Final Term Project Report

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Course: Sustainable Energy and Enabling Net Zero Emissions

The Country's Current and Projected energy demand Profile:

The South Koreas current and future projected energy demand profile have been depicted in the table below. The data for the able have been retrieved from South Koreas as Second master energy plan for 2035 [1] and further upto 2050 has extrapolated using available data. All the data is in million toe.

Table1: Final Energy Demand profile for South Korea

Items	2011	2025	2030	2035	2040	2045	2050
TOTAL							
BAU demand (million toe)	205.9	248.7	254.3	254.1	272.4412	275.14	284.21
Target demand (million toe)	205.9	226.7	226	220.5	230.47	227.37	229.6
Final Energy Consumption							
Coal	33.5	34.7	35.3	34.4	35.25	35.107	35.08
Oil	102	96.2	88.8	80.3	81.87	79.05	78.17
Natural gas	23.7	31.4	33	33.8	35.007	33.4	34.13
Electricity	39.1	53.3	57.1	59.9	59.998	57.698	58.544
Heat energy	1.7	2.8	3	3.2	3.291	3.297	3.32
Renewable energy (non-electricity)	5.8	8.3	8.7	8.8	9.2848	8.798	8.9925
Sector wise Final Energy consumption							
Industry	126.9	151.6	152.3	148.4	153.95	151.55	151.58
Transport	36.9	44	45.5	46.5	47.21	47.23	47.34
Residential	21.6	24.2	24.6	24.9	25.2995	24.78	25
Commercial	15.9	23.6	26	28.1	27.01	26.18	26.81
Public Service & Others	4.6	5.4	5.8	6.2	6.106	6.22	6.233

By comparing with BAU demand level we can see that targeted demand will decrease by 13% (220 million toe) by 2030 and for year 2050 it will be reduced by 19.3%.

Based on the above table it can be depicted that the present energy demand is highly fossil fuel dependent. It is seen that from the South Koreas Energy Bance table for the year 2020 [2], the share of renewable energy in total supply contributed to only 3.5% of total supply and share of nuclear energy was around 15%, whereas the share of fossil-fuel based dependent energy supply is 81.5%. Also, South Koreas Energy supply is heavily import dependent. The country has challenge of increasing share of renewable energy as well as improve energy security by reducing import dependency for energy. The projected demand for 2035 also shows very high dependency on fossil-fuel based energy consumption and a very slight increase in renewable energy use.

Energy demand of major sector:

The above table1 depicts that the industry has the highest energy demand of about 61.47% of total energy demand, followed by transport sector 17.92%, residential 10.49%, commercial 7.72%, and public services including others 2.23%. South Koreas is a developed country whose average economic growth rate projected to be 2.8% from 2011 to 2035 in the South Koreas second energy master plan [1] and also from the table we can say that the projected energy demand is getting flattened by 2035 to 2050. In projected demand profile for 2035 also industry sector is dominating and it will be dominate in 2050 too.

Similar can be seen for 2035 and 2050 by other sectors as same 2020. As we can see that the demand by source wise is increasing mostly for electricity in 2050 which is about 58.544 million toe, it is due to shift of end use towards electrification of end use energy for most of the sectors.

Current Measures and policies in action up to 2035 to reduce demand are:

