

Decarbonization strategies through sectorial integration for the case of Korea

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RE EXPANSION IN KOREA

- ▶ Korea is in a special situation of
 - Being an isolated electricity system in terms of interconnectivity
 - Having a high import share of energy
 - Having a large share of nuclear power production, which is not fast
 - Methodology: Demand– Excel, Supply- optimization model

SECTORIAL INTEGRATION CONCEPT

- ▶ Variable RE will bring
 - Curtailment

ENERGY SYSTEM MODEL

► Energy system model for whole sector

- Started from power system model in project "Accelerating Energy transition in Korea"
- More RE source -> more amount and frequent curtailment
- Transportation, Heating(not cooling), Industry sectors are linked via electrification, hydrogen, energy storage

Power to heat

- Mostly electrification (CHP expansion)
- HP + E-boiler + Thermal energy storage

Power to mobility

- EV
- FCEV(Hydrogen)

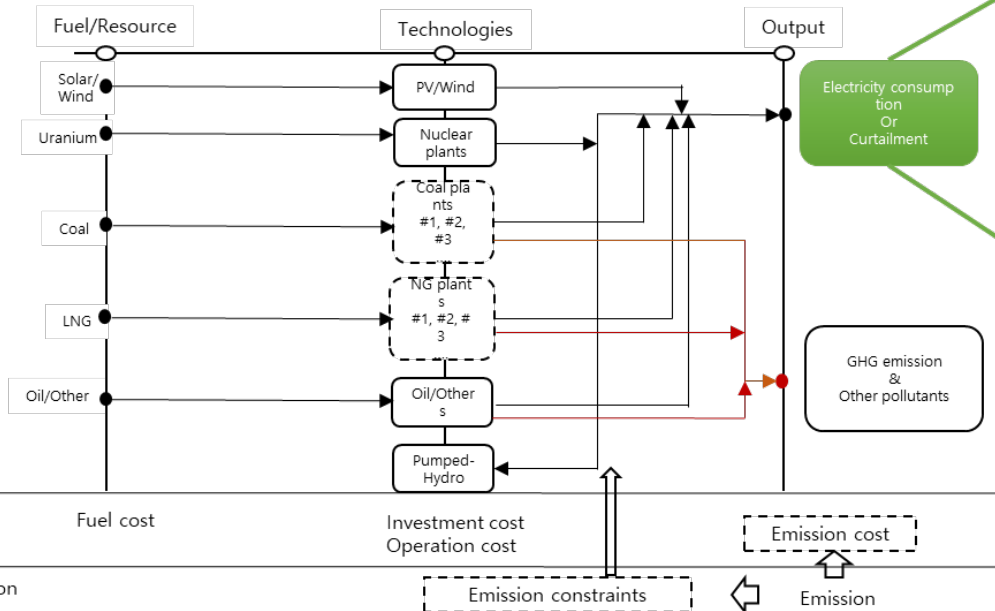
Decarbonization of Industry

- Material
- High and low temperature heat
- Electrification
- Hydrogen

Power to Gas(hydrogen)

- Electrolyzer
- Hydrogen tank

Electricity system model

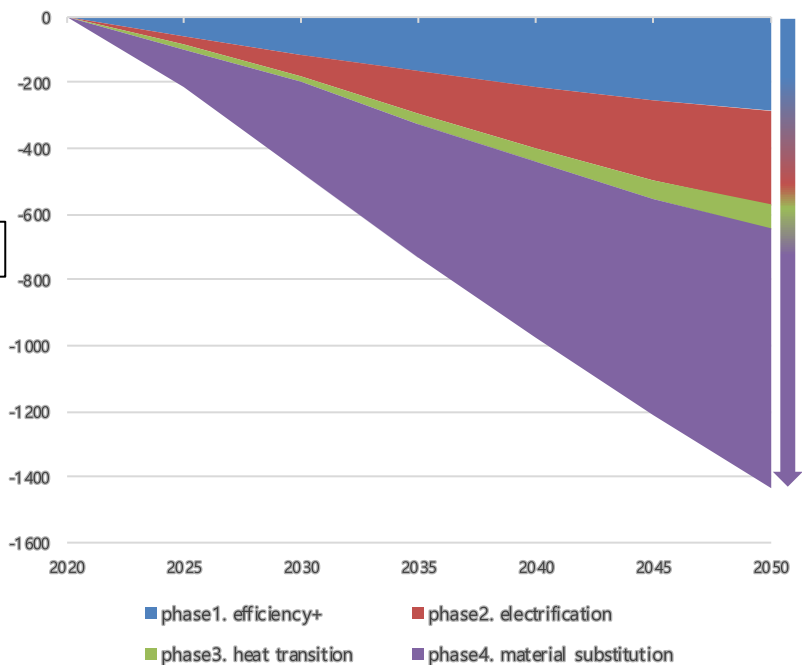


FINAL ENERGY CONSUMPTION FOR THE FUTURE

► Assessment of future energy consumption

- Final energy consumption change by sector started from current level of energy consumption
- Four phases applied for decreasing final energy consumption
- Through the four phases, final energy consumption is decreased by 60%

