UiT NORGES ARKTISKE UNIVERSITET

The School of Business and Economics

Renewable energy policy Comparison between EU and China-An empirical analysis with experience curve on EU and Chinese Solar industry

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Preface

To start with, I would like to say thank you very much to my supervisor Jan-Yngve Sand. Appreciate your patience on my paper and me. As I am always delaying on my submission, I really appreciate your help and your time. Thank you for helping me decides the thesis topic and helps me to make the field work looking for the thesis inspiration.

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I also want to thanks for the support from my family. Thanks to my special half Julie Sandbakken who always stand behind me and show your full support. Without you, I would insist to finish this paper.

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Jiabin Gao

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Abstract

The renewable energy sources (RES) has been largely adopted in the world, especially European Union and it has become the main market for wind energy and solar photovoltaic energy. With the stimulation impact from the Feed-in tariffs (FIT), the Solar PV market blowout since 2004. However, even tough with the stimulation of support schemes, the solar energy is still beyond publics bearing.

The European Union and China have both massively utilized renewable energy in the recent years. Therefore, it is meaningful to review EU and China's renewable energy policies development history. From the comparison to analysis how policy stimulate renewable energy utilizing.

By 2007, China has become the world's largest solar energy producer. With China involved into the market, the solar products prices decline dramatically. Meanwhile, EU is the largest solar energy application market. Therefore, adopt experience curve as a tool to assessment European and Chinese solar industry will help us to reveal the factors that influence the cost reduction of solar products.

Keywords: Renewable energy policy, Experience Curves, Solar PV energy

Context

1. Introduction

1.1 Background

Science and technology has reached a point where our minds finally catching up with our imaginations. Over the last two centuries, the two Industrial Revolutions had successfully changed our world. It is acknowledged that economic growth has already been closely tied up with the fossil fuel, and it has become one of indispensable part of economic growth. Recent surveys showed that energy use has grown significantly in OECD countries (USA, EU, Japan) over the past 20 years. In addition, energy demand has grown rapidly in developing countries over the past few years and expects to continue increase, countries such as, China, India and Brazil. The largely adoption of traditional energy (fossil fuel) has inevitable leads to the raise of greenhouse gas (GHG) emissions into the atmosphere. Carbon dioxide (CO_2) is the effluent from the usage of fossil fuel and it is threatening the life as we used to know it. The rising temperature is changing our landscapes, rising sea level, threatening wildlife and altering weather patterns all over the world. The impact of traditional sources energy has cause environmental concerns by a majority of the public.

To remit the issues accompanied with the adoption of conventional energy resources. Renewable energy sources (RES) has rapidly become one of our choices to overcome these critical issues. The European Union Directive 2001/77/EC defines renewable energy sources as renewable non-fossil energy sources which includes “wind, solar, geothermal, wave, tidal, hydro-power, biomass, landfill gas, sewage treatment plant gas and biogases”(Commission, 2001). The RES not only can decrease GHG emission but also increased contribution to job creation and the security of national energy supply. The hydro power and wind power had been massively adopted in country such as Norway and Denmark, showed an optimistic future of electricity supply.

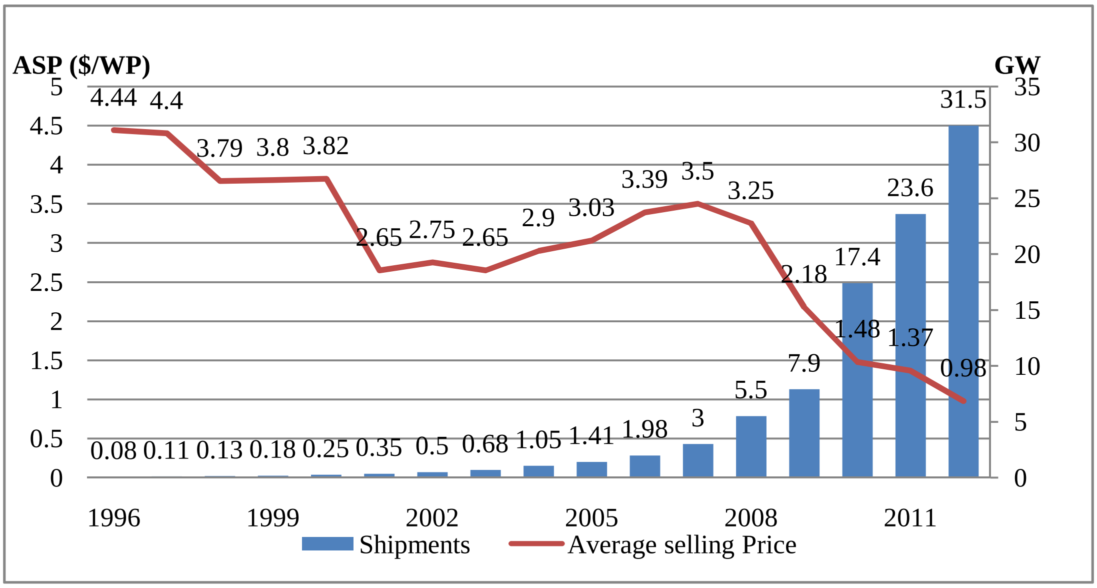
The current economic and social system is still based on traditional source of energy and their distribution system, it takes time for current economic and social system to admit renewable energy sources (Jager-Waldau, 2007). Secondly, renewable energy requires huge initial investment. As the RES efficiency is still relative low which induce longer payback time for the investor. The longer payback time weak the confidence of RES investors. At last, the most crucial barriers for RES is regardless of the type of renewable energy sources, as a matter of fact, current economic costs of KWh obtained from traditional fossil fuel are still lower than renewable energy resources. The higher cost of renewable energy makes it no competition advantage compared with conventional sources of energy. Even though, with the effect of R&D development and learning/experience effect, the cost of renewable energy sources showed slightly decline, it is still unaffordable for the public and the cost of renewable energy electricity still have a long way to reach grid parity.

The RES has been largely adopted in the world, especially European Union and it has become the main market for wind energy and solar photovoltaic energy. Solar Photovoltaic (PV) has showed it is a great potential to be a mainstream electricity provider in Europe. With the stimulation impact from the **Feed-in tariffs (FIT)** incentive measures, the Solar PV market blowout since 2004. According to the data from European Photovoltaic Industry Association (EPIA), the cumulative installation capacity reached 601MW, which almost doubled compared with previous year and the cumulative installation capacity continued double growth since 2008, even during the worst macro-economic period. In 2011, the European market reached its peak annual installation which is 22GW and by 2013, the cumulative installation capacity reached 81GW in European market. However, with the dramatically cost decline of solar PV products, the European markets expansion quickly and soon reached a high penetration level. As a result, currently, the FIT incentives gradually declined in adjust to the falling cost of solar PV products.

The solar photovoltaic (PV) technology had proved it could generate sufficient electricity during the day time to meet the peak hour electricity demand, however, due to its relatively high cost, the deployment of solar PV systems was much slower compared with wind energy. Furthermore, without government subsidies and supports, high cost of solar PV weakened its market competitiveness when compared with convention electricity without government subsidies and supports. Fortunately, the rapidly improvement of the solar technology and tough market competition has induced the cost of solar energy declined dramatically in the last few years. The solar PV modules price trend and the cumulative shipment is showed in **Fig.1**. Just like Nemet (2006) mentioned "no energy technology has changed more dramatically than photovoltaic (PV), the cost of which has declined by a factor of nearly 100 since 1950s." With the technology spread globally, the Chinese solar Manufactures took the dominant position in global solar industry and it became the bigger solar producer since 2007. According to Greentech Media (GTM) Research, Chinese solar manufactures accounts half of the top 10 solar PV manufactures in 2013, see **Figure.2**. With Chinese manufactures' joined into the game and involved into global market, the solar modules prices had decline significantly since 2005 and solar products had been massive utilized in EU, US, Japan and China.

Fig. 1

World PV ModuelsAverage Selling Price (ASP) & Shipments 1996-2012

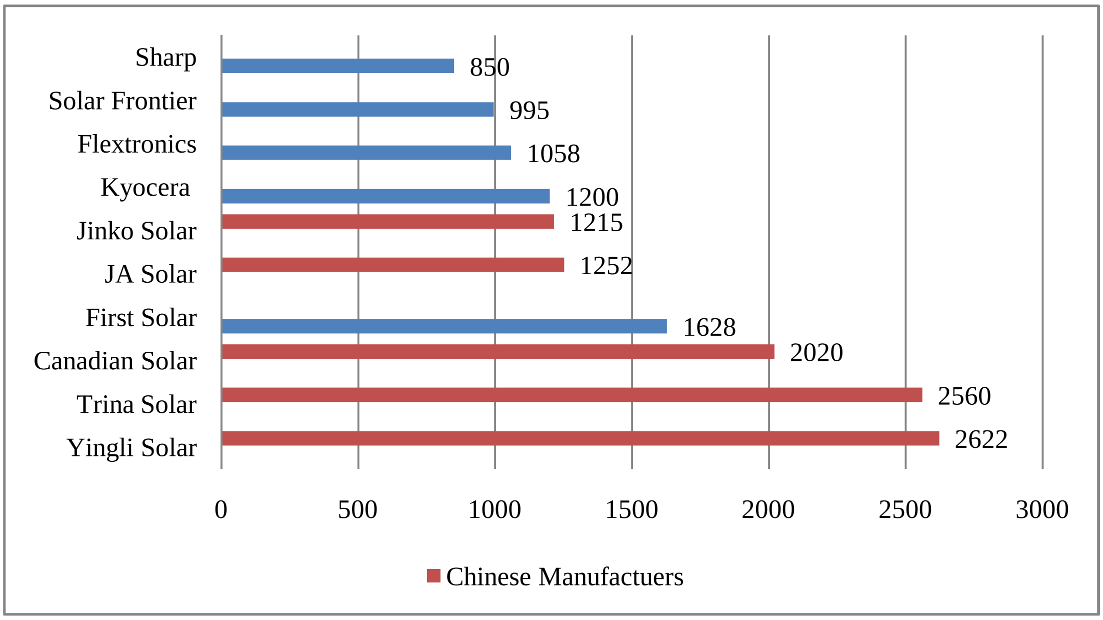


Source: Data colleted from (World, 2012), figure genereted by paper author.

As we know, the diffusion and utilization of renewable energy technologies will depend on their future cost cutting (Neij, 1997). Solar PV energy as a newly immature technology especially depends on their low cost to compete with conventional energy resources. However, in reality, governments ignore the opportunities to massive utilize low cost solar PV energy due to trade protectionism. The German solar company SolarWorld AG filed anti-dumping complaint to European Commission in July, 2012. Afterwards, the European Commission set the duties as average 47.7% for Chinese solar panel manufactures and also set the minimum import modules price for modules produced from China. SolarWorld AG, American Branch, also filed complaint to U.S International Trade Commission (ITC) in 2012. The ITC allows U.S Commerce Department (DOC) to issue anti-dumping and countervailing duty orders on imports of solar products from China for five-year period. In Oct, 2012, the U.S Commerce Department (DOC) set the duties for Chinese solar cells range from 18.32%- 249.96 for different Chinese Manufactures. Through cost cutting, Chinese Solar PV manufactures had successfully stimulated the solar PV utilization into a new stage, however, it is a unoptimistic that the adoption of low cost solar PV energy will be affected by the trade protectionism.

Figure. 2

World Top-10 PV moduel Producer in 2013 (MW)



Source: data collected from GTM research, figure generated by paper author.

1.2 Literature Review

1.2.1 Renewable Energy Policy

The book "*Harnessing renewable energy in electric power systems: theory, practice, policy*" by Boaz Moselle, Jorge Padilla and Richard Schmalensee, provide a detail about European Union renewable energy policy framework and its development history. The EU different Directives o (2001/77EC, 2003/30/EC, 2009/28/EC) indicates the obligations that member states should obey and stipulate measures for member states to promote RES utilization. Schuman and Lin (2012) argues that after China implemented the Renewable energy law in 2005, several mechanisms was established, such as national targets, support schemes and mandatory market connection, etc. NREL (2004) indicates that there exists three levels in Chinese renewable energy policy. The legal documents such as "*Renewable energy law*", "*The Mid-and Long- Term Plan for Renewable Energy*" and "*Amendment of Renewable energy law*" emphasize the regulations and rules for renewable energy development.

1.2.2 Experience Curve

The experience curves were used as an important tool for assessment renewable energy technical change and assessment for renewable energy policies, Neiji (2003),adopted experience curves method to evaluate the different resources of cost reduction and the effect of different renewable energy polices. The experience curves model also proved that learning from market can reduce prices for various technologies. For example, Neij (1997), Neiji (2003) had demonstrated that the price/cost decline is related to the cumulative production, especially in wind energy industry.

There are numerous studies and literatures related on experience curves effect on solar PV technologies. Neij (1997) indicated that the experience curves used for solar PV models are considered to be uncertain, research results shows a highly Progress

Ration (PR=96%) since solar PV is a relatively new coming technology. Maya.Papineau (2006) emphasize on experience curves and dynamic economies in renewable energy technologies. Her analysis point out that experience estimate in US solar industry is either substantially reduced or statistically insignificant when related to experience index. Furthermore, studies also showed that through experience curves analysis; the effect of R&D to solar PV industry is relatively small and statistically significant. Solar industry is similar with other renewable industry; the massive investment on Research & Development (R&D) will gradually reduce the cost of the products. Under the influence of R&D, companies with cutting-edge technology will make them keep a low cost expense for the production which induces the companies be the price maker and maintain leading position in the industry. The R&D effect could not only brings cost curves of solar industry downward shifts but also interact with experience curves to reduce the solar product's price (Maya.Papineau, 2006).

Nemet (2006) indicated that the "*learning by doing*" or "*experience*" effect of cumulative production appears do not have major influence on PV cost reduction. The studies showed that experience curves effects is only one of the explanations to the decrease of solar PV products and the most important factors are plant size and module efficiency.

Moreover, most of these analyses are based on Single Factor Experience Curve model (SFEC) or One Factor Experience Model (OFEC), such as analysis in Neij (1997), IEA (2000), Neiji (2003). The SFEC use cumulative production as independent variable to explain the changes in dependent variable (price or cost). These SFEC studies also had its weakness, for instance, the SFEC study did not include the R&D or other technical improvement as the explanation factor to dependent variable (price or cost). Secondly, the Two Factors Experience Curves (TFEC) and Multi Factors Experience Curves (MFEC) usually suffer from invalid data or poor data quality, and multicollinearity issues, these factors and uncertainties induces the inaccurate of TFEC or MFEC estimation.

1.2.3 Research Questions

This paper aims to investigate what is the truly reason for solar market boom and the cost decline of solar PV products. As showed in figure.1, the Chinese solar manufactures account for the major player in world solar market and it became the biggest producer since 2007. Meanwhile, EU is the area where largest adopt solar energy, therefore it induce the largest solar market in the world. Therefore we will take European and Chinese solar manufactures as empirical analysis object, to further verify and support our assumptions; For R&D effect analysis, we will adopt Chinese manufactures as research object as they have dominant the world production. We will adopt experience curve to examine if R&D could help decrease the cost of solar products.

Association (2013) stated that it is obviously that solar PV market is driven by policies regulations and support schemes. Therefore, the paper will adopt qualitative analysis method to analysis and summary the EU and China's renewable energy policy. The policy analysis will mainly focus on renewable energy electricity policies, the policies refer to the renewable energy heating, and renewable energy transportation is not considered in this paper. Then further move to analysis policies that specified on solar energy. On the other hand, as mentioned above, the experience curve had been adopted in analysis of solar industry. Therefore, we will adopt the quantitative analysis method- experience curves estimation in the paper to assessment the European and Chinese solar PV industry. Based on the historical EU and China's renewable energy policy and historical development of solar industry, we then adopt top-down approach to assess the general renewable energy policies, policies specified on solar energy, solar PV market and solar PV industry.

Research Questions as follows:

Q1: To what extent does renewable energy polices stimulated the development of solar utilization?

Q2: Does experience curve effect exists in European and Chinese solar industry?

Q3: How much cost reduction can experience curves effect induce in EU and Chinese solar market?

Q5: Is there any other factors influence cost reduction in solar PV products?

The rest of the paper is organized as follows: Sector 2 focus on the introduction and analysis of general renewable energy policy development history in EU and China, and the comparison between two regions' renewable energy policy. Section 3, the paper will focus on policies that specified on solar energy in EU and China. Section 4 presents the theory, method of experience curve estimation and data collected for the experience curve estimate on EU and Chinese solar industry. Section 5 provides results of our estimation, while section 6 discusses the result. Finally, section 7 provides ending with answers for our questions and ending conclusion.

