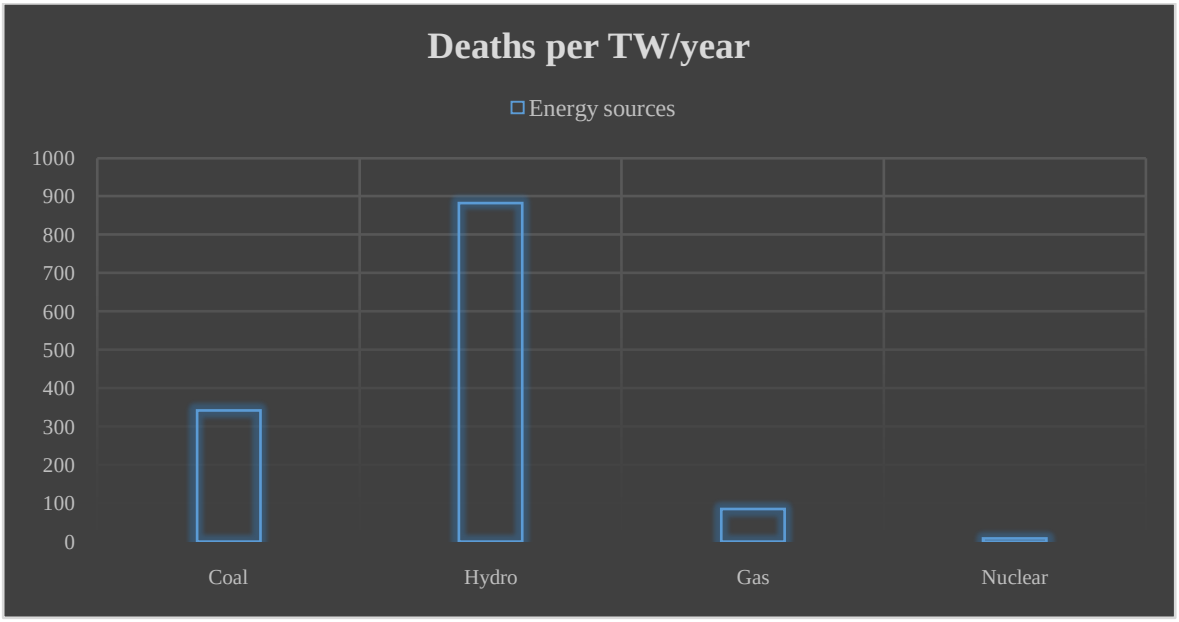

Figure 11 Deaths per TW per year
Source: World Nuclear Association. Energy Subsidies and External Costs (Accessed on 17.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg

According to a report released by OECD in 2010 the balance of fatalities look as presented in the following table. (See Table 4)

	OECD			Non-OECD		
Energy chain	**Accidents**	**Fatalities**	**Fatalities/Gwey**	**Accidents**	**Fatalities**	**Fatalities/Gwey**
Coal	75	2259	0.157	1044	18017	0.597
Coal(data for China 1994-1999)				819	11334	6.169
Coal (without China)				102	4831	0.597
Oil	165	3713	0.132	232	16505	0.897
Natural Gas	90	1043	0.085	45	1000	0.111
LPG	59	1905	1.957	46	2016	14.896
Hydro	1	14	0.003	10	29924	10.285
Nuclear	0	0	-	1	31	0.048
Total	**390**	**8934**		**1480**	**72324**	

Table 4 Total severe accidents in different energy sectors 1969-2000
Source: OECD/NEA 2010, Comparing Nuclear Accident Risks with those from other energy sources. NEA No. 6861 (Accessed on 17.04.2013) http://www.oecd-nea.org/ndd/reports/2010/nea6862-comparing-risks.pdf

According to the entire analysis described above, the number of fatalities that have occurred in the renewable energy sector is by far higher than that in the nuclear power sector. In conclusion the argument of the entities that fight against the development of the nuclear energy pretending that it represents death for the global population is not sustained by the database along the years.

