Renewable Energy Sources in Central Europe and East Asia

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Abstract. This paper provides overview of all sustainable energy resources in two geographic areas- Central Europe and East Asia. Comparison of renewable energy sources in these two areas was not done before. We cover newly emerging important renewable energy sources of wind power, solar energy and bioenergy together with somehow less investigated geothermal sources. Our analysis includes also a well established hydroelectricity and nuclear energy. While nuclear energy is not a renewable resource, it was included into this analysis to provide complete coverage of all competitive energy sources with respect to carbon-based fossil fuels. We provide both descriptive and econometric analysis complemented with appropriate case studies.

Key words: Renewable Energy; Central Europe; East Asia

JEL classification: R11; Q42

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1. Introduction

This paper provides overview of all sustainable energy resources in two geographic areas-Central Europe and East Asia. Comparison of renewable energy sources in these two areas was not done before. We cover newly emerging important renewable energy sources of wind power, solar energy and bioenergy together with somehow less investigated geothermal sources. Our analysis includes also a well established hydroelectricity and nuclear energy. While nuclear energy is not a renewable resource, it was included into this analysis to provide complete coverage of all competitive energy sources with respect to carbon-based fossil fuels. We provide both descriptive and econometric analysis complemented with appropriate case studies.

2. Sustainable Energy Sources in CE and EA

2.1 Wind power

Wind power is the use of airflow through wind turbines to mechanically power generators for electricity. Wind power, as an alternative to burning fossil fuels, is plentiful, renewable, widely distributed, clean, produces no greenhouse gas emissions during operation, and uses little land (Fthenakis V. and Kim H. C. (2009). The net effects and local impacts on the environment are far less problematic than those of nonrenewable power sources.

Regional outlook

According to *Global Wind Energy Outlook (GWEC) for 2012, 2014*, wind power has now established itself as a mainstream electricity generation source, and plays a central role in an increasing number of countries' immediate and longer-term energy plans. (Appendix)

Table 2.1

Wind power production capacities in CE and EA, 2004-2013

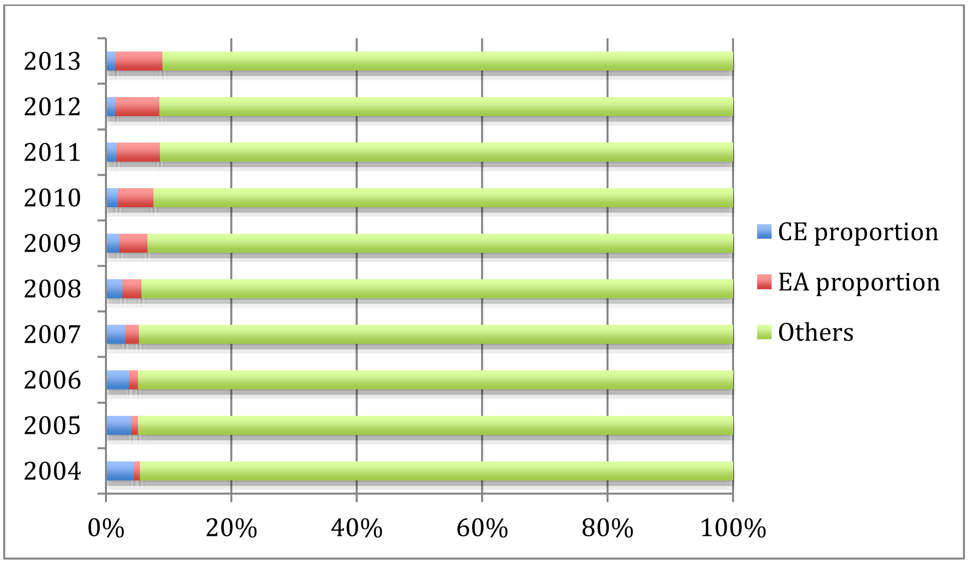
Country	Avg[1] annual production	% Change 2004-2013	Rank
GM	24982.3	7.67%	2
SW	27.5	25.01%	10
CR	152.2	36.41%	9

[1] Simple moving average (SMA)

PL	1044	53.04%	5
HU	175.6	94.40%	8
AU	1052.2	11.42%	4
SR	4	(-4.00%)	11
SV	2	20.00%[2]	12
CH	31866.7	66.83%	1
TW	363.9	91.58%	6
JP	1778.9	15.26%	3
SK	296.5	59.55%	7
World	158691.7	21.25%	
CE avg.	3429.75	30.49%	
EA avg.	8576.5	58.30%	

Figure 2.1

Share of wind production capacities (MV) in CE & EA to world



Source: Wind Energy Market Intelligence[3], 2013

A summary of each CE and EA countries' conditions presented in Figure 4.1 above, every country except Switzerland has strengthened their wind production capacity, while the number in Switzerland decreased at average annual rate 4% from 2004 to 2013. According to Swiss Federal Office of Energy (SFOE) quotes, the climatic conditions for

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[2] Slovenia development in wind power only begins since 2012 at 2 for two successive years, which was 0 until 2012, thus had impact on its average annual growth rate in periods 2004-2013.

[3] Wind Energy Market Intelligence, Online access, wind energy market factors (2013) http://www.thewindpower.net/statistics_en.php

wind power vary from region to region in Switzerland, which is limit the accessibility to many of the locations, many wind power projects are met with opposition. The fear of noise emissions and the protection of the landscape and bird life are the most frequent reasons for objections against wind farm projects. Overall, these conditions do not predestine Switzerland as a land of wind energy. Because wind levels are not constant in Switzerland, the availability of wind energy is distributed unevenly across time; Swiss people only applied wind energy as substitutes combined with other sustainable energy such as hydropower[4]. In addition, both CE and EA areas have growing faster than world average level (21.25%), at 30.49% and 58.3% respectively; indicating CE and EA have expanded its wind power capacity to promoting sustainable energy development. China and Germany shows greater capacity and potential in wind power, with 24,982.2 and 31,866.7 (MV) respectively.

However, Figure 4.1 also shows CE and EA markets are not developing asynchronously as EA market has been taking up more portions, while CE has been losing their advantages in wind sector, shrinking from 7.46% in 2004 to 0.89% in 2013. This trend can also be contributed to other reasons such as energy structure reforms.

Case study: wind power in China

Wind power is one of the most promising sources of sustainable energy. Recently, Hernández et al. (2011) demonstrated that wind is a periodical phenomenon for large geographical areas like China. A review[5] reveals that the growth of wind turbine installations in China is impressive, onshore wind farm development and construction technology is already quite mature. While the grid infrastructure is proving to be a serious issue, especially in areas with high wind speeds. This problem has both institutional and technical aspects. The wind electricity net generation rose from 1.332 billion KWh in 2004 to 95.978 billion KWh in 2012.

Accordingly, using MAVT model (Section 2.3 Eq. (4)) to addressing four main strengths & three challenges in wind power apply in by STATA:

a) PRODUCTION: wind power companies' yield in each year

[4] ALPIQ website (2016):"Swiss hence it can only be utilised in conjunction with other energy sources, for example in combination with hydroelectric power stations − reservoirs and pumped storage power stations. These are available at all times and can step into the breach and generate electricity when the wind slackens."

[5] "China Wind Power Development Road Map 2050" released by International Energy Agency and Energy Research Institute

b) Policy framework improved & law

Main energy political changes: (i) Renewable Energy Law took effect in 2006 with a series of new modifications after 2012; (ii) Three twelfth Five-Year plans supports in China[6]. According to those changes with timeline, divide them into 3 categorical dummy variables:

LAW[7]	0 (Pre 2006)	1 (2006-2011)	2 (Post 2012)

c) Financial support: state, public and foreign investment

Including (i) Large state owned enterprises (SOE) financial injections into wind power projects constructed and completed having investments by these corporations. (ii) Total public investments[8] (iii) Foreign direct investments[9].

Due to imprecision caused by unpublicized data in many years (not presented), transferred this into categorical dummy variables:

INVEST	0 (Pre 2005)	1 (2006-2010)	2 (Post 2011)

d) Technology & innovation development (see INV in Appendix 5)

The w_i represented by weight of patent applications of wind energy company each year, v_i is its portions of total patent applications in SE yearly, from 2004 to 2014:

$$\text{INV}^{10}\ \text{Index Value} = \sum_{i}^{m} w_i v_i \ (a)$$

$$= \sum_{i}^{m} (\text{number of patent applications of wind energy company} \times \text{ portion to total patent applications in SE sector})$$

e) Enormous home market size (see SIZE in Appendix 5)

Market size majorly driven by two factors here: w_i represents population in China each year, v_i is the newly added wind installed capacity in China yearly:

6 China's three Twelfth Five-Year Plans (2001-2005, 2006-2010, 2011- 2015)

7 LAW: including laws and policies for sustainable energy development and legislation changes in this sector; According to energy policy & law records in China, this variable was divided into 3 categorical dummy variables due to its specialty in change with time

8 By the end of 2011, a total of some 700 firms nationwide had invested in wind farm construction, offered a cumulative grid-connected capacity of 37.98 GW, accounting for over 79 % of the country's total grid-connected wind capacity.

9 The International Clean Energy Race | AltEnergyMag, 2013 edition, *"In 2013 alone China garner 29% of G-20 dean energy investment"*.

10 INV: innovation system measured by the multiple *INV Index Value*, combined by the number of companies in wind energy development and the number of patent applications in wind power sector, published by China Intellectual Property Publishing Co., Ltd. 2016

$$\text{SIZE} = \sum_{i}^{m} w_i v_i \ (a)$$

$$= \sum_{i}^{m} (\text{population each year} \times \text{ wind generating electricity consumption})$$

But China is still facing challenges:

a) Efficiency: China has a curtailment issue with wind energy; 10GW large wind power bases, especially difficult to manage. Measured by average EPBT (sustainable energy pay-back time, by year)[11] in Section 2.1 Eq. (3) Appendix 5, see EFFICIENCY, the ratio of wind electricity installed capacity to wind energy electricity production.

b) Wind costs an tariff need reduction (see COST in Appendix 5)

COST variable measured by w_i: the weight of costs of electricity generation displayed in methodology section Eq. (2); v_i : tariff hike or reduction (rate) for wind energy company in China yearly:

$$COST = \sum_{i}^{m} w_i v_i (a)$$

$$= \sum_{i}^{m} (tariff\ hike/reduction\ for\ wind\ company \times\ costs\ of\ electricity\ generation)$$

c) Wind technology: grid integration & turbine quality

Abandoned windrower phenomenon due to inefficient structure integration showed up since 2010 in China. Ironically, it is most common in “Three North Province”[12] which with abundant wind resources and high installed capacity. Abandoned airflow rate (AFR) published by China Wind Power Centre displayed in Appendix 6.