1. Adjustment of relative energy pricing
    a. Electricity energy rate adjustment needed so that it can reflect the various social cost of production, transportation, and power distribution.
    b. Electricity rate rationalisation set to realistic levels, particularly for industry whose power consumption is higher at prices lower than production cost.
2. Measures to improve demand management by sector
    a. **Industry**: energy consumption reduction through target management scheme and other measures in accordance to GHG emission reduction target by 2035 compared to BAU. Encourage small and median scale industries to voluntary energy conservation by providing additional fund and support. Implement energy demand management and energy efficiency activities in industry.
    b. **Transport**: design of new fuel efficiency standard so that average fuel efficiency should reach to the level of EU and Japan standard. Induction of eco-friendly vehicles like hybrid cars, electric cars, building charging infrastructure.
    c. **Building**: Gradually improve the energy efficient design standard for newly build buildings to achieve net zero energy building by 2035. Strengthen the consultation system for energy use plans and recommend efficient use of integrated energy and active use of renewable energy.
3. Improvement in Energy efficiency of appliances
    a. Establish energy efficiency management standards for built-in energy-using appliances installed by developer in buildings.
    b. Enhancement of energy efficiency standards to improve energy consumption efficiency by banning production and sale of incandescent light bulbs and expanding the distribution of LED lights.
    c. Develop a road map for energy efficiency management programs, including energy efficiency labelling on products to reduce market uncertainty.

A study was performed to analyse the demand profile for the 2050 net zero scenario by *Jong Ho Hong and Jitae Kim* in 2019 [3], according to the analysis for net zero scenario the reduction in total demand should be by 23.08% (157.68 million toe) compare to level of 2020 (205.9 million toe) and Compare to BAU level for 2050 it will decrease by 44.51%. According to countries planned measures and current policies in action the countries demand will projected instead of decreasing it increases by 11.5% (229.6 million toe) compare to 2020 level and with comparison to BAU demand it will decrease by 19% by 2050.

Based on Fig1. we can say that South Koreas policies and measures are not sufficient to meet required mitigation level to achieve net Zero target by 2050 as demand is not decreasing further instead following flattened profile.

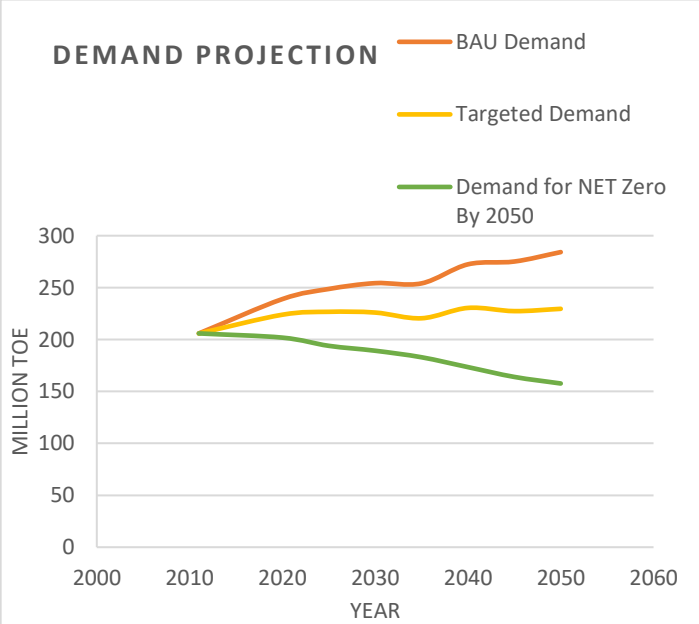


Fig 1. Demand Curve projected, BAU, and Required by 2050

South Koreas Present and Projected Energy Generation profile:

South Koreas final energy consumption present time majorly dominated by electricity as end use energy and it going to increase significantly by 2050 due to significant increase in end use electricity energy as we seen in demand profile for 2050, so the decarbonisation of power (electricity) generation is major carbon neutral strategy. South Koreas electricity generation in 2020 was about 560 TWh [4], which projected to 1200 TWh in 2050. We can see in table 1 that the current share of electricity in final energy consumption is 20% in 2020 which is projected to increase according to current policy scenario to 25.45% of total final energy consumption in year 2050.