Global energy consumption scenario

The following graph illustrates historical data and also a possible path that all energy sources might take in the following years.(See Figure)

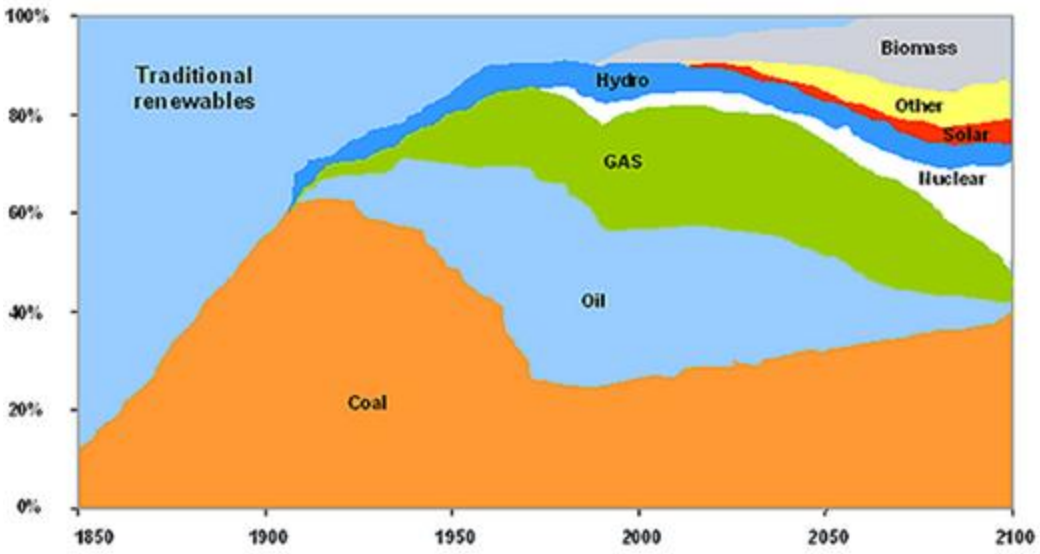

Figure 12 Global energy consumption scenario
Source: HMS Homepage. Primary Energy & Coal (Accessed on 18.04.2013) http://hms-ag.com/en/energy-coal-market/primary-energy-coal.html

One of the most important things that need to be mentioned is that according to the graph, the fossil fuel industry including oil, coal, and gas will remain the main source of electricity of the nation.

Another important aspect depicted from the graph is that nuclear power will start to gain higher market share as the fossil fuel industry will become scarcer, derived by the finite character that it has.

The last category belonging to the world energy mix contains the renewable energy sources. According to the graph the use of biomass will increase in the following years. The same is to be noticed also in the case of the solar power. The only problem with renewable sources is that they are not reliable and controllable do to the fact that they are negatively influenced by the climate change.

Subsidies

One of the most highly subsidized sectors of the modern economy is the energy sector. Particularly a disproportionate supply of energy provided by renewable energy compared to market driven demand shows that out of all of the energy producing technology available to public utility companies these require the most subsidies. To a certain extent the same hypothesis has been made for classical coal and nuclear energy but the evidence there is scarce and not supported by reliable information. However, what is actually taking place for sure are subsidies across the board in different parts of the world including the European Union, where a wide subsidy plan is being executed uniformly across the union.[120]

Eurelectric presents in his paper entitled "A Quantitative Assessment of Direct Support Schemes for Renewables" a more detailed approach on the financial techniques that support in a direct way the development of the renewable energy sources. Subsidies in the European Union work through a variety of mechanisms such as quota based systems, fixed price systems and direct capital investment.[121]

[120] De Moor, A., 2001. Towards a grand deal on subsidies and climate change. Natural Resources Forum 25, 167–176.
[121] Eurelectric, 2004. A Quantitative Assessment of Direct Support Schemes for Renewables (Accessed on 18.04.2013) http://gasunie.eldoc.ub.rug.nl/FILES/root/2004/2913948/2913948.pdf

Quota based systems

The quota system requires a minimum amount of the total energy to be provided by a renewable source, bringing providers to compete for this business. (91)

Fixed price systems

The feed in tariffs (FIT) and fixed price systems offer the producers a guarantee that if they build the renewable systems and provide power to the grid, they will be rewarded with prices per kW which are higher than the rest of the conventional producing systems. The feed in tariffs are not the same in every country, but depend in most of the cases of the extent and the developing status of the generation plant.[122]

For example in Germany, energy retailers can procure electricity from determined renewable energy sources at a fixed price for a timeframe up to 20 years. Depending on the sources the rates can have a higher or a lower value. Hence the rates for solar and offshore wind electricity are greater. This is the case the so called Advanced Renewable Tariffs (ART) come into place. This type of tariffs depend directly on the technology that is being used and also by the extent of the entire project. Important to notice is that for the most part neither an amount nor a proportion are defined. However there might exist the situation where a cap or a quota are set in order to determine the quantity that has to be procured from a specific source.[123]

The grid operator has the obligation to take any supply of renewable energy indifferent of merit order consideration. Turning again to Germany, the operator of a grid buys a kWh of renewable electricity at a named FIT rate and then sells them on a common market. Therefore the gap between the sales operation and the FIT rate they have already paid to their numerous suppliers is filled by the end consumer. The