Table 2.2

[11] Annual average number of mono-Si, multi-Si and ribbon-Si technologies’ EPBT

[12] “Three North Province” of top abandoned wind power areas: Jilin, Inner Mongolia, and Gansu province. CWPC report, 2014

Correlation analysis among strengths & challenges with wind added electricity installed capacity in China, 2004-2014

	AEIC	PRODUCTION	COST	SIZE	LAW	INVEST
AEIC	1					
PRODUCTION	0.8698	1				
COST	0.8859	0.7546	1			
SIZE	0.9999	0.8753	0.8832	1		
LAW	0.7061	0.8480	0.6111	0.7102	1	
INVEST	0.7167	0.8681	0.6186	0.7208	0.8226	1

Firstly, the strong correlations fall close among wind power added electricity installed capacity with wind power electricity production (0.8698), COST (0.8859) and particular the size of home wind power market (0.9999), indicates that there is a strong positive linear relationship between the wind power installed capacity and wind power production, costs & tariffs for producing wind-electricity, and home market size of wind power industry. Non-obvious correlations between wind power added electricity installed capacity and related law system (0.7061) and investment amount (0.7167) when compared with other variables, as legal system effects are considered to be displayed in longer term; hydropower plants construction proven to be investment costly especially in developing markets, thus not showing strong stimulation for wind energy company to producing here.

Secondly, there is no strong linear relationship between costs and law system improvement (0.6111) or costs and home market size (0.6186). This is contributes to significant amount of both small wind turbines and super wind farms in China, small wind farms have made great success especially in rural or some inland areas with scarce natural resources; during which law system barely intervene its expansion and the vast domestic consumption market in China has formed scale-economic effects as well.

However, in order to know the variables' impacts on wind industry in China through years, a detailed regression and ordinary logistic regression for categorical variables separately depicted in Table 4.3:

Table 2.3

Linear regression & ordinary logistic regression among variables contributes into wind production in China, 2004-2014

Type of model	Co-variable (reference)	Coef.	Std.Err.	t (z)	P>|t| (P>|z|)	[95% Conf. Interval]	
Linear regression	AEIC						
	COST	70.3223	39.0368	1.8	0.115	-21.9850	162.6297
	SIZE	0.0007	6.04E-06	123.06	0	0.0007	0.0008
	PRODUCTION	0.0002	0.00004	-3.75	0.007	-7.82E-06	-1.77E-06
	AEIC						
Ordinary logistic regression on law system	LAW 1 |	36.5182	6887.544	0.01	0.996	-13462.82	13535.86
	2 |	37.9077	6887.544	0.01	0.996	-13461.43	13537.25
	INVEST 1 |	36.3780	6512.699	0.01	0.996	-12728.28	12801.03
	2 |	38.0565	6512.699	0.01	0.995	-12726.6	12802.71

Note: large std. err. in this case can be neglected due to small sample.

The hypotheses from regression results are as follow:

a) There is no linear relationship between home market size and added electricity installed capacity of wind power in China, controlling for wind-electricity production and costs to generating wine-electricity; also non-linear relationship exist in wind-electricity production and added installed capacity in China, controlling market size and costs.

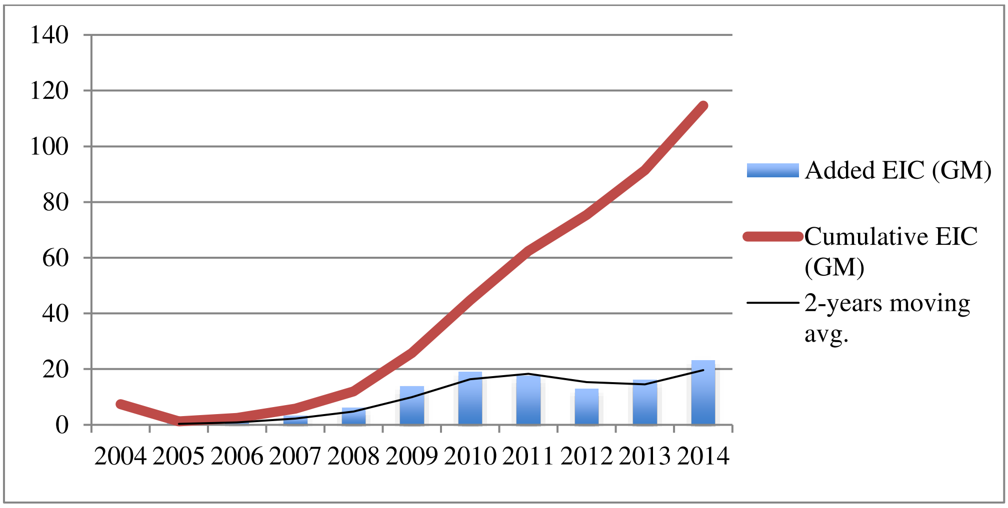
b) However, noticing from those t-value (z-value for ordinary logistic regression) and P-value in table above, the prediction about home market size and wind energy added electricity installed capacity seems like not perfectly convincing due to its high t-value; a more precise conclusion can be made for costs and production towards wind power development: costs actually not impede wind power industry in China but contrarily rise simultaneously with development.

c) Strong and positive correlation found between wind-electricity productions and its added installed capacity in China, which to be proven promoting its development.

Added ordinary logistic regressions for categorical variables LAW and INVEST showing very similar correlation between investment amount and related law & legislative system with wind power development, indicating wind industry development in China greatly relied on financial investment and law system improvement. Nearly 1% z-value indicating high confident level to say the predictions are reliable.

Figure 2.2

Scenario of added & cumulative wind electricity installed capacity in China, (GM)



China has added new capacity at an unprecedented rate since 2012, dropped slightly due to new sustainable energy policies published and stricter and more standardized legal system for wind power development, but benefits quickly showing up in the next year, with growth in added electricity installed capacity since 2013. Positive relationships between INVEST, SIZE with added wind electricity installed capacity (added EIC) (GM) respectively indicates greater investment and market size promoting wind power development. However, more uncertainty exists in correlation between innovations and added electricity installed capacity, on account of highly strict entry requirements can be barriers for wind energy companies.

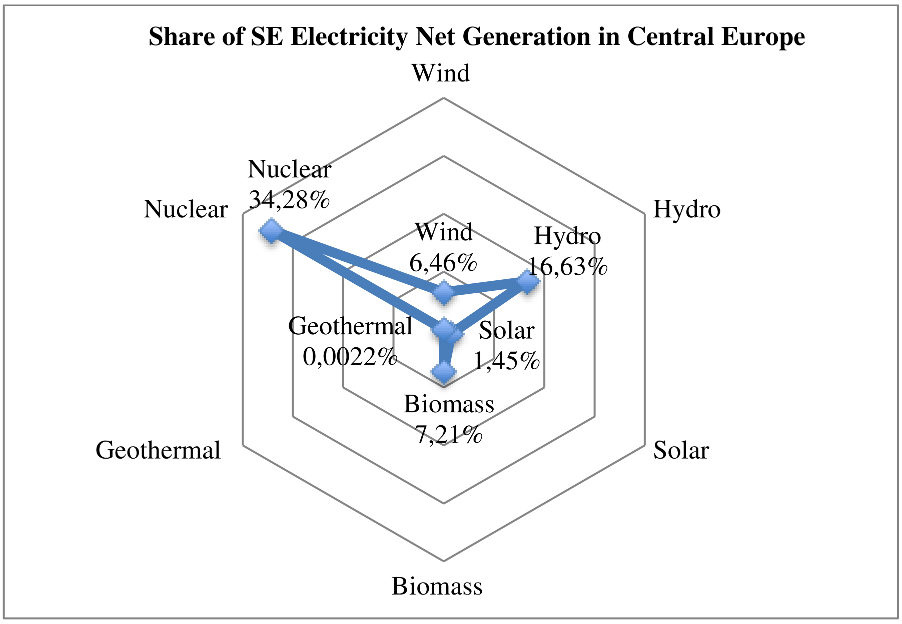
2.2 Hydroelectricity

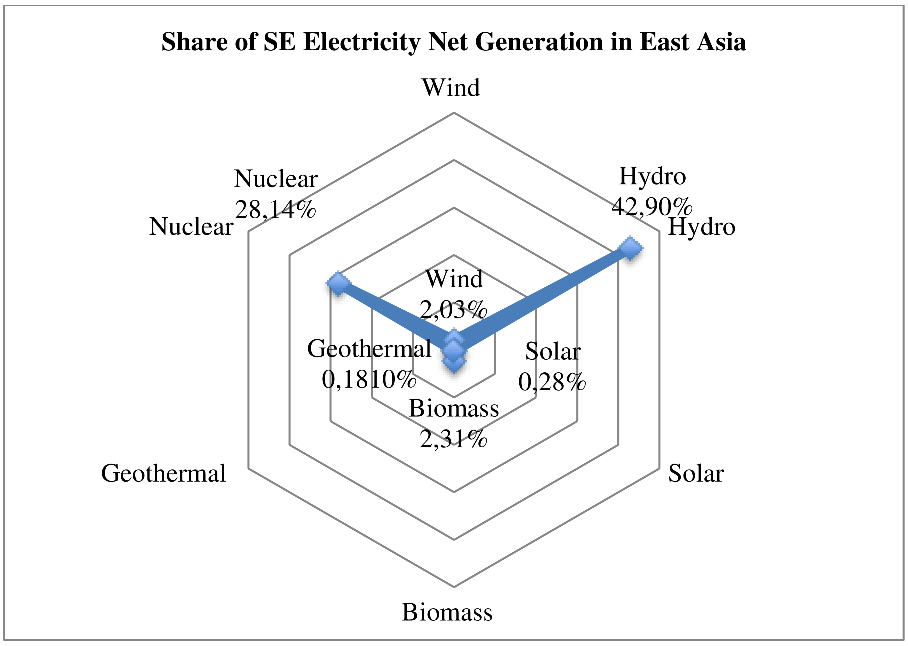
Regional outlook

First of all, most European nations governmental energy policy makers identify hydropower as a renewable resource. and the United Nations include hydropower in their discussions of renewable energy sources, while some interested individuals hold that hydropower is not a renewable resource because of its potentially serious effect on natural resources, often fish. This debate becomes more complex when addressing sustainablility, due to hydropower is also characterized by the large variety of positive and negative effects it can have on the ecosystem. A large-scale hydro project with a reservoir will convert some amount of terrestrial ecosystem to an aquatic ecosystem. It will have positive and negative effects on the downstream river and bentic ecosystems. There are numerous beneficial societal effects, such as flood control, water supply, low-cost energy and increased opportunities for recreation and it will have a generally positive effect on the atmospheric ecosystem. On the other hand, environmental parameters can be affected substantially, its length has adversely affected the opinions of some decision-makers. To weigh the positive effects against the negative ones can be a lengthy and complex task. Hydropower regional coverage depcited in Figure 4.3- 4.4. As discussed in related lieratures, it's impossible to make a generalized statement about the environmental friendliness of hydropower, as each project is site specific, some of them are environmentally highly advantageous, others less so (Gary W.F. and Deborah M.L. 2002).