Table 2: Electricity generation for current and projected

Items	2010	2020	2035	2050
Total Generation				
BAU Scenario	498.378	578.592	809.68	917.64
Net zero Scenario	498.378	578.59	921.57	1200
Source wise Generation for net zero generation				
Coal	219.276	206.456	141.73	0
Oil	18.935	7.294	0	0
Natural gas	103.184	163.074	70.86	0
Nuclear	148.596	160.184	99.16	0
Hydro	6.472	7.148	43.62	28.2
Solar PV	0.772	17.967	350.19	677.64
Wind	0	3.151	141.73	310.56
Biofuels	0.794	8.134	27.64	56.4
Other	0.349	5.184	46.07	127.2

The data for the net zero scenario have been taken from a Jong Ho Hong's [3] long term energy strategy scenario, and the projected generation scenario applied to the MOTIE [1] data for generation to get projected energy generation profile for 2050. The 2020 energy mix for electricity generation is dominated by coal 35%, followed by natural gas 28%, nuclear 28%, 1% oil, 3.1% solar, less than 1% wind and remaining other renewable sources.

According to Jong Ho Hong's prediction to achieve net zero by 2050, South Koreas country's total electricity generation should be fulfilled 100% by renewable energy supply as shown in **Fig2** also as **table 2**, due to fossil fuel-based sources will be no longer in use for electricity generation. In 2050 the share of solar will be dominant about 56%, followed by wind including offshore 26%, 5% biofuels, 2% hydro, and 11% other renewable which includes tidal, ocean, etc. This results in zero GHG emission by power generation sector which accounts for 37% of total emissions [4].

The key assumptions involved in the development of net zero electricity generation are:

- 100 % reliance on Various renewable energy sources for energy generation by 2050.
- Natural gas heating and cooling assumed to be replaced by renewable energy through total electrification.
- All forms of power plants including nuclear and coal- power plants going to be shut down by 2050 and final energy demand will be supplied by renewable energy.

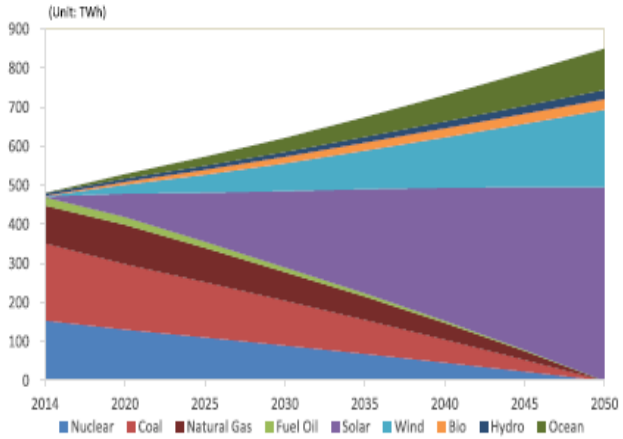
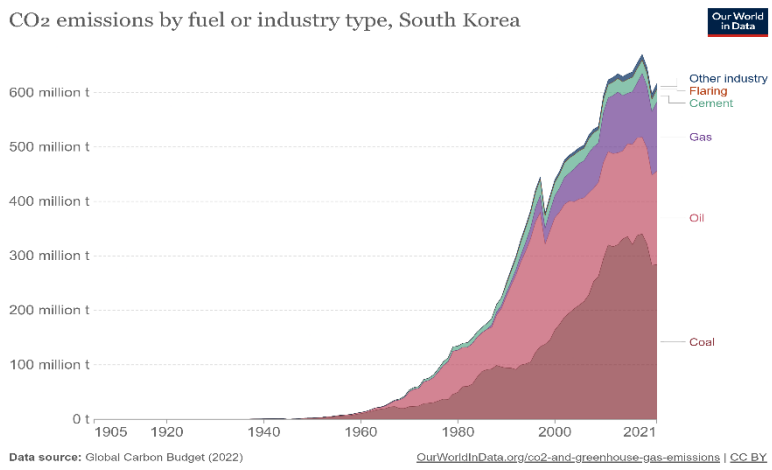


Fig.2: Electricity generation profile for net zero scenario
Source: Long-term energy strategy scenarios for South Korea: Transition to a sustainable energy system

South Korea's GHG emission profile:



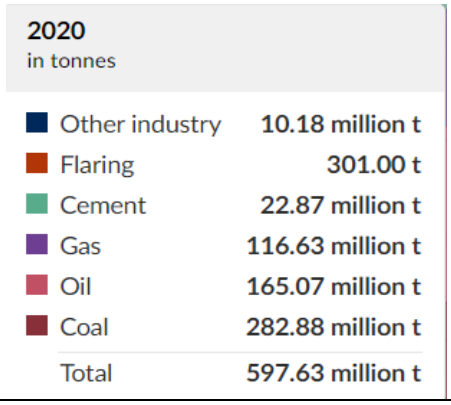


Fig.3: CO_2 emission by fuel or industry type
Source: //ourworldindata.org/co2//south-Korea

South Korea share in global annual GHG emission is about 2%. Its major contributors to annual emissions are power sector 37% and industrial sector 36% [4]. In the year 2020 South Koreas CO2 emission was around 597.63 million tonnes out of which more than 90% are due to the burning of fossil fuels. Approximately 80% of energy supply is fossil fuel dependent which is majorly responsible for the 597.63 million toe CO2 emissions. Coal is the major contributor by fuel type accounts for 282.88 million tone which is 47.33% of total emission, followed by oil 165.07 million tone (27.62%) which is majorly used in transport sector, natural gas 116.63 million tone (19.15%) which is majorly used for heating and cooling purpose.

Net Zero Plan for South Korea:

South Korea announced net zero by 2050. To become carbon neutral by 2050 South Korea needs to reduce its carbon emission from 683 million tons CO2 equivalent [5] in 2023 to zero by 2050 in 27 years. In Paris Agreement, Korea targeted a reduction in emissions to 536 Mt CO_2-eq by 2030 [5]. This was revised in 2021 with a new target of 437 Mt CO_2-eq by 2030 [5] to support the announced net zero goals.

To achieve net zero by 2050 South Korea's proposed Carbon neutral strategy (CNS) [4] with two main scenarios that have varying implications for energy supply and transport sectors:

Scenario A: Total termination of fossil-based energy generation or conversion into zero emission, targeting a 71% share of new renewable energy (NRE), targeting 80% share of electric vehicles in the transport fleet and 17% from alternative fuels such as hydrogen and biofuels.

Scenario B: Partial maintenance of thermal generation while gas remains the primary flexible power source, high carbon capture, utilization and storage (CCUS) deployment, 61% share of NRE, targeting more than 85% of cars with no IC engines.

Emission targets for Korea's Carbon Neutral Strategy

	2018 emissions ($MtCO_2$-eq)	2050 emissions ($MtCO_2$-eq)	
		Scenario A	Scenario B
Power	269.6	0	20.7
Industry	260.5	51.1	51.1
Building	52.1	6.2	6.2
Transport	98.1	2.8	9.2
Agriculture	24.7	15.4	15.4
Waste	17.1	4.4	4.4
Hydrogen	0	0	9
Fugitive	5.6	0.5	1.3
SUBTOTAL	**727.7**	**80.4**	**117.3**
Sink*	-41.3	-25.3	-25.3
CCUS	0	-55.1	-84.6
Direct Air Capture**	0	0	-7.4
TOTAL	**686.4**	**0**	**0**

* Sinks involve measures to reinforce absorption capacity such as: forest cultivation, ecological restoration, reforestation of idle land, cultivation of urban forests, expansion of long-life wood production, expansion of carbon sinks using marine ecology and expansion of grassland area.
** Carbon offsetting using direct air capture (DAC) is used to cover the remaining emissions from the transport sectors

Sources: Government of Korea (2021a), 2050 Carbon Neutral Strategy of the Republic of Korea.

Fig4: Emission targets for Carbon neutral strategy
Source: Reforming Korea's Electricity Market for Net Zero, IEA

To achieve net zero by 2050 South Korea laid out some measures and policy in its most recent Energy master plan in 2019 with the objective targeted for 2040 [4] including NDC target for 2030 also-

- A reduction of 39.2 million toe of final energy consumption by 2040.
- 30% to 35% share of renewable energy in energy generation by 2040.
- Targeted 8.3 million electric vehicles and 2.9 million hydrogen vehicles up from 55000 EV's and 1000 hydrogen vehicles in2018.
- Increase hydrogen supply to 5.26 million tonnes by 2040 up from 130000 tonnes in 2018.
- A reduction of 39.2 Mtoe of final energy consumption.
- Gradual reduction of fossil fuel in energy generation in consultation with affected communities and preparation of retrofits for low carbon fuels such as biofuels, hydrogen, and ammonia.
- Support commercialisation of R&D technologies for floating solar with hydro, hydrogen turbines and marine energy.

Based on above policy, measures and NDC targets by the South Korea, projected CO_2 emission can be shown in Fig. 5, which shows significant reduction in emission.

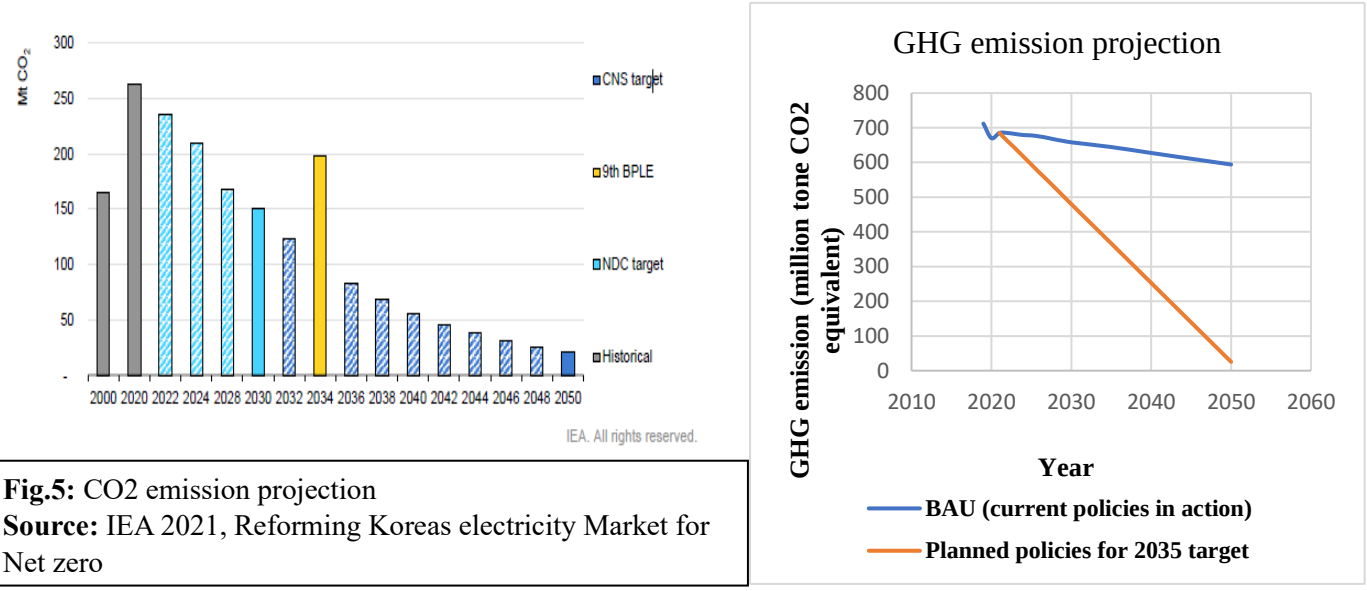


Fig.5: CO2 emission projection
Source: IEA 2021, Reforming Koreas electricity Market for Net zero

It can be clearly seen in the above graph that the Koreas emission reaches almost zero by 2050 based on policies and NDC targets for 2040 and 2030 respectively. The major reduction in CO_2 emission will be due to the decarbonization energy generation system with 100% share renewable energy generation which will reduce by 37% addition to that 19% reduction will be achieved by decarbonization of transport sector with 80% share of EV and 17% by hydrogen fuel and remaining by biofuel and ammonia. The significant reduction will also be seen in building sector due to more and more end use electrification and improvement in energy efficiency by the years. In industrial sector also electrification of various possible industrial processes and use of biofuels, hydrogen, and other possible alternative sources for industrial processes where very high input heat is required which is currently powered by coal, oil, and natural gas.

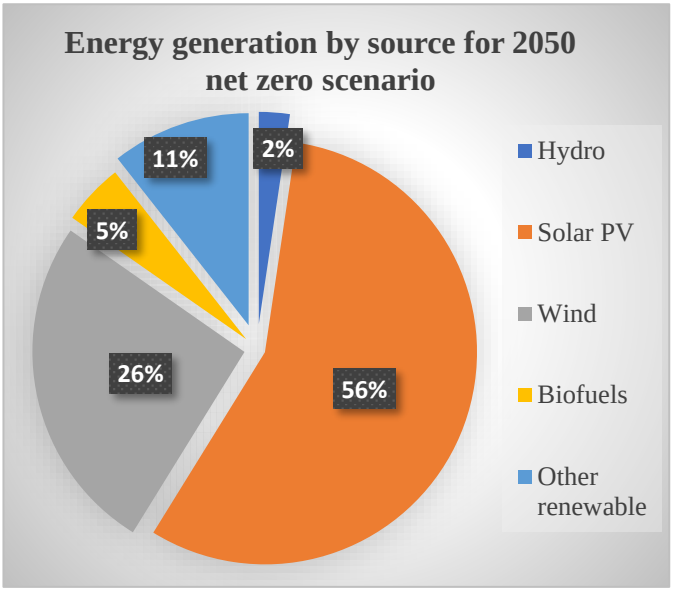
Despite this all, there are some constraints where decarbonization is not that feasible like aviation and transoceanic maritime transport, certain industrial process which involves chemical reactions, as well as other raw materials in manufacturing processes which results in downstream emissions. These should be reduced with deployment of Carbon Capture, Utilization and Storage (CCUS). And Direct air capture will be required for removal of historical emissions.

Net Zero Scenario by 2050:

As the Net Zero Target Achieved by South Korea, the share of renewable energy in its energy system will be projected to rise by almost 98% as the fossil fuel-based supply replaced by renewables.

It will also help to reduce country to achieve energy security by reducing the energy supply dependency on imports.

For net Zero projected scenario, electricity generation by source will be like-
Solar - 56%
Wind including Offshore - 26%
Other renewables include Ocean, Tidal, etc. - 11%
Biofuels – 5%



Additional measures the country should take to achieve net zero:

South Koreas demand side contribution in the CO_2 reduction is relatively lower as we can see that in projected scenario also the demand is getting flattened instead it should be reduced by the years, most of reduction is due to energy generation shift towards the renewable sources, hence Korea need to focus on its demand mitigation to improve demand side contributions in emission reduction.

- South Korea Should Focus on Energy efficiency, It can achieved by research and development in new energy saving products and technology.
- In the Industrial sector, need improve energy and raw material efficiency.
- Optimize the industrial production processes to reduce carbon emissions.
- Increase the deployment rate of renewable energy sources as the current deployment rate of renewable energy is very low which is insufficient to achieve set target by 2050 of 71% renewable energy generation.
- Need to extend the deployment of renewable energy policies to power generation, heat generation, transport sectors. Also implementing a private sector driven deployment system

References

[1] MOTIE, "Korea Energy master plan outlook and policies to 2035," Ministry of Trade, Indusrty and energy (MOTIE), South Korea, 2014.

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[5] "climateactiontracker," [Online]. Available: https://climateactiontracker.org/countries/south-korea/policies-action/. [Accessed 15 november 2023].