[122] Jeremy Badcock, Manfred Lenzen. Subsidies for electricity-generating technologies: A review. Energy Policy 2010;38: 5038-5047

[123] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 17.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg

amount that fills the gap is entitled 'EEG-surcharge' and is being directly placed on the bill. Industries that use electricity intensively have a limited 'EEG-surcharge'.[124]

Feed in tariffs (FIT) are conventional on several continents like Europe, Canada, and China and forthcoming in various states of Australia. They mainly imply that the consumer is in charge to pay the subsidy for electricity from the various sources. These costs are divided among all energy consumers except there is a separate arrangement that allows to purchase renewable energy at a premium.[125]

The contract of difference denoted CFD examines a variation on feed in tariffs. This implies that in case the market price has a lower value than the admitted strike price, then the government has the responsibility to pay that difference. On the other hand, if the market price has a higher value than the strike price, then the operator has to pay that difference back to the government. Hence, the goal is to set the price in such a way as to enable and encourage investments.[126]

One particular problem that pesters a lot of countries, especially considering FITs, is that as consumers adopt the technology, the cost increase. This was a problem in Germany and Spain where the governments were expected to be hit with massive subsidy bills: 46 billion EUR (by 2030) in the former case and costs so high that the Spanish government decided to cancel the subsidy for the latter. Given the current economic climate in Europe, it is then not surprising to observe that there countries such as France, UK and Slovakia are slashing FITs budgets.[127]

[124] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 20.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg

[125] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 20.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg

[126] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 20.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg

[127] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 20.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg

Europe

UK

According to a report from Ofgem (UK's gas and electricity regulator) from February 2010, the UK's Renewables Obligations have followed an ascendant trajectory in the last years; from £7 in 2007 to £13.50 annually on the bills of average households. (93)

The UK renewables Obligation is one way to "force" the market in the right direction. Slowly but surely UK electricity producers are feeling the pinch as the regulator is fining anyone who is not able to meet the required quota of renewable energy. Where is started at 6,7% in 2006, the government has in mind a target of 15% by 2016. This is a cost that is getting passed on partially to the consumer as currently the fine is 3.7 p/kWh (£37 per certificate).[128]

Germany

As mentioned above, Germany mainly uses the FIT rate which is assured for a timeframe up to 20 years. In 2006 the average FIT excluding solar PV amounted for 8.5 c/kWh; including solar PV, the price increases to 16.4 cents. Wind is one of the renewable energy sources that supplies more than half of the renewable outcome. Hence, considering the new plants, the FIT make a difference between land and offshore. Taking that into consideration, the FIT for on land wind energy is 8.2 c/kWh in comparison to 9.1 c/kWh for offshore wind energy. Adding the subsidy that comes from all consumers to the one that directly comes from the government an amount of 16 billion euros annually can be reached.[129]

[128] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 20.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg

[129] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 20.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg

After 2009, when approximately 3000 MWe of solar capacity were added to the network, the government decided to cut the FIT for new installed capacities by 15%. As a result of the entire PV capacity installed before the end of 2011, energy users will have to contribute over the next 20 years with more than 100 billion euros in order to sustain the initial investments. The beginning of 2012 has brought an increase of roughly 5 billion euros to the forecasted amount. Forecasts made by the federal Economy Ministry estimate an increase of nearly 5 c/kWh to the price of 3.59 cents until July 2013. This increase is mandatory in order to sustain economically the renewable energy subsidies on the one hand and on the other hand the expansion of the grid.[130]

France

In contrast to Germany, France has decided at the beginning of 2010 to cut subsidies needed for solar PV input to the grid by almost a quarter. Therefore 0.80 dollar c/kWh have become 0.61 dollar c/kWh in 2010.[131]

Denmark

A country like Denmark encourages the production of renewable energy, especially wind energy. In 1999 the surplus of wind energy produced by the private sector was bought back at a price of DKr 0.60/kWh. This price included a subsidy that was founded by the carbon tax which averaged at DKr 0.27/kWh. Even in this situation customers and power suppliers have to bear an additional cost. As mentioned earlier renewable energy is something that human kind cannot control, in case there is no wind, it cannot be forced to blow artificially. Therefore in such cases in Denmark when there is a drop in wind, the country is has no other option than to buy electricity from the Nordic electricity storage unit at the going market price. The situation can be

[130] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 20.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg

[131] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 20.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg

seen also from another angle. There can be the case of a wind power surplus and in such cases the energy is sold at the same Nordic electricity storage unit. As the capacity of the wind power is developing and expanding, the clear effect of the surplus or deficit of the wind is causing more losses. Experts are estimating that losses will reach the DKr 1.5 billion level and some of them are even more pessimists and expect the double of the mentioned value.[132]

At the beginning of 2009 the statement made by the Nord Pool points to the fact that the spot floor price for the power excess would decrease from the level of zero Euro cents/kWh to minus 20 Euro cents/kWh. That is to say in low demand seasons, wind generators will be forced to pay the chain in order to take the surplus of power. Nord Pool declared "*A negative price floor has been in demand for some time – especially from participants trading Elspot in the Danish bidding areas. In situations with high wind feed in Denmark there have been incidents where sales bids have been curtailed at price €0. Curtailment of sales may give an imbalance cost for the affected seller and thus creates a willingness to pay in order to deliver power in the market.*" Considering the meaningful quantity of wind power production that is involved in the whole process, this statement has had a negative economic impact on the Danish wind power sector.[133]

Sweden

Sweden has an interesting method of subsidizing its renewable energy sources, mainly its large-scale hydropower plants. The whole scheme consist of a tax on nuclear capacity which amounted in 2001 to EUR 0.32 cents/kWh. Except for the

[132] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 20.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg

[133] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 20.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg

solar photovoltaic all other renewable energy sources benefit from a quota and a certificate scheme which enable a price of EUR 6.85c on every KWh.[134]

Italy

Looking at Italy it also benefits from a quota and a certificate scheme for the renewable sources. As in the case of Sweden, it charges a higher price on solar PV 17.27 c/kWh and 12.53 c/kWh on the rest of the renewables. (93)

Norway

The Norwegian government offers a subsidy to the wind energy sector that covers approximately one fourth of the investment allocation. Furthermore it also supports the production of electricity per kWh by offering NOK 0.12/kWh (0.015 EUR) opposing to a spot price of nearly NOK 0.18/kWh (0.023 Euro).[135]

Spain

The Spanish government offers different amount of feed in tariffs depending on the renewable energy source. For example the wind energy sector profits of EUR 7.32 c/kWh, the solar thermal sector of EUR 27 c/kWh and last but not least 31-34 c/kWh for the solar PV sector.[136]

2010 has brought significant cost reduction for people who purchased solar systems. The government subsidized by 25 % less the investments regarding roof-mounted solar systems and by 45% less for the purchasing of larger ones. (In 2010 cuts of 25%

[134] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 20.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg

[135] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 21.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg

[136] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 21.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg

for roof-mounted solar systems and 45% for larger ones were announced) In February 2013 subsidies were reduced once again and tied to an inflation estimate that disregards energy, food, commodities and tax.[137]

After providing energy over more than a decade at a regulated rate which did not even equaled the costs, Spain has decided to initiate higher taxes on electricity production in order to approach the deficit that has amounted EUR 24 billion by the end of 2012. The governmental subsidies still amounted EUR 7 billion annually for renewable sources.[138]

The good thing is that the amount of the subsidy was not transferred on the consumer side. If this would have happened, the purchasing of energy by the consumers would have been unaffordable. Nevertheless foreign investors had to invest significant amounts of money in projects that aimed the development of the wind and solar sectors. The aids have been estimated to nearly EUR 13 billion. However because the government changed the rules of the games with additional tax and lower subsidies, legal actions are planned.[139]

Greece

The feed in tariff practiced in Greece is of EUR 6.1-7.5 c/kWh, while the Netherlands aim to abolish the energy taxes in order to stimulate the production and consumption of renewable energy.[140]

Turkey

[137] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 21.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg
[138] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 21.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg
[139] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 21.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg
[140] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 22.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg

Turkey has an interesting construction of its feed in tariffs regarding each renewable energy source. First of all according to the Renewable Energy Law that was established in December 2010, Turkey has a basic feed in tariff of 7.3c/kWh, value that is placed right below the market price. The interesting part is that taking this basic feed in tariff into consideration every further feed in tariff of the various renewable sources can be calculated by adding a specific value to it that is different for every renewable energy type. For example in order to calculate the feed in tariff for the wind, an increase by up to 3.7 c/kWh should be added to the basic tariff. Looking the concentrating solar thermal an increase of up to 9.2 c/kWh could be considered. In case of the solar PV an increase of 6.7 c/kWh to the basic tariff could be expected. All feed in tariffs take into account the technology of the equipment as well as its local content and therefore all prices have a specific range of value that they might take.[141]