Figure 2.3 & 2.4

Share of different sustaianable energy electricity net generation in regions





Source：U.S. EIA RENEWABLE Statistics 2012

Obviously, hydropower develops with great divergence in Central Europe and East Asia regions, with 16.63% and 42.90% share to total sustainable energy net generating electricity volume(rewable energy plus nuclear power), respectively.

Hydropower has long been a much debated topic in Central Europe, plans to construct such facilities on a larger scale have been opposed by the incumbent coalition in some countries in the past, e.g Hunagry. While governments of East Asia seems like more willing to consider high capacity hydropower a real option compared to other sources of energy, particular in costs consideration, e.g. China has the 91.23% share of hydroelectricity to total SE electricity generation. (Table 5.8) It claims that whether its topographic conditions of each country allow for favourable and economic utilization of hydropower is one of the primitive factors for decision markers to choose energy policy.

Country-level divergence analysis

In this paper, all the sampling countries are recognize hydropower as susatinable enenrgy. A summary of thermal equivalent to hydropower is as follow, detailed country profile in hydro power in Appendix 8.

Table 2.4

Thermal equivalents to hydorpower geneartion

Regional countries	Avg. Hydroelectricity Net Production (Billion KWh)	Avg. change 2014 over 2004	Hydroelectricity Consumption (Million tonnes oil equivalent)	Avg. Hydroelectricity Net Generation of Total RE (%)
Germany	19.90	1.29%	4.6	18.69%
Switzerland	34.16	53.37%	7.9	90.77%
Czech Republic	2.27	1.21%	0.5	41.95%
Poland	2.27	-0.48%	0.5	22.63%
Hungary	0.17	0.09%	0.0	7.23%
Austria	38.94	77.31%	8.5	84.92%
Slovak Republic	4.35	0.03%	1.0	85.98%
Slovenia	4.03	-2.00%	0.0	96.69%
China	633.85	5626.01%	148.1	91.23%
Chinese Taiwan	4.76	27.04%	0.9	54.47%
Japan	79.54	-204.34%	18.9	68.77%
South Korea	3.73	-3.98%	0.8	65.16%
CE avg.	13.26	16.35%	2.89	6.43%
EA avg.	180.47	1361.18%	42.20	87.52%

Even located in closer geographic sites, other cogitations still affect choice for SE application. An example of the trade-off associated with hydropower can be seen in the development of Hungary, Germany and Switzerland. Although those countries are have similar geography basic while have totally different hydroelectricity developemnt scenarios, with average hydroelectricity net generation share to total renewable energy 7.23%, 18.69% and 90.77%. According to the findings of the related EU studies and conferences, some factors are contributes to the divergences:

a) Geographic nature environment

Firstly, Switzerland has 6% of all freshwater reserves in Europe, and it also has considerable reserves of groundwater and a large number of lakes, large and small, can be found in most areas. Exceptional geographic conditions enable hydropower the backbone of Swiss electricity supplies.

In Germany and Hungary, share of electricity from hydro power is generated intermittently, although Germany has much higher hydroelectricity generation than Hungary. Hungary is one of the less mountainous countries in Eastern Europe. Therefore it has limited hydropower potential and since the 1970s there have been only a few small hydropower developments. Besiedes, Hungary's hydro resource potential is located on the Danube basin (66%), the Tisza (10%) and other rivers (24%). It is estimated that only 5%-6% of the potential hydro energy can be developed. New hydropower projects consist primarily of small plants, with the possibility of re-using water from existing hydropower plants, Geographic environment considered as the most important limitation for hydro power development in Hungary.

b) Technology

The hydro technology situation in Hungary, which puts the squeeze on hydroelectricity generation and consumption is socially questionable, but it is justified due to the threat of job losses. A lose-lose rather than win-win situation.

On the contrary, hydroelectricity in Switzerland is more commercially developed, with average annual change rate 53.37% through 2004 to 2014. Most of the energy produced within Switzerland is renewable from Hydropower and biomass, with its advanced technology and hydro power in Switzerland is subsidised and accorded privileges. Similarly, Germany mstered hydro technology for longer time thus hydro energy structure only changed a little (1.29%) while with lower hydroelectricity net production (19.9 billion KWh, avg.) and consumption (4.6 million tonnes oil equivalent) volume than Switzerland (34.16 billion KWh, 7.9 million tonnes oil equivalent), so mature sondition that while narrowing the grow space on hydropower section in Germany.

c) Government policy

In spite of share of hydroelectrocity in Switzerland is now around 56% and remains Switzerland's most important domestic source of renewable energy, hydro energy was meaning to be taken down in 2013 with new energy laws to be put in place but they were scrapped for a more eco-friendly plan.

In Germany, Energiewende ("energy transition") designates a significant change in energy policy in 2010. After Fukushima nuclear accident, legislative support was passed in 2011 to phase-out nuclear energy in Germany which benefit other sustainable energies' expansion. The policy has been embraced by the German government and has resulted in a huge expansion of sustainable energies, particularly wind power and hydro power.

As mentioned before, energy decision makers of Hungary claims that the topographic conditions of Hungary do not allow for favourable and economic utilization of hydropower thus .

d) Costs and tariffs

Hydro energy sector in German was aided especially by the Renewable Energy Sources

Act that promotes renewable energy mainly by stipulating feed-in tariffs and recently also market premiums that grid operators must pay for hydro power fed into the power grid. People who produce hydro energy can sell their 'product' at fixed prices for a period of 20 or 15 years. This has created a surge in the production of hydroelectricity. In the same way, almost half of Swiss hydroelectricity production costs consists of taxes and fees levied by the state: water rates, licences, compensation for reversion of property, special measures, so some predict a hydropower transformation in both Germany and Switzerland (Hans E. S., 2014).

Overall, for the periods 2004-2014, EA market had hydropower resources capacity expanded more largely than CE, with an average hydroelectricity net production of 180.47 billion KWh across 7,000 hydropower stations. The leading generating and consuming countries were China; with 633.85 billion KWh generation and 5626.01 per cent change during 11 years, 148.1 million tonnes (oil equivalent) consumption which is 7 times than the sum of other 3 EA countries. While Japan and South Korea witnessed a decrease in hydroelectricity generating, especially in Japan (decrease at 204.34% in average); although it is worth noticing that all EA countries have significant hydropower generation share of total sustainable energy (including nuclear energy) at average 87.52% particularly compare to their numbers and later begin of hydroelectricity technology; contrarily, only 6.43% in average for CE countries, leading by Switzerland, Austria, Slovak Republic and Slovenia.

2.3 Solar energy

Compared to some sustainable energy technologies, solar power has probably the greatest potential of any single renewable energy area, but has been delayed in market development since the 1980s because of market resistance to large plant sizes and poor political and financial support from incentive programmes. However, at this time there is rapid development occurring both in the basic technology and the market strategy, and prospects for rapid growth appear in Asia now to be very bright for newer approaches.

Outlook of solar power

On the one side, a record amount of solar power was added to the world's grids in 2014, around 40 GW of solar power was installed alone in 2014, pushing its contributions to meet world electricity demand, prompting solar energy associations to claim that a tipping point has been reached that will allow rapid acceleration of the PV and thermal technology. Besides, for the first time ever in Europe, other sustainable energy produced more power than nuclear – and solar power was key in achieving this remarkable achievement.

The PV industry, even though with many years of experience, is still in its juvenile phase. Despite the huge market growth in recent years needs to be followed by a phase of consolidation, and the impressive growth in production than previous years, solar energy isn't taken up impressive figure neither in the share to total energy production nor to total sustainable energy (0.3%) (Figure 4.5), most possibly due to:

a) Industry structure reform

As PV moves into mainstream energy markets, standards, laws and regulatory arrangements made when fossil fuels dominated energy supply may no longer be suitable.

b) High costs & tariffs for introducing

For instance, the European pace of solar development in 2014 slowed to its lowest since 2009, as incentives known as feed-in tariffs were removed across Europe in 2014. Even Germany, the continent's largest solar market, saw a slight decline in annual installed capacity to 1.9GW, as incentives were cut and market uncertainties increased. On the contrary, for countries in East Asia, particularly China has been showing strong potential in solar energy development.

c) Requirements for advanced technology

Noticing in Appendix 9, solar power in Poland, Hungary, Slovakia and Slovenia is near critical threshold before 2009, one key reasons is the non-widespread situation for solar technology and leads to expensive costs to generate.

Solar power technology majorly includes: grid stability, distribution networks, market structures will need to be developed which accommodate on-site generation, two-way electricity flows, and associated energy efficiency and demand management opportunities[13].

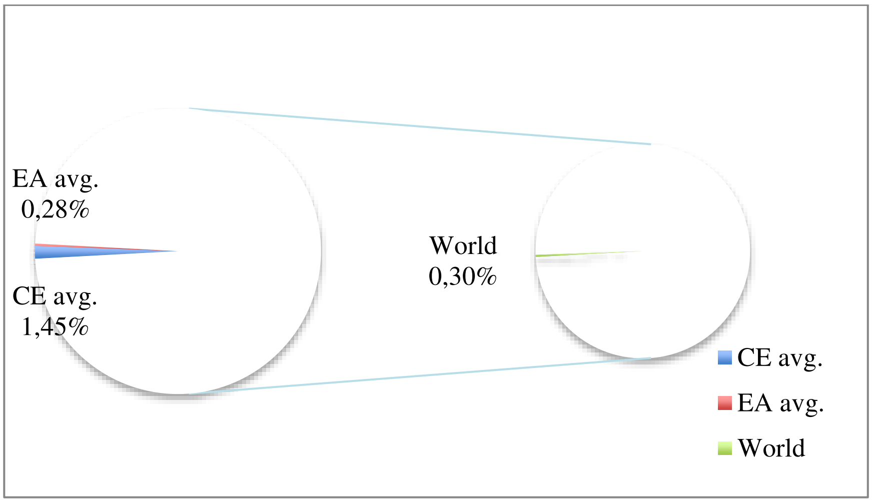
d) Availability of sunlight during daytime only.

Figure 2.5

Share of electricity net generation from solar energy[14] (billion KWh)

[13] IEA PVPS annual report (2015)

[14] Results come from simple moving average (SMA) calculation with data from 2004-2014 for each country.