Final energy consumption reduction



Phase1> Efficiency enhancement

Phase2> electrification

- Transportation: EV Building: HP + E_boiler

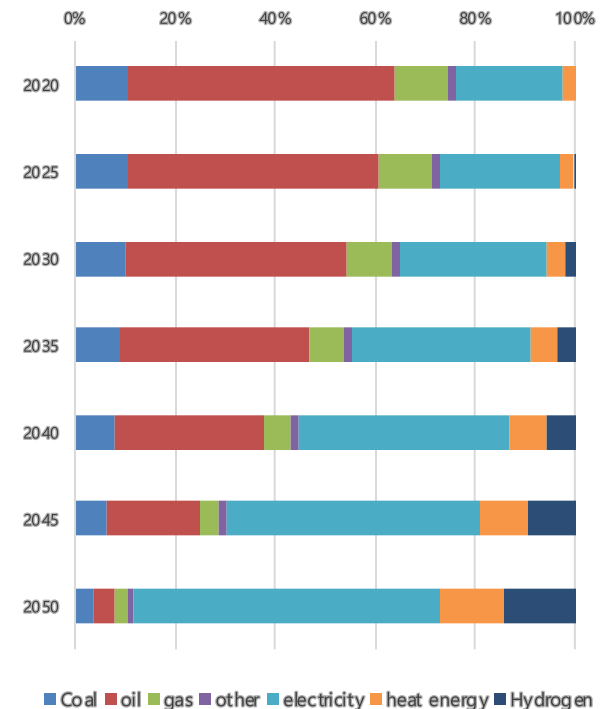
Phase3> heat transition(low temp.)

- Building: district heating expansion
- Industry: decarbonization of heat energy

Phase4> material substitution

- industry: decarbonizing industrial material
- Transportation: FCEV

Energy source change



INDUSTRY SECTOR

▶ Main assumptions

- Electrification of industrial processes and heat consumption
- Decarbonization in industrial materials
- Decarbonization strategy by industry
 - Refinery: oil demand decreased in transportation sector, naphtha affluent fuel import to decrease GHG
 - Petrochemical: recycle of chemical products, replace with hydrogen
 - Steel: electric furnace and replace coke with hydrogen (direct reduced iron)

✓ Fuel consumption and material consumption in industry sector

✓ Fuel consumption replacing with electricity and heat generation

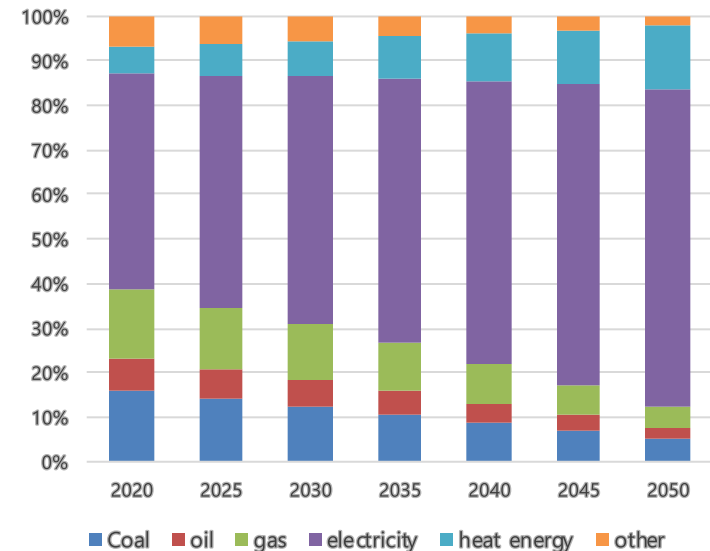
✓ Low and high temperature heat demand by industry

(TWh)	Iron	Cement	Refinery	Chemical	Etc	total
Low temp(=<100)	2.9	0.6	21.7	20.1	12.1	57.4
High temp(>100)	82.7	17.2	79.9	73.8	38.2	291.8

✓ Material consumption assessment (fossil fuel)

(TWh)	Iron	Cement	Refinery	Chemical	Etc	total
coal	152.79	15.05	-	-	-	167.8
oil	-	-	449.04	316.06	-	765.1

Energy source change in industry sector



INDUSTRY SECTOR

► