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How is 100% Renewable Energy Possible in South Korea by 2020?

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Margaux CHANAL
Research Associate, Global Energy Network Institute (GENI)
m.chanal.10@groupe-esigelec.fr

Under the supervision of and edited by
Peter Meisen
President, Global Energy Network Institute (GENI)
www.geni.org
peter@geni.org (619) 595-0139

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Abstract

Replacing oil, coal or gas with clean energies has become one of the most crucial issues that the world faces. 77% of the energy demand could be filled by renewable energy by 2050. About half of the renewable energy potential is operating and 2.5% of the technical potential in renewable energy use has been mastered, that's why any question of the possibility of using clean energy is not justified.

South Korea is a country without many primary resources; the country imports most of its energy. It is one of the 5 biggest importers of fuel fossil energy in the world. To be less dependent on foreign countries includes reducing these imports, so the part played by using renewable energy has to be increased. Moreover, the greenhouse gases emissions have to be reduced or at least the rise of such emissions has to be stopped. To this end, the country has planned to invest more in green energies, such as tidal and ocean power, wind and solar power, or hydro.

I. Presentation of South Korea

1. South Korea background

a. Introduction

The Republic of Korea (RoK) is located in the southern half of the Korean Peninsula (see Figure 1 and 2). It occupies 98,480 square kilometers and has a 238 km boundary with North Korea. The country also includes about 3,000 mostly small, uninhabited islands. RoK, with a population of 48 million, about 85% of which live in urban areas, is a mountainous country, with lowlands accounting for only 30% of the total land area. The climate is temperate, with rainfall heavier in summer than in winter. In 2003, Seoul's population of 10.3 million people (excluding greater metropolitan areas) made it the world's most populated city. Other large cities include Pusan (3.8 million), Inchon (2.6 million), Daegu (2.5 million), Daejeon (1.4 million) and Gwangju (1.4 million).

Figure 1: South Korea on Earth[1]

[1] World map, http://www.mapsnworld.com/korea/where-is-korea.html

Figure 2: Map of South Korea[2]

b. International organization memberships

South Korea imports many primary energy sources. With a lack in natural resources, South Korea has a high dependence on imports. As a major energy importer, which includes oil, natural gas and coal, [3] South Korea is the 4th largest importer of oil in the world, the 3rd largest importer of coal, and the 2nd largest importer of Liquefied Natural Gas (LNG).

[2] http://koreanpeacetalks.edublogs.org/
[3]"U.S Energy Information Administration", *South Korea* http://205.254.135.7/countries/cab.cfm?fips=KS

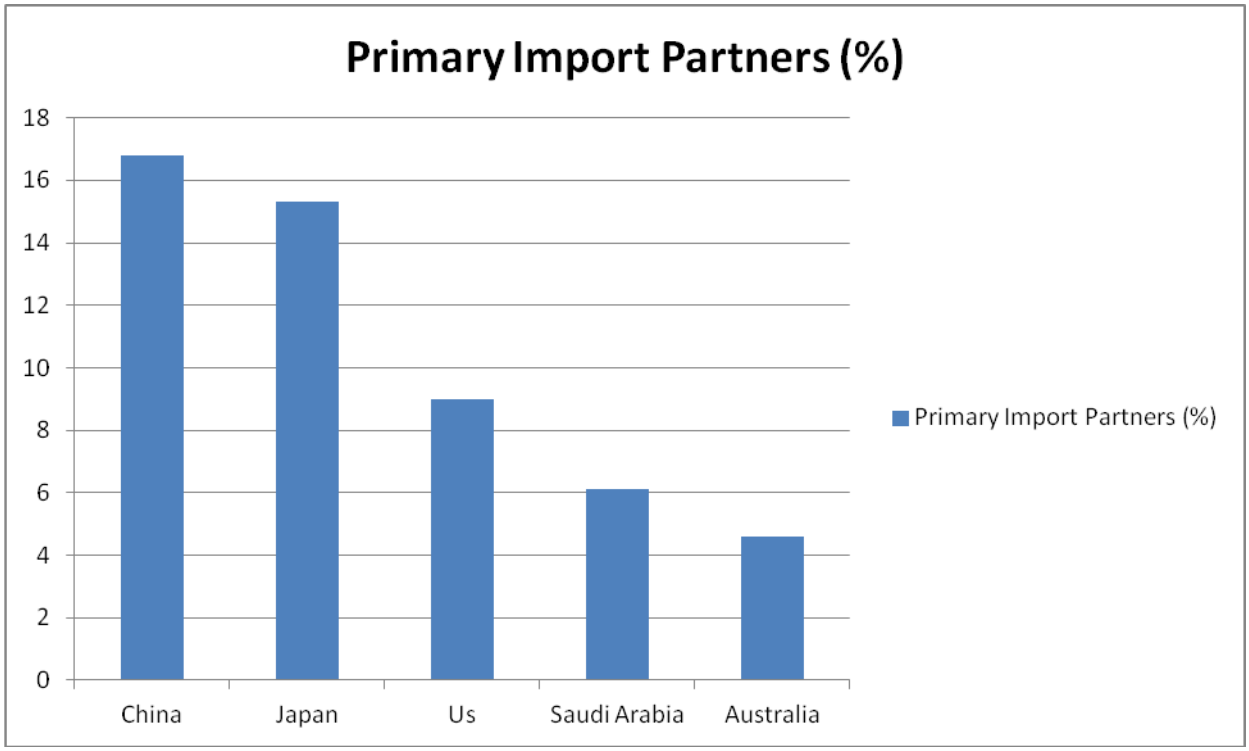


Figure 3: import partners of South Korea[4]

South Korea is a member of several worldwide organizations, such as Asia-Pacific Economic Cooperation (APEC), European Bank for Reconstruction and Development (EBRD), International Energy Agency (IEA), Organization for Economic Cooperation and Development (OECD), World Trade Organization (WTO). [5] As a membership of these organizations, South Korea helps to create new policies, which includes facing global warming.

[4] Author, inspired by "South Korea, Import & Trade", http://www.economywatch.com/world_economy/south-korea/export-import.html

[5] Central Intelligence Agency, "South *Korea",* https://www.cia.gov/library/publications/the-world-factbook/geos/ks.html

2. Background with renewable energies

a. Introduction

South Korea has not been a model when it comes to renewable energy. In fact, they did not sign the Kyoto Protocol, but despite that, have decided to make efforts. The government in South Korea decided in July 2008 to increase investment in renewable energy. They wanted especially to reduce the dependence on foreign oil imports. To accomplish this, the Ministry of Knowledge and Economy decided to spend $195 million on technologies and projects, including solar, wind and biofuels.

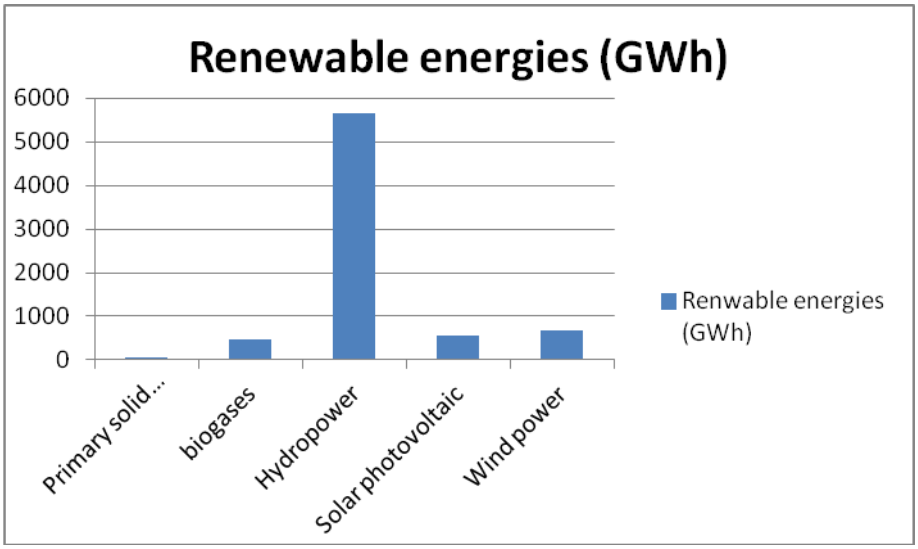


Figure 4: part of renewable energies in 2009[6]

b. Wind power

Wind energy in South Korea is still in its infancy, but the Korean government has made "green growth" with low carbon emissions one of its priorities for national development. The existing feed-in tariff, which was too low to support wind power development, was recently replaced with a Renewable Portfolio Standard (RPS) scheme. In addition, several Korean heavy manufacturers have started to include wind turbines in their portfolios to compete both domestically and in the international marketplace. [7]

[6] *International Energy Agency*, "Balance for Republic of Korea", 2009, http://www.iea.org/stats/balancetable.asp?COUNTRY_CODE=KR

[7] *Global Wind Energy Council*, "South Korea" http://www.gwec.net/index.php?id=177

Thirty two wind farms have been installed in South Korea. The figure below shows Total Installed Capacity in MegaWatts (MW)

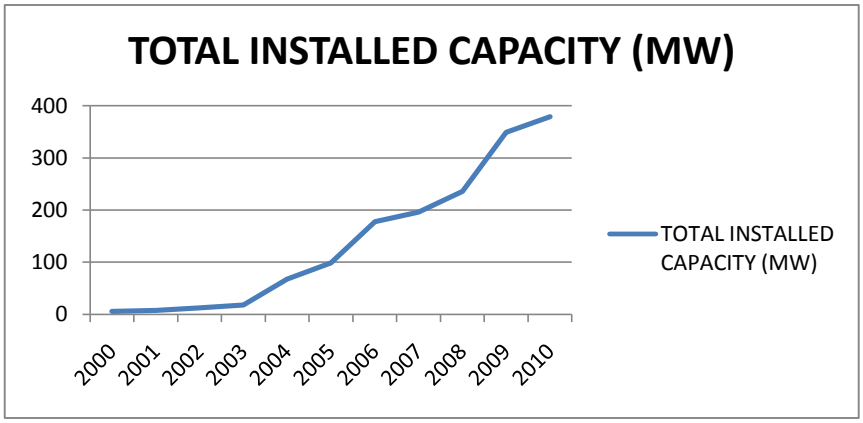


Figure 5: evolution of wind power use[8]

Figure 6 : Map of wind farms, South Korea[9]

[8] Author, inspired by http://www.gwec.net/index.php?id=177
[9] *Wind turbines and wind farms database*, "South Korea", http://www.thewindpower.net/country_windfarms_en_23_south-korea.php

c. Hydropower and tidal

The Korea Hydro & Nuclear Power was founded in 2001. It provides hydroelectric plants in South Korea and is responsible for 40% of the country's electric power supply. It runs 27 hydro power units through South Korea with a generating capacity reaching 540 MW.

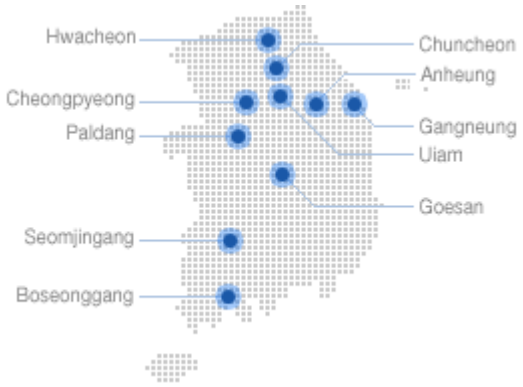


Figure 7: Hydroelectric Power Plants, South Korea[10]

Figure 8: Cheongpyeong Hydro Power Plant[11]

[10] KHNP, http://www.khnp.co.kr/en/030201

[11] http://tribune.com.pk/story/320451/hydropower-project-south-korea-announces-largest-investment-yet/

South Korea has installed the largest tidal power installation, **Sihwa Lake Tidal Power Station.** The massive hydropower generator can generate up to 254 MW of hydroelectricity. It became fully operational in 2001. [12]

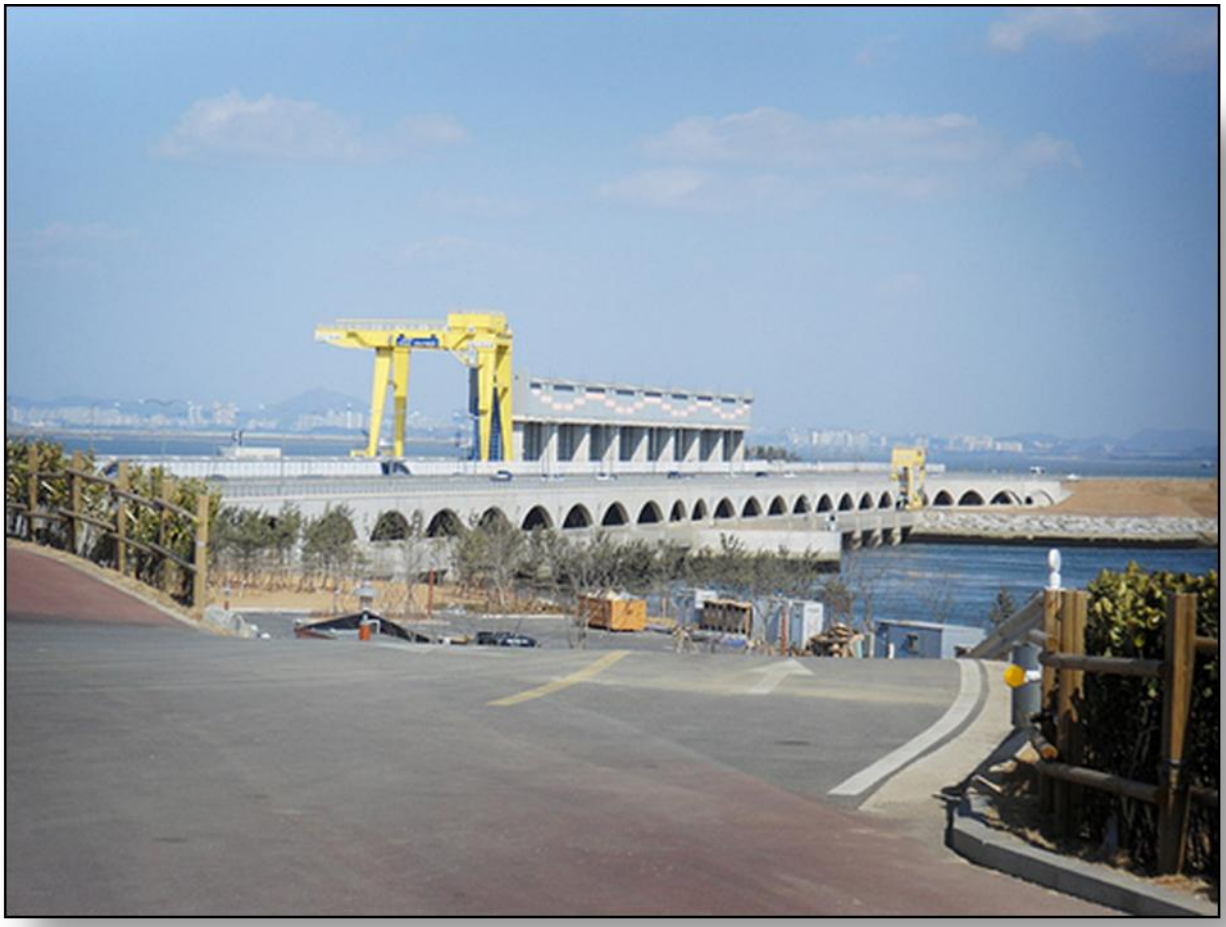


Figure 9: Sihwa Lake Tidal Power Station, construction[13]

[12] *Koreascene*," Sihwa lake tidal power Station", http://www.koreascene.com/sihwa-lake-tidal-power-station-the-largest-tidal-power-station-in-the-world-2/

[13] http://www.koreascene.com/sihwa-lake-tidal-power-station-the-largest-tidal-power-station-in-the-world-2/

3. The energy issue

Renewable energy is a crucial issue because of the consequences it includes:

- Energy security: many countries have to reduce their dependence to oil and increase their energy independence.
- Environmental benefits: the world has to reduce environmental impacts. Biodiversity must be preserved, and greenhouses emissions must be regulated.
- Economy – jobs: new investments and new facilities to provide clean energy creates jobs and fuels the local economy.

4. 100% clean energy?

South Korea aims to be a net exporter of clean energy. From 2005 to 2010, its renewable energy capacity grew by 88%. Its total investment in the renewable energy field in 2010 was US$356 million, particularly in wind and solar technologies. By 2015, South Korea aims to be one of the five best users of renewable energies.

"The South Korea government has given out tariff and tax exemptions for penetration of these technologies, and there is a bigger focus in organizing the industries to cater to its markets as well as emerging demands. That's the difference between what South Korea is doing and what others are doing"[14], says Ravi Krishnaswamy, Frost&Sullivan's vice-president for energy practice.

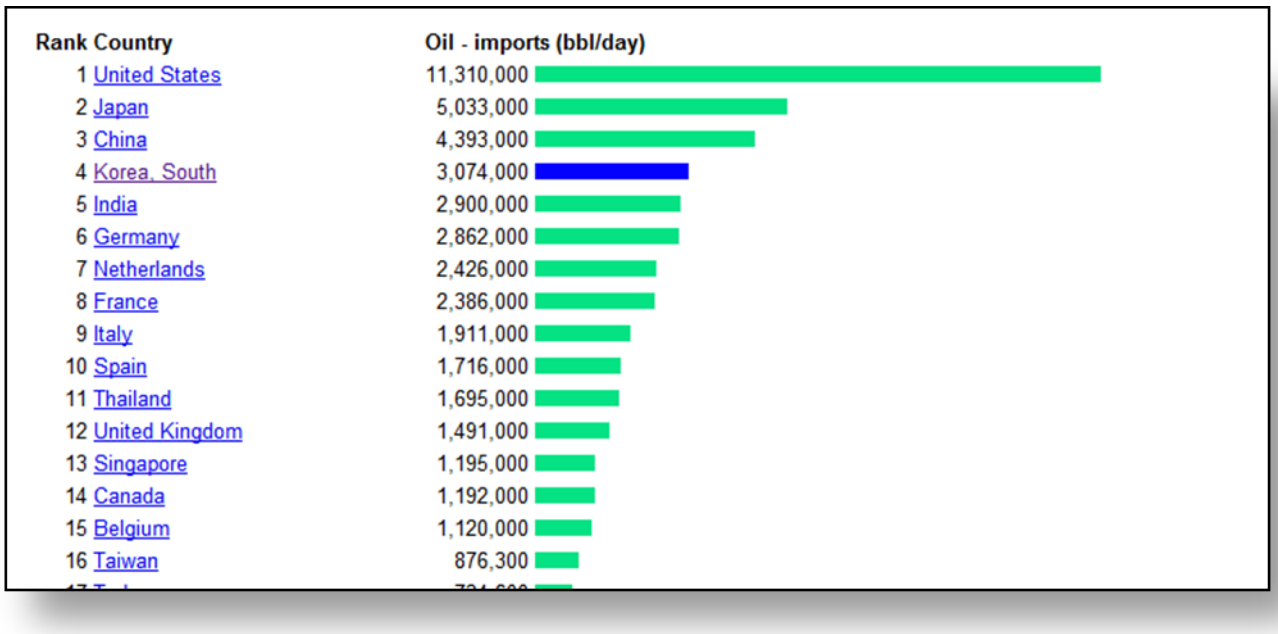
[14] South Korea aims to be net exporter of clean energy, http://www.greenprospectsasia.com/content/south-korea-aims-be-net-exporter-clean-energy

II. Energy profile of South Korea

1. Energy sources

a. Oil

South Korea must import all of its crude oil because of the lack of domestic oil reserves. Most of South Korea's oil imports come from the Persian Gulf. South Korea produces less than 0.4% of its own consumption as seen in this chart below.



Rank	Country	Oil - imports (bbl/day)
1	United States	11,310,000
2	Japan	5,033,000
3	China	4,393,000
4	Korea, South	3,074,000
5	India	2,900,000
6	Germany	2,862,000
7	Netherlands	2,426,000
8	France	2,386,000
9	Italy	1,911,000
10	Spain	1,716,000
11	Thailand	1,695,000
12	United Kingdom	1,491,000
13	Singapore	1,195,000
14	Canada	1,192,000
15	Belgium	1,120,000
16	Taiwan	876,300

Figure 10: Position of South Korea in oil imports[15]

Compared to most IEA countries, Korea uses a very large share of oil for the industrial sector, over 40% of all oil consumed, nearly double the IEA average. [15]

[15] http://www.nationmaster.com/red/pie/ene_oil_con-energy-oil-consumption
[16] "Energy Profile of South Korea", http://www.eoearth.org/article/Energy_profile_of_South_Korea

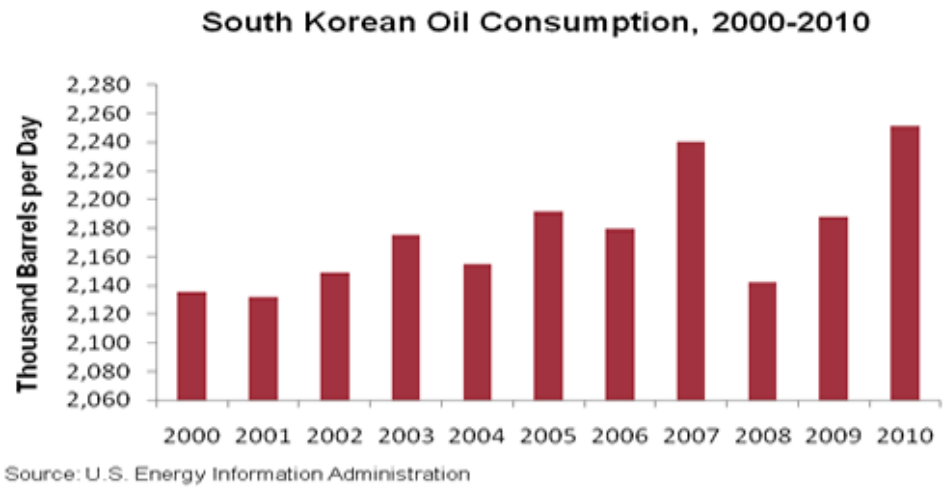


Figure 11: South Korea oil consumption[17]

The figure below shows the increase in oil consumption among the different uses:

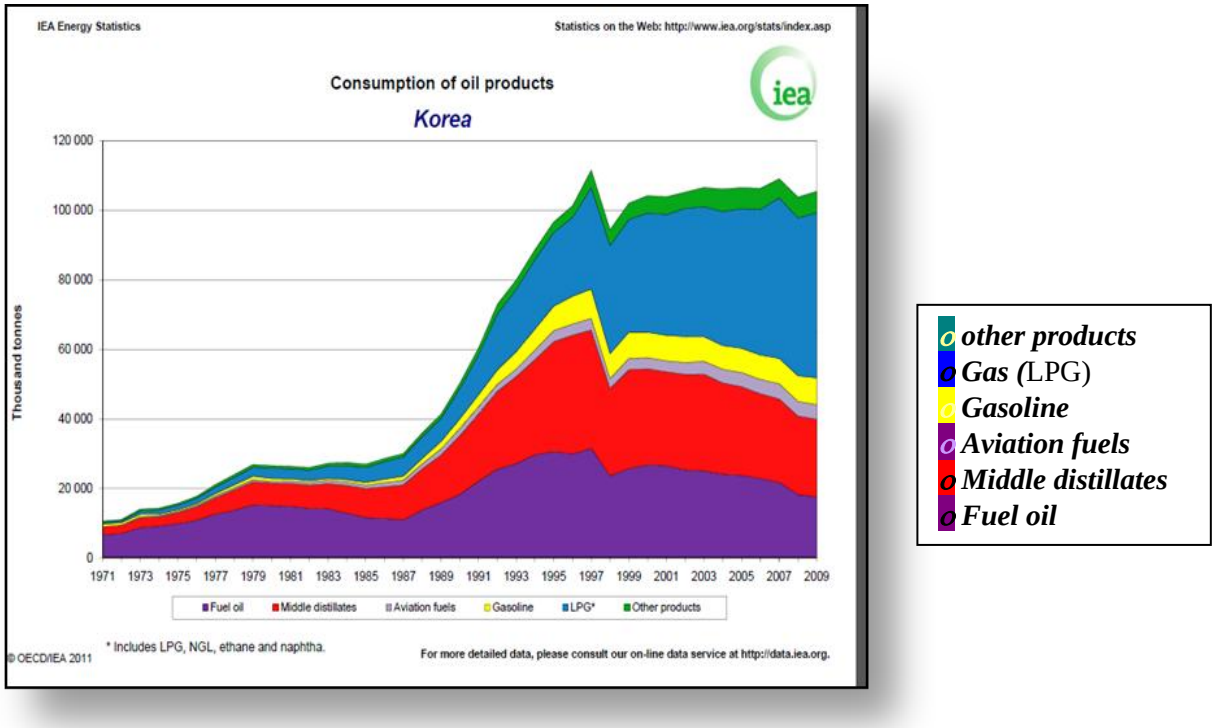


Figure 12: Oil Consumpiton by use[18]

[17] http://www.eia.gov/cabs/South_Korea/Full.html
[18] http://iea.org/stats/pdf_graphs/KROIL.pdf

b. Natural Liquefied Gas

Natural Gas consumption of South Korea has doubled over the past decades. From 2009 to 2010, it increased 25%.

South Korea is the second largest importer of LNG in the world after Japan. [19] The largest use of that gas is for power generation - electricity (42% in 2004). Currently, the policy is to increase use of nuclear power to offset a decline of gas consumption – meaning gas imports.

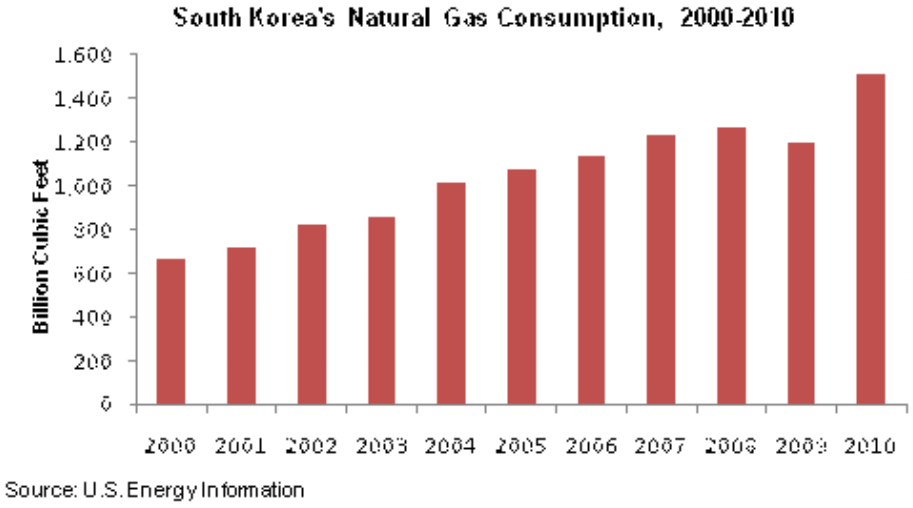


Figure 13: Gas consumption South Korea from 2000 to 2010 [20]

c. Nuclear power

Nuclear energy provides nearly 40% of Korea's electricity supply. Twenty three nuclear units are in operation on four sites. All nuclear power plants are owned by Korea Hydro and Nuclear Power. [21]

According to Korean data, nuclear generated electricity is the country's cheapest available electricity option. The total generation cost is about KRW (South Korean Won, 1KRW=0.0009 US dollar) 40 per kWh (Kilo Watt Hour), compared to 42 for coal, 57 for hydro and 80 for gas.

[19] "South Korea", http://205.254.135.7/countries/cab.cfm?fips=KS
[20] http://www.eia.gov/cabs/South_Korea/Full.html
[21] KHNP, http://www.khnp.co.kr/index_en.jsp

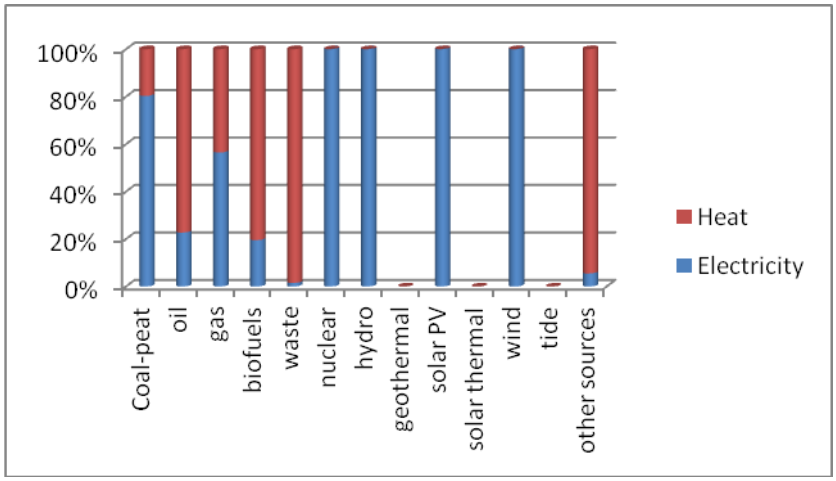


Figure 14: Electricity and Heat in the Republic of Korea, 2009[22]

Nuclear energy remains a strategic priority for South Korea, and capacity is planned to increase by 56% to 27.3 GWe (GigaWatt electricity) by 2020, and then to 43 GWe by 2030.

2. Energy demand

Power demand in South Korea has increased by 9% per year since 1990 but slowed by 2.8% between 2006 and 2010 and is projected to slow by 2.5% to 2020.[23]

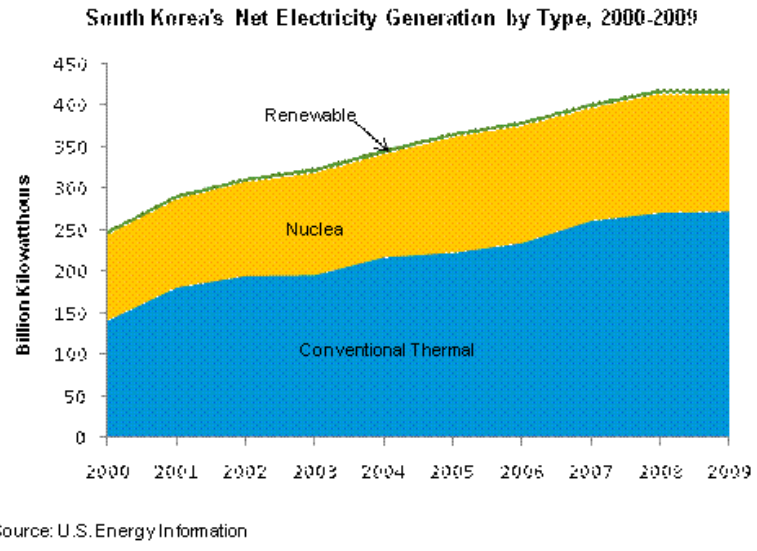


Figure 15: Electricity Generation by Type, South Korea[24]

[22] Author, inspired by http://www.iea.org/stats/electricitydata.asp?COUNTRY_CODE=KR
[23] World Nuclear Association, "Nuclear Power in South Korea", http://www.world-nuclear.org/info/inf81.html
[24] http://www.eia.gov/cabs/South_Korea/Full.html

In 2005, Korea's total electricity generation was over 365 TWh (TeraWatt hour). The country has over 60 000 MW of installed electricity capacity, which is split between six different companies and independent power producers. Nuclear, coal and LNG each make up more than a quarter of total capacity.

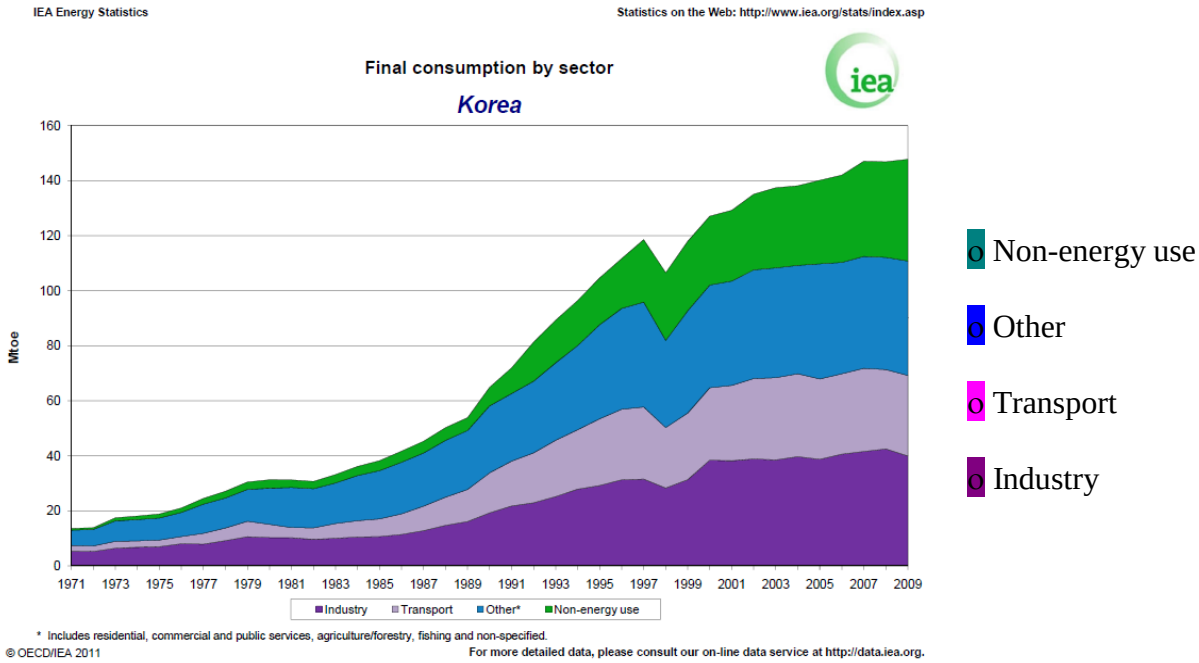


Figure 16: Final consumption by sector[25]

3. CO_2 emissions

Energy-related emissions of carbon dioxide have grown dramatically in recent years, more than doubling between 1990 and 2004, equivalent to an average annual growth rate of 5.2%.

[25] http://iea.org/stats/pdf_graphs/KROIL.pdf

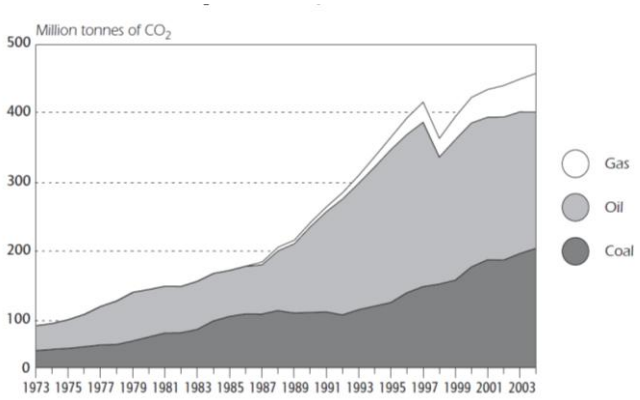


Figure 17: CO_2 emissions by Fuel, 1973 to 2004[26]

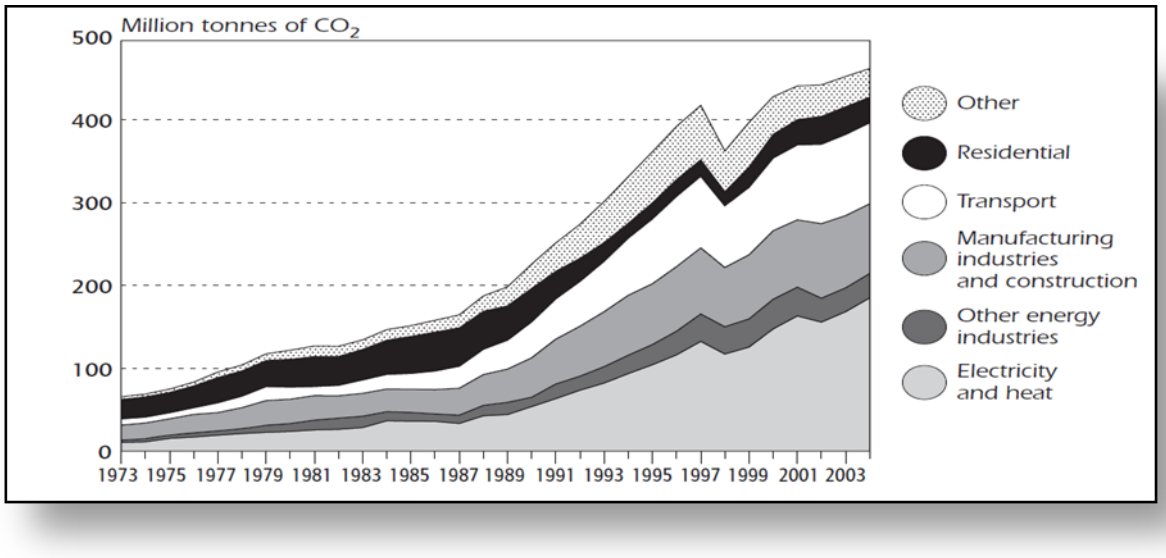


Figure 18: CO_2 emissions by sector, 1973 to 2004[27]

The CO_2 emissions in South Korea increased by 11.5% between 1946 and 1997, which made South Korea the tenth largest emitter of $C0_2$ in the whole world. Nearly half of those emissions were due to coal consumption (46.9%). Oil consumption since 2004 and even now has become the main source of carbon dioxide emissions. When South Korea increased its LNG imports, natural gas also became an important contributor of CO_2 emissions. [28]

[26] http://iea.org/publications/freepublications/publication/korea2006.pdf
[27] http://iea.org/publications/freepublications/publication/korea2006.pdf
[28] Carbon Dioxide Information Analysis Center, "South Korea Fossil-Fuel CO_2 emissions", http://cdiac.ornl.gov/trends/emis/tre_rok.html

4. Energy demand in 2020

South Korea's population reached more than 48 million in 2012 at growth rate estimated at 0.23% annually. At that rate, South Korea would add 110,000 more people in 2013. More generally, as we can see on Figure 19, when the population increases, the energy demand increases too. That means that Korea's energy demand will increase accordingly as population grows.