Source：U.S. EIA Rewewable Statistics 2012

Table 2.5

Total solar power electricity net generation (billion KWh)

	2004	2007	2010	2011	2012	Avg.	% of Total SE
CE avg.	0.07	0.39	1.57	2.82	3.72	1.16	1.454%
EA avg.	0.32	0.55	1.38	2.18	3.61	1.17	0.278%
World	3.297	7.452	31.674	61.031	96.352	26.846	0.299%

Source：U.S. EIA RENEWABLE Renewable Statistics 2012

The solar power generation market in East Asia is poised for expansion on the back of favorable policy environments and falling costs of solar components, thus catching up with European countries despite of the exist gap (EA: 0.278%, CE: 1.454% of solar energy total sustainable energy). As of mid-2012, all four EA countries, either already had operational solar policies or was expected to announce them soon. All of these countries receive sufficiently projects. Even countries with land constrains, such as Japan, South Korea and Taiwan, have, nonetheless, decided to promote solar power, a decision made from the typical view points of energy independence and climate change concerns.

On the other side, the shift from Europe to Asia (EA accounts for more than 80% markets share) has to do with how EA incentivizes solar power compared to its competitors, along with the sheer size of the solar panel manufacturing industry in this area, which dominates the market for solar PV construction.

Germany used to be the undisputed solar champion. And while the country is still a leader in solar power generation, it is being surpassed by China and to a lesser extent, Japan, which embraced solar-powered electricity after the Fukushima nuclear power plant

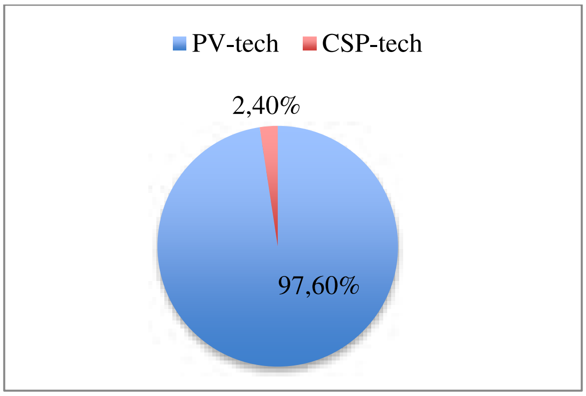
meltdown in 2011. That event forced Japan to change its energy policy to shut down all of its nuclear reactors, and look to other sources to meet its electricity needs.
In addition, solar power consists of solar photovoltaic, solar thermal and heating which enable plenty of non-power plant applications, for instance, solar desalinization, solar green-architecture and agriculture & horticulture.

Solar photovoltaic (PV) & solar thermal

Solar PV energy conversion directly converts the sun's light into electricity. This means that solar panels are only effective during daytime because storing electricity is not a particularly efficient process, but accounts for major share of worldwide capacity of solar power technology, total of 142 GW in 2013. (Figure 2.6)

Figure 2.6

Worldwide capacity of solar power by technology, 2013



Source: PV-Solar Power Europe Associate (EPIA); CSP-REN21 2014: Global Status

Firstly, according to a report by Hanergy Holding Group[15] in 2014, Asia, especially East Asia market had installed increasing amount of new solar PV generation capacity through 2004 to 2013; there is a massive 232% increase in China over the previous year, in 2013 accounted for the largest proportion of global solar industry financing ($23.5 billion), equivalent to the entire amount raised in Europe.
Same trend can be witnessed in Appendix 9. Compare that to East Europe, taking Germany for example, whose new PV capacity dropped 56.5%, and Italy, where new solar power additions fell by 55%. The report also notes that China
Secondly, consumption of solar PV power has biggest potential and incentive of technology, consumption growth in the near future.
Solar thermal technology is quite different from solar PV, which generating electricity by

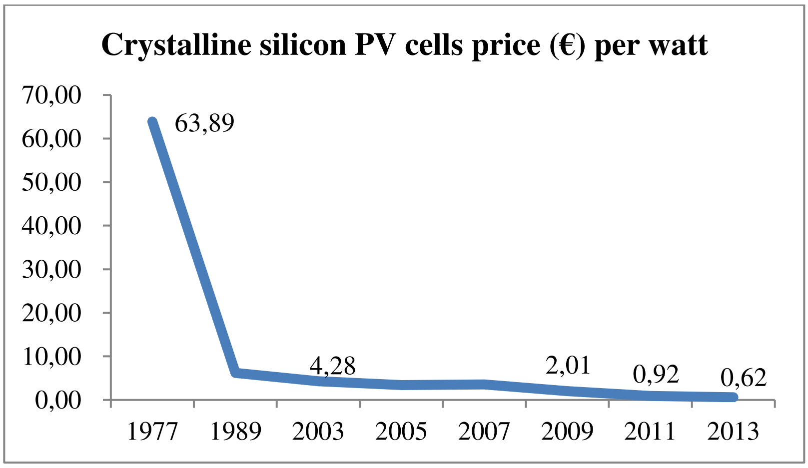
[15] Outlook for Photovoltaic 2014-2018". www.epia.org, EPIA 2014.

concentrating the light from the sun to create heat, and that heat is used to run a heat engine, which turns a generator to make electricity. Heat storage is a far easier and efficient method, which is what makes solar thermal so attractive for large-scale energy production. Heat can be stored during the day and then converted into electricity at night. Solar thermal plants that have storage capacities can drastically improve both the economics and the dispatch ability of solar electricity.
As for solar thermal energy, it uses the sun's energy to generate low-cost, environmentally friendly thermal energy, which can be stored so that can be widely applied in commercial sectors. Solar thermal energy showing trend of increasing its widespread both in CE and EA countries thanks to the heating and cooling system can benefits rural and developing places. For example, in some smaller towns and villages in East Asia, with a large rooftop area per capita, are likely to continue to be the primary market, although multi-family apartment buildings can effectively use solar hot water if not too tall, which solar PV introduction and consumption might be limited by technologies in those areas.

To sum up, solar energy bloom in deployment within a suite of CE and EA policymakers' supportive strategic policy and tariff structures, and other complementary policies that aligns most appropriately with unique national circumstances and goals. Drawing from regional experience and lessons in EA market, it is found that solar-specific good practices for renewable electricity standards (RES), feed-in tariffs (FIT), and collaborations projects to scale-cost effectiveness, financial incentives, and further approaches to enable price reduction.

Figure 2.7

Price change of crystalline silicon photovoltaic cells



Source: Bloomberg, New Energy Finance
Note: Converted from 1€=1.2$

However, undercutting the competition is not the only reason that has the edge when it comes to solar PV power growth. For example, while Germany and the rest of Europe have scaled back government incentives to install solar, in China, increasing targets for solar power generation have been backed by programs to boost market demand. A feed-in tariff passed in 2013 amounts to a subsidy for PV generation per KWh, and applies to both ground-mounted and rooftop panels. Feed-in tariffs incent SE producers by allowing them to charge higher price for electricity than the retail rate. China's solar competitors have also implemented government incentives, but not as effectively. Following Fukushima, Japan rolled out a feed-in tariff, which is twice that of Germany and France, with the goal of producing up to 17 GW of solar capacity. But over the past two years, the ministry cut the tariffs by a fifth and imposed time limits on installations, leaving only 13% of approved projects actually installed and operating, as Reuters reported.

Advantages and risks of solar energy

Solar energy is obviously environmentally advantageous relative to any other energy source, and the linchpin of any serious sustainable development program. It does not deplete natural resources, does not cause gaseous emission into air or generates liquid or solid waste products. Concerning sustainable development, the main direct or indirectly derived advantages of solar energy are the following: (i) No emissions of greenhouse or toxic (SO_2, particulates); (ii) Reduction of transmission lines from electricity grids, accelerating the grid integration; (iii) Diversification and security of energy supply, increasing regional/national energy independence; (iv) Acceleration of rural electrification in developing countries

Despite significant growth of solar markets in many countries, barriers to solar deployment still exist. Common critical barriers include: (i) Lack of consistent policy signals, which can create uncertainty in markets; (ii) Restrictive and time-consuming regulatory and permitting processes; (iii) Concerns of utilities and integration of power in the grid; (iv) Higher cost of solar technologies (real or perceived), especially compared to fossil fuel subsidies; (v) Lack of affordable financing; (vi) Need for skilled labor to support solar technology deployment, including system design, installation, and ongoing operation and maintenance.

2.4 Bioenergy sources

The reason why bioenergy sources (includes solid biomass, liquid biofuels and biogas in this paper) currently attracts attention is its renewability, potential for decentralized production and more importantly its carbon neutrality and hence its role in climate changes mitigation. Furthermore, it can be transformed into electricity, heat and power and used in forms, which are more convenient.

There is a continuously increasing interest concerning the bioenergy sources implementation in Central Europe[16] and East Asia, mainly because of environmental protection and energy supply security reasons, which can benefits transportation, commercial and households sectors.

Biomass & biofuels

Various studies expressed the opinions about implementation of bioenergy sources in Central Europe and East Asia is an interesting issue, since these countries have both a significant potential in biomass and biofuels, either in the raw materials or in the biofuels production. Solid and liquid biofuels, produced from biomass such as agricultural crops, wood and food-processing residues, being introduced into slight different sectors in Europe and Asia areas.

In most places of Central Europe, biofuels which are generated from biomass can be used as transportation fuels in a large range of vehicles and offer the potential for development towards sustainable mobility with the involvement of the agricultural, energy and automotive sectors.

When it comes to East Asia, primary solid biomass contributes the major share compared to other types of combustible renewable energy (CRE)[17] in this region, and also in the world in general, followed by biogas that contributes a small share to total production.

[16] According to the European Union (EU) policy, it strongly encourages the use of biofuels through a number of Directives. To that effect, Central Europe members follow the Directives implementing various political, fiscal and technical measures and incentives.

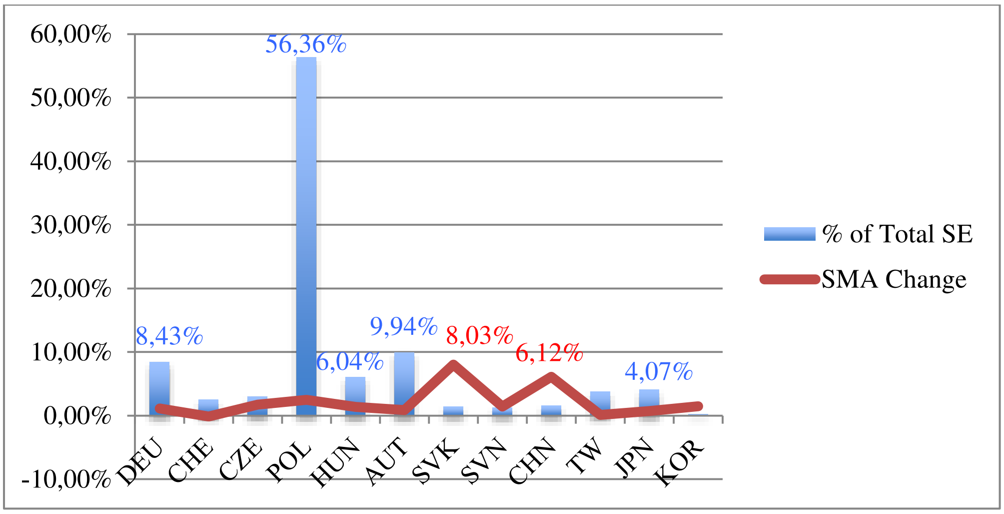
[17] CRE and waste comprise solid biomass, liquid biomass, biogas, industrial waste and municipal waste (OECD/IEA, 2007).

Bioenergy is used predominantly in East Asia where mainly are developing countries, mostly in the form of wood and agricultural residues as the most common fuel for households (cooking and heating).

Regional outlook

Figure 2.8

Share of biomass energy to total sustainable energy and its change in deployments through 2004-2012, in CE and EA countries respectively (see Appendix 10)



Source: OECD & U.S. EIA Renewable Statistics 2016; data of Taiwan are collected from BOE[18]

Amongst all of the countries in these two regions, Poland (56.36%), Austria (9.94%) and Germany (8.43%) have the highest share of bioenergy to total sustainable energy (Figure 5.8). The Polish energy policy supported co-firing of coal and biomass by which produced €1.7 billion amount between 2004 and 2012, compared with 1.5 billion for other new SE (excludes nuclear energy). Not only Poland has appetite for biomass. Throughout Austria and Germany new investments or upgrades of existing, usually coal-fired installations are underway.

Another interesting fact is, although Slovak Republic and China showed the smallest share, with less than 2 percent, (the former has limited sources, low feedstock availability for producing biofuel; while the reason for the later is that China largely rely on wind and hydro power to produce sustainable energy.) these two countries showed largest growth rate, at SMA annual growth rate 8.03% and 6.12% respectively.

To sum up, bioenergy application is lagging, constitutes only 0.63% to total global sustainable energy (Figure 4.9), mainly due to economic barriers, lack of legislative and

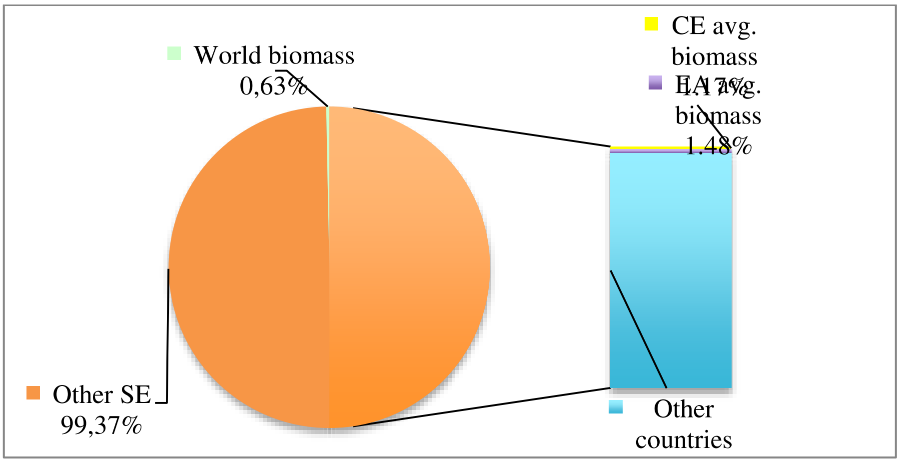
[18] Note: data were converted from 1 KWh=0.248 KLOE

regulatory framework and poor infrastructure.

Although with current small scale of bioenergy in CE (1.7%) and EA (1.48%) countries, markets are now much larger, the supply chain is more extended, the opportunities for rural development are significant and small-scale production investments are more attractive under supportive policies and incentives, thus it is fair to predict a brighter future for bioenergy (E.M. Kondilia and J.K. Kaldellis, 2007).

Figure 2.9

Share of global biomass energy to total sustainable energy and contributions of CE and EA markets through 2004-2012, respectively



Source: OECD & U.S. EIA Renewable Statistics 2016; data of Taiwan collected from BOE

Data analysis

In the general case, the value chain for bioenergy includes the following activities, with its variable name in STATA panel data analysis, based on data in 2012:

a) RAW: related to bioenergy feedstock production and land availability, thus combined with forest area and agriculture area (% of land area);

b) EFFICIENCY: Ratio of biofuels electricity net production (transformed from total production deduct wastes) to its total consumption:

$$= \frac{total\ biofuels\ electricity\ net\ generation}{total\ biofuels\ consumption}$$

c) COST: represented by bioenergy electricity distribution losses

d) LAW: law system and energy policy

e) GDP: GDP per capita in 2012

The decision on the point of entry into the biofuel value chain raises the question of whether a country is able (technically, economically, etc.) to produce and/or import feedstock and/or biofuels. This poses questions such as whether each country intends to encourage capacity building or cover the required quantities via imports.

Table 2.5

Linear regression & ordinary logistic regression on variables' impacts on bioenergy across countries, 2004-2012

Type of model	Co-variable (reference)	Coef.	Std.Err.	t (z)	P>|t| (P>|z|)	[95% Conf. Interval]	
		Comparison					
Linear regression	PRODUCTION						
	RAW	28.0793	83.2022	-0.3400	0.7460	-224.8213	168.6627
	EFFICIENCY	2.7431	12.7879	0.2100	0.8360	-27.4954	32.9816
	COST	0.0610	0.0606	1.0100	0.3480	-0.0823	0.2043
	GDP	0.0002	0.0002	1.0300	0.3370	-0.0003	0.0007
Ordinary logistic	PRODUCTION						
regression on law system	LAW	2.6980	1.2826	2.1000	0.0350	0.1843	5.2118

In parallel, the domestic production of bioenergy is promoted or impeded largely by its raw materials (Coef. 28.07931); lack of a sufficient amount of nature resource would limit sustainable energy development from the beginning, which makes geographic and environmental consideration such crucial for decision makers. Besides, efficiency of generating bioelectricity (Coef. 2.74307) and the improvement for bioenergy (Coef. 2.698047) play an important role as well.

However, following the EU regulations, a market will be formed in these countries, e.g., via obligatory minimum requirements on biofuel share.

Overall, in bioenergy deployments in Central Europe and East Asia regions, geologic and raw materials have been put into first consideration, law system and beneficial energy policy also play crucial parts, while costs during bioenergy construction process and other losses shows minor impact on its expansion, thanks to structure reform in earlier stage which reduce the fluctuations. Although with steadily growth rate in total production volume, bioenergy only accounts for minor share in sustainable energy apply when compare to other sustainable sources, e.g., wind power and hydropower.

2.5 Geothermal sources

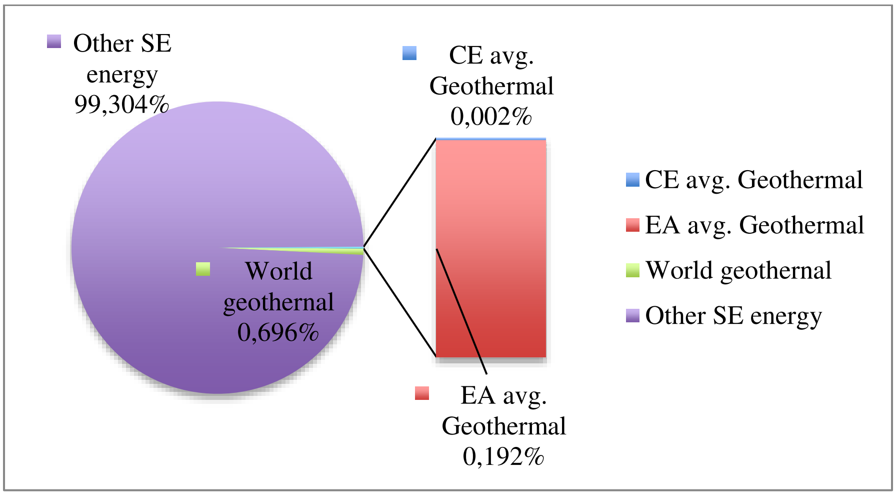
Geothermal energy is the energy contained as heat in the Earth's interior, it was not until a period after World War II, when it attracts global attention to be used as an important sustainable energy to generate electricity.

Geothermal energy, as natural steam and hot water, has been exploited for both in space heating and industrial processes, considering it to be economically competitive with other forms of energy. But because of the extremely uneven distribution of heat-flow sites, both in continents and oceans, feasibility to introduce geothermal power varies from countries. In some cases, it was the major or even only energy source that available locally.

Regional outlook

Figure 2.10

Share of geothermal energy to total sustainable energy, and the share of CE and EA markets to world level, respectively[19], 2004-2012

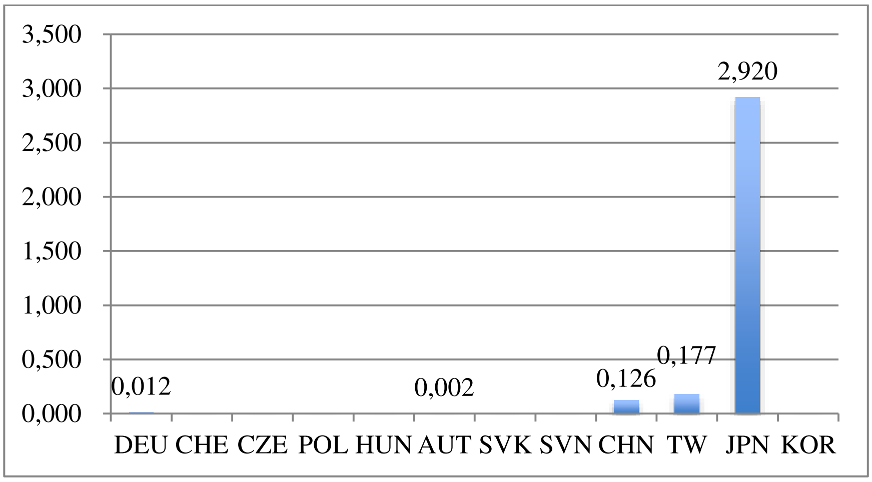


Source: OECD & U.S. EIA RENEWABLE Statistics 2016; data of Taiwan collected from BOE

Figure 2.11

Geothermal electricity net generation in CE and EA countries, 2004-2012 (Billion KWh) (see Appendix)

[19] World avg., CE avg. and EA avg. are calculated from data in 2004-2012 periods by simple moving average (SMA) method.



Source: OECD & U.S. EIA Renewable Statistics 2016; data of Taiwan collected from BOE

Fairly to say, the geothermal energy is although immense, but only a fraction has been utilized by mankind which with only 0.7 per cent of total sustainable energy worldwide (Figure 2.10). East Asia benefited more from its location atop a series of volcanic systems than Central Europe[20].