Czech Republic

The Czech Republic is one of the countries where the government charged a feed in tariff of EUR 0.47 c/kWh. This was ten times higher than the cost of the electricity generated by the CEZ Group. The high placed feed in tariff had a negative impact on the grid and endangered its stability. Therefore the feed in tariff had to be reduced by the end of 2010 to EUR 0.21 c/kWh for new project over 100 kW regarding the bigger PV units and 0.29 c/kWh for smaller projects that did not exceed 100 kW.[142]

The entire capacity of 1600 MWe that was built up by that time was believed and hoped to bring stability and higher profits. It was forecasted that the electricity prices consumed by the residents will increase by 13% while those consumed by the industry by 18 % in 2011. Above all these another tax, (entitled retroactive tax) was

[141] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 22.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg

[142] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 22.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg

introduced that had the purpose of charging solar power installations with a capacity over 30 kW with up to 28%.[143]

The International Photovoltaic Investors Club (IPVIC) was accused of arbitration. The investors will try to recover about EUR 100 million in damages. The year 2012 brought direct support which amounted for EUR 1.8 billion for renewable sources while the state itself contributed directly with the amount of EUR 0.5 billion.

Slovakia

Slovakia was forced to excessively reduce the amounts of subsidies that were invested in the solar power resources. This followed as a response to the boom that has taken place because of the attractive feed in tariff which led to the increase of the household electricity price by up to 5%. Not every part of the solar energy sector was affected by this increase. For example the solar panels that were built on the roofs of the households and provided a capacity that did not exceed 100 kW, were spared from any price increase. From 2010 to 2011 the subsidy needed for the renewable sources escalated form EUR 10 million to EUR 117 million. Originally 8 MWe was the plan for new solar capacity but because of the generous subsidies 145 MWe were actually brought online at the end of 2010. This is considering that there was still a half year left until the June 2011 cut-off.[144]

[143] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 22.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg

[144] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 23.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg

Latvia

Latvia offers feed in tariffs for the wind sector that rely upon the size of the reactor that is being used; tariffs can range between EUR 9.6 to 18.2 c/kWh. Solar PV feed in tariffs have a considerable 42.7 c/kWh.[145]

Lithuania

The feed in tariff in Lithuania for the wind renewable energy source is 8.7 c/kWh.[146]

Portugal

In the rest of the EU countries, where only small-scale PV are operating nowadays the governments are paying high feed in tariffs. For example in Portugal the feed in tariff is EUR 50 c/kWh in order to encourage and stimulate the establishment and development of such kind of renewable energy sources.[147]

America

As reported by the Congressional Budget Office, the US government has invested significant amounts in order to sustain the production of electricity that derives from renewable sources. In total 24 billion dollars subsidized the energy sector in 2011; out of this 16 billion dollars directly for renewable energy containing 6 billion dollars for ethanol tax credit. 1.6 billion dollars were allocated for the wind production tax credit whereas 2.5 billion dollars in tax breaks for the fossil fuels industry.[148]

[145] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 23.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg
[146] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 23.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg
[147] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 24.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg
[148] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 24.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg

The US government aims to support renewable energy generators by offering them over the first ten years of the project's lifetime a direct subsidy (wind subsidy totals 2.2 c/kWh), also known as Production Tax Credit. The goal of the whole process is to encourage and sustain the renewable energy supplier so that they are able to sell the energy at a price that is placed below the actual cost. The subsidy is actually given as a tax credit, though according to the American Recovery & Reinvestment Act (ARRA) a 30% credit can be received if construction is finished by the end of 2013.[149]

Under the project entitled ARRA, 16.8 billion dollars have been used as direct subsidies in order to increase the energy efficiency and development of the renewable energy activities. The US government tries to build a Renewable Portfolio Standard which will assure that a chosen and well defined amount of electricity will be procured from the renewable energy suppliers. This type of incentive for the increase in the use of renewable energy is already running in California and a couple of other states in the US. The Production Tax Credit is besides being listed/classified (linked) to the inflation has been prolonged every year. There are a couple of states in the United States which are thinking of introducing the feed in tariff. Among the ones that already introduced this type of subsidy are Vermont, Gainesville and last but not least Florida which has one that ranges between $ 26-23 c/kWh.[150]

Canada

The feed in tariffs were introduced in Ontario in the 2009 under the Green Energy Act. The feed in tariffs are different for each type of renewable source. Hence landfill

[149] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 24.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg

[150] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 24.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg

gas enjoys $11 c/kWh, wind 13 c/kWh while the solar PV has a FIT of 80.2 c/kWh.[151]

East Asia

Japan is one of the countries that needs more and more power and therefore tries to sustain the production of every new and promising source of energy, especially renewable ones as much as possible. Hence, since the feed in tariff was introduced in 2009 utilities are obligated to buy the excess of solar power, which is generated domestically by a price that reaches JPY 48/kWh. The solar sector was the first that received the feed in tariff followed by hydro, wind and geothermal energy at JPY 17-20/ kWh. The subsidy received was high in comparison with the based-load energy whose value was JPY 5-7/kWh. As the consumption of energy increased so did the feed in tariff. Therefore in 2012 the energy generated from the sun received JPY 42/kWh. This tariff is high in comparison with other countries; it is twice the tariff provided in Germany and more than three times that offered in China. The feed in tariff for the wind power sector is divided into two groups. Units that have a capacity above 20kW will receive JPY 23.1/kWh and those under JPY 57.75/kWh.[152]

China

"*The fact that wind is heavily subsidized*" is something widely recognized by the Global Wind Energy Council in China. To be considered is that the subsidy is mainly capacity oriented and not output oriented. All this is associated with the 16% capacity

[151] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 24.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg

[152] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 24.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg

factor which was so low during 2007 to a great extent because of the grid constraints that were implemented by that time.[153]

In China, the solar power sector took advantage from the government support which in 2011 introduced a national feed in tariff of RMB 1.15/ kWh (EUR 14 c/kWh). This tariff suffered a decline during 2012 reaching a low value of RMB 0.55/kWh (EUR 7 c/kWh). At the end of 2012 the solar power sector was stimulated by a total of CNY 13 billion (EUR 1.6 billion) encouraging the efficiency and production of electricity. The subsidies were aimed to sustain the 5.2 GWe domestic production of solar power.[154]

Australia

In 2001, Australia's Mandatory Renewable Energy Target, also known as RET or MRET has recommended retailers to purchase a fixed amount of electricity they supply from renewable sources except the hydropower ones at any price they can get. Otherwise they will be penalized with a shortfall charge which totals 4.2 c/kWh American dollars.[155]

The target set for 2010 was at 10% representing 9500 GWh is supposed to increase up to 20% representing 45.000 GWh by 2020. In case if it succeeds, this will be a considerable increase in electricity production from non-hydro renewable sources. Any shortfall penalty will be payable from 4 cents to 6.5 c/kWh and these will be tradable. During 2011, the subsidies that were given to the renewable energy sector amounted for $ 12 billion accomplished 0.6 c/kWh. Since the population faces

[153] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 25.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg
[154] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 25.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg
[155] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 25.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg

constant growth every year the consumption of energy will increase and higher subsidies will be needed. The government of Australia estimates and forecasts that net global power cost for end users will increase from 0.5 c/kWh by 2015 to 0.77 c/kWh by 2020. According to a research published by Carbon Marker Economics the proposed price of $ 23 a ton for the CO2 that is being eliminated into the atmosphere by the renewable energy plants, has been more than three times higher in 2010 requiring a price of $76 a ton in subsidies.[156]

Householders of the two States Victoria and New South Wales sell solar photovoltaic power to the grid at a price that reaches even 60c/kWh. Comparing this with the coal-fired electricity that is being dispatched to the city at a price of 8 c/kWh it can be noted that the difference is very big.[157]

Subsidies for nuclear power

Subsidies is the direction that a government might take in order to sustain the development of energy. If going in the opposite direction of subsidies, the government might introduce taxes on specific sources of power. This different sources of energy are characterized by climate change and low production cost but at the same time offering high opportunity. For example, Sweden charges a tax on the nuclear electricity which sums up at EUR 0.67 cents/kWh. This represents almost one third of the costs that are needed for the operation of nuclear power plants. Belgium also has introduced a fee of 0.5 cents/kWh on nuclear power.[158]

[156] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 25.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg
[157] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 25.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg
[158] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 26.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg

The UK has introduced a tax on the power that is being consumed by companies which is being entitled Climate Change Levy. This tax was estimated by 0.43 p/kWh. 2006 represented a change because since then this tax on energy has been indexed. The interesting part is that the energy which is provided by the renewable energy source is not subject to the levy fee but the nuclear energy is.[159]

Germany is one of the countries that implemented a fee on almost everything regarding nuclear power. For instance since 2010 it introduced a tax of € 145 on each gram of uranium or plutonium fuel up to 2016. This tax is supposed to bring € 2.3 billion annually, representing 1.6 c/kWh. The levy that is being introduced on nuclear generators is presumed to bring up to € 300 million per year in the first two years 2011 and 2012. For the other 4 years: 2013-2016 the levy is considered to bring up to € 200 million followed by a tax equal to € 0.9 c/kWh after 2016. All these taxes are supposed to subsidize the renewable energy sector.[160]

Beginning with 2013, Finland is planning on introducing a new tax on nuclear fuel in order to gather € 170 million annually. According to the Ministry of Employment and Economy starting with 2011, the profits that will derive from the windfalls would be charged at a rate between 43% and 45% of the CO2 emission rights market price. The charged rate will depend on the adopted model and will amount at least € 0.2 c/kWh. There have been proposed two type of tax models.[161]

[159] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 26.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg
[160] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 26.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg
[161] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 27.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg

The first one entitled "minimum tax model" should create a minimum of € 67 million annually at a rate of € 15 per ton of CO2 and € 223 million at a rate of € 30 per ton (representing €0.67 c/kWh). [162]

The second model named "flexible tax model" charges first of all the uranium with € 0.17 c/kWh and second of all the extra profit with 30%. A price of € 15 per ton of CO2 is estimated to sum up € 57 million while doubling the price would lead to the generation of € 207 million. This model offers the possibility to get a tax credit in years where trading is less than 9.3 EUR per ton of CO2 and debit it against years where there is a positive surplus. This design has been widely criticized as it acts against an essential purpose of the EU regulations, which state that low-carbon production in comparison with high carbon units will be rewarded.[163]

Denmark and northern Germany implement every now and then a tax on the surplus of wind production. This is most of the time a case of the low demand seasons in those areas.[164]

When there is low demand, Nord Pool requires generators to give approximately EUR 20 c/kWh for consumers to procure the surplus of energy. Using the same philosophy, Germany has broken the record in October 2008 when the price hit 50c/kWh. The West of Texas also experiences a similar situation as the countries described above.[165]

As probably noticed, none of the described countries have offered any subsidies for the nuclear energy sector. The only country which subsidizes the nuclear power is the

[162] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 27.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg
[163] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 27.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg
[164] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 27.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg
[165] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 27.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg

USA. It offers a 1.9 c/kWh as production tax credit for the first 6000 MWe during the first eight years of activity. The only condition is that it has to be produced by new generation nuclear power units; in comparison to the renewable energy where for example the wind power plants enjoys the same parameters but with unlimited basis. The USA subsidized during 2007 the renewable energy sector with $ 724 million while the nuclear power sector received $ 199 billion. The great amount received by the nuclear power was due to an adjustment linked to decommissioning regulated by the Energy Policy Act in 2005.[166]

Direct capital investment

Capital investment subsidies ensure that energy consumption produces from renewable sources will be rewarded directly. Basically, subsidies as a category are defined as financial or other benefits that derive from one party and go towards helping the producing party meet its goal by either directly or indirectly making the projects achievable. This could be either through financial rebates, allowance of public utility companies to run at below cost (achieving a lower return on investment) or any other means of directly or indirectly interfering with market forces which would dictate the contrary position on renewable energy sources.[167]

From the different types of renewable energy sources, Germany is the single biggest supporter of Photovoltaic (PV) energy while the rest of the EU-15 (mainly France, Denmark, Spain etc.) show their support for wind based energy systems.[168]

Tax breaks

[166] World Nuclear Association. Energy Subsidies and External Costs (Accessed on 27.04.2013) http://www.world-nuclear.org/info/Economic-Aspects/Energy-Subsidies-and-External-Costs/#.UV1Tz5P-GHg
[167] Jeremy Badcock, Manfred Lenzen. Subsidies for electricity-generating technologies: A review. Energy Policy 2010;38: 5038-5047
[168] Jeremy Badcock, Manfred Lenzen. Subsidies for electricity-generating technologies: A review. Energy Policy 2010;38: 5038-5047

While direct transfers are one way of swaying the market to work towards a desired outcome, tax breaks are another. In the United States there are two current tax incentives for the production of renewable energy. Firstly, the US Production Tax Credit commonly known as PTC has been providing wind, geothermal and closed loop biomass energy producers a 1,9 cent $ tax break per kWh produced by their facility. The PTC has been introduced around since 1992 but has been renewed numerous times after expiry and has shown quite clearly that the market finds these tax breaks crucial in the pursuit of such energy sources, since at every expiration the production of such energy stagnated. The PTC also applies to nuclear energy but at a much lower rate with only 6GW of capacity on an eight year lifetime duration. As of 2007 it is clear that PTC subsidies have the biggest portion of financial subsidies when looking at the total $ amount subsidized with $608 million representing a total of 84% of the total.[169]

