Study of Energy Efficiency Technologies for Renewable Energy Supply

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Abstract- *Electricity consumption will comprise an increasing share of global energy demand during the next two decades. In recent years, the increasing prices of fossil fuels and concerns about the environmental consequences of greenhouse gas emissions have renewed the interest in the development of alternative energy resources. In particular, the Fukushima Daiichi accident was a turning point in the call for alternative energy sources. Renewable energy is now considered a more desirable source of fuel than nuclear power due to the absence of risk and disasters. Considering that the major component of greenhouse gases is carbon dioxide, there is a global concern about reducing carbon emissions. In this regard, different policies could be applied to reducing carbon emissions, such as enhancing renewable energy deployment and encouraging technological innovations. Two main solutions may be implemented to reduce CO2 emissions and overcome the problem of climate change: replacing fossil fuels with renewable energy sources as much as possible and enhancing energy efficiency. In this paper, we discuss alternative technologies for enhancing renewable energy deployment and energy use efficiency*

Keywords- energy resources, renewable energy, energy use efficiency, generation technology, carbon emission, green employment.

I. INTRODUCTION

Considering that the major component of greenhouse gases (GHGs) is carbon dioxide, there is a global concern about reducing carbon emissions. In this regard, different policies could be applied to reduce carbon emissions, such as enhancing renewable energy deployment and encouraging technological innovations. In addition, supporting mechanisms, such as feed-in tariffs, renewable portfolio standards and tax policies, are employed by governments to develop renewable energy generation along with implementing energy use efficiency for saving energy.

Many countries have started to install facilities that use renewable energy sources for power generation. The importance of alternative energy sources comes together with climate change challenges associated with the excessive use of fossil fuels. There are three primary motivators that stimulate the growth of renewable energy technologies: energy security, economic impacts and carbon dioxide emission reduction. The term “alternative energy” refers to any form of energy other than the conventional sources of energy, including hydropower. In recent years the focus has been on renewable energy sources. IEA (2012d) refers to two significant global trends that should characterize the deployment of renewable technologies over the medium term. First, as renewable electricity technologies scale up, from a total global supply of 1,454 gigawatts (GW) in 2011 to 2,167 GW in 2017, they should also spread out geographically. Second, the more recent years of high fossil fuel energy use has led renewable technologies to become increasingly competitive on a cost basis with their alternatives in a number of countries and circumstances. According to IEA calculations, wind is the most competitive type of renewable energy technology among the other options, if local conditions such as financing, CO2 emission levels and fossil fuel prices prove favorable (OECD, 2010).

When talking about clean technologies, there are two primary concepts of energy technologies: energy supply technologies, which refers to alternative sources of renewable energy (e.g., wind and solar power), and energy efficiency technologies, or those technologies which are hired to enhance energy use efficiency, (e.g., combined heat and power (CHP), virtual power plants (VPP) and smart meters). It should be noted that transforming the energy sector and replacing conventional energy with renewable energy is evolutionary associated with technological change and forming markets. Jacobsson and Bergek (2004) indicate that the transforming process for certain forms of renewable energy, such as wind and solar, will happen after 2020, even if the growth rate of consumption is strongly increasing over the next decade. Also, renewable energy markets are not easily formed due to cost disadvantages and the subsidizing of fossil fuels.

The remainder of this study proceeds as follows. In Section 2 we present the different renewable energy supply technologies including solar, wind and hydro power, geothermal and other sources. In Section 3 different energy use efficiency technologies are discussed. These include electric vehicles, combined heat and power, virtual power plants and the application of smart meters. The final section provides a summary and concludes.

Renewable Energy Supply Technologies

The renewable energy supply is continuously increasing. A large amount of investment has been made during recent years and the advancement of technology has enabled countries to produce renewable energy more cost effectively. It is forecasted that the number of countries producing above 100 megawatts (MW) of renewable energy will increase significantly 2017 (IEA, 2012d). Due to some negative and irreversible externalities coming with conventional energy production, it is necessary to promote and develop renewable energy supply technologies. These technologies may not be comparable with conventional fuels in terms of production cost, but they could be comparable if we consider their associated externalities, such as their environmental and social effects. Also, it should be noted that economies of scale could play a key role in reducing the unit production cost. Transmission and distribution costs, as well as technologies, do not differ much among the conventional and renewable energies. Below we present facts about the development of the main renewable energy supply technologies.