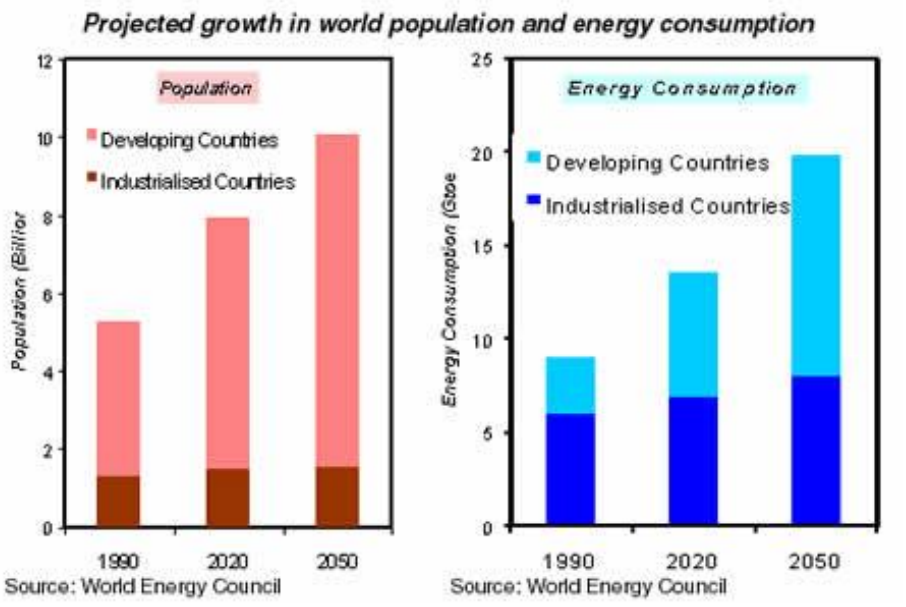


Figure 19: link between growth population and rising energy consumption[29]

[29] http://www.worldenergy.org/

III. Current Renewable Energy

South Korea has the lowest level of renewable energy among the IEA countries.

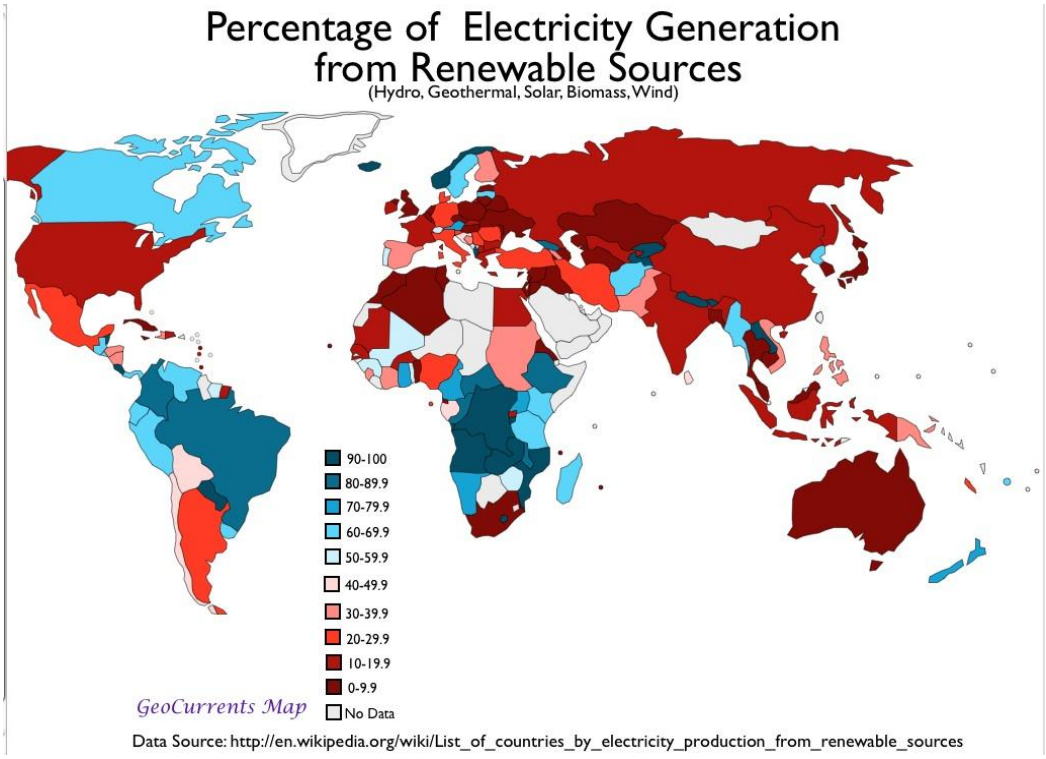


Figure 20: Mapping renewable electricity generation[30]

The largest share of renewable energy is from hydropower and wind. In 2009, Korea generated about 417 Billion kWh of net electricity. Roughly 1% came from renewable energy, and in 2010, 2.4% of the energy produced came from renewable energy.

South Korea wants to make its renewable sector one of the country's priorities despite the current minimal investment given, just $20 million in 2009, placing it 19th among G-20 members.

In 2012, the target of share of primary and final energy from renewables is 4.3% by 2015, 6.1% by 2020 and 11% by 2030.[31]

[30] http://geocurrents.info/wp-content/uploads/2012/07/Renewable-Energy-by-County-Map.jpg
[31] Renewables 2012, « global status and reports », http://www.map.ren21.net/GSR/GSR2012_low.pdf

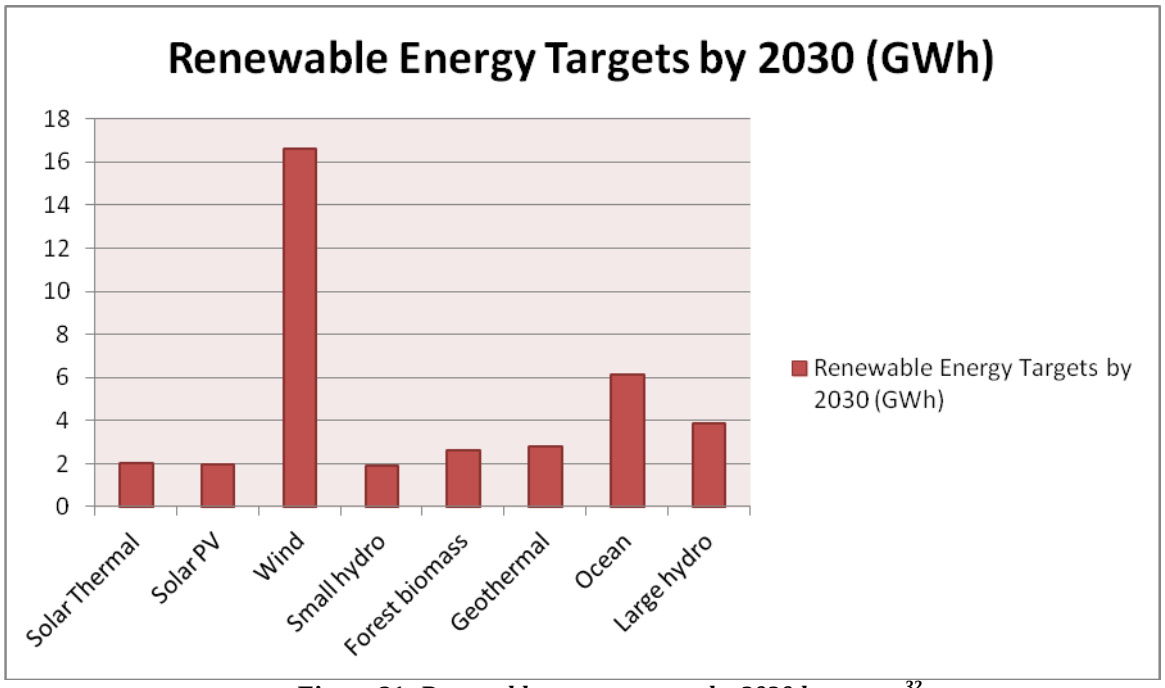


Figure 21: Renewable energy targets by 2030 by source[32]

1. Wind farms

South Korea wants to become one of the three best world wind power generation countries. So the governmemt has announced that the offshore wind farms that are going to be installed by 2019 will be capable of producing the same amount of electricity as two nuclear power plants. It represent a $8.2 billion investment. First, 100 MW of electricity will be generated by 2013 thanks to wind farms with 20 turbines of 5 MW capacity each. After that, the total capacity will reach 900 MW by 2016 and 2,500 MW by 2019.

[32] Author, inspired by http://www.map.ren21.net/GSR/GSR2012_low.pdf

2. Others

Geothermal energy plays a negligible part in South Korea, whereas hydro generation represents 40% of the country's energy supply. The following map shows the world electricity generated by geothermal and by hydro.

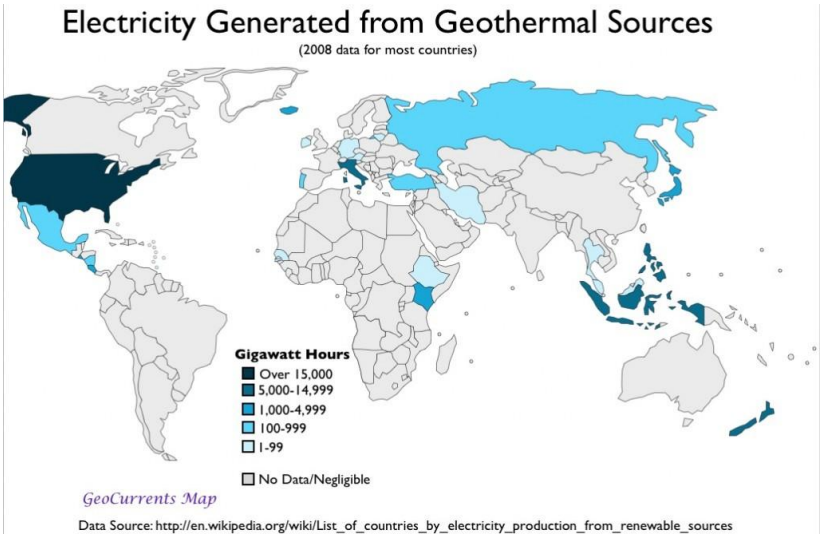


Figure 22: Electricity generated from geothermal sources[33]

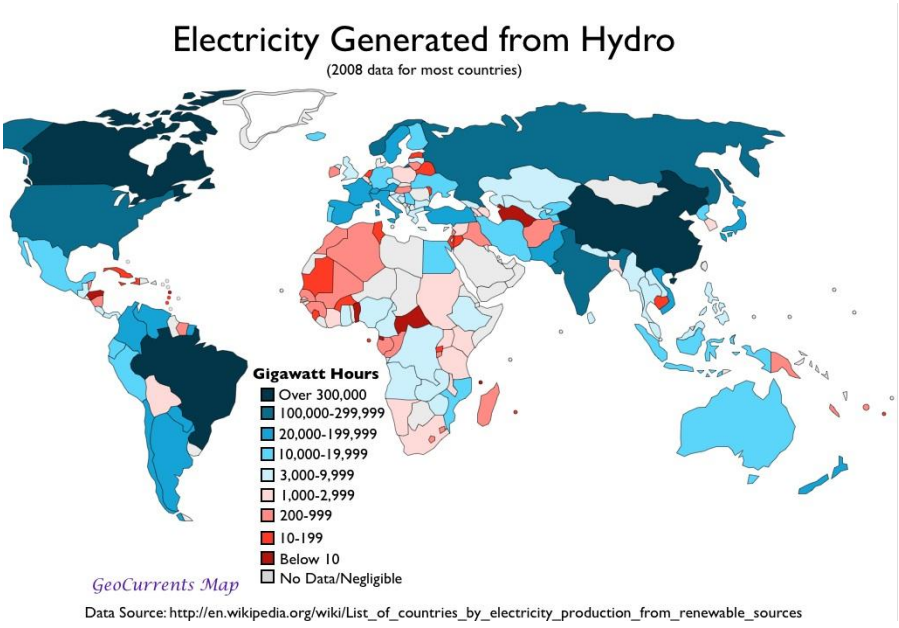


Figure 23 : Electricity generated from hydro[34]

[33] http://geocurrents.info/geonotes/renewable-electricity-production-mapped
[34] http://geocurrents.info/geonotes/renewable-electricity-production-mapped

3. Renewable Energy Potential for South Korea

The government of South Korea aims to produce 6.1% of energy from renewables by 2020. There is a strong sense of willingness to accelerate renewable energy development. They also want to reach the target "one million green homes" with PV, solar thermal or wind installations on 1 million houses.

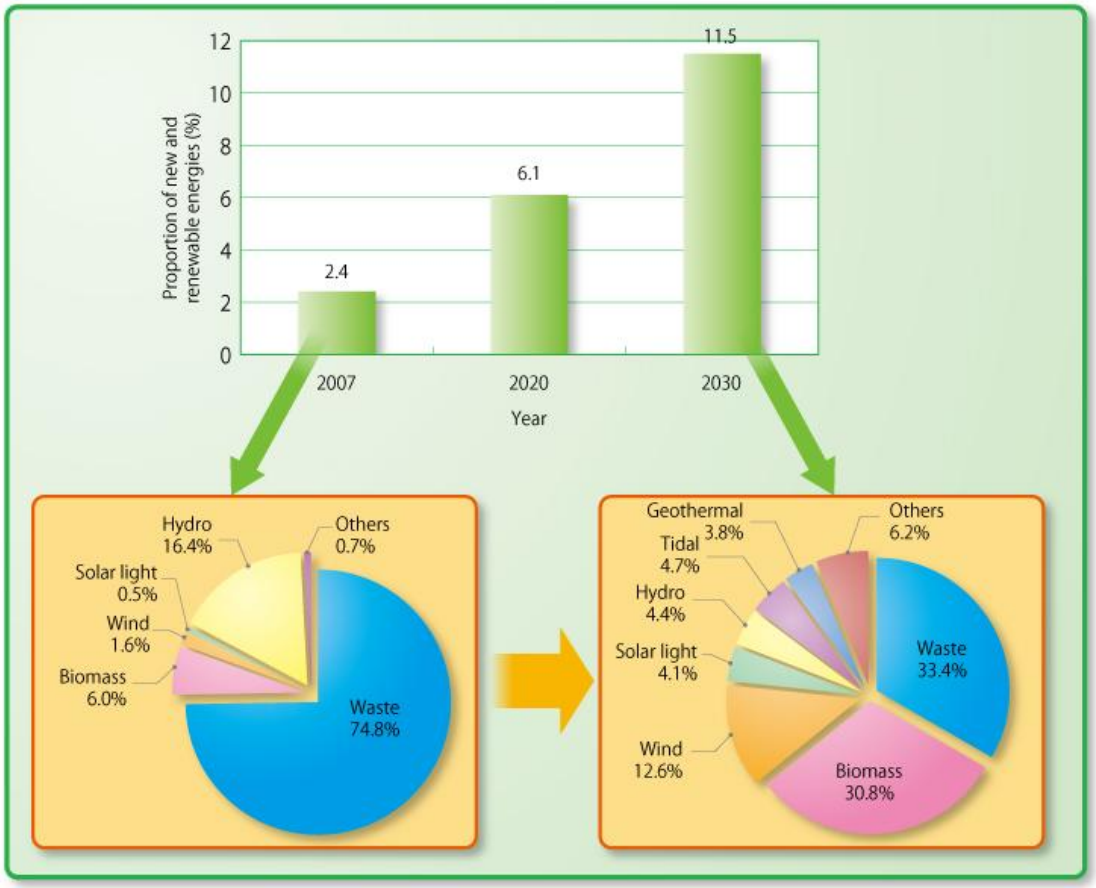


Figure 24: Proportion of new and renewable energy (%)[35]

a. Wind capacity

It is estimated that South Korea has wind power potential of 186.5 TWh per year. In 2010, the installed capacity was about 350 MW. According to *the wind power* website, the wind energy capacity was 407 MW at the end of the year 2011, which represents a 7.4 % rise over the previous year.

[35] http://www.asiabiomass.jp/english/topics/1107_04.html

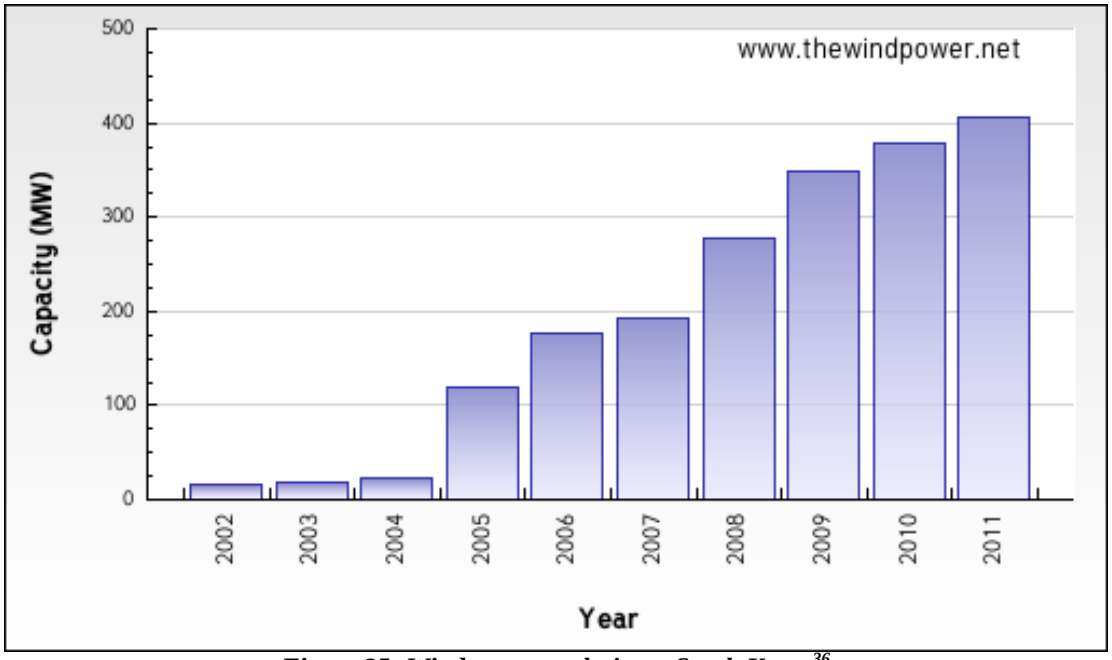


Figure 25: Wind power evolution – South Korea[36]

The evolution that can be seen in figure 24 shows that if the increase of wind power generation continues, South Korea is about to get involved in a major way.[37] As of August 2012, an offshore project is about to start and includes 500 turbines, providing a total of 1.5 GW. [38] An agreement has recently been signed between South Korea and UK to increase wind energy trades. The South Korean government is currently exploring the country to find locations for further suitable sites for the expansion of offshore wind power sites.

b. Solar capacity

In 2011, South Korea's market of solar power represented a tiny part of the global market (0.1 GW) and declined for the second year in a row. [39] In 2011, the renewable energy target for solar PV was 1.3MW by 2012. An incredible project has been led successfully on the Korean Island of Donggwang on the western half of Jedu-do. This has been a technological feat: total energy independence with clean technology. Each house has solar panels on it; schools are independent in energy, thanks to free electric energy from the sun.[40]

[36] http://www.thewindpower.net/country_en_23_south-korea.php
[37] Wind power and wind farms database, « South Korea », http://www.thewindpower.net/country_en_23_south-korea.php
[39] Earth Techling, "Clean Energy, A Big Future Focus Of South Korea", http://www.earthtechling.com/2012/06/clean-energy-a-big-future-focus-of-south-korea/
[40] Renewables 2011, Global Status Report, http://www.ren21.net/Portals/97/documents/GSR/REN21_GSR2011.pdf
[41] New energy blog, Solar System Powers Donggwang Green Village, http://newenergy08.blogspot.com/2008/06/solar-system-powers-donggwang-green.html

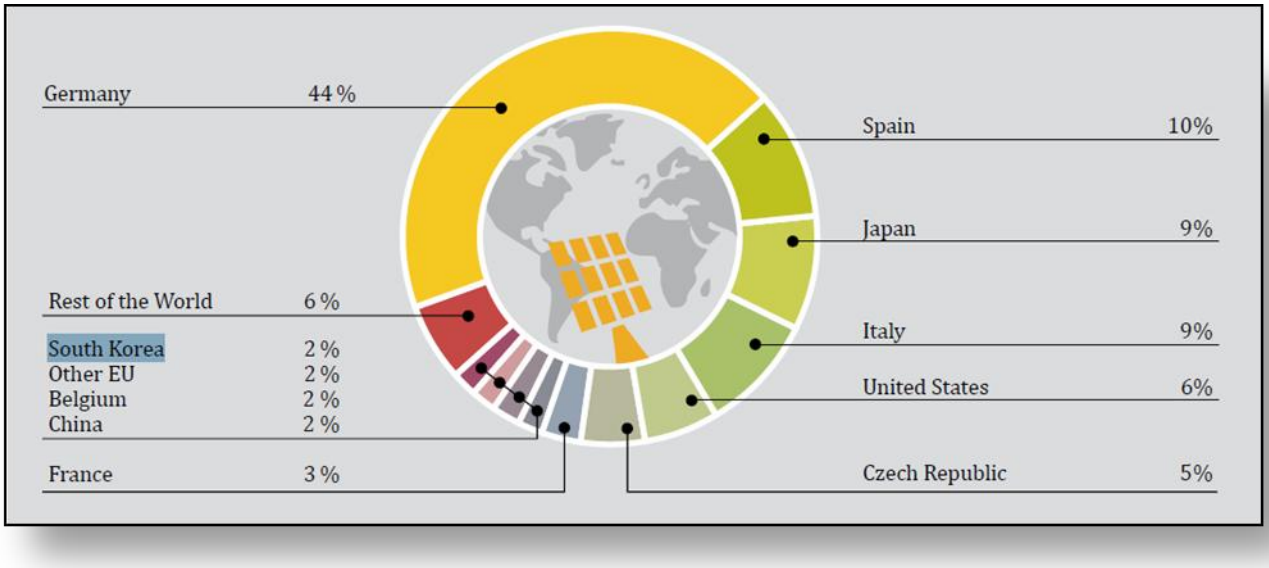


Figure 26: Solar PV Capacity, Top 10 countries, 2010[42]

According to the Ministry of Economy, solar panels should have been installed on 60% of households by 2012.

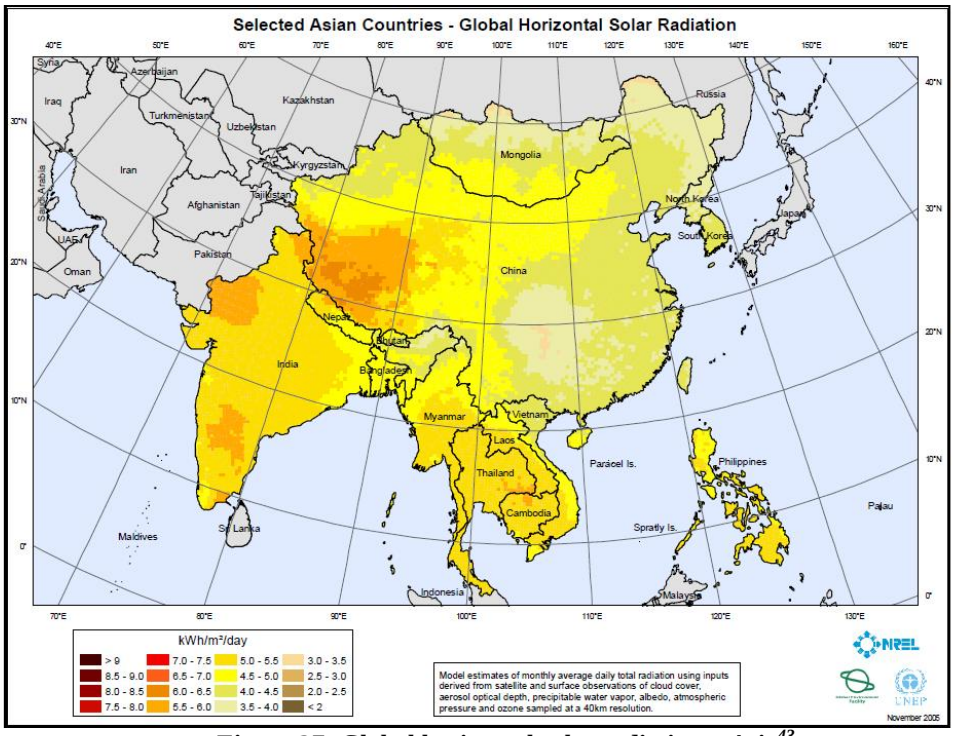


Figure 27: Global horizontal solar radiation – Asia[43]

Figure 27 show that South Korea clearly has a potential for solar electricity generation.

[42] http://www.ren21.net/Portals/97/documents/GSR/REN21_GSR2011.pdf
[43] http://en.openei.org/w/index.php?title=File:NREL-asia-glo.pdf&page=1

c. Hydropower

Currently, 16% of the electricity produced in the world comes from hydropower plants, and just one third of the economical potential has been installed. Considering technically, economically and environmentally realistic conditions, countries could produce twice as much as they currently produce. Hydro electricity represents a well known technology and could fulfill rising energy needs. Moreover, the highest potential of hydroelectricity left is located in developing countries in Asia and Africa. [44]

There are many advantages to producing electricity by hydropower:

- This energy is **natural** and **green**
- **No emissions** of greenhouse gases are produced
- It does not cost too much money
- About 90% of the water energy is transformed into mechanic energy, a high **yield**

Hydroelectricity is currently the main renewable source of power generation (71.8% of the renewable production) as shown on next graph: [45]

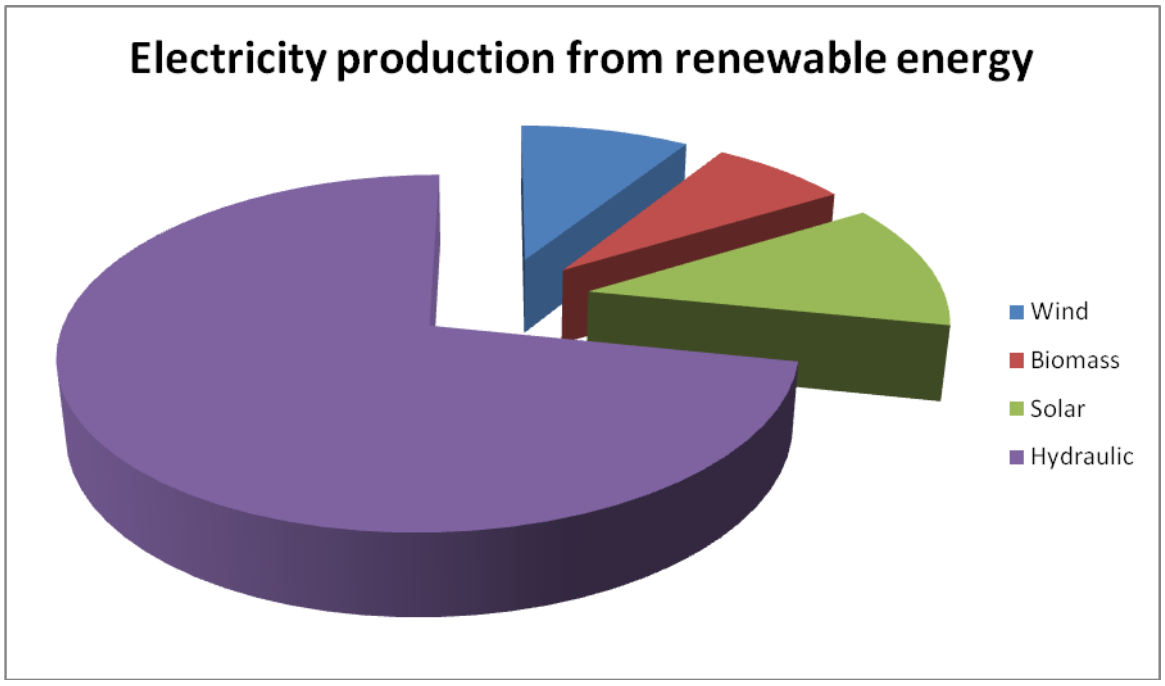


Figure 28: structure of electricity production from renewables – 2010[46]

[44] Hydro-electric power, http://www.groept.be/www/dam/HYDROpower.htm
[45] "South Korea", www.energies-renouvelables.org
[46] Author, inspired by www.energies-renouvelables.org

d. Tidal – Ocean

In using tidal power and its potential energy, electricity is created. The main advantages of such a production are the low price and the large size of production. And it is a clean energy. South Korea has built the largest tidal power plant of the world, The Shihwa Lake. Its capacity is 254MW and can generate 552 million kWh per year, which represents enough energy to supply 500,000 houses. As a consequence, the government has planned to reduce oil imports by 862,000 barrels, and such a power plant aims to reduce CO_2 emission by more than 300,000 tons. [47]

Figure 29: Shihwa Lake Tidal Power Plant

The figure below shows the plans for South Korea's government for developing tidal power. Shihwa Lake Power Plant is the only one that has been built and the smallest of those planned. South Korea has a huge tidal power potential on the entire west cost of the country. Unfortunately, environmental and ecological issues are slowing down of development these plants.

[47] Energy Korea, *"World's Largest Tidal Power Plant-Shihwa Lake in Korea"*, http://energy.korea.com/archives/6887

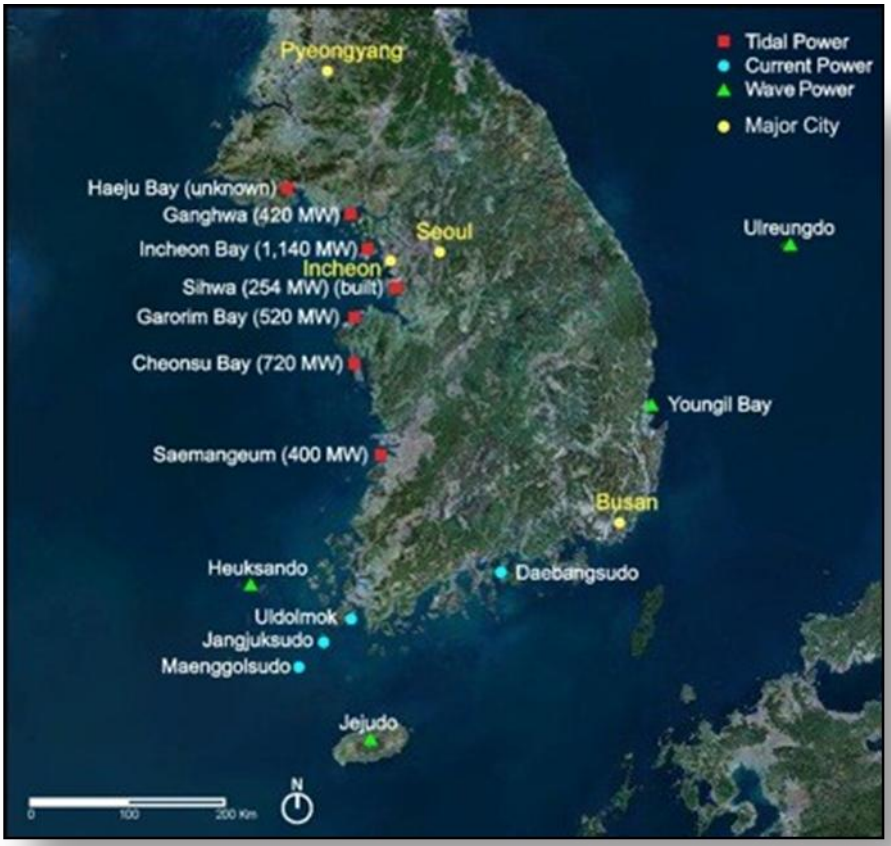


Figure 30: Future Tidal power plants in South Korea[48]

e. Biomass

The Knowledge & Economy Minister of South Korea declared in 2008 that biomass and bioenergy was going to be "the most important and useful among new sources of renewable energy for a significant time in the future."[49] In 2007, biomass as a portion of renewable energy was about 6.0%, and the government wants to increase it to more than 30% by 2030. The forests represent 63% of the Korean landscape. In 2010, the government decided to build 8 wood pellets plants.

[48] http://nautilus.org/napsnet/napsnet-special-reports/south-koreas-plans-for-tidal-power-when-a-green-solution-creates-more-problems/

[49] Biopact, South Korea Minister: "*biomass most important of all renewables*", http://news.mongabay.com/bioenergy/2008/09/south-korea-minister-biomass-most.html

f. Geothermal

The figure below shows the distribution of heat flow in the Republic of Korea from geothermal energy. The country has a huge potential in geothermal for low temperature. [50]

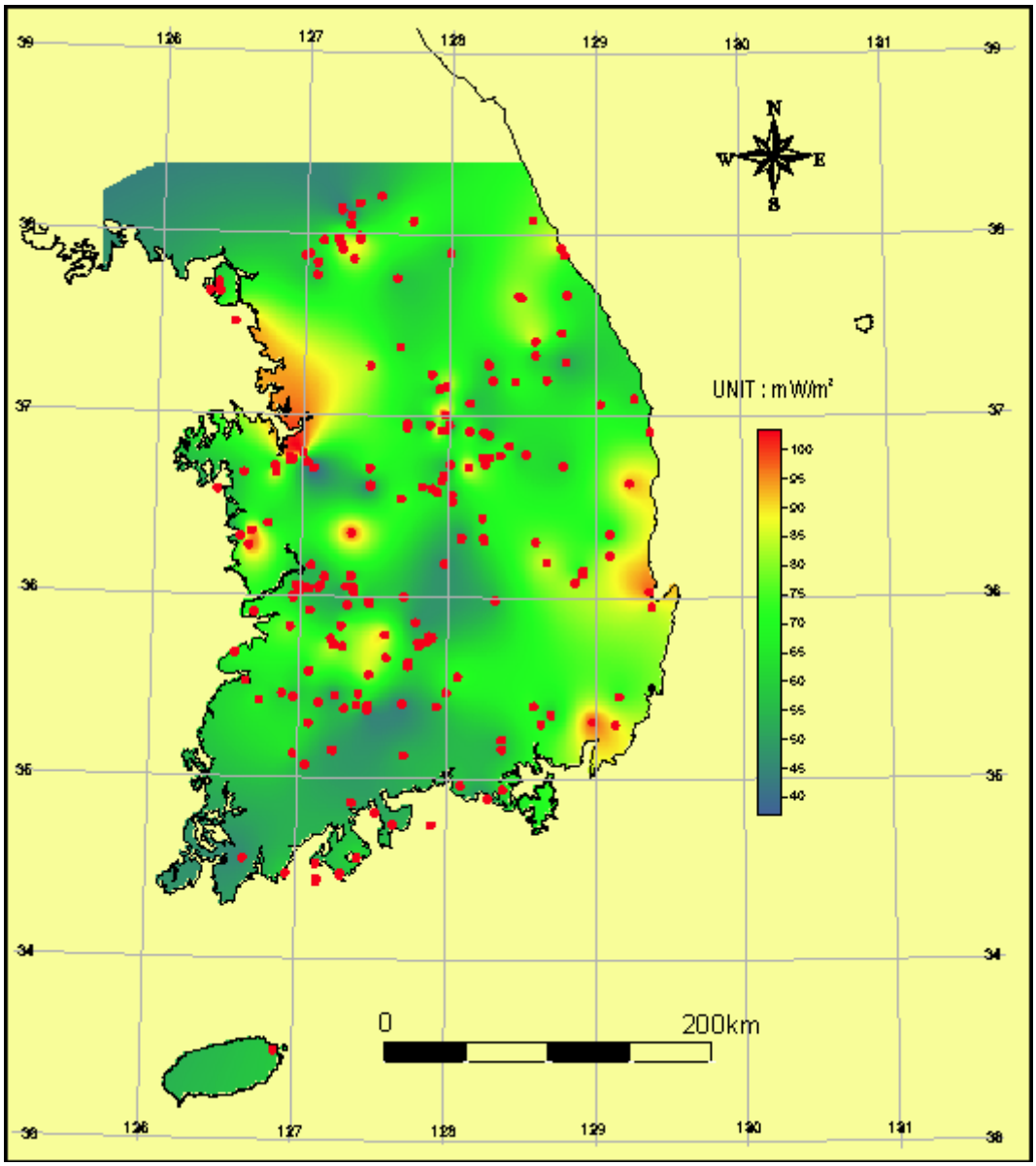


Figure 31: Heat Flow Distribution map of South Korea [51]

According to the International Geothermal Association data, South Korea has an installed capacity of geothermal of 229.3 MW with a capacity factor of 0.27. This quantity of energy is produced thanks to 3,000 units all over the country.

[50] Characteristics of Geothermal Anomaly in South Korea, http://www.geothermal-energy.org/pdf/IGAstandard/WGC/2005/0643.pdf

[51] http://www.geothermal-energy.org/pdf/IGAstandard/WGC/2005/0643.pdf

Conclusion

South Korea has a huge potential in renewable energy and could fill the demand with such clean energies. They know how to exploit its potential; investments are rising to provide green electricity production. The biggest challenge is to respond to the growing demand for energy from the increase in population. There are 2 more people on Earth every second. To cope with this increase, countries and government have to change there energies habits. Even if the Republic of Korea did not sign the Kyoto protocol, they are ready to make efforts.

South Korea is 97% dependent on foreign imports, and uses 83% of fossil energies. Nuclear energy takes a huge part in the share of energies. The government wants to increase the percentage of nuclear power generation by 35%. The situation is getting worse. That's why the government leans more towards clean energy.

Projects such as the huge solar power plant installation in South West Korea that can provide electricity for 10,000 houses are successful initiatives. Korea has decided also to bet on wind farms: the government is seeking 10% share of the global market for wind power production. The Korean territory counts the biggest tidal power plant of the world and 500 turbines are going to be installed before 2019.

How is 100% renewable energy possible in South Korea by 2020? All the natural resources have to be exploited: the west coast should be the primary source of wind power and offshore wind. The solar radiation in South Korea is not the best, but it is enough to make entire villages so energy efficient that they could become autonomous. Hydropower is the main renewable source of the country, but half of its potential is unexploited. Every source of renewable energy offers prospects. Partnerships with other countries can be the solution, because it could share and reduce the costs. The first step was to become aware that the situation is urgent, and now that that's done, South Korea is in position to respond.

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