Data analysis

So far geothermal utilization of this energy has been limited to areas in which geological conditions permit a carrier. For the most part, Central Europe has only low-enthalpy geothermal resources. Hungary, however, due to its unique geological position astride the Pannonia Basin -- a "geothermal hot spot", is the exception to the rule. Only Germany, Austria and Hungary showing interactive potential in the geothermal heating (Pan-European Thermal Atlas/ Heat Roadmap Europe 2015), On the one hand, in some countries, non-electric uses of geothermal energy are far more developed, such as Hungary, Slovak Republic and Slovenia (Lund and Freeston, 2001). But the potential in those countries was also restricted by its technology status and energy policy. On the other hand, other literatures[21] show the different heating options in Europe, with current heat demand, potential for solar energy, biomass and geothermal for district heating. In conclusion, for other Central Europe countries, its geothermal electricity generation seems like to be not that appealing when compared with other sustainable energy. However, innovative techniques in the near future, may offer new perspectives in this sector.

[20] International Geothermal Association, (2014)
[21]As part of a European funded study, an online "Pan-European Thermal Atlas" (Peta): http://maps.heatroadmap.eu/maps/31157/Renewable-Resources-Map-for-EU28

In addition, the utilization of geothermal energy in East Asia has exhibited an interesting trend over the years. Japan as the No.1 leading country that installed great geothermal generating capacities, it has favorable sites for geothermal power because of its proximity to the Izu-Bonin-Mariana Arc (IBM). At the beginning of 2004, its installed capacity reached 560.9 (MWe), and generated net electricity 2.920 (billion KWh) through a period 2004-2012 (Figure 4.11). For other East Asia areas, such as China (0.126 billion KWh) and Chinese Taiwan (0.177 billion KWh) also have made achievements.

Generally, necessary geological condition decides whether production of geothermal electricity on an industrial scale; then give policy makers enough stimulation to (or not) set promoting energy policy and tariff structure; expert knowledge, technologic equipment and experience is another reason. Despite all these drawbacks, it is a fact that the geothermal power is generally cost-competitive with other conventional sources, if can be produced by means of well-proven conventional technology (E. Barbier 2002).

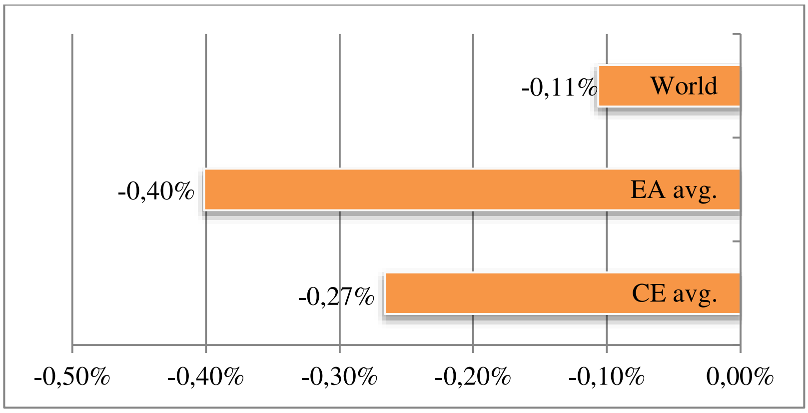
2.6 Introduction and phase-out of nuclear energy

Outlook of nuclear energy

Nuclear power is not regard as renewable sources of energy since it is responsible for polluting the environment, but the energy chain release vast amounts of energy from a very small fuel quantity of nuclear reactions and therefore this source can be regarded as sustainable. A controlled use of nuclear electricity generation process would provide society with a cheap and sustainable source.

Figure 2.12

Scenario of nuclear energy structure change in nuclear electricity net generation (billion KWh) in CE, EA areas and world level, 2004-2012



Source: OECD & U.S. EIA Renewable Statistics 2016

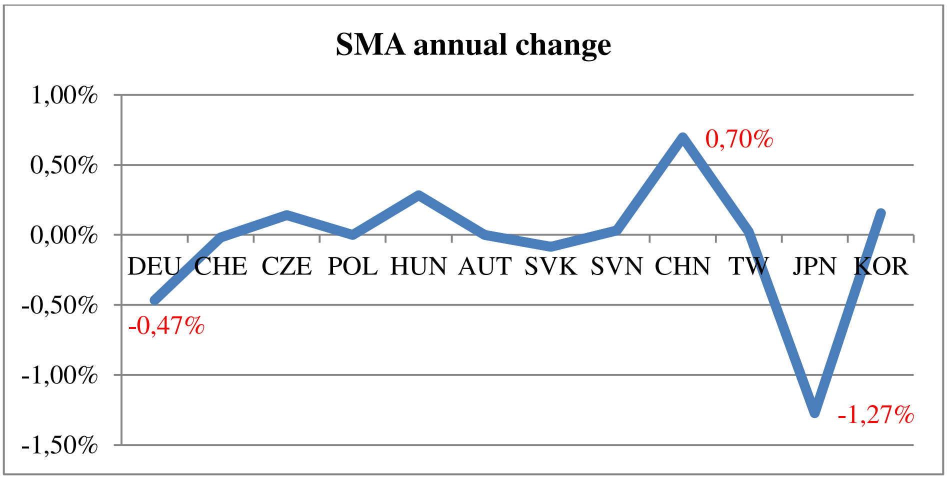
However, nuclear power generation process releases radioactive wastes that may cause irreversible damage to all living organisms. In 2004 nuclear power provided 10% of the world's electricity while witnessed its greatest worldwide decline in 2011 due to Fukushima nuclear disaster in Japan, which prompted a re-examination of nuclear safety and nuclear energy policy in many countries (Sylvia W., 2011). Germany plans to close all its reactors by 2022; Italy has re-affirmed its ban on electric utilities generating, but not importing, fission derived electricity.

Overall, data from the OECD and U.S. EIA shows nuclear power falls short on the worldwide sustainable electricity criteria dropped at 0.11 per cent and same trends showed up in Central Europe and East Asia countries through the period, but generally since 2011. Another database from International Atomic Energy Agency found that nuclear power plants globally produced 2346 TWh of electricity in 2012, which is 7% less than in 2011. Nuclear power has even lower public acceptance and more uneven deployments across areas in recent years, indicates it is to great extent affected by energy policy factors.

Different policies across countries

Figure 2.12

Change of the share of nuclear electricity net generation (billion KWh) to total sustainable energy) to each countries in CE and EA areas, 2004-2012

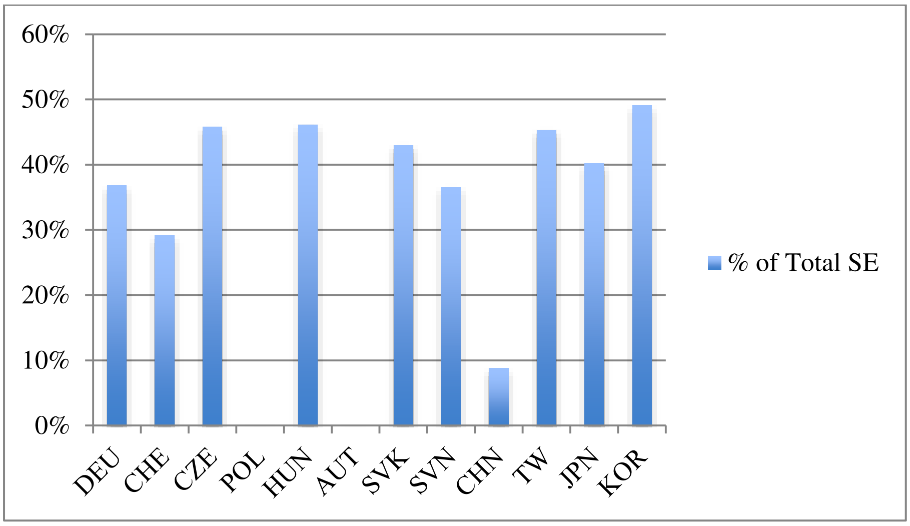


Source: OECD & U.S. EIA Renewable Statistics 2016

In 2011 worldwide nuclear output decreased by 4.3%, the largest decline on record, on the back of sharp declines in Japan (-44.3%) and Germany (-23.2%) in particular, its electricity net generation share of total sustainable energy was dropped largely through the period, at 0.47% and 1.27% respectively; China on the contrary enables more share for nuclear electricity to its total sustainable energy electricity generation at the same time, grows at average annual rate 0.7%.

Figure 2.13

Structure of nuclear electricity generation deployments in CE and EA, 2004-2012

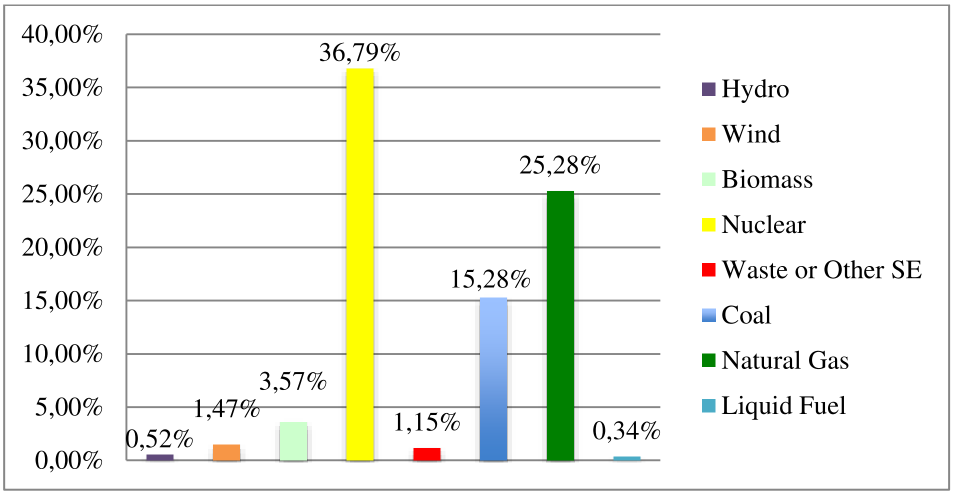


Source: OECD & U.S. EIA Renewable Statistics 2016; data of Taiwan collected from BOE

In Poland, there isn't electricity generated by nuclear power according to U.S. EIA statistics (Appendix 12), due to cancellation of nuclear project by Zarnowiec Nuclear Power Plant, the public carried a referendum had an exit poll of strong "no" towards nuclear plants when Chernobyl disaster was up-to-date event. Similar situation presented in Austria, the Austrian Parliament passed legislation to remain an anti-nuclear country. In other EA areas, nuclear energy remains a strategic priority for South Korea, in which is a major world nuclear energy country, with 49.07 per cent nuclear electricity net generation to total sustainable energy; the figure in Taiwan is nearly 45 per cent, although anti-nuclear movements are rising after Fukushima accident since 2011.
As for Europe, Hungary and Czech Republic experienced slight increase of nuclear electricity, and remains high share to total sustainable energy; in Hungary, still 36.79% electricity generated from nuclear power in 2012 (Figure 4.14). However, Switzerland instead remains low but stable nuclear electricity share in same period.