Energy efficiency technologies

As previously mentioned, there are two main solutions to reducing CO2 emissions and to overcoming the climate change problem: replacing fossil fuels with renewable energy sources as much as possible and through enhancing energy efficiency. We discussed the state of the art methods for technical and economic feasibility of expanding the use renewable energy sources and the possibility of substitution in the first part of this review. In this part that follows, we discuss energy efficiency technologies. Energy efficiency for an electricity network could be considered in different stages, such as the power generation, transmission, distribution and consumption. The different technologies that are currently available include electric vehicles (EV), combined heat and power (CHP), virtual power plants (VPP) and smart grids, each of which are discussed below.

Electric Vehicles

Electric vehicles (EV, including the battery, fuel cell, and hybrid types) have the potential to be considered viable options for both electricity storage and power generation. Considering that the transportation sector is one of the main sources of emissions, improving fuel efficiency enables us to achieve the largest fuel savings and CO2 reduction in the short term. Thus, the increased usage of EVs and increasing their share of the vehicle fleet can play a key role in the long term. IEA (2012c) forecasted an increased share of plug-in hybrid electric vehicles (PHEV) over the next two decades, with a total increase of up to 50% by 2050. "In long-term, smart grid technology may enable EVs to be used as distributed storage devices, feeding electricity stored in their batteries back to the system when needed (vehicle to grid), to help provide peak-shaving capability."(IEA, 2012e) Ford (1995) examined the impact of the large scale use of electric vehicles in southern California and concluded that Southern California Edison (a power company in the area) was able to accommodate a large number of EVs with their existing capacity, particularly if the charging system was managed by smart control. Ford argued that EVs can improve load management, enhance efficiency and save energy. He also calculated that EVs are able to reduce emissions at a value of around 9,000 USD per vehicle. Kempton (1997) calculated the present value costs for an EV owner and the benefits to utilities. Based on the results, all three vehicle/battery combinations are cost-effective power sources during the peak time for the short-term. He argued that if a part of the transportation section is utilized by electric vehicles with connections to the electricity network, there will be less demand for base-load generation. In addition, the use of intermittent renewable energy sources becomes more applicable due to a lack of concern about the time-of-day match between demand and supply. Kempton and Tomic (2005) investigated the systems and procedures required to use energy in vehicles, as well as the implementation of vehicle to grid (V2G) technology. The most important role of V2G could be its support to renewable energy in the emerging power markets through managing load and supply fluctuations. They argued that after initially tapping EVs for their high value, market saturation and cost reduction, V2G fleets could be used as storage capacity for renewable energy power generation. Tomic and Kempton (2007) examined the economic feasibility of battery-electric vehicles to supply power for a particular market in the US. The results show that V2G electricity is able to provide a significant income flow, contributing to the feasibility of grid connected vehicles and furthering support for adoption. Lund and Kempton (2008) evaluated the integration of renewable energy into the transport and electricity sectors by V2G. They applied a model to analyze energy integration for electricity, transport and heating. V2G technology has been found to provide storage for the matching time of generation and time of load. Adding EVs and V2G technology to power networks enables the system to be integrated with wind electricity without extra power generation and also makes a significant reduction in CO2 emissions. Steenhof and McInnis (2008) analyzed three scenarios to evaluate the impacts of increasing ethanol 85, hydrogen, and electricity powered vehicles into the passenger transportation fleet starting in 2010, and reaching 100% of the new vehicle market by 2050. The results show that CO2 emissions will be reduced by 153 Mt from the use of electric vehicles to 156 Mt from the use of hydrogen fuel cell vehicles by the year 2050. It is also forecasted that ethanol driving cars will be cellulose based by 2050, generating a significant reduction in CO2 emission, but still producing an unsustainable amount of crop residues. Andersen et al. (2009) introduced an intelligent electric recharging grid operator (ERGO) for the creation of a market that coordinates the production and consumption of renewable energy. They argued that an ERGO model could overcome the problems of GHG emissions and power fluctuations through converting EVs to be distributed storage devices for electricity. The introduction of V2G distributed power sources and IT intelligence to the grid, the creation of virtual power plants through distributed resources and the provision of new applications for carbon credits have been documented benefits associated with the ERGO model.

Weiller (2011) applied a model that examines the impacts of different charging scenarios for PHEVs in the United States on electricity demand, accounting for the time of day and charging place. The results show that possibility of being able to charge in places other than the home increases the fraction of daily energy use of PHEV from 24% to 29% (1.5-2.0 kWh/day). Based on the results, PHEV-20 (vehicles with a 20 mile range) shifts 45-65% of the miles traveled to electricity, compared to 65-80% for PHEV-40. Furthermore, it is surmised that PHEVs enable US drivers to cut gasoline consumption by more than 50% through shifting 45-77% of the miles traveled to electricity power. Weiller indicated that PHEVs could be considered a cost-effective solution when we compare electricity costs at about $0.03/mile ($0.13/kWh) to gasoline which costs $0.12/mile ($3/gallon). Environmental and transportation policy, as well as public financial incentives regarding a carbon tax, can influence the early and comprehensive implementation of EVs.

Combined Heat and Power

Cogeneration, or combined heat and power (CHP), is the use of heat and electric power together. It is expected to have a substantial gain in efficiency over each source separately. Most power distribution companies supply only electricity, not hot water or steam. Considering that almost 30-40% of a country's total energy load is used for heating, CHP is an efficient use of fuel when a portion of the energy is discarded as waste heat. It captures some or all of the waste energy as a by-product for heating. In Reykjavik and New York, end users are able to purchase both electricity and thermal energy from a utility company (Tester, 2005). An example of cogeneration is the CHP unit in Avedore, Denmark which is a multifuel plant (Ngô and Natowitz, 2009). Shipley et al. (2008) calculated that increasing the CHP capacity of the United States to 20% by 2030 would lead to a reduction of 5.3 Quads (Quadrillion British Thermal Units) of energy consumption and 848 MMT of carbon dioxide emissions. Based on their findings, the United States would save more than 1.9 Quads of fuel consumption and 248 million metric tons of carbon dioxide emissions by employing CHP.

According to the WEO (2012) report, the average efficiency of power plants is 41% worldwide, with almost 60% of the primary energy being converted to waste heat (IEA, 2012e). CHP could transform a significant part of the waste heat into a positive economic value for industrial processes or heating in residual and commercial buildings. It is estimated that new CHP units could improve energy efficiency to a level greater than 85%. Madiment and Tozer (2002) investigated the application of combined cooling heat and power (CCHP) for supermarkets in the UK and compared it to the energy savings/capital cost of conventional technology. The results show that CCHP is able to provide a significant amount of primary energy while reducing CO2 emissions compared to conventional schemes, but it is also believe to be competitive with more efficient technologies in long term. They argued that new technologies, such as fuel cells, could provide improvements in energy efficiency for CCHP in refrigeration.

Hawkes and Leach (2007) examined cost effective operating strategies of three alternatives micro-CHP technologies (Sterling engine, gas engine and solid oxide fuel cell-based (SOFC) system) for residential application in the UK. They evaluated the economic and environmental attributes on the abovementioned technologies for heat-led, electricity-led and least-cost operating strategies. The results showed that the SOFC-based system had the maximum operating cost and the largest CO2 emission reduction following the least-cost operating strategy. You et al. (2009) examined the electricity export capability of aggregated micro-CHP units as a virtual power plant (VPP) through participation in the electricity wholesale market. They found that the export capability of micro-CHP systems strongly depends on technical parameters, associated energy price, and the demand profile. Based on applied model, it is surmised that the marginal price for a micro-CHP system is higher than the spot price for most of the year. Kiviluoma and Meibom (2010) analyzed the impact of variable power generation by wind turbines and EVs stored electricity on the ability to enhance the flexibility of a power grid. Based on the results, CHP units could be viable options for making power systems more flexible in terms of production and the use of heat. Christidis et al. (2012) investigated the contribution of heat storage to optimize CHP units in liberalized electricity markets, applying a model that measures the economic potential and optimal capacity of heat accumulators. They concluded that separating electricity production and heat demand could provide a profitable payback period for storage devices in the proposed energy system.

Virtual Power Plant

A Virtual Power Plant (VPP) is a cluster of distributed energy resources, such as micro-CHP, wind turbines, and solar photovoltaic panels, which are controlled and managed by a central control unit. The term distributed energy resources (DER) can be used for fossil or renewable energy fuels. A DER system has been defined in order to overcome energy waste problems due to long distances and transmission losses. Therefore, DERs are generally located close to the distribution networks. The concept of VPP is used for DER integration. According to the Europe FENIX project (Kieny et al., 2009); there are two types of VPPs, the Commercial VPP (CVPP) and the Technical VPP (TVPP). DERs can simultaneously be part of both a CVPP and a TVPP. A commercial VPP is defined as a portfolio that could be used by a DER to participate in electricity markets. CVPPs can represent a DER from any geographic place in an electricity network. A technical VPP enables operators to facilitate DER energy capacity and optimize the power balance in the system with the minimum cost (Pudjianto et al., 2007). The share of distributed generation (DG) in an electricity network is increasing in importance and VPP is considered to be an emerging technology that enhances energy efficiency. Schulz et al. (2005) analyzed the technical and economic feasibility of operating a VPP with micro- CHP units. They explained that, due to Germany's plan to abandon nuclear power plants until 2020, a part of the new capacity should be comprised of renewable energy sources and CHP utility, which are considered DG units. VPP is an alternative to the management of these units, as of the absence control needs provides an advantage for renewable energy technology. Based their findings, the power generated by an individual owner is too small to supply, with the amount of the power output needing to be 30 MW or higher based on existing regulation. A VPP operator can integrate a large number of DERs and provide 30 MW through aggregating 6,000 micro-CHP units, each with a power output of 5 kW. They estimated that every unit is charged 300 Euros for connection into the integrated system. Ruiz et al. (2008) applied a model to manage a VPP made up of a large number of customers with controlled home appliances in order to optimize load reduction over a certain time schedule.

Jansen et al. (2010) examined an architecture and communication pattern for employing a large number of electric vehicles to be integrated into a VPP system. They argued that EVs have a strong potential to be a component of the electricity network if the fleet of vehicles is managed appropriately. It is indicated that intelligence is required to optimize the charging of EV batteries in order to manage the integration of EVs into the electricity network. You et al. (2009) proposed a market-based VPP model constituted with DER units which have access to electricity markets. Based on the model, general bidding and price signals are considered two operation scenarios performed by one market-based virtual power plant. Haussmann et al. (2010) developed a mathematical optimization model for the management of CHPs.

Considering the main task of a VPP is to increase generated electricity by DG units, the operation of individual generators should be optimized. Next, their contribution to output of VPP is calculated. They applied this model for a local heating system populated by 5 CHP units, and their results indicate a 10% increase in benefits compared to a general CHP system.

Smart meter

The most important objective for power generation companies in demand side management is to reduce peak demand during a certain period. In this regard, a smart meter is a device to record the consumption of electricity in hourly intervals and the information is monitored by both the utility and customer. A smart meter is able to have two way communication and intelligence management for home appliances. Hartway et al. (1999) examined the application of smart meters and customer choice control in order to show that a time-of-use (TOU) strategy can be beneficial for a utility company. The results show that the TOU rate option could result in a 107 kWh energy savings for each customer per year. They calculated the annual savings on customers' electricity bills to be $77 with a cost savings of $134 per customer for the utility company. Applying smart meters could facilitate a significant change in the energy efficiency of electricity networks.

Faruqui et al. (2007) calculated that a decrease in the US peak demand through the installation of advanced metering infrastructure could have a substantial savings in generation, transmission, and distribution costs. For example, a 5% decrease is enough to eliminate 625 peak load power plants and their associated infrastructure, saving roughly $3 billion a year. Karnouskos et al. (2007) indicated that smart meters and advanced metering infrastructure allows one to adapt production and consumption proactively. They argued that smart meters could provide new opportunities in the electricity network and system integration through data processing and making decisions based on capabilities. This role enables managers and policy makers to take advantage of real-time data. It is believed that smart meters could be a gateway for home appliance communication through the internet that will enable the use of advanced communication capabilities in the future. Faruqui et al. (2010) quantified the long term costs and benefits of investing in dynamic pricing and installing smart meters for the EU. They estimated that the installation costs of smart meters will be 51 billion Euros with operational saving of 26-41 billion, creating a gap of around 10-25 billion Euros. In their view, smart meters have the capability to cover this gap through the use of dynamic pricing and reducing peak demand. They suggested that policy makers and utility companies should increase the adoption rate by applying innovative policies that encourage customers to participate. It is expected that the amount of saving due to the reduction in capacity and transmission costs will be 67 billion, if 80% of customers reduce their electricity consumption during peak hours. Depuru et al. (2011) examined the different features and technologies to be integrated with smart metering to figure out what is required to implement a network appropriated for smart grid communication. It is indicated that the worldwide integration of smart meters is estimated to reach nearly 212 million units by 2014. They indicated that Home Area Networks (HAN) technology could support PHEVs and DG units in the communication network. Considering a significant growth rate of PHEV's penetration in the future, there could be a substantial increase in the demand for smart meter application. Due to increasing fuel prices and high initial costs of developing conventional infrastructure for the supply side of an electricity network, improvements in energy efficiency and the implementation of demand response (DR) program through smart metering are attractive options (see Heshmati, 2014). Baltimore Gas and Electric has estimated that the capital cost of a DR program at (Vojdani, 2008). Krishnamurti et al. (2012) discussed consumers' expectations and their behavioral decisions, applying a model to measure the impacts of smart meter installation on their diffusion. Based on the results, there is a misconception on the part of the consumers about the impact of smart metering integration. They suggested that this misconception could be remedied by the electric utilities, who can explain the potential risks and benefits clearly and ease the Concerns about privacy and loss of control. McKenna et al. (2012) analyzed consumer privacy concerns about smart metering and some applications of smart meters' data required for the electricity industry. They examined how much sensitivity is acceptable for obtaining data and investigated whether the leakage of personal data can be minimized or avoided.

Based on the results, it is suggested that power supply requirements for sensitive smart metering could be reduced by applying appropriate privacy techniques. Privacy concerns have a strong potential to delay smart meter penetration. McHenry (2013) discussed the technical and governance considerations for smart meter infrastructures including the technical and non-technical requirements, costs and benefits of smart meter infrastructures, and impact of smart meter installation on stakeholders. He argued that the full benefits of advanced metering infrastructure (AMI), along with other technologies, enable stakeholders to take advantage of intelligent management in order to minimize costs, improving efficiency and remote monitoring. Although the potential benefits of AMI could be significant, it is stated that scale of smart meter investment and its distribution among power users and providers is considered as unprecedented challenge for policy makers.

Main drivers for using renewable energy technologies:

1. Energy security:

Concerns about the security of the energy supply were raised after the Arab oil embargo in 1973. Additional factors included high oil prices, the increasing dependency on oil imports, the depletion of fossil fuels, an increasing competition from emerging economies, political instability in major oil producers and a high impact due to any disruption in energy supply on developed and rapidly developing countries (Bhattacharyya, 2011). The level of insecurity was shown by the risk of supply disruption and estimated costs associated with security improvement. Owen (2004) called the security of energy supplies a key requirement for the economic, environmental and social objectives of sustainable development policies. In his view, the energy security risk could be classified as strategic and domestic system risks. He also defined damage costs and control cost as potential costs imposed by energy insecurity. He argued that the damage cost could be evaluated by potential decreases in GNP, but that it is difficult to estimate how much money is spent as control costs. For example, it's very difficult to estimate how much money has been spent by the United States to control oil security. Concerns about climate change had an additional impact on energy security objectives. The diversification of the energy supply to promote energy security could be considered a policy for climate protection (Bhattacharyya, 2011). Before the era of industrialization when coal was used as the main source of energy (mid-19th century), renewable energy sources were widely used. There is the potential to use renewable energy (e.g., hydropower, solar, wind and biomass) around the world, which enables the supply of clean energy and enhances the long term sustainable energy supply (Asif and Muneer, 2007). Renewable energy sources may have security issues as well, a result of the intermittent characteristics for some energy types including solar and wind energy, as well as the possibility of low rainfall for hydropower consumption. Therefore, such factors should be considered in the sectors that heavily rely on these sources. Renewable energy technologies are beneficial for both energy producing and consuming countries. Renewable energy technologies reduce the domestic demand for fossil fuels and increase the export capability. For example, Iran was the 4th largest producer of natural gas worldwide in 2011, but it was a net importer because of high domestic demand. Also, a high dependency to import could create a serious problem if there is any kind of disruption in the energy supply. For example, European countries are dependent on Russia to import natural gas, and in turn, experienced great difficulties when Russia cut off the gas supply transmitted by Ukraine in 2006.

Furthermore, we should also consider the external costs spent on energy security indirectly in our calculation. Along with storage costs and military expenditures, there is a relatively large externality cost associated with the possibility of accidents at nuclear power plants, as was seen by accidents at Three Mile Island (1979), Chernobyl (1986), and Fukushima Daiichi (2011). Around 6,000 cases of thyroid cancer have been recorded in contaminated regions from the Chernobyl accident to date, and it has been estimated that an additional 10,000- 40,000 cases of cancer may arise over the next few decades (Hoeve and Jacobson, 2012). The number of accidents at nuclear power plants may be rare, but the economic, social and environmental costs can be extreme. If we include all the external costs in our evaluation, including those related to social and environmental security, renewable energy sources will be feasible.

2. Economic impacts:

The emphases for economic impacts are job creation, industrial innovation and balance of payment. Renewable energy technologies could enable countries with good solar or wind resources to employ these energy sources to meet their domestic demand. Also, renewable energy technologies may even enable these countries to utilize renewable energy sources with long-term export potential. Moreover, the cost of importing fuels can affect economic growth. If these countries could reduce their balance of payment by producing their own renewable energy to replace their dependence on fossil fuels, it could raise the capacity for investment in the other sectors. IEA created a cost-benefit analysis for the investment in low-carbon energy systems based two scenarios: ETP 2012 6˚C (6DS), which assumes business as usual, and 2˚C (2DS), which targets the reduction of carbon dioxide emissions by 50 percent, using 2005 levels as the benchmark. The results estimate that 103 trillion dollars will be saved during the years 2010-2050 by reducing fossil fuels consumption. This calculation is based on the reduction in fossil fuels purchases (214 Gtoe), although the estimate could increase to 150 trillion dollars if the impact of lower fuel prices is taken into consideration (IEA, 2012c). A main economic driver to the enhancement of renewable energy technologies is their job creation potential. It's estimated that 5 million people work in renewable energy industries. Although, total employment in these industries has continued to increase, the recent global recession, coupled with policy changes, has caused the employment in some countries (e.g., Germany and Spain) to decrease (Martinot and Sawin, 2012). Figure (9) shows the distribution of estimated jobs in renewable energy worldwide by industry based on the GSR 2012 report.

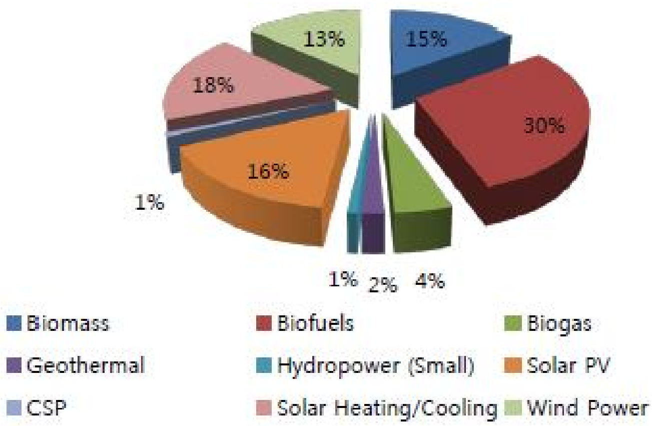

Figure: Estimated jobs in renewable energy worldwide, by industry

In the GSR 2012 report, the breakdown of job creation by sector is as follows: 1.5 million workers in the biofuels industry, 820,000 in the solar PV industry and 670,000 in the wind power industry. Currently, more than 1.6 million workers are employed in the renewable energy industry (Martinot and Sawin, 2012). The majority of jobs in renewable energy industries are located in China, Brazil, the United States and the European Union. Germany has been the front runner in Europe in terms of job creation in the renewable energy industry. It has sharply increased its power generation by renewable technologies since the beginning of this century, with a share of almost 15 percent of the total electricity production in 2008 (Frondel et al., 2010). Ragwitz et al. (2009) investigated the gross and net effects of renewable energy policies in the European Union. In particular, they analyzed the past, present and future effects of renewable energy policies on employment and the economy at the overall and member levels. They found that the current economic benefits of the renewable energy sectors can and should be increased in future by improving the existing policies, "in order to reach the agreed target of 20 percent renewable energies in Europe by 2020." They argued that increasing the share of renewable energy sources not only has minimal negative effects on the economy, but that it could also help the economy through job creation and increasing the GDP. From their point of view, the economic advantages of renewable energy could be even higher if external costs were included in calculations.

3. CO_2 emission reduction:

Renewable energy technologies could reduce carbon dioxide emissions by replacing fossil fuels in the power generation industry and transportation sector. Life-cycle CO_2 emissions for renewable energy technologies are much lower than fossil fuels. The life-cycle balance is also considered to be an important factor in the heat and transportation sectors. Based on an analysis performed by the IEA, renewable power generation enabled countries to save 1.7 Gt of CO_2 emissions in 2008, a figure that is more than the total power sector's CO_2 emissions in the European region (1.4 Gt) (Ölz, 2011). This analysis shows that hydropower technology constitutes the largest share for saving CO_2 emissions with 82 percent, followed by biomass and wind with 8 and 7 percent, respectively.

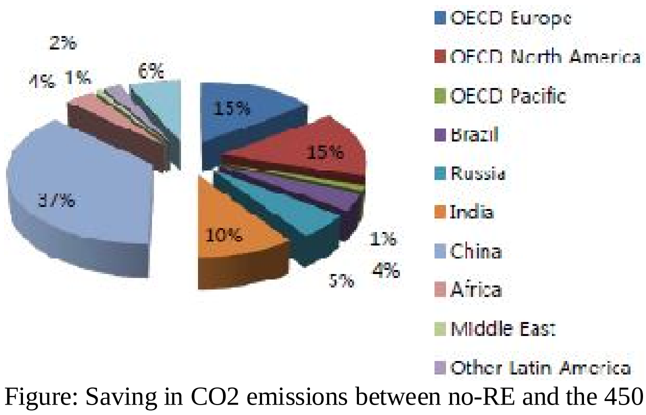

Figure: Saving in CO_2 emissions between no-RE and the 450 ppm scenarios in 2030

According to the IEA analysis, the potential savings for the OECD and BRICS countries is roughly 5.3 Gt in the year 2030, almost the same as is forecasted for power-related CO_2 emissions in the WEO 2010 report for the these countries in 2030 under a 450 ppm scenario (5.8 Gt). Figure shows the CO_2 saving under the WEO 450 scenario compared to a no renewable energy scenario in 2030. The key point is that most CO_2 savings are concentrated in the OECD countries and China. According to the IEA report, CO_2 savings in China on a 450 ppm scenario would be 2.2 Gt, constituting 64 percent of the BRICS countries' total saving (Ölz, 2011). Edenhofer et al. (2010) examined the technological feasibility and economic consequences of achieving greenhouse gas targets and found that these targets are low enough to be feasible, both technically and economically. They stated that this crucially depends on the particular technology. For example, the availability of carbon capture storage technology is very important in the removal of CO_2 from the atmosphere. Also, they argued that additional political and institutional prerequisites are required to achieve the targets.

II. SUMMARY AND CONCLUSION

Ongoing concerns about climate change have made renewable energy sources an important component of the world energy consumption portfolio. Renewable energy technologies could reduce carbon dioxide emissions by replacing fossil fuels in the power generation industry and the transportation sector. Due to negative and irreversible externalities in conventional energy production, it is necessary to develop and promote renewable energy supply technologies. Power generation using renewable energy sources should be increased in order to decrease the unit cost of energy and to make them compatible with a competitive alternative to the conventional energy sources. Two main solutions may be implemented to reduce CO_2 emissions and to overcome the problem of climate change: replacing fossil fuels with renewable energy sources as much as possible and enhancing energy efficiency regardless of type. In this review, we considered hydro, wind, solar and geothermal sources, because of their significant contribution to power generated by renewable sources. Renewable energy production and supply is continuously increasing on the global level. Following the drastic increase in oil price and its impacts on both coal and gas prices, a large amount of investment has been made over recent years in renewable energy. These advancements in technology have enabled countries to produce renewable energy in larger quantities and more cost effectively. Due to negative and irreversible externalities associated with conventional energy extraction and consumption, it is necessary to promote and develop renewable energy supply and consumption. The IEA forecasts positive developments in renewable energy sources. They act as substitutes for fossil fuels and reduce emissions. In the short term, some renewable technologies may not be comparable to conventional fuels in the scope of production costs and transmission, but they could be comparable if we consider their associated positive externalities, such as their environmental and social effects. Also, it should be noted that economies of scale could play a key role in reducing the unit cost of production. Transmission and distribution costs and technologies do not differ much among the conventional and renewable energy sources. In this review we have presented detailed facts about the main renewable energy supply technology developments, including hydro, wind, solar, and geothermal in detail and other sources such as biomass, ocean waves and tides in brevity. The emphasis has been on current production capacity and the estimated capacity, as well as development costs which are sunk. We have also presented empirical findings from comparative studies of alternative energy technologies. Hydro power is the largest renewable energy source for power generation around the world. Despite its large energy generation contribution, its development is difficult due to a high initial fixed investment cost and environmental and population relocation costs. Hydro power is attractive due to a combined supply of water for agriculture, household, recreation and industrial use. Additionally, it can store water and energy that can be used for both base and peak load power generations. The availability of funding, political and market risks, resource allocation priorities and local environmental concerns are considered to be barriers to the development of hydro power capacity. The installed wind power capacity has also been increasing, especially in countries like China, the US, Germany and Denmark. Advantages of wind power plants include the installation as turnkey contracts within a short period, a lower investment compared to nuclear and hydroelectric plants, economies of mass production, an absence of fuel costs and low operation and maintenance costs. The problems associated with the use of wind power include intermittency of wind energy and an added cost for power transmission to users. Generation cost is dependent on location, feasibility and the minimum required speed for wind turbines. China has developed its own solar power capacity, decreasing the cost of generation due to the availability of cheap labor and public subsidies. Another source of the reduced costs is in advances and the high efficiency in concentrated solar power technologies in the US. The negative effects include land, material and chemical use and impacts on buildings' esthetics. The performance is dependent on location.

Geothermal energy has been used throughout history for bathing, heating and cooking. The geothermal gradient and permeability of rocks determines its economic implementation feasibility. Unlike wind and solar power, geothermal is continuously available through the year, although technology has some negative environmental effects. Improved energy efficiency is an important way to reduce energy use, and thereby CO2 emissions, and to overcome the climate change problem. We discussed state of the art methods for the technical and economic feasibility in the implementation of renewable energy sources, as well as the possibility of their combined use and substitution in the first part of this review. In the latter part we discussed energy efficiency technologies. Energy efficiency for electricity networks can be considered in different stages, such as power generation, transmission, distribution and consumption. For this purpose, different energy efficiency technologies are available, including electric vehicles, combined heat and power, virtual power plants and smart grids. Each of these technologies were discussed in detailed and their performances compared.

A virtual power plant is a cluster of distributed energy resources controlled and managed by a central control unit, allowing for the possibility to control home appliances to optimize load reductions. It helps to combat the energy waste problem due to distance and transmission losses. The driving force for using renewable energy technologies are energy security, economic impacts, and CO2 emission reduction. The level of insecurity is reflected by the risk of supply disruption and the estimated costs of security itself. The emphases for the economic impacts are job creation, industrial innovation and balance of payment. Renewable energy technologies could enable countries with good solar or wind resources to implement these energy sources to meet their own domestic demand. Moreover, the cost of importing fuels can affect economic growth. If these countries could reduce their balance of payment by producing their own renewable energy to replace their dependence on fossil fuels, they could expand their capacity for investment in other sectors. Renewable energy technologies could reduce carbon dioxide emissions by replacing fossil fuels in the power generation industry and transportation sector. Life-cycle CO2 emissions for renewable energy technologies are much lower than fossil fuels.

This review of renewable energy generation and efficiency technologies has provided detailed and useful information that can be used in the decision making of different stakeholders in the rapidly developing market. Each technology has both advantages and disadvantages that vary by location, availability, the technological capability of producers, financial limitations and environmental considerations. Each municipality, region or country has different initial conditions that determine the energy mix that can be produced at the lowest cost while minimizing the harm done to the environment. Thus, there is no single solution to every energy need and problem, but rather an optimal location specific solution among a set of possible renewable solutions.

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