2. General Renewable energy Policy in EU and China

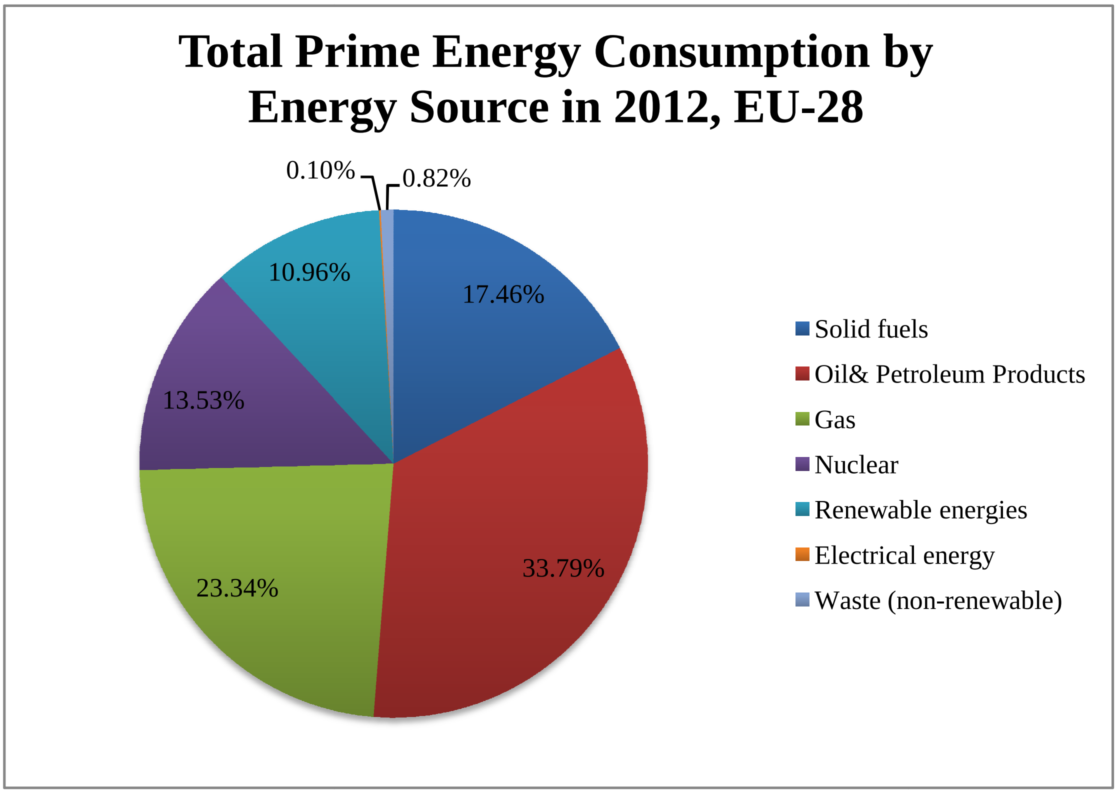
2.1 European renewable energy policy

2.1.1 Current renewable energy utilization in EU

Currently, EU is the most successful area where massively utilized RES. In 2012, the renewable energy accounts for almost 11% of total energy consumption in EU-28 (see Figure.3). The largest share is still dominated by oil and petroleum products. The Directive 2009/28/EC on the promotion of renewable energy set the targets for renewable energy to account 20% of total energy consumption by 2020. European Union is on its track to meet the setting targets.

Figure.3

Total Energy Consumption by Energy Source



Source: (Eurostat, 2014c)

2.1.2 European Union Renewable energy Policy review

It was indistinct when is the exactly time that the European Union start to set up the policies for renewable energy resources adoption. However, it is considered that the EU initial start to push toward developing policies for renewable energy resources can date back as early as 1996 (Moselle, Padilla, & Schmalensee, 2010). A Green paper- *A European Strategy for Sustainable, Competitive and Secure Energy* was issued by the Commission of the European Communities in 1996. The Green paper proposed an energy strategy for Europe which was balancing sustainable development, competitiveness and security of supply. Nowadays, the European Union has became a vital player in world economic development and it is no doubt that EU will demand massive of energy resources to support its' massive economic ship advance. As a consequence, the massive energy consumption induce EU's energy import dependency gradually arise. The Green Paper indicated that Union's external dependency of energy is constantly increasing and will increase to approximately 70% in the next 20 to 30 years compared with 50% in 1996. Also, most of the energy products the European Union imported were from the regions threatened by uncertainty or insecurity. The Green paper also indicated that the world energy demand is increasing dramatically which lead to the raise of oil price and gas price. From 1994 to 1996, the oil and gas price had almost doubled during two year. The large demand of energy products not only increase the price of energy products but also increase Green House Gas (GHG) emission. According to the Green paper, the CO_2 emission is expected to increase 60% by 2030. Largely increased greenhouse gas had made our climate getting warmer and the information from the Intergovernmental Panel on Climate Change (IPCC) shows that the green house gas had made the world 0.6 degrees warmer. (Commission, 1996). If the global warming can not be ceased, the earth will face a catastrophe in the near future. Concerned of the threat of the energy dependency and the global warming, the European Union carry out the green paper and suggests developing clean energy as a solution.

The 1996 Green paper was like a spark. As a consequence, the European Union has gradually carried out policies for its renewable energy adoption. The 1997 White paper set an indicative objective of 12% of energy consumption from the contribution of renewable energy and fulfilled by 2010.(Commission, 1997). The Commission sees the target as an indicative target and described as a good policy that gives a clear political signal and impetus to action. The target was also described as an ambitious but realistic objective. However, this pioneer policy did not legislation the target for each member states in the Union. It is only mentioned that "targets in each member state could stimulate the effort towards increased exploitation of the available potential and could be an important instrument for national industry and creating jobs" The white paper also indicates that "each Member State should define its own strategy and within it propose its own contribution to the overall 2010 objective"(Commission, 1997).

The 1997 White paper indicates some Main features of the Action Plan to stimulate renewable energy resources adoption. The main features of the action plan including four major parts, which are Internal market Measures, reinforcing community polices, strengthening co-operation between Member states and Support Measures. The white paper had presented political support and financial support to stimulate renewable energy resources adoption.

The White paper of 1997 promotes the renewable energy sources on the basis of diversification of energy supplies, environmental protection, cost reduction, financial aid and social job creation. In a way of sense, the White paper of 1997 became a foundation point for recent renewable energy sources development in Europe.

On September 27th, 2001, the Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources in the internal electricity market was issued by European Parliament and of The Council. The purpose of carry out 2001/77/EC directive is "to promote an increase in the contribution of renewable energy sources to electricity production in the internal market for electricity and to create a basis for a future Community framework" (Commission, 2001). In addition, there are other purposes for carry out 2001/77/EC directive, including the security and diversification of EU energy supply. The directive made a clear definition about renewable energy resources and also the scope of the directive. "The renewable energy resources shall mean renewable non-fossil energy sources (wind, solar, geothermal, wave, tidal, hydro-power, biomass, landfill gas, sewage treatment plant gas and biogases)" (Commission, 2001). The directive first time emphasized the national indicative target for the share of electricity produced from the renewable energy resources in each member state. In Article 3(1) the directive makes it clear that all member states must apply the provisions and take appropriate steps to stimulate the electricity production from the renewable energy resources in consistent with each member's indicative target (Commission, 2001). In Article 3(2), the directive emphasis that each member state have to summary information and submit a research report about electricity produced from renewable energy resources no later 27th October 2002 and every five years thereafter. The report should describe the proportion of electricity produced from renewable energy resources in total electricity production in each member state. The report should also emphasis that what measures had been taken or planned by each member state to ensure their own indicative target. Each member's target shall take account of the reference values in the directive's annex and these targets should compatible with any national commitments entered into Kyoto Protocol (Commission, 2001). In Article 3 (4), the European Commission also has the responsibility to publish a report not later than 27th October 2004 and every next two year to examine the progress of each member states in fulfills its indicative target (Commission, 2001).

As we can see, to start with, the directive (2001/77/EC) set down the indicative target of electricity consumption from renewable energy resources was 22.1% for EU-15 by 2010. With the Accession Treaty on April 2003, the gross indicative target for the proportion of electricity produced from renewable energy resources was set up as 21% for EU-25 by 2010 (Kanellakis, Martinopoulos, & Zachariadis, 2013). In addition, the directive set the measures to evaluate each member's progress on electricity produced from renewable energy resources. These measures were taken at national and community level. The report announced by each member state every five year can reflect the progress of each member state's electricity production from renewable energy resources toward achieving their own target. The report published by the commission every two year will show the whole pictures of the electricity production from renewable resources in the union. The national and community mechanism will no doubt stimulate the renewable energy resources deployment in its initial developing stage. The directive (2001/77/EC) also set up the following provisions:

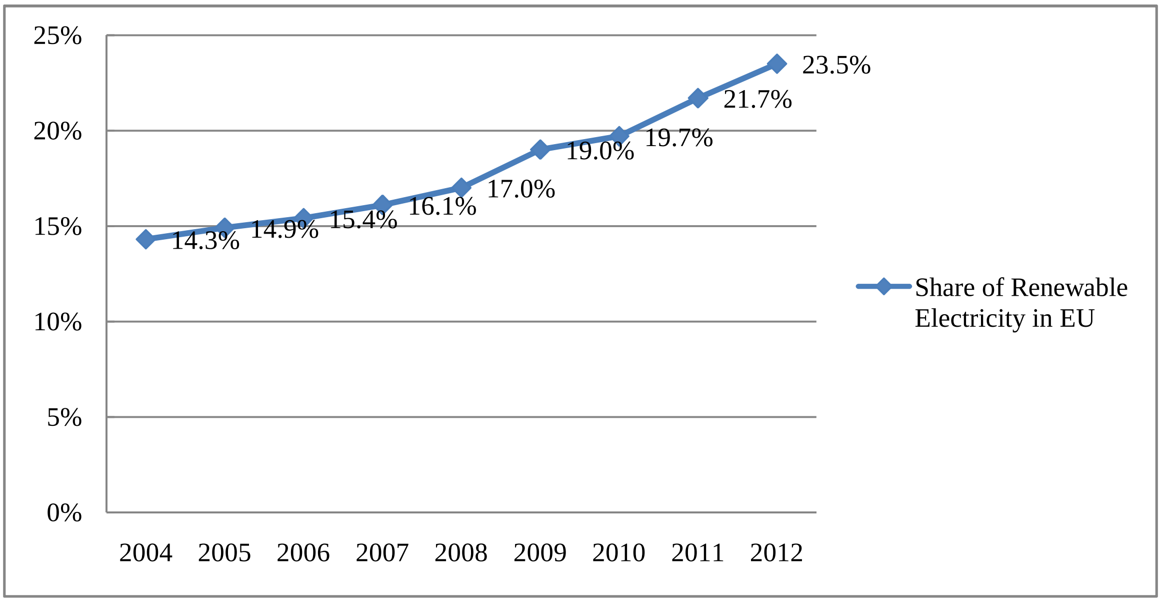
- Present a report followed with a proposal refer to support schemes. The proposal should be able to stimulate the renewable energy resources development and contribute to the achievement of national target. The proposal should also help the RES-E compatible with electricity from fossil fuels. Secondly, the proposal should consider the different character of renewable energy resources, technology and geographical difference. Moreover, the proposal should be able to promote renewable energy resources deployment and contribute to renewable energy resources cost reduce.(Commission, 2001)
- The directive (2001/77/EC) required member state to guarantee the origin of RSE-E. This mechanism provides the transparency of RSE-E production. The mechanism required to provide the full information of electricity produced from renewable energy resources. For example, electricity comes from which kind of renewable energy resources, notify the date and the places of the production. The distributor of the RSE-E shall provide evidence to show that electricity they sell is produced from renewable energy resources.
- Required member state to gradually eliminate the administrative and non-administrative barriers to RES-E producers. Provide convenience and fast-track planning to RSE-E producers. To ensure the rules are objective to renewable energy resources when compared with traditional fossil fuel.
- Proposed amount of measures to simplify grid connection for RSE-E. Also proposed to eliminate any potential discrimination for RSE-E grid connection and distribution. The directive (2001/77/EC) required each member state to ensure RSE-E transmission and distribution, also required grid operator to give priority grid connection and generating installation for electricity produced from

renewable energy resources. It also required that grid transmission operator and distributor should bear the full cost or the part of the cost for grid update to accept the RES-E. The directive also request each member states to set up legal framework for grid operators and electricity distributor related to the cost of grid connection and grid update. Each member states should have no discrimination when transmits and distribute the electricity produced from renewable energy resources.

- Finally, the directive required the commission to present a report to the European Parliament and Council every five year to describe the implementation of the directive.

The directive first set up the indicative target for each member state, however, it does not set up the legally obligations on member states. Surly, the Commission set up the directive to make a guideline role for each member state. But in fact, according to the statistic data from Eurostat, the 2010 indicative target mentioned in the directive (2001/77/EC) was not fulfilled. The statistic result shows that the electricity generated from renewable energy resources was 19.7% for EU (28 countries) in 2010. The target was achieved in 2011, which is 21.7%.

Fig.4 Share of renewable electricity in EU (2004-2012)



Source: (Eurostat, 2014a)

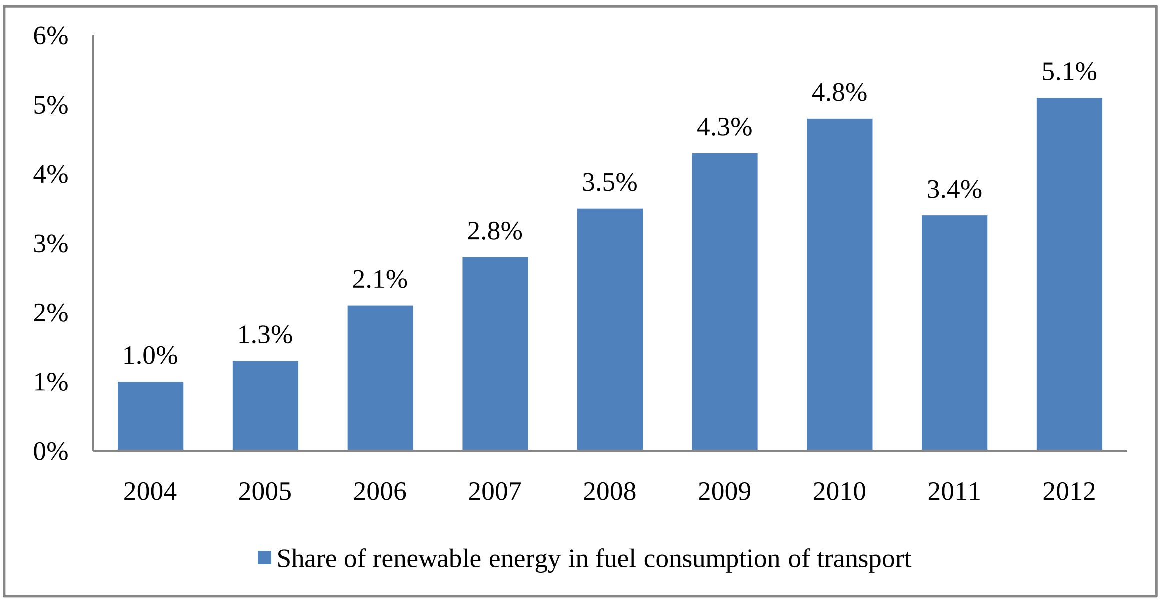
The figure above shows the share of electricity generated from renewable energy resources in total EU electricity generation. Even though the 2010 indicative target was not achieved, the directive largely stimulated the development of renewable energy resources adoption and there is no doubt that each member state progress varies significantly on the renewable energy adoption, few member states over-achieving targets and some member states missing their targets (Klessmann, Held, Rathmann, & Ragwitz, 2011). From 2001/77/EC directive, we have already seen that EU has showed their determination to develop renewable energy. Also, we saw from the directive that the European governments are getting more and more involvements into renewable energy source sector. Government involvement is essential in the embryonic phase of renewable energy source development, its policy and measures will protect renewable energy resources and renewable energy technology from direct competition with conventional energy and technology. Without administrative and fiscal support, renewable energy will force big challenge from traditional fossil fuel. The directive guide the renewable energy resources adoption maintain in the right track.

In 8th May 2003, the directive 2003/30/EC was set up by the European parliament and of the Council, which is on the promotion of the use of biofuels or other renewable fuels for transport. The directive aims at promoting the adoption of biofuels and other renewable fuels to replace conventional fuel in transport sector for each member state, also with a view to ensure EU to meet the climate change commitments, energy security and accelerate renewable energy resources adoption (Commission, 2003). The directive requires each member state to set national indicative target for biofuels and other renewable fuels in transport sector in 2005 and 2010.These targets were calculated on the basis of all gasoline and diesel for transport purpose placed on the markets, the target was set for 2% by 31st December 2005 and another target was set for 5.75% by 31st December 2010 (Commission, 2003). According to the data, the transport sector accounts for 30% of energy consumption in EU. It is a huge portion compared with other sector. The directive not only considered using biofuels to replace conventional fuels but also help EU to achieve CO_2 emission reduction, the

CO_2 emission from transport sector "between 1990 and 2010, to around 1113 million tones, the main responsibility resting with road transport, which accounts for 84% of transport-related CO_2 emissions" (Commission, 2003). It could help each member state to meet its commitment accepted by the Community under Kyoto Protocol. From Article (4) in the directive we can see that the monitor mechanism on national and Commission level was introduced again. Member states are responsible to report to the Commission on what measures had been taken to accelerate the deployment of biofuels and renewable fuels to replace traditional petrol fuels, what is the total amount that transport fuels sold and the share of biofuels and other renewable fuels account in the total amount of transport fuels sold. The report had to be submitted to the Commission before 1st of July every year. The directive also required Member states to "bring into force the laws, regulation and administrative provisions necessary to comply with it". The Member states shall also noticed to the Commissions that what provisions they had modified with their national law to adjust with Directive (Commission, 2003).

Fig 5.

Share of renewable energy in fuel consumption of transport (2004-2012)



Source: (Eurostat, 2014b)

Fig 5 shows the share of renewable energy in fuel consumption of transport in EU from 2004 to 2012. The target for 2010 is 5.75% by the directive 2003/30/EC, however, according to the data from Eurostat, the share of renewable energy in fuel consumption of transport in 2010 was 4.8%. Thus, EU as a whole was failed to achieve its 5.75% target. The latest Renewable energy progress report from European Commission shows that 22 member states are failed to achieve their 2010 targets of 5.75% (Commission, 2013).

The statistic result from Eurostat and varies reports from European Commission had demonstrate that none of the blinding targets and objectives set in 1997 White Paper, the directive 2001/77/EC and the directive 2003/30/EC were accomplished. The missing target may break down European Commission's ambitious to promote renewable energy adoption in EU and it will much harder for EU to overcome its multi challenges. Nevertheless, we have to admit that these legal documents issued by European Commission are playing a significant role in recently renewable energy adoption in EU. During the period when the White paper and these directives were adopted, the development of renewable energy resources growing rapidly and make EU to be a global leader in renewable energy adoption. Although, it is icebreaking for the renewable energy adoption and we saw great achievement in EU, it is become clear that these measures proposed in the directives are not adequate enough to stimulate the member states to achieve the 2010 renewable electricity and biofuels target. Therefore, EU needs some new and strict policies to meet the challenges of climate change, energy dependence for the 21st century.

In 10th January 2007, the European Commission issued a strategic review of the European energy situation. The Communication titled "Communication from the Commission to the European Council and the European Parliament- An Energy Policy for Europe(Communities, 2007a). The communication emphasized the challenges that EU were facing and introduced a complete set of European energy police measures. These measures are also so-called (the energy package). The communication was established under EU's main energy principle as a background, which is sustainability, Security of supply and Competitiveness. This principle was reflected in the 1996

Green paper. The 1996 Green paper emphasized an energy strategy for Europe which was balancing sustainable development, competitiveness and security of supply. In 2006, the Commission issued a Green paper- “A European Strategy for Sustainable, Competitive and Secure Energy”(Commission, 2006). The 2006 Green paper set out the latest realities that EU were facing which are continuously growing Global energy demand, EU energy import dependency rapidly increase, oil and gas price continuously growing and world’s climate persistently getting warmer. In the 2006 Green paper, it directly points out that “Europe’s energy policy should have three main objectives” (Commission, 2006) and these three main objectives with no doubts are Sustainability, Competitiveness and Security of supply. We can conclude from 1996 Green paper and 2006 Green paper that the European Union constantly took these three objectives as the main principle rule for Europe’s Energy policy. The 2006 Green paper also emphasized that to achieve these three objectives, it is critical to put these three objectives in an overall framework, in the first Strategic EU Energy Review (Commission, 2006). Thus, the communication is the part of the movement begun by the 2006 Green Paper and places energy policy as a core of European Policy.

The communication involves EU’s determination to reduce worldwide and its own green gas (GHG) emission to limit the global temperature increase to 2° compared with preindustrial level and it pointed out the threaten of energy import dependency the EU were facing. It also emphasized that the communication will endorse measures to enhance the competitiveness of the European energy market and boosting investment on improving energy efficiency, promoting renewable technologies and contributing to create jobs in Europe.

The Communication of an energy policy for Europe proposed following strategic objectives to guide Europe’s Energy policy.

- “an EU objective in international negotiations of 30% reduction in greenhouse gas emissions by developed countries by 2020 compared to 1990. In addition, 2050 global GHG emissions must be reduced by up to 50% compared to 1990, implying reductions in industrialized countries of 60-80% by 2050;

- an EU commitment now to achieve, in any event, at least a 20% reduction of greenhouse gases by 2020 compared to 1990” (Communities, 2007a).

The reason that reducing GHG emission and became the centre of the new European energy policy was based on following reasons:

- CO_2 emission accounts for 80% of EU GHG emissions. Reducing GHG emissions will bring less traditional energy use and using more renewable energy.
- Avoid the risk for EU from the highly volatility world oil and gas price.
- Enhancing the competitive of European Energy market, promoting new technology innovation and creating jobs.

To help the Strategic objectives to be achieved, the communication endorsed the following provisions in its action plan.

- A commitment to achieve 20% reduction of greenhouse gas emission by 2020 compared to 1990.
- An objective of improving its energy efficiency by 20% by 2020
- A blinding target of increase the share of renewable energy in EU’s overall energy mix to 20% by 2020 and minimum 10% of biofuels share in total transport consumption.

The strategic energy plan set out above was catalyzing as a **new industrial revolution**. It will Europe into a highly energy efficient and low CO_2 energy economic. The energy plan was complemented with few changes and in legislation shortly after Lisbon Treaty (Kanellakis et al., 2013). The provisions mentioned above were became known as 20-20-20 target or 20-20-20 package. It is necessary to go through the 20-20-20 target. First of all, the 20-20-20 target is a long term and ambitious target. The reduction of 20% greenhouse gas emission by 2020 compared to 1990. It shows the EU’s determination and ambitious, however, the realistic is not optimistic. The IEA expects twice more electricity will be produced from coal by 2030, the burning of the coal will potentially release approximately 5 billion tones of CO_2, representing 40% of potential increase CO_2 emissions. Also, with rapidly growth of world energy demand, the total CO_2 emission will increase 60% by 2030 (Communities, 2007a). The European Union needs amount of actions to achieve this GHG 20% reduction. Secondly, as we can see from the previous directive, EU had failed to achieve the indicative target of 12% share of renewable energy by 2010. Also it failed to achieve the target of directive 2001/77/EC and directive 2003/30/EC. By 2020, the share of renewable energy accounts for 20% of the total EU energy consumption seems like facing huge challenges. The cost of renewable energy still higher compared with conventional energy, most of the consumers are not prepared to pay a higher price for a public goods which everyone will be benefit from (Menanteau, Finon, & Lamy, 2003). Nevertheless, with technical innovation, economics of scale and market competition, the cost of renewable energy has decreased significantly, in some well development country of renewable energy; it can compete directly with traditional energy in the energy market. It is a huge progress for renewable energy adoption in European market. In general, EU as a whole is still lack of effective policy to support renewable energy development. Currently, only a limit member states had made significant progress on renewable energy adoption, rest of the member states still need fiscal and policy support to develop renewable energy resources. Due to the cost of renewable energy resources and lack of policy support, the increasing the share of renewable energy to 20% of total EU energy mix by 2020 will not expected to be achieved without strengthened political support (Kitzing, 2012).

In the same day, the European Commission proposed “Renewable Energy Road Map Renewable energies in the 21st century: building a more sustainable future” (Communities, 2007b). The Road map is integral part of the First Strategic European Energy Review which agreed by European Council on March 2007. The road map stetted out a long-term framework for renewable energy in European Union and aims at accelerate renewable energy deployment in EU. It is obviously that EU had achieved huge progress on renewable energy adoption after proposed directive 2001/77/EC and directive 2003/30 /EC, however, from the projection of renewable energy deployment, EU is hardly to meet its 2010 target (12% of renewable energy share in total EU energy consumption). The European Council realized that strengthen rules must be implemented in order to ensure member states to achieve their indicative targets of the energy package. The Road Map proposed to establish a mandatory (legally blinding) target for renewable energy to be account for 20% of EU's total energy consumption by 2020 and a minimum target of 10% for biofuels. It also proposed a new framework to support and accelerate renewable energy adoption in European Union. The Road Map pointed out some factors which may prevent EU meeting its 2010 target. These factors include high cost of the renewable energy, administrative burdens installation procedures and discrimination for RSE-E grid access. It also emphasized that the old framework without legally blinding target only made progress in some member states, the old framework induced the varies development of renewable energy among member states, these drawbacks greatly blocked European Union achieve its 2010 target. These drawbacks also convinced the European Commission to believe that the legally binding targets will be a great catalyst to help Member states to achieve its 20-20-20 targets. In 2007, the EU proposed to Member states to have an agreement on Lisbon Treaty. The Lisbon Treaty imposed Article 194 to establish legal basis for EU on the energy filed. The Treaty implemented from 1st of December 2009, the Treaty ensured the power for EU on energy sector legislation. The Article 194 aims to (1) ensure the security and function of EU's internal energy market; (2) improve energy efficiency and promote renewable energy development and renewable energy innovation (3) improve interconnect existing energy network (Kanellakis et al., 2013).

In order to achieve the 20-20-20 targets by 2020, the European Union proposed Renewable Energy Directive 2009/28/EC on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directive 2001/77/EC and 2003/30/EC (Commission, 2009). The directive established a new common framework regards to promote renewable energy adoption, reduce greenhouse gas emission and improving energy efficiency. The outstanding measure of renewable energy directive 2009/28/EC was sets mandatory legal binding target for each member states. Such national overall targets are consistent with the overall 20-20-20 target for the community, the mandatory legal binding target requires the overall share renewable energy account for 20% of EU total energy consumption by 2020. The mandatory legal binding target also requires the share of renewable energy in transport sector must achieve to at least 10% of the total energy consumption in EU. The mandatory national overall targets in the renewable energy directive were divided among the member states and the target was given legal statues in community legislation. Besides the mandatory national overall targets, the following provisions were endorsed in the renewable energy directive:

- Required member states to establish National renewable energy action plan (NREAP) which set the share of renewable energy consumed in transport, electricity, heating and cooling in 2020. The plan had to consider the effects of other energy policy regard to the energy efficiency on the final energy consumption.
- Member states may agree and make statistical transfer of a specified amount of energy from renewable energy resources to one member state to another. Member states also may build joint projects between each other, the member states could corporate on a joint project concerning the production of electricity and heating from renewable energy resources.
- Member states may joint projects with an third countries regard to the production of electricity from renewable resources, and the project could also involves private operators, however, for the joint projects between member states and third countries, the electricity must be consumed in the Community and must be produced from a newly installation that operated after 25th June2009.
- Member states could agree on joint support schemes. As a results, a certain amount of energy from renewable energy resources produced in one member states may count towards the national overall target of another participate member state.
- Ensure member state to guarantee the origin of electricity produced from renewable energy resources.

- Member states should take procedure to complete their transmission and distribution infrastructure in order to fulfill the expand capacity of future produced RSE-E.
- The directive take account of the biofuels and bioliquids for achieve the long-term target, it required the usage of biofuels and bioliquids should contribute to the reduction of greenhouse gas emission at least of 35%. By 1st January 2007, the reduction of GHG emission contributed from biofuels and bioliquids should be increase to 50% and increase to 60% by 1st January 2008.
- Member states are request to submit a comprehensive report to the Commission on the progress of the renewable energy adoption by 31st December 2011 and afterward every two years. To start with, the report should include the share of energy produced from renewable energy in the last two years and what measures did members states implemented to stimulate the renewable energy development. Secondly, it should also includes what support schemes were used from member states to promote renewable energy resources, measures that had been taken to eliminate administration barriers and ensure the transmission, distribution RES-E. Thirdly, it covers the statues of biofuels development and impact of biofuels production. At last, the report should provide the estimated excess energy produced from renewable energy and estimated demand of energy from renewable resources to fulfill member states' domestic energy production.
- The European Commission was request to monitor member states' progress toward the 20-20-20 targets. The Commission should submit a comprehensive report which includes the analysis and comment from member states' report. It should contain what measures member states implemented to promote renewable energy and the latest renewable energy deployment status. Moreover, the estimate impact of biofuels and bioliquids adoption and production in the community, the number of greengas reduced by using biofuels should also involved in community's report. The future energy policy is also mentioned, the commission shall propose a Renewable Energy Roadmap for the post-2020 period. By 2021, a

report shall be presented by the commission to fully review the application of this directive.

- Directive 2001/77/EC and Directive 2003/30/EC will be replaced by this Directive 2009/28/EC from 1st January 2012.

It was a great achievement that member states in the European Union agreed to legally binding national targets for renewable energy. The directive created a new framework for community to reduce GHG emission and promote renewable energy deployment. It established the mandatory National overall targets and indicative trajectory for member states in European Union, greatly achieved the progress of renewable energy development. After the implement of the directive, the renewable energy growth significantly, according to the data and analysis, the EU as a whole is on its track to achieve the 2020 targets, however, some member states need to make more effect to achieve its own target (Commission, 2013).

Table 2 shows the national overall targets for different member states in the directive 2009/28/EC and table 3 includes that data collected from the Eurostat. The calculations of estimated indicative trajectory was based on the formula from the directive ANNEX *I* (B). The formula was stated in Annex below. As we can see through the Table.3, most of the member states had a significantly progress on renewable energy growth after the directive implemented and most of them keep the same direction as indicative trajectory required. These member states achieved 2% more than indicative trajectory or even more than 2%. Ex: Austria, Bulgaria Germany, Denmark, Estonia, Italy and Sweden. Some of the member states also had great progress, there actual average target is between 1% and 2% more than indicative trajectory, countries such as: Belgium, Ireland and Portugal. Surprisingly, we can see from the table that some of the countries are below the indicative trajectory and these countries (France, Netherland and UK) are all developed countries with well-functioned support mechanism and energy market. As the trajectory grows steeped in the future, France, Netherland and UK need to undertake more effects to achieve the indicative target and lead the EU to achieve the 2020 targets.

Table. 1
Indicative Trajectories

	S_{2005}	S_{2020}	S_{2011}	S_{2012}	Actual Trajectory(average for 2011 to 2012)	Estimate Trajectory (average for 2011 to 2012)	Difference between actual and estimate trajectory
Austria	23.30%	34%	30.8%	32.1%	31.45%	25.44%	6.01%
Belgium	2.20%	13%	5.2%	6.8%	6.00%	4.36%	1.64%
Bulgaria	9.40%	16%	14.60%	16.30%	15.45%	10.72%	4.73%
Cyprus	2.90%	13%	6.0%	6.8%	6.40%	4.92%	1.48%
Czech Republic	6.10%	13%	9.30%	11.20%	10.25%	7.48%	2.77%
Germany	5.80%	18%	11.60%	12.40%	12.00%	8.24%	3.76%
Denmark	17%	30%	24%	26%	25.00%	19.60%	5.40%
Estonia	18%	25%	25.60%	25.80%	25.70%	19.40%	6.30%
Greece	6.90%	18%	10.90%	13.80%	12.35%	9.12%	3.23%
Spain	8.70%	20%	13.20%	14.30%	13.75%	10.96%	2.79%
Finland	28.50%	38%	32.7%	34.3%	33.50%	30.40%	3.10%
France	10.30%	23%	11.30%	13.40%	12.35%	12.84%	-0.49%
Hungary	4.30%	13%	9.1%	9.6%	9.35%	6.04%	3.31%
Ireland	3.10%	16%	6.60%	7.20%	6.90%	5.68%	1.22%
Italy	5.20%	17%	12.3%	13.5%	12.90%	7.56%	5.34%
Lithuania	15%	23%	20.2%	21.7%	20.95%	16.60%	4.35%
Luxembourg	0.90%	11%	2.9%	3.1%	3.00%	2.92%	0.08%
Latvia	32.60%	40%	33.5%	35.8%	34.65%	34.08%	0.57%
Malta	0.00%	10%	0.7%	1.4%	1.05%	2.00%	-0.95%

Netherlands	2.40%	14%	4.3%	4.5%	4.40%	4.72%	-0.32%
Poland	7.20%	15%	10.4%	11.0%	10.70%	8.76%	1.94%
Portugal	20.50%	31%	24.5%	24.6%	24.55%	22.60%	1.95%
Romania	17.80%	24%	21.2%	22.9%	22.05%	19.04%	3.01%
Sweden	39.80%	49%	48.8%	51.0%	49.90%	41.64%	8.26%
Slovenia	16%	25%	19.4%	20.2%	19.80%	17.80%	2.00%
Slovak Republic	6.70%	14%	10.3%	10.4%	10.35%	8.1%	2.19%
United Kingdom	1.30%	15%	3.8%	4.2%	4.00%	4.04%	-0.04%

Note: 1. S_{2011} and S_{2012} represent the share of energy from renewable sources in gross final consumption of energy in 2011 and 2012. (Eurostat, 2014b)

2. The Formula of Indicative trajectory was listed in Annex.

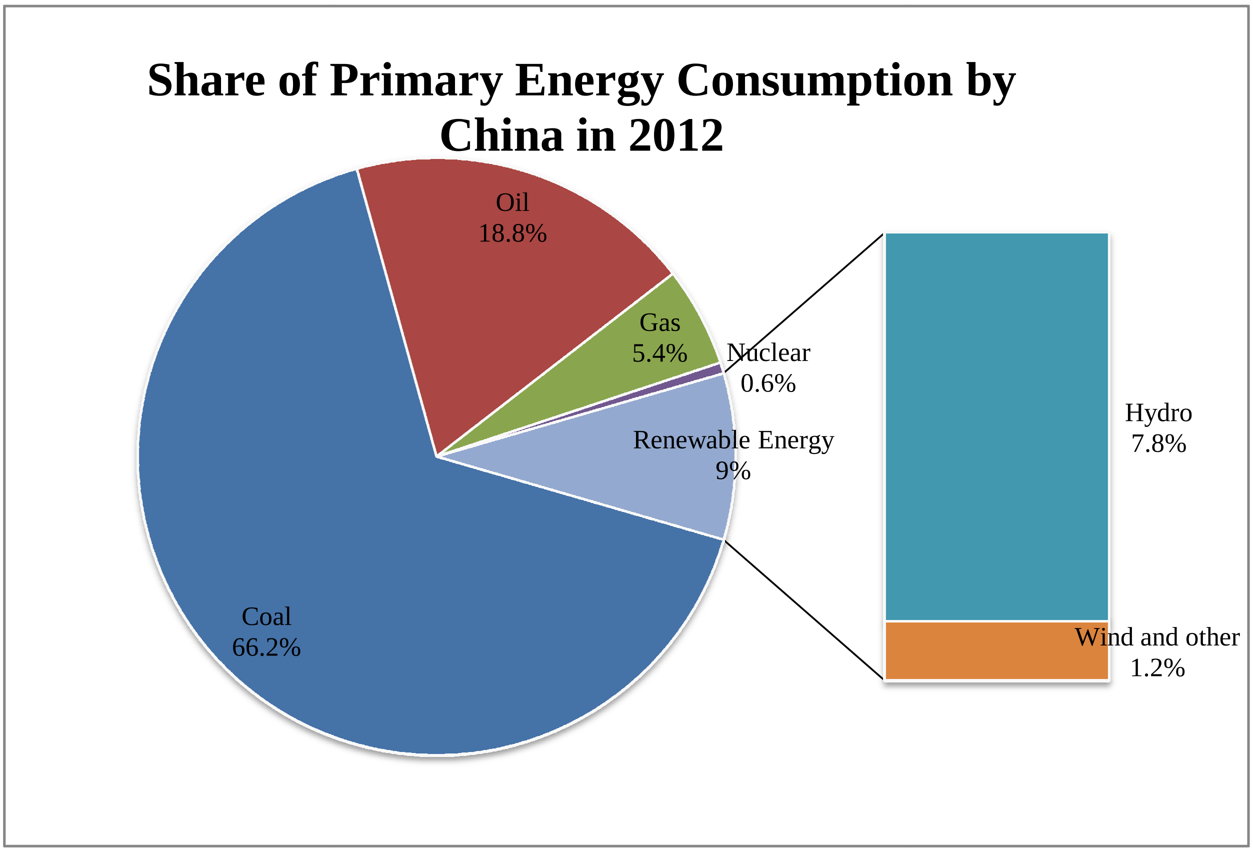
3. Actual average values based on arithmetic mean

2.2 China renewable energy policy

2.2.1 Current Primary Energy Consumption in China

Figure. 6

Primary Energy consumption share of different energy resources by China in 2012



Note: Data collected from (C. N. R. E. Center, 2012), figure generated by author.

As we can see from the figure.6, the primary energy consumption proportion by China in 2012, the main energy consumption source is coal which accounts for 66.2% of the total energy consumption in China. The renewable energy resources which accounts for 9% of the total energy consumption in 2012, China committed non-fossil fuel achieve 11.4% of total energy consumption by 2015 and the numbers in 2012 shows China is in a good trend to fulfill its commitment. Even though, China is on its way to meet its 2015 commitment, we can still see that the hydro power accounts for the major part of the renewable energy consumption, wind, solar and biomass only accounts for 1.2% of the total primary energy consumption, therefore, there is great potential to develop wind energy, solar energy and biomass energy.

2.2.2 Two stages of China's renewable energy policy development

Before we further explore China's renewable energy policy, it is necessary to illustrate its overall renewable energy policy. The Chinese government holds different view of renewable energy resources development in different periods. China's renewable energy development initially starts from the ninth FYP and the government has established some renewable energy programs in some rural areas in mid-1990s, the renewable energy resources were mostly used as heating and small hydro power station. The renewable energy resources were not massive promoted until 2005, after the Renewable Energy Law implemented, the renewable energy deployment had a stunning growth in China. China has reached a remarkable achievement on renewable energy resources promotion from 2005 and became the leading player in the world. As a consequence, we may see year 2005 as the divide point of China's renewable energy development. Thus, we can divide China's renewable energy policy development in two stages, which are prior year 2005 and after year 2005.

The Chinese renewable energy policies basically divide into three layers, which are the first-level policy, the second-level policy and the third level policy. The central government establishes and legislate the first level and the second level policy. The different local governments including provincial level, municipality level and county governments carry out different measures and policies to stimulate renewable energy adoption and deployment. These measures and policies are under the principle and direction of the central government.

- The first-level policy: provide national guidance and directions for Chinese renewable energy industry and renewable energy adoption.
- The second-level policy: clearly set the objective and target for renewable energy adoption and development in China, specify plans for renewable energy industry develop and renewable energy adoption in the whole country, establish

framework and specific provisions to support renewable energy technology innovation and to achieve the energy target. The second-level polices build a solid foundation for renewable energy adoption and renewable energy industry development in China. *"Second-level policies have played a very important role in promoting renewable technologies in China"(NREL, 2004)*

- The third-level policy: mostly established by provincial or municipal governments. It clearly set the support scheme to stimulate local renewable energy adoption and local renewable energy enterprise development. In addition, it also provide specific and detail guideline for developing renewable energy and its adoption. The third-level policy provide both fiscal and administrative scheme to help renewable energy compete with traditional fossil fuel energy.

These three levels policy established the general renewable energy policy in China. The general policy made China become the leader in renewable energy production and renewable energy investment in the world(NREL, 2004).

2.2.3 China's renewable energy policies prior year 2005

Since 1978, the economic reform implemented in China, China experienced the significantly economic growth and became the second largest economic in the world. The huge consumption of energy resources and severe environment issues have arisen Chinese government's notice, meanwhile, China is the largest developing country in the world and two thirds of its population lives in the rural area. Electricity shortage has become a critical barrier for remote and rural areas development. As a consequence, renewable energy resources become the critical solution for electricity shortage in rural areas. Since the late 1970s, Chinese government gradually implemented some polices to promote the renewable energy resources adoption in remote and rural areas (Peidong et al., 2009). The policies aim to support renewable energy resources by incentive subsidiary, especially for the form of biogas in most of rural areas of China. In mid-1990s, Chinese government has realized that China have huge potential natural advantage to develop renewable energy resources, such as wind power, solar power, hydro power and biogas. During this time, some renewable energy project and programs were established by the central government in order to contribute to the sustainable development in China. Furthermore, the government largely increased the support for renewable energy technology research by fiscal funding and project subsidiary. Governments also carry out measures, such like subsidiary and tax reduction to promote renewable energy adoption and stimulate renewable energy industry development. Moreover, with the concern of the rapidly growth of the environment issues, the government established laws, regulations and administrative regulations to stimulate renewable energy development, in addition, the support schemes objects also expand to wind energy, solar energy and biofuels.

In 1995, the National People's Congress Standing Committee passed the *Electricity Law of the People's Republic of China.* It was the first law specific on energy and electricity sector. In Article 5, Chapter 1 the General Rules, it emphasized that national government encourage and support to adopt renewable energy resources to generate electricity. Article 48 states that national government encourage and support local governments to utilize solar power, wind power, geothermal energy and biofuels for rural areas energy and electricity supply (Committee, 1995). The *Energy Conservation Law of People's Republic of China* was passed by National People's Congress, Standing Committee in 1997 (amended in 2007). The energy conservation law also stated that national government encourage and support to develop and utilize renewable energy resources in Article 7. The energy conservation law also emphasized in Article 59 that national government encourages and supports to utilize biogas, biofuels, wind energy and solar energy in remote and rural areas(Committee, 2007). Another legal document that refers to the promotion of renewable energy resources was *Law of People's Republic of China on the Prevention and Control of Atmospheric Pollution,* which implemented in 2000. In Article 9, it stated that national government encourage and support scientific and technology research which benefit to control of the air pollution, in addition, the national government support and encourage to utilize solar energy, wind energy and hydro energy. In Article 25, department under National State and local government should take proper measures to improve urban energy consumption structure, make effort to promote the production and adoption of renewable energy resources(Committee, 2000). These laws had stipulated that utilize renewable energy resources and promote renewable energy adoption were supported and encouraged by the national government. The State Departments also carried out series of regulations and documents, such as *Ninth Five-Year Plan and 2010 Plan of Energy Conservation and New Energy Development, Ninth Five-Year Plan of Industrialization of New and Renewable Energy, Tenth Five-Year Plan for New and Renewable Energy Commercialization Development and Rural Energy Development Plan to 2020 for Western Area of China*. These rules and regulations mainly focus on the aspects of renewable energy future development plan, renewable energy industry develop, future renewable energy adoption goal and renewable energy’s role in energy saving and CO_2 emission reduction(Peidong et al., 2009).

General speaking, prior 2005, China’s renewable energy progress was based on the policies which lack of systematic, stably and sustainability. No mater *Electricity Law of PRC* or *Energy Conservation Law of PRC* or *Law of the People’s Republic of China on the Prevention and Control of Atmospheric*, these laws only stipulated that National government encourage and support to utilize renewable energy in general and seldom mentioned any effective detail measures to promote renewable energy adoption in China. Meanwhile, the incentives provided by the government are not tempting enough to attract state-owned enterprises or private enterprises to massive invest on renewable energy in China.

2.2.4 China's renewable energy policies after year 2005

Renewable Energy Law of PRC

The new stage of China's renewable energy development starts from 2005, at the same time China took a big step towards establishing a legal framework by implemented of *Renewable Energy Law of the People's Republic of China* as the first law regards to renewable energy. The Renewable Energy Law (REL) was passed by the Standing Committee of National People's Congress on 28th February, 2005 and effective on 1st of January 2006. The purpose of establishing Renewable Energy Law was stated in Article 1, which is to promote the development and utilization of renewable energy resources, enhance energy supply, improve energy structure, guarantee energy supply security, protect environment and achieve the sustainable development on social economic development. Also, in Article 4, it states that national government will place the development and adoption of renewable energy resources as priority, the government should also establish future goal for renewable energy development and adopt effective measures to promote the establish of renewable energy market and its development (Congress, 2005). The passage of Renewable Energy Law shows Chinese government's determination to bring in new energy concept into its traditional energy structure to overcome the huge energy demand from the spectacular economic growth.

The Renewable Energy Law shows renewable energy development in China has first time got on a track under the legislation guidelines and it established a legal framework for stimulate renewable energy development in China, by stipulated several mechanisms to support and stimulate renewable energy growth in China (Schuman & Lin, 2012).

- National Government establish renewable energy target for its future development and establish future renewable energy development plan to achieve and fulfill the future target.
- Set on-grid price for renewable energy electricity according to different region and different character of renewable energy resources. Clearly defined the

priority for renewable energy electricity connected grid. The grid operators are required to purchase all the electricity produced from the authorized renewable energy generators.

- National Government encourage to construct off-grid renewable energy generator to produce electricity in remote and rural areas and encourage private enterprise and individual to install solar heater, solar pv system.
- Set up Renewable Energy Development Special Fund to support and cover activities such as research for renewable energy technology to promote its utilization and development, Standard setting, pilot programs, the adoption and utilization of renewable energy in remote and rural areas, detect and evaluate for renewable energy potential and information system establish.
- Loan and tax reduction mechanism for authorized renewable energy projects (Congress, 2005).

The Passage of Renewable Energy Law significantly stimulated the development of renewable energy in China. As follows, national government implemented relevant supporting regulations and laws. Wind, solar energy utilization and wind, solar energy industry had an outstanding growth. Renewable Energy Law had become the fundamental of Chinese renewable energy development.

The Mid-and Long- Term Plan for Renewable Energy

In order to accelerate RE development, face the challenge of climate change, the National Development and Reform Committee announced *the Mid- and Long- Term Plan for Renewable Energy* in 2007. The plan is the first national plan set by the government for stimulate renewable energy development (Hong, Zhou, Fridley, & Raczkowski, 2013). It set the future RE consumption target for 2010 and 2020 which is increase the share of RE consumption in total energy consumption from 7.5% in 2005 to 10% by 2010 and 15% by 2020 (NRDC, 2007). The Plan also set the future RE installation target for 2010 and 2020 (see Table.1). Moreover, the plan set various measures to guarantee the future 2010 and 2020 targets to be achieved.

- Set Mandatory Market Share (MMS) target for Non-Hydro renewable energy electricity. The non-hydro renewable energy electricity shall accounts for 1% of the total gird capacity by 2010 and 3% by 2020.
- Increase fiscal funding and tax reduction.
- Complete RE industry and stimulate RE technology development.

Table. 2
The future RE installation targets, the Mid- and Long- Term Plan for Renewable Energy

	2005 Cumulative Installed Volume (GW)	**2010 Target (GW)**	**2020 Target (GW)**	**2012 Cumulative Installed Volume (GW)**
Hydro-Power	117	190	300	248
Wind-Power	1.26	5	30	62.7
Biomass Power	2	5.5	30	7.7
Solar PV	0.07	0.3	1.8	4.2

Note: Data collected from (NRDC, 2007) and (C. N. R. E. Center, 2012), table generated by author.

The Mid-and Long-Term Plan for Renewable Energy greatly stimulated the renewable energy development in China. As (Schuman & Lin, 2012) mentioned in their paper, the 2020 installed capacity target for wind power has already achieved by 2010, in addition, (Hong et al., 2013)express in their paper only after 4 month of implement of the plan, the 2010 wind energy target 5GW was surpassed. We can also see from the Table.2 that the 2012 installed capacity of wind energy has significantly overpass the 2020 target as well, the installed capacity of wind energy in 2012 reached 62.7GW, compared with 2005, it has increased almost 60 times. Solar energy also experience an explosion growth, in 2012, the cumulative installed capacity was 4.2 GW, compared with 2005, the growth rate of installed capacity of solar energy increased 881%. These data shows that China experience high growth rate of renewable energy and the policy makers need to quickly adjust their setting targets in their future rules and regulations in order to avoid the targets be easily surpassed.

Eleventh FYP for Renewable Energy

In order to adapt to the rapidly development of RES in China, the National Development and Reform Committee announced the 11th Five- Year Plan (2006-2010) for Renewable Energy on 18th March, 2008. The plan shows that improve the share of renewable energy in total primary energy is the top priority during the 11th FYP. Compared with the Mid-and Long-Term Plan for Renewable Energy, only the wind energy target for 2010 was amended. In the new plan, the wind energy target for 2010 was increased to 10GW, other type of renewable energy targets for 2010 remains the same (see table. 2). As (Hong et al., 2013) mentioned in their paper, by the end of 2010, the actual installed target for Hydro energy, wind energy and solar PV had surpass the initial 2010 targets.

Table.3

2010 RE target from 11th FYP

	Cumulative Installed Capacity 2005 (GW)	**2010 Target (GW)**	**Cumulative installed Capacity 2010 (GW)**
Hydro-Power	117	190	216
Wind-Power	1.26	10	31
Biomass Power	2	5.5	5.5
Solar PV	0.07	0.3	0.8

Note: Data collected from (T. B. o. E. a. C. R. E. Center, 2012), table generated by author.

The Amendment of the Renewable Energy Law

President Jintao, Hu made the commitment on behalf of the Chinese government in Copenhagen climate conference. The Chinese government commit to the world that by 2020, the share of non-fossil energy will account for 15% of the total primary energy consumption. Also Chinese government makes the commitment that by 2020, the Carbon intensity (CO_2 emission per unit of GDP) will reduce 40%-50% compared with 2005. Chinese government commits to make full effort to achieve these targets by 2020 (China, 2012). In order to fulfill this commitment, Chinese government need to implement new laws, rules and regulations.

After implemented the Renewable Energy Law, wind energy and solar energy had a significantly growth, however, serious problems come with the fast growth, according to NDRC, in 2008, about 40% of electricity produced from wind energy unable to connected with grid. To restrain the over speed and maintain the healthy growth of Chinese renewable energy utilization and development, the National People's Congress, standing committee passed the amendments of Renewable Energy Law of China on 26th December, 2009. The amendments of Renewable Energy Law effect on 1st April, 2010. The amendments aim to restrain over explosion of renewable energy utilization and renewable energy industry development in China.

- Strengthen national government oversight on renewable energy project permission caused by the unbalance development of wind energy and solar energy after 2007. In the amendment Article 8, the oversight right for renewable energy project planning and permission was amended from the local government to provincial government. In order to start to construct the project, the provincial government has to further register the project with the energy department of State Council and National Electricity regulation authority. The new measures aims to restrain the over explosion of RE project development.
- In Article 14, national government implements RES-E guarantee purchase policy, setting the minimum RES-E purchase target for grid operator. The grid operator no longer requires purchasing all the RES-E from the renewable

energy generators as mentioned in the original Renewable Energy Law. In Article 14, it also shows the grid operator shall strengthen smart grid construction in order to maximum capacity to receive RES-E in the future.

- In Article 24, National Government establishing renewable energy development fund in order to maintain the grid operator's enthusiasm on purchasing RES-E, strengthen renewable energy development in China and support RE project development in remote and rural area (Congress, 2009)

The amendments of renewable energy law are much more focus on governments function on coordinate and guidance on renewable energy development. The renewable energy law also provides efficient solutions for the challenge of the renewable energy in which the government confronts and further strengthen China's legal framework on renewable energy.

Twelfth FYP for Renewable energy

As we mentioned previous, the 12th FYP emphasized that the share of non-fossil fuel will accounts for 11.4% of the total primary energy by 2015 and the share of non-fossil fuel will accounts for 15% of the total primary energy by 2020, energy intensity reduce 16% and CO_2 emission reduce 17% compared with 2010. Under the guidance of the Renewable energy Law and 12th Five-Year Plan, the National Development and Reform Committee carried out the 12th Five-Year Plan for Renewable Energy on August, 2012. The plan set the ambitious target for different type of renewable energy source by 2015 and renewed the 2020 setting targets (see Table.3). The plan shows that the newly installed capacity for renewable energy should totally reach 160GW during the 12th FYP period (2011-2015) and we can also see from the table 3 that the setting target by 2015 for hydro power, wind power, solar PV and Biomass is 290GW, 100GW, 21GW and 13GW. The plan also set the targets of five year period (2011-2015) for renewable energy, during this five year period, the installation capacity for Hydro, wind, solar PV and biomass should reach 61GW, 70GW, 20GW and 7.5GW respectively. The plan emphasized to focus on important big scale project construction, such as hydro power plant, wind farm, off-shore wind farm and solar PV plant. The plan had carried out some provisions to support renewable energy development:

- Promote decentralized grid system to fulfill the rural areas energy demand.
- Develop smart grid system, strengthen smart grid concept to grid end user.
- Complete the whole value chain of RE industry and establish innovation technology for RE industry. Enhance talent reserve in order to fulfill the labor requirement created by RE development.