Figure 2.14

Scenario of electricity generation distributions in Hungary, 2012



Source: Hungarian Energy Office 2012

Sustainable criteria analysis

Examine what decides nuclear power deployments based on its performance on the five sustainability criteria (Aviel V., 2008):

Table 2.6

Evaluation of renewable electricity sources on the criteria of sustainable backstop supply technology

Criteria	Sustainable electricity sources performance
Unlimited	Geographic factors barely affect raw materials and its burning fuels are abundant on earth; Nuclear power recognized as unlimited source of energy considering both fusion and fission reactions could be self-sustaining in power plants after "ignition"; But only when this will be technically and safely used.
Democratic Decided	Nuclear technology and the nuclear fuel cycle require secrecy and protection against intruders. Nuclear material can be abused for state or private terrorism (Cornelis and Eggermont, 2006); Several markets in CE and EA gradually phase-out nuclear energy by public roll, e.g., Germany, Austria, in which public acceptance for nuclear power is low, e.g., Taiwan and Japan.

Globally Accessible	Nuclear power requires huge capital and technology intensity that makes this option inaccessible for many developing economies, e.g. Hungary, Slovak Republic and Slovenia; In addition, proliferation of know-how and nuclear capabilities creates a more dangerous world than the containment and reduction of its spreading, and finally the banning of the nuclear technology in all uses but the medical ones (Aviel V., 2008).
Environmental Consideration	Carbon-free process of generating; Inert gases emissions from Nuclear fission but not as massive and diverse compared to fossil fuel combustion; Release of radioactive especially from nuclear fusion isotopes is the most significant contamination; massive releases happen if any disaster or accidents.
Low Risk	Polar opinions about nuclear power risk: some consider it as minor given the probability of accidents (see nuclear development in South Korea, which is one of the major nuclear markets), some define it as huge since eternal lifetime of radioactive waste influence towards all living organisms; Risk perception and assessment are circumstantial and personal matters that are difficult to define, measure and compare (Shrader F., 1991); Considering the social risks and public acceptance in CE and Asia markets, the nuclear risks have to aware and it should be accepted by the lay people of present and future generations.
Affordable	Large amounts of nuclear power can be generated at affordable monetary spending (see China over the last decades); But ‘‘safe’’ nuclear power is too costly to establish and operate. Huge costs of possible accidents and of the eternal concern for the high-level waste are neglected somehow, some experts argue people overestimated the real price of nuclear power (Taiwan, Austria and Switzerland); Nuclear power can be used as a validation because the low costs, However, there are extra arguments to adopt or phase-out nuclear power in CE and EA markets, attitude and policy extremely varies from markets.

Proponents and opponents, the two antagonists however are mutually exclusive on the five major directions of future nuclear power systems, indicates there is not a “common nuclear future” among areas in Central Europe and Asia, but collaborations opportunity still exist in some countries who sharing similar policy and energy goal, e.g., Czech

Republic and Hungary can corporate together and creates scale benefits and safer method.

3 Conclusions

This paper provided a comprehensive overview of sustainable energy deployments scenarios in country level and region level in Central Europe and East Asia territories. We show that current energy resources and structure differ between countries in these two regions.

CE markets have lower social acceptance to nuclear energy while EA markets such as China and South Korea have been leading economies in nuclear energy utilizations. Solar energy generation will be deployed rapidly and massively both in CE and EA area, differently for wind and geothermal, because they will be limited to regions where wind or geothermal is economically available, and will be limited by the materials quantity, extent and quality of the electricity distribution grid, or utilization degree of geothermal technology.

Generally we found out that development of sustainable energy, and of CE and EA energy systems for that matter are determined by the following major factors: Costs of energy resources; Materials and necessary factors; Financial investments; Public will and legal system; Technology accessibility and Local impacts.

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List of Appendices

Appendices

Appendix 1: Electricity Consumption per Capita (MWh/capita)

Country	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	% Change 2004-2013
GM	7.11	7.14	7.21	7.23	7.19	6.82	7.27	7.15	7.14	7.02	(0.01)
SW	8.13	8.23	8.28	8.09	8.24	7.96	8.12	7.93	7.89	7.81	(0.03)
CR	6.22	6.34	6.51	6.50	6.46	6.11	6.32	6.30	6.31	6.29	0.01
PL	3.42	3.44	3.59	3.66	3.73	3.59	3.75	3.83	3.85	3.89	0.05
HU	3.68	3.77	3.88	3.98	3.99	3.77	3.88	3.90	3.92	3.89	0.02
AU	7.81	7.98	8.22	8.19	8.21	7.95	8.38	8.43	8.55	8.52	0.07
SR	5.09	4.92	5.14	5.25	5.27	4.93	5.16	5.35	5.14	5.20	0.01
SV	6.83	6.92	7.12	7.13	6.92	6.10	6.52	6.81	6.78	6.83	0.00
CH	1.58	1.79	2.04	2.33	2.47	2.64	2.94	3.31	3.48	3.77	0.22
TW	9.23	9.59	9.88	10.17	9.97	9.53	10.25	10.41	10.34	10.46	0.12
JP	8.05	8.21	8.25	8.48	8.05	7.81	8.34	7.84	7.75	7.84	(0.02)
SK	7.40	7.80	8.05	8.48	8.79	8.90	9.74	10.16	10.35	10.43	0.30
CE avg.	6.04	6.09	6.24	6.25	6.25	5.90	6.18	6.21	6.20	6.18	0.01
EA avg.	6.57	6.85	7.06	7.37	7.32	7.22	7.82	7.93	7.98	8.13	0.16

Appendix 2: Share of SE in Total Energy Production (%)

Country	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Avg.	% Change
GM	11	12	14	17	17	19	22	24	26	28	19	1.7
SW	35	38	34	36	37	37	39	37	41	41	37.5	0.6
CR	5	6	6	7	7	8	9	9	10	12	7.9	0.7
PL	6	6	6	7	8	9	10	11	12	12	8.7	0.6
HU	9	11	12	13	15	17	17	17	19	20	15	1.1
AU	67	72	70	72	74	72	74	73	75	78	72.7	1.1

SR	12	13	13	16	16	21	23	22	22	22	18	1
SV	24	22	22	21	23	27	27	25	28	30	24.9	0.6
CH	15	14	14	13	14	13	13	15	15	16	14.2	0.1
TW	8	9	9	10	10	9	10	12	13	13	10.3	0.5
JP	18	16	17	18	18	17	19	38	66	72	29.9	5.4
SK	2	2	3	3	3	3	4	4	5	6	3.5	0.4
CE avg.	21.13	22.50	22.13	23.63	24.63	26.25	27.63	27.25	29.13	30.38	25.4625	0.925
EA avg.	10.75	10.25	10.75	11.00	11.25	10.50	11.50	17.25	24.75	26.75	14.475	1.6

Appendix 3: Renewable electricity output (% of total electricity output)

Country	2004	2005	2006	2007	2008	2009	2010	2011	2012
GM	9.17	10.06	11.24	13.85	14.63	16.02	16.66	20.33	22.93
SW	29.20	30.09	51.73	54.90	55.68	55.54	56.71	54.07	59.48
CR	3.27	3.82	4.21	3.89	4.49	5.70	6.92	8.34	9.29
PL	2.02	2.48	2.67	3.42	4.27	5.74	6.93	8.05	10.44
HU	2.78	5.23	4.16	4.71	5.89	8.06	8.08	7.53	7.65
AU	64.20	63.39	66.00	69.22	69.25	71.15	66.22	65.65	74.54
SR	13.55	14.91	15.37	17.69	15.87	18.95	21.63	17.67	19.32
SV	27.60	23.65	24.50	22.46	26.27	29.91	29.19	24.37	27.81
CH	14.75	14.84	14.43	14.25	16.56	16.73	17.62	16.02	19.13
TW	1.77	2.18	2.21	2.39	2.44	2.36	2.51	2.60	3.44
JP	10.75	9.33	10.36	8.99	9.60	9.96	11.24	12.26	12.00
SK	1.26	1.04	1.00	1.07	0.99	1.04	1.25	1.44	1.34
CE avg.	18.97	19.20	22.49	23.77	24.54	26.38	26.54	25.75	28.93
EA avg.	7.13	6.85	7.00	6.68	7.40	7.52	8.16	8.08	8.98

Appendix 4: Global wind production capacities (oil equivalent)

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Avg.	% Change 2004-2013
GM	16,629	18,428	20,621	22,247	23,903	25,777	27,190	29,060	31,308	34,660	24982.3	7.67%
SW	9	12	12	12	14	18	42	46	50	60	27.5	25.01%
CR	17	29	57	116	150	192	215	217	260	269	152.2	36.41%
PL	58	73	153	276	472	725	1,180	1,616	2,497	3,390	1044	53.04%
HU	3	17	61	65	127	201	295	329	329	329	175.6	94.40%
AU	606	819	965	982	995	995	1,014	1,084	1,378	1,684	1052.2	11.42%
SR	5	5	5	5	5	3	3	3	3	3	4	-4.00%
SV	0	0	0	0	0	0	0	0	0	2	0.2	20.00%
CH	764	1,266	2,599	5,912	12,210	25,104	41,800	62,364	75,324	91,324	31866.7	66.83%
TW	13	104	187	280	358	436	519	564	564	614	363.9	91.58%
JP	896	1,040	1,309	1,528	1,880	2,056	1,304	2,501	2,614	2,661	1778.9	15.26%
SK	23	119	176	192	278	348	379	406	483	561	296.5	59.55%
WLD	47,662	59,063	74,175	93,869	121,247	157,910	194,558	237,023	282,678	318,732	158691.7	21.25%
CE.	2165.875	2422.875	2734.25	2962.875	3208.25	3488.875	3742.375	4044.375	4478.125	5049.625	3429.75	30.49%
EA.	424	632.25	1067.75	1978	3681.5	6986	11000.5	16458.75	19746.25	23790	8576.5	58.30%

Appendix 5: Analysis of related variables to wind power deployments in China

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Added EIC (GM)	0.1969	0.5069	1.2876	3.3113	6.1537	13.8032	18.928	17.6309	12.96	16.089	23.196
Cumulative EIC (GM)	7.43	1.25	2.537	5.848	12.002	25.805	44.734	62.364	75.324	91.413	114.61
LAW	0	0	1	1	1	1	1	1	2	2	2
INVEST (covering grid-connected wind capacity, GW)	0	1	1	1	1	1	1	2	2	2	2
Number of patent applications in SE	4	11	10	35	50	90	75	245	290	244	180
Number of patent applications of wind power company	2	3	3	8	13	12	16	38	24	26	23
INV (Portion of wind to total SE patent applications)	50.00%	27.27%	30.00%	22.86%	26.00%	13.33%	21.33%	15.51%	8.28%	10.66%	12.78%
Population of China (million)	1299.88	1307.56	1314.48	1321.29	1328.02	1334.5	1340.91	1347.35	1354.04	1360.72	1367.82
SIZE	255.95	662.80	1692.52	4375.19	8172.24	18420.37	25380.74	23754.99	17548.36	21892.62	31727.95
EFFICIENCY	2063.88	2573.56	3913.48	7233.29	13538.02	26438.5	43140.91	63711.35	76678.04	92684.72	101512.82