Tax deduction

The second type of subsidy being found in the EU is the tax deduction. On PV technology, (in the EU-15 countries) companies receive up to 70% tax deduction in countries such as Sweden. This is an alternative to the PTC model where companies constantly receive tax incentives.[170]

[169] Jeremy Badcock, Manfred Lenzen. Subsidies for electricity-generating technologies: A review. Energy Policy 2010;38: 5038-5047
[170] Jeremy Badcock, Manfred Lenzen. Subsidies for electricity-generating technologies: A review. Energy Policy 2010;38: 5038-5047

Conclusion

As predicted by many scientists the use of energy will increase worldwide in the next few years. According to a recent study the consumption of energy will increase by more than 50% until 2035. The highest growth will take place in China and India.[171]

Therefore, some quick and effective decisions have to be taken. Measuring the potential that every source of renewable energy has, the solar and geothermal power should be developed more. Hence, the government should propose more attractive offers and benefits in order to lock in the solar energy customers. Another thing that the government should do is raise awareness of the energy saving importance.

Regarding nuclear power the most important parts that still need to be developed are the storing and disposal techniques. The fission process looks very promising and therefore more R&D investments should be made.

As mentioned in the nuclear energy section of the paper, according to Abu-Khader" *Nuclear power alone won't get us to where we need to be, but we won't get there without it*".[172] Therefore, opponents of the nuclear power sector should look at the data that was collected over the years and analyze everything very objectively according to the numbers that speak for themselves.

To conclude, in order to give an answer to the problems and questions that arose in this thesis it is clear that the world is a vastly more complicated place and there are black and white answers. Hence, the segmentation made at the beginning of the paper about what people should choose "renewable or nuclear energy?" is not entirely correct. It should not be a choice of one or the other. The world should have one common aim and that is to fight for a sustainable future. This can only be realized by

[171] OPB Homepage (Accessed on 22.04.2013) http://www.opb.org/news/blog/ecotrope/10-predictions-for-the-worlds-energy-future/
[172] Mazen M. Abu-Khader. Recent advances in nuclear power: A review. Progress in Nuclear Energy 2009;51: 225-235

using all the existing resources in order to meet the upcoming energy demand. This includes all forms of energy whether renewable or nuclear sources.

Abstract

This thesis deals with renewable and nuclear energy sources and tries to give a better understanding of the importance of having enough energy in order to meet future energy demand. Besides the continuing growth of the global population, Earth is experiencing climate change, described as global warming. This process leads to the fact that the population is not capable of fully relying on renewable sources which are strongly influenced by weather and natural resources. Therefore society should undertake a weighing of interests and consider nuclear power generation as a good alternative for a sustainable future. The nuclear energy sector is a widely debated matter that has two camps: opponents and supporters. Even while being part of one of the other group one should analyze the situation in an objective way, not being influenced by others and aim for a better future, a future where there are less CO2 emissions and there is enough energy for sustaining a more energy demanding future.

Zusammenfassung

Diese Arbeit beschäftigt sich mit dem Thema der erneubaren sowie nuklearen Energiequellen und versucht, ein besseres Verständnis zu vermitteln sowohl für die Bedeutung genug Energie zu haben, als auch beim zukünftigen Energiebedarf nachhaltig zu sein. Neben dem anhaltenden Wachstum der Weltbevölkerung erlebt die Erde einen Klimawandel, der als globale Erwärmung beschrieben wird. Dieser Prozess führt zu der Tatsache, dass die Bevölkerung nicht mehr in der Lage ist sich vollständig auf erneubare Quellen zu verlassen, die stark von Wetter und natürlichen Ressourcen beeinflusst werden. Daher sollte die Gesellschaft eine Neuorientierung vollziehen und die nukleare Energie als eine gute Alternative für eine nachhaltige Zukunft wahrnehmen. Die nukleare Energie ist ein sehr stark diskutiertes und sogar umstrittenes Thema, die zwei Parteien hat nämlich Gegner und Befürworter.

Egal ob man zu der einen oder zu der anderen Mannschaft gehört, sollte man die Situation in einer objektiven Weise analysieren, sich nicht von anderen beeinflussen lassen und für eine bessere Perspektive kämpfen, die weniger CO2-Emissionen verspricht und genug Energie für die Aufrechterhaltung einer Zukunft, die immer mehr Energie verlangt, ermöglicht.

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Sprachen

Rumänisch	Muttersprache
Deutsch	Verhandlungssicher-Business Level
Englisch	Verhandlungssicher-Business Level
Spanisch	Gute Kenntnisse