Table. 4

RE targets from 12th YFP for renewable energy development

	Target by 2015 12th FYP(GW)	**Target by 2020 12th FYP(GW)**	**Planning Installation during 12th FYP (2011-2015) period (GW)**	**Cumulative Installed Capacity 2012 (GW)**
Hydro-Power	290	420	61	248
Wind-Power	100	200	70	62.7
Solar PV	21	50	20	7.9
Biomass	13	N/A	7.5	7.7

Note: Data collected from (T. B. o. E. a. C. R. E. Center, 2012) and (C. N. R. E. Center, 2012), table generated by author.

2.2.5 Conclusion

Energy supply security, CO_2 emission reduction and reform primary energy structure is the strategy for Chinese renewable energy. After the implemented of *Renewable Energy Law of People's Republic of China*, renewable energy resources have experienced a bullet speed growth. As we can see from table.4, the cumulative installed capacity of different types of renewable energy in 2012 has already surpassed the 2020 targets that stipulated in 2007 by the Mid- and Long Term Plan for Renewable Energy. Compared with table.4 that the cumulative installed capacity in 2012 has reached the setting targets from the 11th FYP for renewable energy, especially hydro and wind energy, greatly surpassed the setting targets, the data had illustrated that China is making great effort to develop renewable energy resources and through renewable energy to solve the problems such as air pollution, electricity shortage in rural areas.

Even though the 2012 cumulative installed capacity showed a positive trend on reach the 2015 targets, we also noticed that there also exist numerous problems for China' renewable energy development, such as renewable energy industry over expansion, grid connection issue, administration barriers for project permission and region protectionist. To achieve the target of 15% share of non-fossil fuel by 2020, the Chinese government needs to make more effort.

3. Comparison between China and EU renewable energy policy frameworks.

It is no doubt that European Union is taking the leading position on renewable energy utilization and policies setting. Meanwhile, China has the most cumulative installation capacity of renewable energy and also it is the country who invests the most on renewable energy resources in the world (C. N. R. E. Center, 2012). After the implement of Renewable Energy Law, China has achieved remarkable achievement on renewable energy development, however, the drawbacks of Chinese renewable energy policies still exists. Therefore, it is necessary to review China's renewable energy polices and compared with European Union. From our review about renewable energy policy in European Union and China, we can conclude that they have the common features about renewable energy policy, such as setting development targets, fiscal funding for renewable energy project and priority for renewable energy electricity grid connection. As (Schuman & Lin, 2012) mentioned in their paper "China appears to have the most unified, top- down approach to implementing renewable energy policies and programs, whereas the EU have a greater degree of autonomy and diversity among their member states in term of renewable energy policy".

3.1 Legislation difference

3.1.1 Renewable energy legislation in EU

Compared with China's RE legal documents legislation, European Union had shown a great difference. The European Union takes comprehensive and research before RE legal documents legislation. The research and investigate results will announced through "green paper" or "white paper" in order to accept the feedback from the member states. The European Union will modify the document based on the feedback and opinion from the public, research institutions and member states, these modifications were adopted by the Directives and Regulations. (Cheng, 2012). It is an indispensable precondition that all the member states achieved the agreement that EU could implement its legal documents. Therefore, the member states could fully debate and discussion on the legislation. With the consistency among the member states, the legal documents could obtain the greatly support and it is easier for each member states to execute and implement.

3.1.2 Inadequate research before renewable energy legislation in China.

Recently, China had made progress on renewable energy legislation, such as implemented of Renewable energy Law and the Amendments of Renewable energy law, however, Chinese government still has drawbacks on legislation of renewable energy. Before legislate the legal document, the center government inadequate on information research and investigate on the renewable energy development potential in different region of China. As we can see above, the frequently modified on setting future renewable energy targets demonstrate that policies makers are lack of research and investigate. On the other hand, the local governments are seldom able to participate and debate about the renewable energy legal documents legislation, and the local governments are not able to coordination with central government. Hence, the legal documents and regulation carried out with insufficient discussion and demonstration. In addition, the public and private enterprise are seldom to have the opportunities to express their opinion about the renewable energy development. In addition, there exists inconsistency of central and local polices. As a consequence, when the renewable energy legal documents implemented, it is difficult to get the full support and execute from the local governments, private enterprise and the public. It is critical for Chinese government to focus on the pre-legislation, which means strengthen research and investigate, general accept different opinion and feedback from local governments and the public in order to stimulate Chinese renewable energy policy more effectiveness, consistent and central government with the local governments could coordination on future renewable energy’s sustainable development. The National Energy Administration and China National Renewable Energy Center was founded in 2010 and 2012, respectively. The establishment of these organization aims to provide national strategy, research and investigate information for policy makers.

3.2 Renewable energy legal framework difference

3.2.1 The completeness legal framework of renewable energy in EU

In 1st December of 2012, the implemented of *Lisbon Treaty* established EU's foundation on energy legislation. The legal framework in EU clearly divide into four parts which are renewable energy resources, energy saving, energy efficiency and energy market competition (Cheng, 2012). The legislation in EU not only set up the strategic for the whole energy sector, but also carries out rules and regulations for different energy resources adoption. After two or three years, the European Union will announced a review for the previous implemented directive or regulations, to inspect the progress of the previous directive or regulations in order to keep the member states achieve the setting targets. Meanwhile, the European Union is also keep modify the policies to fit the new status of renewable energy development.

3.2.2 China need to unify its renewable energy polices.

As the special political system and national conditions of China, energy sector was administrated by administration measures, so does for renewable energy resources. Currently, there are numerous administration departments involving establishing different renewable energy polices, such as NDRC, National Energy Bureau and Department of Agriculture. When different departments and local governments establish renewable energy regulations or policies, inadequate coordination appears, in occasion, it also appears the contradiction between different documents or regulations. Inadequate coordination will no doubt affect the effectiveness of renewable energy laws and regulations; therefore, it is critical for central government to unify the legal framework on renewable energy. Recently, China has implemented some legal documents such as Renewable Energy Law and Energy Conservation Law; these legal documents effetely promoted the renewable energy adoption and develop in China. But the general situation is not optimistic, therefore, China needs to establish a unified and long-term legal framework for renewable energy’s sustainable development.

3.3 Law enforcement Difference.

3.3.1 Strong enforcement power on renewable energy legislation in EU

European Union Commission implemented the legal documents, setting future targets and forward to member states government and member state governments set these regulations targets into their national law to achieve the target. If the member states fail to achieve their targets, the member states will be sued to European court. Most of directives about renewable energy in European Union contains administration measures to supervise renewable energy development, these measures have greatly improve public’s confidence on renewable energy and with public’s support, the legal document in EU will more easy to enforce.

3.3.2 Inadequate enforcement on renewable energy legislation in China.

As we mentioned above, (Schuman & Lin, 2012) express in their paper that “China appears to have the most unified, top- down approach to implementing renewable energy policies and programs”. However, the situation is quite different in reality, the inadequate enforce power has reduced the effectiveness of renewable energy legislations, many rules and regulations are unable to be achieved. For example, the amendments of renewable energy law strengthen the obligation of grid operator to upgrade their gird in order to accept renewable energy electricity; however, most of the grid operators ignore the requirement or delay the grid connection has result gird connection issue for renewable energy resources (Cheng, 2012). Take wind energy as an example, about 25% to 30% China's wind turbines are not able to connect with the grid (Schuman & Lin, 2012). Besides, the rapid growth of renewable energy utilization also result large low quality products flood into the market and the authorities did not fulfill their supervise duty on the market. Therefore, it is a urgent issue to ensure the enforcement power on renewable energy legislations.

3.4 Polices difference on Power Grid.

In Directive 2001/77EC and Directive 2009/28/EC, the European Union set numerous provisions for grid operator for accept RES-E, such as simplify grid connection for RSE-E, eliminate any potential discrimination for RSE-E grid connection and distribution. Grid operator have to give priority grid connection and generating installation for electricity produced from renewable energy resources, grid transmission operator and distributor should bear the full cost or the part of the cost for grid update to accept the RES-E, etc. These provisions stipulated grid operators have to ensure the gird connection for RES-E.

In China, the grid bottleneck had become a serious barrier for adoption RES-E. In the amendments of Renewable Energy Law, it states that grid operator shall set the minimum RES-E purchase target for grid operator. However, the current Renewable Energy Law has no detail procedures on grid connection. As most of the grid operators in China are state owned- enterprise, their motivation to accept the RES-E is not strong enough compared with traditional electricity. Hence, it is more difficult for RES-E connected on grid and the RES-E operators have to bare the economic risk by themselves and it will also decrease renewable energy investors and operators' confidence. Therefore, "a clear definition of procedure, responsibility, compensation between RES-E operators and grid companies needs to be supplemented in the Renewable Energy Law" (Hong et al., 2013)

4. General RE Support Schemes in EU

4.1 RE support Schemes in EU

- **Feed-in Tariff (FIT)**

The Fit Schemes is probably the most widely adopted in European Union. Most of the member states in EU adopt FIT schemes on Biomass, Wind and Solar energy.

According to the different characteristic of renewable energy resources, the member states government decides what level of subsidies should be given to different kinds of renewable energy. To most of the renewable energy electricity producer, they can choose to self use of their RES-E and the governments guaranteed the price for the excess produced of electricity to be sold to the grid. It is usually grid distributors or grid operators are given the obligation to purchase these excess electricity.

- **Feed-in premiums (FIP)**

In general, we can think of FIP as a subcategory of FIT schemes. The Feed- in premiums “are guaranteed premiums paid out as fixed add-on to the market price”(Kitzing, Mitchell, & Morthorst, 2012). The RES-E producers receive a premium per unit of electricity they sold to the grid operator in addition to the subsidies acquired from selling RES-E to the grid.

- **Tenders (TND)**

The member states government determines how much electricity from renewable energy it need and organize bidding RES-E producers to compete with each other. The potential company or RES-E producer will compete to win the opportunity to construct the project and operate capacity for the lowest subsidy (Moselle et al., 2010)

- **Quota and Green Certificate**

The Quota require the energy producer or supplier are obligated to have a certain share of renewable energy in their whole energy compose. Green Certificate requires a member states government set a target for electricity retailers to ensure that a minimum percentage of their electricity sales come from renewable energy electricity. These retailers are required to achieve certain amount of certificate to reach the minimum level. These certificates can be sold to the market, thus, these certificates price are determined by the market (Moselle et al., 2010).

- **Investment Grants (INV)**

The member states governments granted a financial support to the renewable energy project developers. The form of the financial support is given by non-reimbursable payments to the project developer during the project construction period. These allowance various from different amount, from 5% to approximately 70% of the total cost (Kitzing et al., 2012).

- **Financing support**

Government financial institutions, such as (German kfw) provides a low-interest loan or interest subsidy to for developer to invest or construct a renewable energy project. The financing support is aim to reduce the high cost investment risk of RE project investors. However, governments facing financial pressures when implements this measure.

- **R&D investment**

Member states focus on R&D development in order to promote RE utilization, establish national laboratory in order to provide technical guidance and support. For example, Denmark has spent in total about 2 billion Euros on R&D sector of wind energy development. Both US and Japan spent almost 0.1 billion US. Dollars on PV solar energy research.

Table.5
RES-E support policies in EU member states 2000-2011

	Number of countries that have implemented the scheme			
	2000	**2005**	**2010**	**2011**
Provision of renewable support	15	24	27	27
Provision of major support schemes FIT FIP TND or Green Certificate	10	22	27	27
Major support schemes				
Feed-in tariffs (FIT)	7	16	23	21
Feed-in premiums (FIP)	n/a	7	7	
Tenders (TND)	2	2	6	5
Quota and Green Certificate	1	6	6	6
Supplementary support schemes				
Investment grants (INV)	5	10	20	20
Fiscal measures (TAX)	9	10	12	13
Financing support (FIN)	4	4	9	9

Source: table from (Kitzing et al., 2012)

4.2 General RE Support Schemes in China

Since 2006, the implemented of renewable energy law of China, the support schemes gradually play a significant role accompany with rapidly development of RE deployment in China.

- **Feed-in Tariffs (FIT)**

The same concept with EU FIT, also Feed-in tariffs is one of the most important measures in promoting RES in China.

- **Competitive Tendering**

Same concept with EU tenders.

- **Government Financial support**

Government provides financial support on renewable energy project and renewable energy industry. For example, government launched “solar roofs programme” in 2009 and provide 50% subsidy for the solar components. Governments also provide low-interest and interest subsidy for renewable energy producer and renewable energy project investors.

- **Mandatory Market Share (MMS)**

The Mandatory market share was required the by the renewable energy law. The grid operators are obligated to purchase certain amount of electricity produced from renewable energy resources. The grid operators should accept 3% of non-hydro renewable energy electricity by 2020 (Zhang, Andrews-Speed, Zhao, & He, 2013).

- **Tax Reduction**

Tax reduction has been one of the most important measures in promoting RES adoption in China. The renewable energy law stipulates that the government should offer tax reduction to renewable energy project. Currently, the import duty for whole wind turbines is 0% and the PV products are 12%.

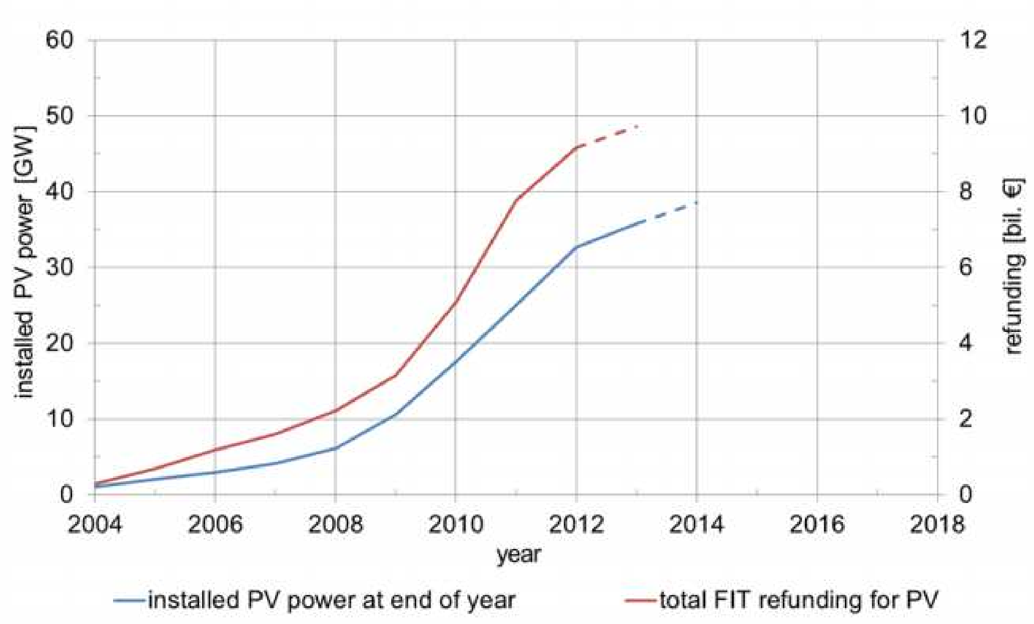
4.3 EU support schemes on Solar Energy.

The adoption of Directive 2009/28/EC has created a optimistic future for renewable energy utilization in EU. Currently, most of the member states are on their track to meet the 2020 targets.

The major support scheme for solar PV energy development in EU is **Feed-in Tariffs (FIT).** The excellent FIT incentives in EU has cost the massive production of PV products and also leads to the significantly decline of PV products. The research had shown that only dominant factor for future solar industry is the **current FIT** incentives(ISE, 2014). As we can see from figure.7, the installation PV capacity showed a positive correlation with the FIT refunding. Therefore, it is obvious that the FIT plays a significant role on solar PV deployment.

Figure. 7

German PV expanding and total feed-in tariff refunding



Sources: Figure from (ISE, 2014)

4.4 China's support Schemes on Solar Energy

Since the implement of renewable energy law in 2006, the Solar PV energy had a significantly growth in China. Currently, there are two parallel incentives method on solar PV energy. The two incentives methods are Feed-in Tariffs (FIT) and direct subsidies.

- **Feed in Tariffs**

Currently, the solar PV energy FIT incentives are inadequate to support RES-E producers. For project approved before 1st July of 2011 and completed before the end of 2011, the solar PV project will receive the FIT at the amount of 1.15 CNY/KWh. For the project approved after 1st July of 2011 and unable to complete before the end of 2011, the solar PV project will receive the amount of FIT at 1 CNY/ KWh. In 26th August, 2013, NRDC implement the "Notice on Giving Play to the Role of Price Leverage in Promoting Healthy Development of the Solar PV Industry". The document specified the solar PV FIT incentives for power plant and incentives for distributed solar PV according to different solar zones. (See table 6)

Table.6
FIT incentives for PV Power Plant and Distributed PV from 2013

Solar Irradiation Zone	**PV Power Plant**	**Distributed PV Benefits**	
	FIT	Subsidy for self-consumed PV electricity	Subsidy for Surplus PV electricity Feed-back to Grid
	(CNY/KWh)	(CNY/KWh)	(CNY/KWh)
Ⅰ	0.9	Retail Price of grid-electricity +0.42	Whole-sell Tariff of coal-fire Power +0.42
Ⅱ	0.95		
Ⅲ	1		

Source: Data collected from (Agency, 2013), table generated by author.