Sources:

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2. Population resource: www.statistista.com, 2014

3. Wind generating electricity consumption: U.S. Energy Information Administration (EIA), 2014

Appendix 6: COST & tariff of wind energy company in China

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Tariff rate (average nationwide rate) (€/KWh)	0	0	0	0	0	0.057	0.057	0.057	0.057	0.057	0.057
Costs of electricity generation by wind power (€/KWh)	0.04 - 0.07	0.04 - 0.07	0.04 - 0.07	0.04 - 0.07	0.04 - 0.07	0.04 - 0.07	0.03 - 0.05	0.03 - 0.05	0.03 - 0.05	0.03 - 0.05	0.03 - 0.05
Avg. costs	0.055	0.055	0.055	0.055	0.055	0.055	0.04	0.04	0.04	0.04	0.04
VAT	17%	17%	17%	17%	17%	17%	8.50%	8.50%	8.50%	8.50%	8.50%
Corporate income tax	33%	33%	33%	33%	33%	33%	15%	15%	15%	15%	15%
COST	0.01815	0.01815	0.01815	0.01815	0.01815	0.02784	0.010845	0.010845	0.010845	0.010845	0.010845

Appendix 7: Wind power electricity consumption (million oil equivalent)

	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**Avg.**	% of Total SE
GM	25.509	27.229	30.71	39.713	40.574	38.639	37.793	46.5	50.67	37.482	10.31%
SW	0.006	0.008	0.015	0.016	0.019	0.023	0.037	0.037	0.088	0.028	0.03%
CR	0.01	0.021	0.049	0.125	0.245	0.288	0.335	0.397	0.416	0.210	0.38%
PL	0.142	0.135	0.256	0.522	0.837	1.077	1.664	2.69	4.747	1.341	16.28%
HU	0.006	0.01	0.043	0.11	0.205	0.331	0.534	0.626	0.77	0.293	0.99%
AU	0.934	1.331	1.752	2.037	2.011	1.968	2.064	2.086	2.463	1.850	4.21%
SR	0.006	0.006	0.006	0.008	0.007	0.006	0.006	0.004	0.006	0.006	0.02%
SV	0	0	0	0	0	0	0	0	0	0.000	0.00%
CH	1.332	2.028	3.868	5.71	14.8	26.9	44.622	73.2	95.978	29.826	4.03%

TW	0.025	0.091	0.277	0.444	0.589	0.787	0.976	1.7	1.7	0.732	0.85%
JP	1.31	1.754	2.21	2.624	2.946	3.616	3.962	4.345	4.838	3.067	0.54%
SK	0.047	0.13	0.239	0.376	0.436	0.685	0.817	0.858	0.917	0.501	0.18%
CE	3.33	3.59	4.10	5.32	5.49	5.29	5.30	6.54	7.40	5.151	6.459%
EA	0.68	1.00	1.65	2.29	4.69	8.00	12.59	20.03	25.86	8.532	2.028%
WLD	84.136	104.021	131.830	170.563	220.298	276.045	341.582	446.427	520.001	254.989	2.844%

Appendix 8: Hydroelectricity consumption (Billion KWh)

	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**Avg.**	**%Change 2014- 2004**
GM	4.5	4.4	4.5	4.8	4.6	4.3	4.8	4.0	5.0	5.2	4.6	4.6	0.91%
SW	7.6	7.1	7.0	8.0	8.2	8.1	8.2	7.2	8.6	8.6	8.5	7.9	8.18%
PL	0.5	0.5	0.5	0.5	0.5	0.5	0.7	0.5	0.5	0.6	0.5	0.5	0.00%
CR	0.5	0.5	0.6	0.5	0.5	0.6	0.6	0.4	0.5	0.7	0.4	0.5	-0.91%
HU	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.1	0.0	0.64%
AU	8.3	8.3	8.1	8.4	8.7	9.2	8.7	7.7	9.9	8.4	8.1	8.5	-1.82%
SR	0.9	1.0	1.0	1.0	0.9	1.0	1.2	0.9	0.9	1.1	1.0	1.0	0.91%
SV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00%
CH	80.0	89.8	98.6	109.8	144.1	139.3	163.4	158.2	197.3	208.2	240.8	148.1	1461.82%
TW	0.7	0.9	0.9	1.0	0.9	0.8	0.9	0.9	1.2	1.2	0.9	0.9	1.82%
JP	21.1	17.9	20.4	17.5	17.5	16.4	20.6	19.3	18.3	19.0	19.8	18.9	-11.82%
SK	1.0	0.8	0.8	0.8	0.7	0.6	0.8	1.0	0.9	1.0	0.8	0.8	-1.82%

Appendix 9: Solar Electricity Net Generation (Billion KWh)

	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	Avg.	% of Total SE
GM	0.557	1.282	2.22	3.075	4.42	6.584	11.729	19.599	26.38	8.427	2.318%
SW	0.017	0.019	0.023	0.027	0.034	0.05	0.083	0.149	0.32	0.080	0.092%

CR	0	0	0.001	0.002	0.013	0.089	0.616	2.182	2.149	0.561	1.007%
PL	0	0	0	0	0	0.001	0.0015	0.0015	0.001	0.001	0.007%
HU	0	0	0	0	0.001	0.001	0.001	0.001	0.008	0.001	0.005%
AU	0.018	0.021	0.022	0.024	0.03	0.049	0.089	0.174	0.337	0.085	0.193%
SR	0	0	0	0	0	0.0002	0.017	0.397	0.424	0.093	0.268%
SV	0	0	0	0	0.001	0.004	0.013	0.065	0.163	0.027	0.181%
CH	0.068	0.074	0.084	0.105	0.152	0.392	0.939	2.605	6.355	1.197	0.162%
TW	0.230	0.242	0.254	0.262	0.272	0.281	0.283	0.281	0.283	0.265	0.307%
JP	1.189	1.493	1.794	2.015	2.251	2.758	3.8	5.16	6.963	3.047	0.533%
SK	0.01	0.015	0.031	0.07	0.285	0.566	0.772	0.917	1.103	0.419	0.147%

Appendix 10: Bioenergy Electricity Net Generation (Billion KWh)

	2004	2005	2006	2007	2008	2009	2010	2011	2012	Avg.	SMA Change
GM	16.033	16.589	21.335	29.074	29.219	35.562	39.865	43.57	44.628	30.653	1.14%
SW	1.987	2.109	2.334	2.303	2.39	2.374	2.426	2.45	1.533	2.212	-0.16%
CR	0.72	0.738	0.927	1.202	1.459	1.857	2.188	2.696	3.343	1.681	1.71%
PL	1.181	1.749	2.229	2.787	3.825	5.463	6.548	7.907	10.103	4.644	2.49%
HU	0.751	1.73	1.396	1.709	2.052	2.452	2.449	1.923	1.655	1.791	1.38%
AU	2.334	2.879	3.775	4.597	4.763	4.86	5.034	6.322	4.728	4.366	0.86%
SR	0.035	0.056	0.423	0.499	0.535	0.553	0.686	0.686	0.928	0.489	8.03%
SV	0.126	0.12	0.117	0.118	0.292	0.192	0.222	0.258	0.267	0.190	1.42%
CH	2.414	2.406	2.396	2.387	2.354	2.351	11.406	34	44.668	11.598	6.12%
TW	3	3	3.1	3.4	3.2	3.2	3.4	3.4	3.4	3.233	0.13%
JP	18.183	22.096	22.315	22.998	22.434	21.446	23.454	23.146	33.227	23.255	0.70%
SK	0.368	0.294	0.347	0.573	0.667	0.715	1.107	1.209	1.174	0.717	1.48%

Appendix 11: Geothermal Electricity Net Generation (Billion KWh)

	2004	2005	2006	2007	2008	2009	2010	2011	2012
GM	0.0002	0.0002	0.0004	0.0004	0.018	0.019	0.028	0.019	0.025
SW	0	0	0	0	0	0	0	0	0
CR	0	0	0	0	0	0	0	0	0

PL	0	0	0	0	0	0	0	0	0
HU	0	0	0	0	0	0	0	0	0
AU	0.002	0.002	0.003	0.002	0.002	0.002	0.001	0.001	0.001
SR	0	0	0	0	0	0	0	0	0
SV	0	0	0	0	0	0	0	0	0
CH	0	0.115	0.126	0.116	0.144	0.153	0.162	0.162	0.153
TW	0.006	0.023	0.069	0.110	0.147	0.197	0.261	0.388	0.393
JP	3.374	3.226	3.081	3.043	2.75	2.886	2.632	2.676	2.609
SK	0	0	0	0	0	0	0	0	0
CE	0.00028	0.00028	0.00043	0.0003	0.0025	0.00263	0.00363	0.0025	0.00325
EA	0.845102	0.84097	0.81896	0.81714	0.76026	0.80909	0.76372	0.80640	0.78887
WLD	55.84918	56.59095	57.99743	60.63261	63.38798	65.53966	66.29721	67.256	68.1923

Appendix 12: Nuclear Electricity Net Generation (Billion KWh)

	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	% Of Total SE
GM	158.71	154.61	158.71	133.21	140.89	127.72	133.01	102.31	94.10	36.78%
SW	25.61	22.11	26.37	26.49	26.27	26.27	25.34	25.69	24.45	29.12%
CR	25.01	23.26	24.50	24.64	25.02	25.67	26.44	26.70	28.60	45.79%
PL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00%
HU	11.32	13.02	12.51	13.86	13.87	14.30	14.66	14.71	14.76	46.13%
AU	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00%
SR	16.18	16.34	16.60	14.16	15.45	13.08	13.54	14.34	14.41	42.95%
SV	5.21	5.61	5.29	5.43	5.97	5.46	5.38	5.90	5.24	36.48%
CH	47.95	50.33	51.81	59.30	65.33	65.71	70.96	82.57	92.65	8.80%
TW	37.94	38.40	38.32	38.96	39.30	39.89	39.89	40.37	38.73	45.30%
JP	268.32	280.50	291.54	267.34	241.25	263.05	280.25	156.18	17.23	40.18%
SK	124.18	137.59	141.18	136.60	144.26	141.12	141.89	147.76	143.55	49.07%
CE avg.	30.25	29.37	30.50	27.22	28.43	26.56	27.30	23.71	22.70	34.28%
EA avg.	119.60	126.71	130.71	125.55	122.53	127.44	133.25	106.72	73.04	28.14%
World	2618.89	2624.98	2659.76	2608.05	2597.34	2560.02	2629.71	2517.74	2344.81	28.70%