- **Feed in Tariffs Surcharge**

From 2006, the NRDC set the surcharge for electricity from renewable energy resources. The surcharge collected from end user of REs-E through the form of FIT. The RES-E surcharge was 0.001 CNY/KWh in 2006, then increases to 0.004 CNY/KWh in 2006, as follows increase to 0.008 CNY/KWh in 2011. In 2013, the NRDC raising the FIT surcharge from 0.008CNY /KWh to 0.015CNY/ KWh. The increase of FIT surcharge will generate about 40 Billion subsidy fund to cover the all forms of renewable energy (Agency, 2013). Compared with international level, China's surcharge is much lower, by contrast, Germany's RES-E surcharge reached 0.053 €/KWh (approximately 0.43 CNY/ KWh) in 2013. Therefore, it will the lower surcharge of FIT will lead to plenty room for future FIT increase (Lo, 2014).

- **Direct Subsidies**

Besides FIT and FIT surcharge, the Chinese government also provide direct subsidies for solar PV development. In 2009, in order to stimulate domestic solar PV utilization, Chinese Ministry of Finance (MOF) initiated two national subsidies solar programme, which are “solar Roofs Program” and the “Golden Sun Demonstration” project. The solar Roofs Program includes the distributed PV project and building integrated photovoltaic (BIPV). The central government prepared 1.27 billion CNY as budget and the direct subsidies provide 50% subsidy for the solar components. When the solar Roof Program initiated in 2009, the subsidy for BIPV system is 20 CNY/ KWh and 15CNY/KWh for roof PV system. Till 2009, the subsidy decreased to 9 CNY/ KWh and 7.5 CNY/KWh for BIPV and roof systems perceptively. Another direct subsidies program is Golden Sun Demonstration project for PV utilization. The Golden Sun project covers more types of PV projects compared with previous program. The more detail about Roofs Program and Golden Sun Demonstration project see Appendix. (Table.1)

5. Current PV market development

5.1 World Cumulative installed capacity

Solar PV energy has experienced a stunning growth rate in the past 6 years-even in the difficult macro-economic environment. At the end of 2013, the globally total cumulative installation of solar PV energy reached 138.9GW and with this amount, it can produce electricity 160TWh in a single year. In 2013, the leading cumulative installed capacity region is Europe with 81.5GW which accounts for 59% of global cumulative installed capacity, then follows with Asia Pacific region 22GW and China 18.6GW. However, as we can see from the figure.8, the cumulative installed capacity in outside EU region is almost approaching to the amount of EU region, therefore, it illustrate that the global solar PV market are facing rebalancing (Association, 2013).

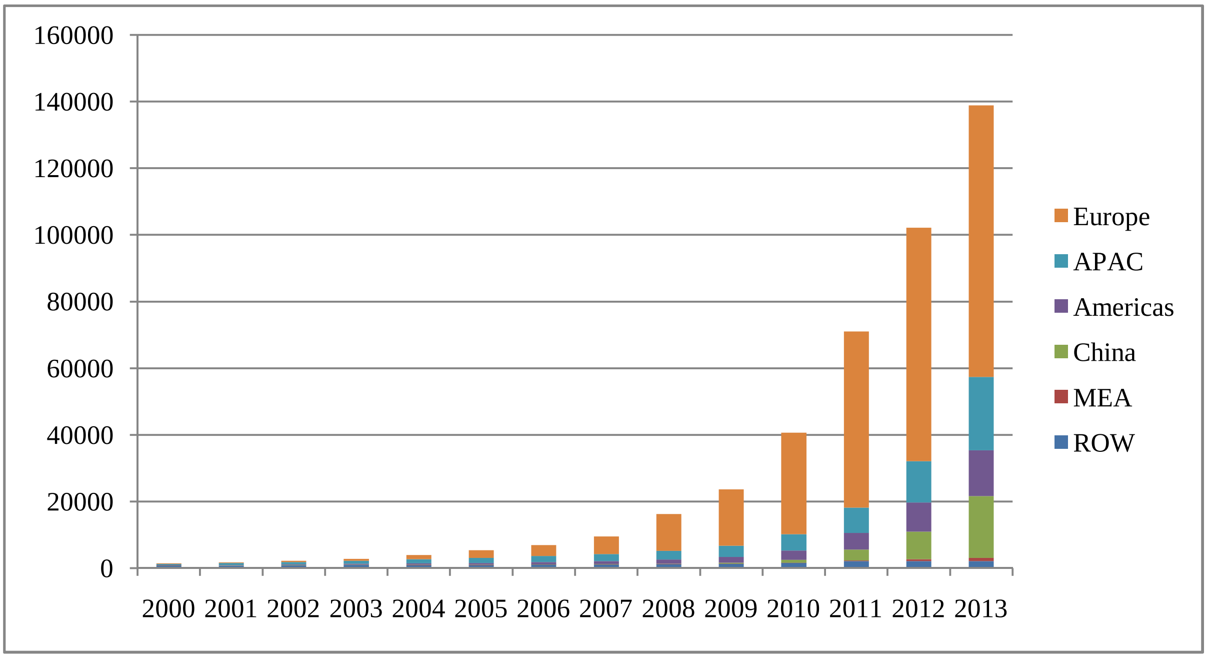
5.2 World PV market development

In 2013, the global total annual capacity reached historical peak 38GW, surpass the two years of 30GW annually installation. But as we can see from figure 9, in 2013 it is surprisingly that EU first time have a significantly drop on annual installation (11GW), a rapidly growth of annual installation capacity in Asia (21.6 GW) have greatly surpassed EU. China first time becomes the top solar market in 2013, reached 11.8GW of annual installation. It also has been the biggest solar producer since 2007.

As we can see from Figure.3, the European Market experience significantly growth since 2007, a market volume reached 13.7GW and 22.3GW in 2010, 2011 respectively. In 2012, the European market had a slight decline to 17.7GW. In 2013, the annual installation capacity is only 11GW reached the lowest since 2009 (Association, 2013).

Figure.8

Global PV cumulative installed Capacity 2000-2013 (MW)

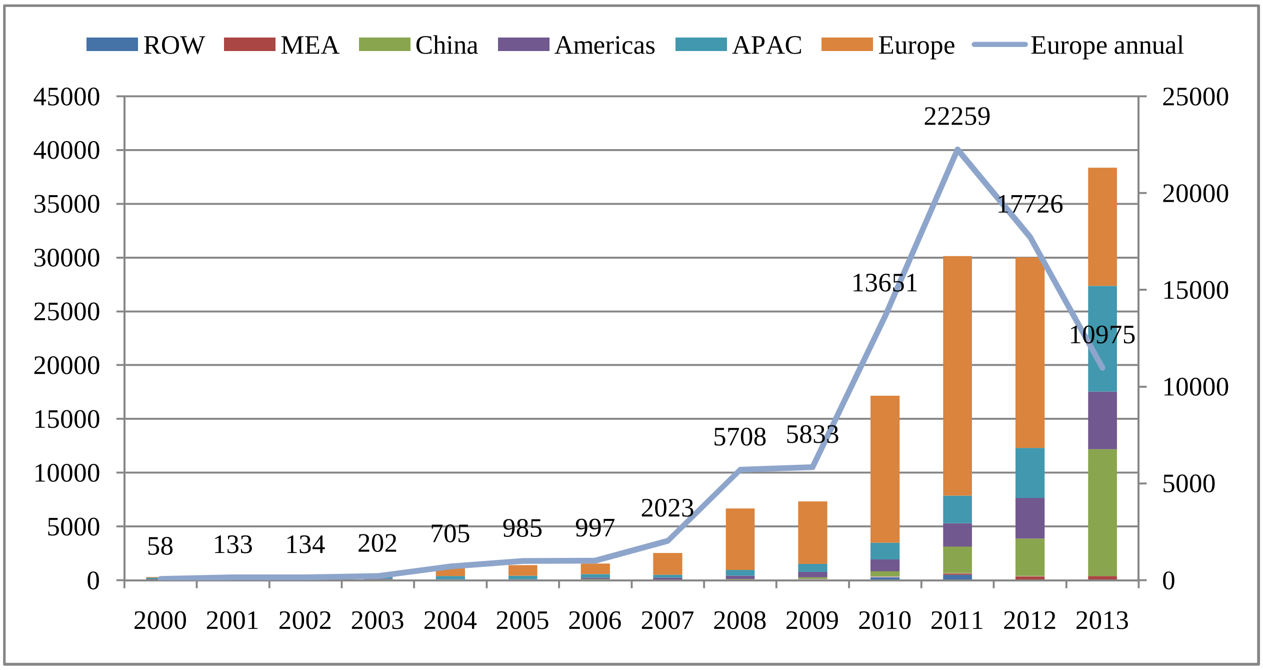


Source: data collected from (Association, 2013), figure generated by author.

Row: Rest of the World. MEA: Middle East and Africa. APAC: Asia Pacific

Figure.9

Global PV annual installation 2000-2013 (MW)



Source: data collected from (Association, 2013), figure generated by author.

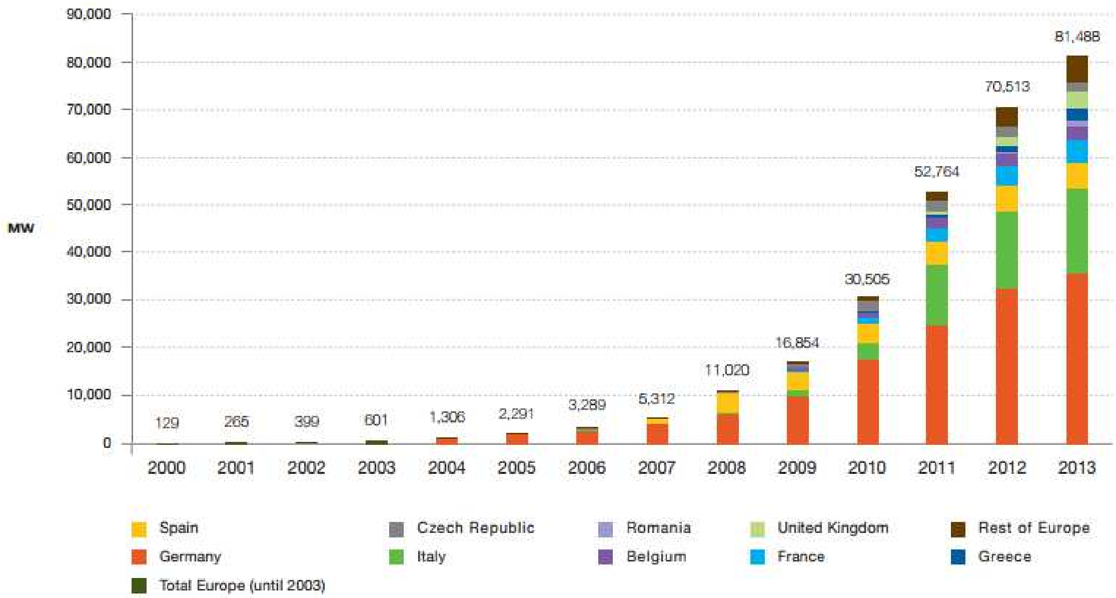
Row: Rest of the World. MEA: Middle East and Africa. APAC: Asia Pacific

5.3 The European market development

After the 2008, with vanish of Spain market, the Germany market is the only main driver of European Market. The European market major return happened in 2010, with Germany market remain strength, Italy and Czech market continue grow. In 2013, the cumulative installed capacity reached 80GW. As we can see from Figure.10, the Germany market was the dominant market in EU. It steady growth since 2007.

Figure. 10

European PV cumulative installed capacity from 2000-2013



Source: (Association, 2013)

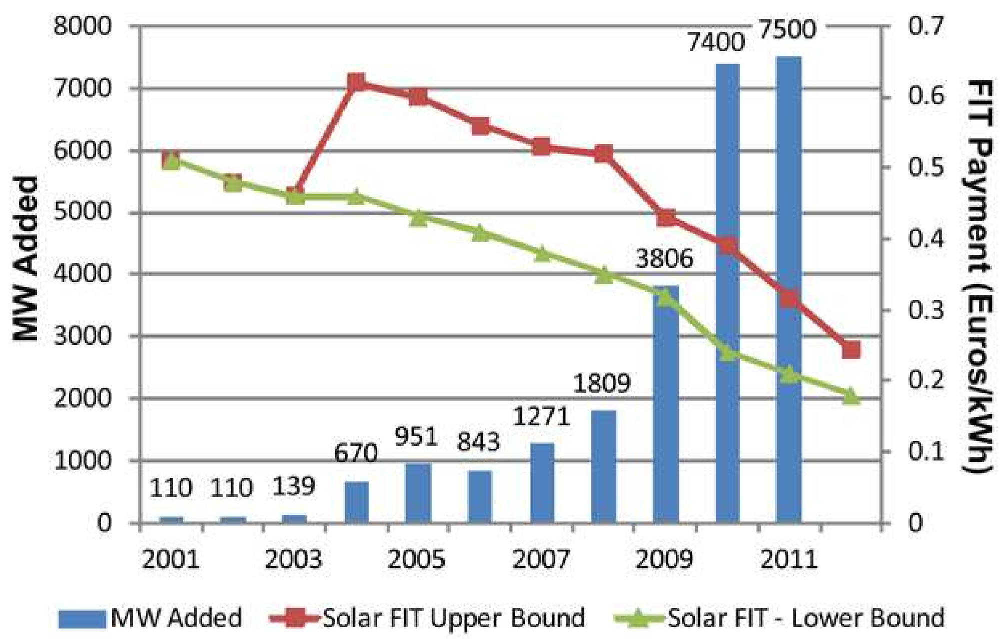
However, the pace of PV market deployment in EU has been clearly reduced, which will have consequences for the ability of PV to reach high penetration levels in the short to medium term in Europe. Germany saw steady growth for nearly a decade and clearly represents the most developed PV market, despite the 2013 market downturn. Countries which got a later start – the Czech Republic, Italy, Greece and Belgium – quickly reached high levels, and decreased rapidly afterwards.

5.3.1 Germany Market.

As we mentioned above, Germany is the dominant solar PV market of EU since 2004, therefore, we will use the Germany Market as an example to research the connections between FIT incentives and solar energy utilization and solar industry development.

The feed-in tariff support incentives for solar PV energy have permitted PV industry to grow up, and PV to step up to become a mainstream power generation technology. As we can see from the figure.11 that the significant growth of Germany solar market from 2004. During the same time, the incentives FIT is reaching its historical peak. With the stimulation of high FIT incentives, Germany solar market gradually growth. By 2008, the annual installation capacity reached 1.8GW. Even during the- difficult macro-economic environment, the Germany market reached 3.8GW of annual installation. Meanwhile, as most of Chinese solar Manufactures reach their economic scale and start to release its capacity, the solar products price declined dramatically.

Figure.11
PV installation and FIT in Germany



Source: (Laboratory, 2012)

The growth of the PV market was unanticipated by national authorities, despite the application of a number of complex schemes which were intended to take market dynamics into account. It appears now that the combined effect of reduction of the support schemes, introduction of caps, and restricted access to finance will limit the growth of PV installations in Europe.

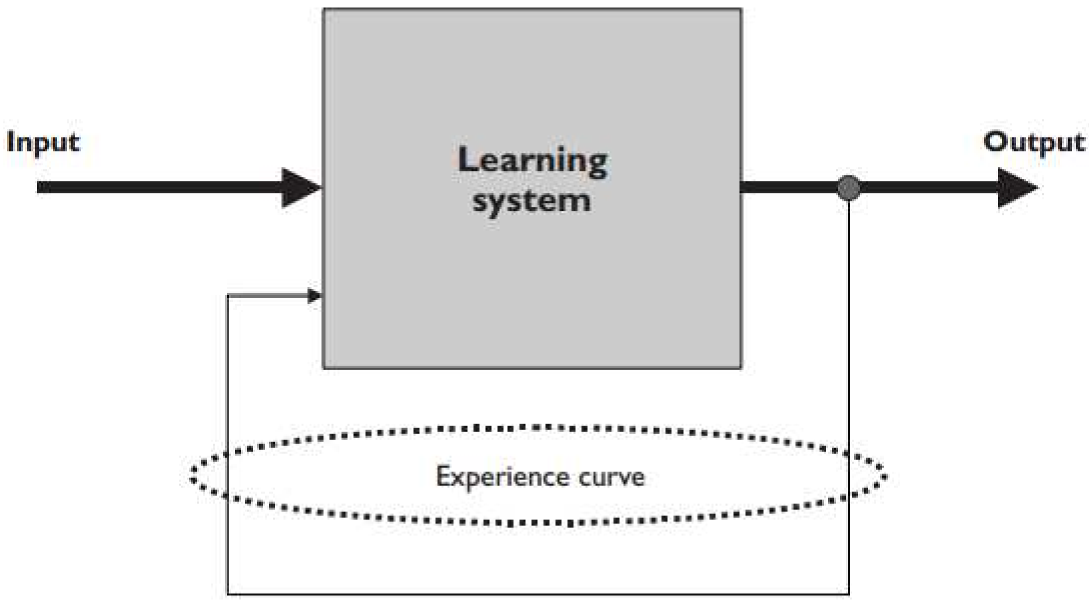
6. Experience Curve Analysis on US and Chinese Solar Market

6.1 Theory

The *experience curves* had been used as an important tool to analysis the cost reduction of various new technologies for decades (Neiji, 2003). The experience curves expressed the quantitative relationship between cost reductions and cumulative production, and it is derived from *learning curves*. The learning curves originates from Wright (1936), Wright observed that workers production efficiency increase when they manufactures more and more airplanes. Wright also observed that the unit cost of airplanes declines with the increase amount of airplanes produced. In 1950s, the learning curves were suspected by researchers if it was applied to other products' manufactures. However, through numerous researches, Wright's learning curve theory was accepted by the general (Lieberan, 1984).

In mid-1960s, the *Boston Consulting Group* (BCG) developed the experience curve and by then, the experience curve became a signature concept of BCG (Martin Reeves, 2013). The experience curve is a more general form of learning curves where learning curves focus on the analysis of labor cost per unit of cumulative united products produced. In 1966, the founder of Boston Consulting Group, *Bruce Henderson* imposed the experience curves, it refers to the concept "learning by doing" and it also express the relationships between cost reductions and cumulative productions of the products. Henderson claimed that the experience curve shows the products costs decline 20% to 30% when each time cumulative production (experience) is doubled. BCG had concluded that the experience not only include the labor costs, but also includes cost such as administrative cost, marketing cost and capital cost. The cost reduction under experience curves was also the results of total cost (labor cost, administration cost, marketing cost and capital investment cost), labor learning process improvement which can be express as " learning by doing" (labor skills improved through learning, production process improved, technical update of equipment), market share and market potential, products standardization and economics of scale. However, BCG did not try to disassemble the detail relationship between cost reduction and these elements and simply describes prices or costs reduction as a function of cumulative production (Lieberan, 1984). The experience turned to be a valuable predictor of competitive dynamic economics and it is also adopted as a tool for strategic decisions in 1970s. As we can see from the **Figure.12**, the cybernetic model simply describes how experience curves effect improves internal working of one company in the competitive industry. Through experience curve effect, company gained experience from the process of transforming input to output, during this process, company will gain newly experience and adopted the newly experience into new production procedure to transform input to output. The repetitive procedure of learning will be measured by the progress ratio (PR), which is the loop procedure from output back to input (IEA, 2000).

Figure.12
Cybernetic Model of the experience curve



Source: Figure from (IEA, 2000)

The founder of BCG, *Henderson* claims "*The experience curve effect can be* *observed and measured in any business, any industry, any cost element, anywhere*"(Henderson, 1974). However, there are numerous researchers and literatures suspects and criticized the experience curve model. (Dutton & Thomas, 1984) had suspected on the explanation power of experience curve through their research, their research shows that an extensive variation during their research of 108 experience curves studies. The appealing reasons of experience curves are as follows. Firstly, the experience curves model requires availability of empirical data on price/cost and cumulative production data to construct the experience curves and run the test. As a consequence, large accurate data is required and the viability of the data and data quality could have a huge impact on research result. Secondly, researchers indicate that in some industries, companies and firms learn from the historical experience. Thirdly, the goodness-of-fit the experience model requires the empirical data at least for decades or even several years. Finally, the cost reduction in experience curves only related to the accumulated experience or cumulative production and ignores the effect of R&D research (Nemet, 2006). During the application of the experience curves, it failed to materialize as a strategic decision tool, and the concept of experience curves gradually lost its favor in late 1970s (Lieberman, 1987).

The experience curves were brought back our attention in recent years and it had been used to assessment government's energy policies and modeling technical change of various energy, research showed in IEA (2000), Neiji (2003). The Boston Consulting Group indicated that the experience curves still applicable in today's business environment (Martin Reeves, 2013). However, it is only applicable in a "relative stable, cost-sensitive, competitive and production-insensitive" industry. BCG also developed the classic experience into two new models in order to fit into today's business environment (Martin Reeves, 2013). In this paper, we will adopt the Single Factor Experience Curve, which is the classic experience curve model to analysis the relationship between cost reduction and cumulative production of Solar PV modules in solar industry.

6.2 Method

The experience curves express the quantitative relationship between cost decline and cumulative production, where cumulative production is also described as accumulated experience in production progress. A characteristic of experience curves is that a constant percentage of cost declines associated with doubling cumulative production (Neiji, 2003). The experience curves model is expressed in Neiji (2003) as follows:

$$C_{cum} = C_0 \cdot CUM^b \quad (1)$$

Where C_{cum} represent the unit cost as a function of output. C_0 represents the first unit cost of products produced, CUM is the cumulative production of the products during the estimate time period and power ***b*** is the experience index. With experience index, we can calculate the "learning rate". The learning rate is expressed as the relative cost reduction for each of doubling cumulative production of products. The calculation of "learning rate" is as follows:

$$LR=1-2^{\mathbf{b}} \quad (2)$$

The expression 2^b in formula (2) represents progress ratio (PR). For example, if we have a progress ratio of 90% in our estimation which means that the price/cost of our estimate products will decline 10% after doubling the cumulative production.

The learning curve model is generated as a form of regression model. Initially, the learning curve estimated the relationship between unit labor cost per hour and aircraft production. Base on Wright's theory, the curve was further developed as (W. Z. Hirsch, 1952)

$$\mathrm{Log}N_t = \alpha + \beta \log X_t \quad (3)$$

Where N_t is per unit labour input of total output in time period t, X_t is cumulative output, α is constant parameter and β is the coefficient which measures the relationship between the per unit of labour input N_t and the cumulative output X_t. We can see that equation (3) is a log-log formula which means the characteristic of log- log model is when X_t increase 1%, N_t will changeβ%.

Tthe Boston Consulting Group later promoted the experience curve and BCG (1970) derived the equations as follows:

$$\text{LogC}_t = \delta + \gamma \log X_t \qquad (4)$$

Where C_t replaced N_t in equation (3) and C_t represent the total cost of products (C_{cum}) in the experience curve model. X_t remain the same which is the cumulative production and γ is the parameter to express the products cost response to the cumulative production change. When the cumulative production X_t increases by 1%, it will lead C_t , the cost of product changes $\gamma\%$ accordingly.

As the difficulty of acquire cost data, the cost factors are replaced by price factor in the experience curves. The regression model was showed in Lieberan (1984) we will use in this study is as follows :

$$\text{LogP}_{i,t} = a_i + b_1 \log X_{1,i,t} + \cdots b_j \log X_{j,i,t} + \cdots + b_n \log X_{n,i,t} + u_{i,t} \qquad (5)$$

Where $P_{i,t}$ represent the average technology price in country i during period t or specific products price, in our research $P_{i,t}$ will represent the average price of solar modules. $X_{n,i,t}$ is the multi experience indices. a_i is the constant parameter and $u_{i,t}$ is the random error terms. As we can see from equation (5), when n=i=1, the equation become to be the classic experience curve regression model, which is Single Factor Experience Curve (SFEC).

$$\text{LogP}_t = a_i + b_1 \log X_{1,i,t} + u_{i,t} \qquad (6)$$

The SFEC model as we mentioned earlier, it has been adopted into many experience curves analysis, such as Neij (1997), IEA (2000), Neiji (2003). The theory indicates the experience index b_1 should be negative, thus, we expect that from equation (6), 1% of increase of cumulative production will leads to b_1% decrease of price P_t. With the estimation result of coefficient b_1, we can adopt coefficient b_1 to calculate the progress ration, which is showed in Hirsch (1956)

$$\text{PR}=2^{b1} \qquad (7)$$

And the learning rate (LR) is

$$\text{LR}=1\text{-PR} \qquad (8)$$

In our analysis, we will use Solar PV Modules price as a proxy of solar Modules cost. Generally speaking, the experience curve is aims to express the relationship between products cost and cumulative production rather than the products price and cumulative production. However, due to the strong market competitive, most of the solar manufactures are confidentially strict about their products cost data. Therefore, this paper will adopt available price data as a proxy of cost. As we will adopt price as a proxy of cost, then we must correct our nominal solar modules price by GDP deflator in order to make our estimation unbiased and accurate and also eliminate the inflation effect on our collected price data.

$$P_{t,Real} = {}^{P_t}/_{K_t} \qquad (9)$$

Where:

$P_{t,\ Real}$ = inflation-corrected price for year t

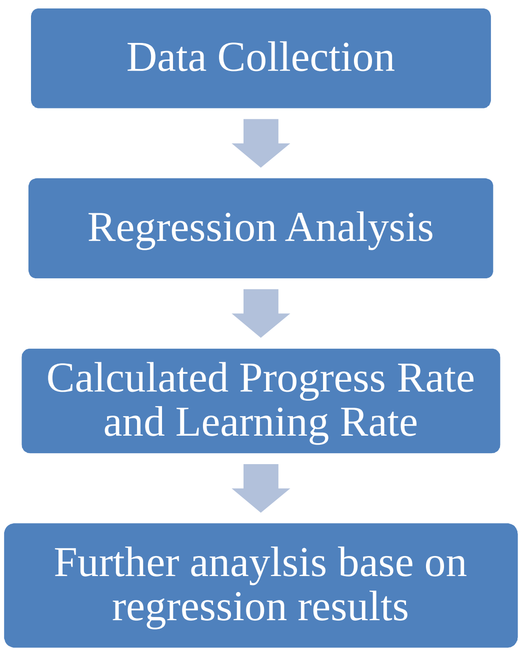
P_t = solar modules nominal average selling price (ASP)

K_t= country- specific GDP for year t

Hence, the experience curve analysis for solar PV modules was constructed as follow procedures:

Figure.13

Flowchart for experience curve analysis



6.3 Empirical Data Collection

Solar PV modules average selling price (ASP), Solar PV cumulative production and R&D investment data were collected from European Union and China. In order to eliminate the inflation effect, the country-specific GDP deflator was also collected in order to recalculate the real price of the solar modules prices. Moreover, due to limit access to the accurate data, the data collection in this paper is insufficient to fully describe the cost reduction of solar PV modules in European Union and China The data collection related to European Union and China described below:

6.3.1 Data for European Union

Data collection for European Union covers the year from 1999 to 2010, total solar PV modules production and average solar modules price were collected.

The total solar PV modules production volume were collected from (Maycock, 2005). As we mentioned above, European Union is the leading region for solar PV energy utilization. After 2008, the low cost Chinese manufacture plays a dominant position in the EU solar market. Due to the high cost of solar production in EU and the impact of Chinese solar manufactures, most of European solar manufacture reduce or shut down their production. Therefore, the data from 2011 to 2014 shows a decline trend, therefore, we omitted the data from period 2011-2014. The production volume was measured in MW (megawatt).

The average solar modules prices are collected from (Solarbuzz, 2012), the famous solar research agency. All the price data were converted to 2010 real price, the GDP deflator of European Union in 2010 is 1% and the data collected from The World Bank Database. However, the major concern about the price and production data is data is inadequate. The EU solar modules prices were measured in €/watt. The price and production data can be seen in **Appendix, table.4**

6.3.2 Data for China

The data collection for China includes solar module production, average solar modules prices and R&D expenses for individual leading manufactures. The data for solar modules production and ASP ranged from 1976 to 2013, which is in total 37 years. The solar modules production and average selling price data from 1976 to 2000 were collected from (Zheng Zhaoning, 2005). Data from 2001 to 2013, including production volume and price were collected from IEA's PV Power Systems (PVPS) Programme, which is (Agency, 2013). The GDP deflator for year 2010 and 2012 is also collected from the World Bank Database. The GDP deflator is 7% and 2% for 2010 and 2012. The price data from 1999 to 2010 was converted to 2010 real price, in order to compare the experience curve effect on European and Chinese solar industry in same time period. Also, the price data from 1976 to 2013 was converted to 2012 real price, as the GDP deflator for 2013 is not available at the moment. The production was measured by MW and the average selling price was measured by CNY/watt.

6.3.3 R&D data for China

As the inadequate statistic system in China on the solar industry, the validity R&D expense data are not able to access. Therefore, the R&D expense data were collected from the representative Chinese solar manufactures. As we saw from figure.2, half of the top ten solar modules manufactures are Chinese companies, the R&D expense data were collected from Yingli Solar, Trina Solar, Suntech Solar, Hanwa Solar and Canadian Solar from 2007 to 2012. As most of the Chinese leading manufactures are listing on New York Stock Exchange (NYSE), therefore, it is able to access R&D expense in their Quarterly or Yearly Earnings Releases. The R&D expense was measured in million US dollars. The price data, production data and R&D data can be seen in **Appendix.**

In our analysis, the regression will base on SFEC model and MFEC model. We will adopt Ordinary Least Square method and analysis software SHAZAM was used to run the analysis. In this paper, the experience factor will be used is showed as below:

1. Total Output (TP): The total output produced by solar PV manufactures of each observation year. Measured by MW
2. Time (T): The time series observation years.
3. Research & Development (R&D): The amount of R&D expense. Measure by $/ million.

6.4 Results and Interpretations

This section presents the main result of the thesis from our estimation. The estimation was based on Single Factor Experience Curve and a interpretations will be given regards to our estimations results. Result summary table was presented below in order for ease of reading. More detail about estimation command can be seen in **Appendix**.

6.4.1 Empirical Results for EU (1999-2010)

Table. 7
Estimation result for EU solar industry from 1999 to 2010

Index	Regression (1)
TP	-0.12281**
	(0.018)
PR	0.918
LR	0.082
R^2	0.8172
Observation	12

Standard errors are in brackets,
**significant level 1% *significant level 5%

Estimation results for EU solar products based on single factor experience curve analysis (SFEC) present table.7. The standard error is stated in brackets. In the estimation, average sells prices (ASP) is adopted as dependent variable. Total output (TP) as independent variable and the R-squared also presented for the SFEC estimates.

In regression (1), the average selling price is adopted as dependent variable and express in € /watt. As we can see from the regression (1), the estimated coefficient is -0.12281 and it is statistically significant at the 99% confidence level. The statistically significant coefficient proved our second research questions that the experience curve effect do exist in European Solar industry. According to equation (8) and (9), we can then easily calculate the progress ration, which is 91.8% for regression (1) and learning rate is 8.2%. The research from IEA (2000), indicates that the Progress ratio (PR) is 79% for the solar PV modules in EU region from the time period 1976 to 1996. Moreover, the study from Hamon (2000) shows that the Progress ration (PR) is 79.8% for the solar PV modules from the world during the time period of 1968 to 1998. Our research data various from these two previous studies and we will discuss the reasons that may cause the PR difference in discussion sector.

The result above, present us that SFEC estimation shows that from 1999 to 2010, the learning rate (LR) for solar PV modules in EU region is 8.2%. The result of 8.2% represent when the cumulative production doubled, the solar modules prices will decline 8.2% compared with current level.At last, the estimation presents a value for R^2 =0.82. As the paper adopted time- series data from 1999-2010, the value of $R^{2,}$ 0.82 is relatively a good result. About 82% of our data can be explained by our SFEC estimation model.

6.4.2 Empirical Results for China (1999 to 2010)

Table. 8

Estimation result for China from 1999 to 2010

Index	Regression (2)
TP	-0.1006**
	(0.014)
PR	0.9326
LR	0.067
R-Square	0.8409
Observation	12

Standard errors are in brackets,

**significant level 1% *significant level 5%

Estimation results for Chinese solar products based on single factor experience curve analysis (SFEC) present in table.8. In regression (2), the average selling price is adopted as dependent variable and express in CNY /watt, total output (TP) as independent variable express with MW.

As we can see from table.2, the estimated coefficient is -0.1 and it is statistically significant at the 99% confidence level. The statistically significant coefficient also proved that the experience curve effect exist in Chinese solar industry as well. The result shows that the progress ratio (PR) is 93.3% and learning ratio (LR) is 6.7% in Chinese solar industry. Compared with our estimation above, the Chinese Solar industry has a lower learning rate compared with European peer during the same period. This phenomenon may indicate that the low cost of Chinese solar modules price is not mainly because of experience curve effect. The reason of low cost of Chinese low cost of solar products is could due to the scale effect and industry integrate full value chain (Goodrich, Powell, James, Woodhouse, & Buonassisi, 2013).

The PR result presents in table.2 indicates that when double the cumulative output, the Chinese solar module price will decline 6.7% decline compared with current solar products price. The R^2 in regression (2) is 0.84, which is slightly higher than the European part estimation. About 84% of our data can be explained by our SFEC estimation model when estimate Chinese Solar industry.

6.4.3 Empirical Results for China (1976 to 2013)

Table. 9

Estimation result for China from 1976 to 2013

Index	Regression (3)
TP	-0.15221** (0.013)
PR	0.8998
LR	0.1002
R-Square	0.7965
Observation	38

Standard errors are in brackets,

**significant level 1% *significant level 5%

As we mentioned above, China had become the biggest solar PV producer in the world since 2007. Therefore, it is necessary to estimate the Chinese solar PV industry during its whole development history in order to better understand the effect of experience curve in solar industry analysis.

The estimation covers the data from 1976 to 2013, and same as regression (1) and (2) that the average selling price is adopted as dependent variable and expressed in CNY/watt, total output (TP) as independent variable expressed in MW. The estimation result shows the estimated coefficient is -0.152 and is statistically significant at the 99% confidence level. The progress rate is 90% during the period of 1976 to 2013. The learning rate is 10% and it greatly improved compared with the learning rate 6.7% for 1999 to 2010. Therefore, when the cumulative production doubled, according to the 10% of learning rate, the solar price will have huge decrease compared with the 6.7%

learning rate, therefore, the result we have also expose another drawback of experience curve which we will talk about in discussion sector.

7. Discussion

7.1 EU solar industry analysis

The result present above shows that the estimate coefficient for European solar industry is statistically significant at the 99% confidence level. Therefore, our research question 2 had been answered, which there exist experience curve effect in European Solar Market from 1999 to 2010. With the coefficient value -0.12281, the Progress rate is 91.8%, learning rate 8.2%. As we mentioned above, that research from IEA (2000) and Hamon (2000) shows their research result show various difference. The reason could possibly as follows:

- Data inaccurate and less validity. The first reason could be data inaccurate and less validity. As experience curve estimate demand highly accurate and validity data, then the results produced from the estimation will more accurate. Therefore, our research result could be possibly a result of collection data inaccurate and less validity.
- Solar Manufacture progresses are more depend on automatic operation now. If we go back to the initial concept of experience curve, the learning rate is closely related to the experience that workers acquires. IEA (2000) and Hamon (2000), their research time start from 1976 and 1968. At the early stage, the manufacturer progress need workers to collect silicon wafer after slice silicon ingot. Moreover, after solar cells produced, workers need to assemble and welding the solar cells into solar modules. However, as robotic technology adopted into production process, automatic control has gradually replace the man power. Therefore, the learning in the near future gradually decreases. As the paper covers from 1999 to 2010, the robotic technology and automatic control had already changed the solar production process. It could be the reason that the learning rate in recent years is

much lower than early years.

Our estimation results show the learning rate in European Solar industry is 8.2%. Therefore, as our data shows that in 2010, the total solar production capacity in EU is 3.8 GW (1GW =1000MW), hence, if EU cumulative production doubled to 7.6 GW, then we will have 8.2% price reduction on solar PV products. In 2010, the average selling price of EU production solar module is 3.25 €/Watt. As the cumulative capacity doubled, the solar module price will decrease to 3.25*(1-8.2%) =2.98 €/Watt. When the cumulative capacity doubled again , according to the same learning rate, the solar modules price will decline to 2.98*(1-8.2%)=2.73€/Watt. Besides the experience curve effect, there also exits other factors which may induce cost reduction of solar modules prices.

7.2 Chinese solar PV industry (1999-2010)

The estimate results show that the estimate coefficient is -0.1006 and statistically significant at the 99% of confidence level. The statistically significant result indicates that experience curves effects exist in Chinese Solar PV industry from 1999 to 2010. The estimate coefficient induces the learning rate 6.7% for Chinese Solar industry. As we can see from our data that the Chinese solar module product price in 2010 is 13 CNY/watt. If the cumulative production doubled, from 10.8GW in 2010 increase to 21.6GW, the Chinese solar PV price will decline 6.7%, then we will acquire the new price for solar PV modules which is 13*(1-6.7%) =12.13CNY /watt. Based on 2010 exchange rate (1CNY=0.16€), the module price in China will be 1.43€/watt. The price is nearly 50% cheaper compared with European production Solar Modules.

There have been numerous factor could induce the low cost of Chinese solar module Prices.

- Indigenous factors, such as low-cost labour. China’s economic could success partly due to the low-cost labour. The low-cost labour provide the employer relatively competitive advantage. The research by Goodrich et al. (2013) indicates that for a integrated value chain Chinese solar manufactures, the low-cost of labour could induce $0.07 per watt cost advantage compared with a integrated value chain US manufactures.

- Tax deduction and government subsidies. The Chinese central government and local government provide tax deduction to Chinese solar industries as a measure of support high-tech enterprise. Local government provides land renting deduction, low price industry production electricity in order to increase local fiscal income.
- Scale effect. One important factor is Chinese solar manufactures acquires capacity advantage compared with European manufactures. For example, in 2010 just two Chinese manufactures Yinli Green Energy and Suntech Solar, their total capacity is 3.56GW. By contrast, the total output in EU is 3.8 GW. Moreover, research from Goodrich et al. (2013) shows that due to scale effect advantage, the Chinese solar manufactures acquire a $ 0.08 per watt advantage compared with US or European Solar Manufactures.
- Integrated full value Chain. When most of Chinese solar manufactures involved into solar market, their main business mainly focus on modules assemble and solar cells production. With year’s development, most of Chinese solar manufactures achieved full integrated value-chain. From silicon production, silicon ingot, silicon wafer, solar cells production and modules assemble. Cover both up-stream and down-stream sector. By contrast, most European solar manufactures either down-stream player or up- stream player. Only few manufacture attempts to build integrated value-chain.

7.3 Chinese solar industry (1976-2013)

Firstly, we can see from the result presented above, the coefficient is statistically significant at 99% confidence level. The result indicates that from 1976 to 2013, during this time period, the experience curves exist in Chinese solar industry. The learning rate is 10% from 1976 to 2013. The SFEC model is relatively sensitive to the input data, in 2013, the cumulative production capacity in Chinese solar industry is 26GW, and the solar products price is 4.2 CNY/Watt. Adopt with 10% learning rate, which means when double cumulative production, the products price will decline 10%, 4.2*(1-10%)=3.78 CNY/Watt, and the cumulative production will be 52GW. As SFEC mode is relatively sensitive to the accuracy and validity of input data, even a small error, can lead huge deviation in the coming result. If experience curve was adopted to future grid parity analysis, a small error could deviate the break even time point to 10 or 15 years. Therefore, this drawback greatly limited the experience curve as an accurate tool to analysis future technology change and assessment on energy policy. However, if researcher constructs the accurate model and input accurate, valid data, the experience curve is still a useful tool to guide policy and decision making.

8. Conclusion

The purpose of this paper is to examine the general renewable energy policy in European Union and China, and adopt experience curves as a tool to analysis European and Chinese solar industry to reveal except experience curve, what other factor can induce solar cost reduction.

The paper first review the renewable energy development history in EU and China. Then the paper adopt experience curve as tool to assess the European and Chinese Solar industry. The production capacity and solar products prices data were selected from 1999 and 2010 for EU and Chinese solar industry. Meanwhile, in order to assess the main dominant producer of solar modules in the world, the modules production capacity and products prices from Chinese solar industry was selected for the time period (1976-2013). The analysis is successful, proved our assumption.

Below, section 7.1 presents the answers to the research questions.

8.1 Answers to Research Questions

Q1: To what extent does renewable energy polices stimulated the development of solar utilization?

From the qualitative analysis of general renewable energy policy in EU and China, we can conduct that the general RE policy in EU and China has significantly stimulated the renewable energy utilization. The Directive 2009/28/EC clearly set the 20-20-20 targets for member states. Under the policy regulations, governments impose support schemes, which greatly stimulated the solar adoption, especially in Germany. The incentive FIT had greatly made Germany as the world's largest solar market. Meanwhile, the renewable energy policy in China also greatly stimulated the renewable energy industry development. By 2007, China had become the world's largest solar producer. With the support schemes gradually mature, the emerging China solar market have a great potential to replace Germany and become world No.1

Q2: Does experience curve effect exists in European and Chinese solar industry?

Our analysis show, experience curve effect do exist in European and Chinese solar industry.

Q3: How much cost reduction can experience curves effect induce in EU and Chinese solar market?

Presented by our analysis, the learning rate is 8.2% in European solar industry during the period 1999-2010. When double cumulative production, the solar products price will decline 8.2%. In 2010, the production of solar PV in EU is 3.8GW, when production reaches 7.6 GW, the price will decrease from 3.25 €/Watt to 2.98 €/Watt.

In China solar industry, the learning rate is 6.7% during 1999 to 2010. The cumulative production in 2010 was 10.8GW, when cumulative production reaches 21.6GW. The solar modules price will decrease from 13 CNY/watt to 12.13CNY

/watt.

Take time period from 1976 to 2013, the learning rate in Chinese solar industry is 10%. The cumulative production in 2013 was 26GW, when it doubled to 52 GW, the solar modules price will decline from 4.2 CNY/Watt to 3.78 CNY/ Watt.

Q5: Is there any other factors influence cost reduction in solar PV products?

Yes, there do exists some factors influence solar PV products price decline, factors such as low-cost labour, tax deduction, government subsidies, scale effects and manufactures integrated value- chain.

The experience curve analysis in the paper do describes how price reduction related to the cumulative production. If input data accurate, the experience could also used as a tool for policy assessment and policy decisions (Neiji, 2003). The drawbacks are, experience could only assess the cost reductions relationship with cumulative production and the successful experience curve analysis rely one reliable data. Therefore, data availability limitation blocks the adoption of experience curve analysis. At last, it is pity the paper can not link the experience curve analysis with R&D effect. If this research had be conducted in the paper, the discussion about solar industry in European Union and China will be more compelling.

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Appendix

1. Indicative Trajectory

The formula of indicative trajectory referred to Directive 2009/28/EC as follows:

$S_{2005} + 0.2(S_{2020} - S_{2005})$, as an average for the two-year period 2011 to 2012;

$S_{2005} + 0.3(S_{2020} - S_{2005})$, as an average for the two-year period 2013 to 2014;

$S_{2005} + 0.45(S_{2020} - S_{2005})$, as an average for the two-year period 2015 to 2016;

$S_{2005} + 0.65(S_{2020} - S_{2005})$, as an average for the two-year period 2017 to 2018.

S_{2005}= the share of the energy consumed in 2005

S_{2020}= the share of the energy consumed in 2020 (Commission, 2009)

Table. 1

China's First-level Renewable Energy Policy

China Policy documents	
First-Level	
1983	Suggestion to Reinforce the Development of Rural Energy
1992	The strategic on China's Environment and Development
1995	Outline on New and Renewable energy development in China, State Planning Commission (SPC), State Economic and Trade Commission (SETC)
1995	Electric Power Law
1996	Guidelines for the 9th Five-Year Plan and 2010: Long Term Objectives on Economics and Social Development of China
1997	Energy Conservation Law
2000	Law of PR.C on the Prevention and Control of Atmospheric Pollution
2003	Renewable Energy Promotion Law
2005	Renewable Energy Law
2006	The Medium and Long-term Plan for the Development of Scientific and Technology , State Council

2006	The 11th Five-Year Plan for National Economic and Social Development
2007	The Amendment of Energy Conservation Law
2007	China’s Energy policy 2007, State Council
2008	Circular Economy Promotion Law
2009	The Amendment of Renewable Energy Law
2010	The Decision of Accelerating Development of Emerging Industry, State Council
2011	The 12th Five-Year Plan for National Economic and Social Development
2011	China’s Policy and Actions for Addressing Climate Change, State Council
2011	The Guideline for regulate of Emerging Industry
2012	China’s Energy Policy 2012, State Council

Note: Data collected from (NREL, 2004) and (Portal, 2014), table generated by author.

Table.2

China’s Second-Level Renewable Energy Policy

China Policy Documents	
Second-Level Policy	
1994	Brightness Program and Ride the Wind Program by State Planning Commission
1995	New and Renewable Energy Development Projects in Priority(1996-2010) China, by State Science Technology Commission, State Power Corporation and State Economic and Trade Commission
1996	Ninth Five-Year Plan and 2010 Plan of Energy Conservation and New Energy Development by State Power Corporation
1996	9th Five-Year Plan of Industrialization of New and Renewable Energy by SETC
1998	Incentives Policies for Renewable Energy Technology Localization by State Development and Planning Commission(SDPC) and Ministry of Science & Technology (MOST)
2001	10th Five-Year Plan for New and Renewable Energy Commercialization

	Development by SETC
2003	Rural Energy Development Plan to 2020 for Western Area of China
2006	The Administrative Guideline of Electricity produced from Renewable Energy Resources by National Development and Reform Commission (NRDC)
2007	The Plan for High-Tech Industry develop during the 11th Five-Year Plan Period, by NRDC
2007	In Mid- and Long- Term Development Programming for Renewable Energy
2008	11th Five-Year Plan for New and Renewable Energy development
2010	The Standard Guideline for Wind Energy Construction, by National Energy Bureau
2011	Guidelines for Encouraging and Guidance Private Enterprises to Invest and Develop Renewable Energy, by NRDC
2011	12^{th} Five-Year Plan for New and Renewable Energy development

Note: Data collected from (NREL, 2004) and (Portal, 2014), table generated by author.

Table.3

Chinese Government direct subsidies Projects

LARGE SCALE PV		
PHASES	APPROVED CAPACITY	FEED-IN TARIFF
First Bidding 2009	2 projects, 20 MW	FIT = 1,0928 CNY/kWh
Second Bidding 2010	13 projects, 280 MW	FIT = 0,7288-0,9907 CNY/kWh
2011 FIT	2 000 MW	FIT = 1,15 CNY/kWh
2012 FIT	2 000 MW	FIT = 1,0 CNY/kWh
Total (until 2012)	4 300 MW	
Financial Source	**Surcharge for Renewable Energy**	
PV BUILDING PROJECT		
PHASES	APPROVED CAPACITY	SUBSIDY TO CAPITAL (CNY/W)
1st phase, 2009	111 projects, 91 MW	BIPV 20, BAPV 15
2nd Phase, 2010	99 projects, 90,2 MW	BIPV 17, BAPV 13
3rd phase, 2011	106 projects, 120 MW	BIPV 12, CNY/W
4th phase, 2012	250 MW	BIPV 9, BAPV 7,5
Total (until 2012)	About 550 MW	
Financial Source	**Special Fund for Renewable Energy**	
GOLDEN SUN DEMONSTRATION		
PHASES	APPROVED CAPACITY	SUBSIDY TO CAPITAL (CNY/W)
1st Phase 2009	140 projects, 304 MW	PV Building 14,5 off-grid 20
2nd Phase 2010	46 projects, 272 MW	PV Building 11,5 off-grid 16
3rd Phase 2011	129 projects, 692 MW	C-Si 9.0, a-Si 8.5
4th Phase 2012	155 projects, 1 709 MW	PV Building 5,5, off-grid >7,0
Total till 2012	2 977 MW	
Financial Source	**Special Fund for Renewable Energy**	

Source: Table collected from (Agency, 2013).

Table.4

Solar modules production and average selling price in EU

Year	Total Output (MW)	ASP (€/watt)	Real Price in 2010 (€/watt)
1999	53	7	5300
2000	72.7	6.2	7270
2001	108.8	6	10880
2002	135.05	5.5	13505
2003	210.35	5.2	21035
2004	483.1	4.8	48310
2005	742.3	4.9	74230
2006	1016	4.8	101600
2007	1657.6	4.87	165760
2008	2389.7	4.75	238970
2009	3419	3.75	341900
2010	3837	3.25	383700

Note: EU 2010 GDP deflator (1%)

Table. 5

Solar modules production and average selling price in China (1999-2010)

Year	Total Output (MW)	ASP(CNY/Watt)	Real Price in 2010(CNY/Watt)
1999	2.8	37.7	538.5714
2000	2.7	36.46	520.8571
2001	4.6	36	514.2857
2002	6	35.7	510
2003	12	34.8	497.1429
2004	50	33.2	474.2857
2005	146	32	457.1429
2006	438	28	400
2007	1088	26	371.4286
2008	2600	20	285.7143
2009	4011	19	271.4286
2010	10800	13	185.7143

Note: China GDP deflator in 2010 is 7%

Table 6
Solar modules production and average selling price in China (1976-2010)

Year	Total Output (MW)	ASP(CNY/Watt)	Real Price in 2012(CNY/Watt)
1976	0.0005	400	20000
1977	0.001	200	10000
1978	0.002	120	6000
1979	0.005	100	5000
1980	0.008	80	4000
1981	0.015	77.5	3875
1982	0.02	70	3500
1983	0.03	60	3000
1984	0.05	50	2500
1985	0.07	47.5	2375
1986	0.08	42.5	2125
1987	0.1	40	2000
1988	0.35	30	1500
1989	0.55	28.9	1445
1990	0.5	35.9	1795
1991	0.55	36.2	1810
1992	0.65	29.07	1453.5
1993	0.9	38.64	1932
1994	1.1	40.318	2015.9
1995	1.35	40.58	2029
1996	2.02	39.28	1964
1997	2.23	39.875	1993.75
1998	2.37	39.12	1956
1999	2.8	37.7	1885
2000	2.7	36.46	1823
2001	4.6	36	1800
2002	6	35.7	1785
2003	12	34.8	1740
2004	50	33.2	1660
2005	146	32	1600
2006	438	28	1400
2007	1088	26	1300
2008	2600	20	1000
2009	4011	19	950
2010	10800	13	650
2011	21157	9	450
2012	23000	4.5	225
2013	26000	4.2	210

Note: China GDP deflator in 2012 is 2%, GDP deflator is not avaiable

2. Estimation Command for EU

```
sample 1 12
read year tp asp
genr lnasp=log(asp)
genr lntp=log(tp)
ols lnasp lntp /loglog
genr pr=2**(-0.12281)
print pr
stop
```

3. Estimation Command for China (1999-2010)

```
sample 1 12
read year tp asp
genr lnasp=log(asp)
genr lntp=log(tp)
ols lnasp lntp /loglog
genr pr=2**(-0.1006)
print pr
stop
```

4 Estimation Command for China (1979-2013)

```
sample 1 38
read year tp asp
genr lnasp=log(asp)
genr lntp=log(tp)
ols lnasp lntp /loglog
genr pr=2**(-0.15221)
print pr
stop
```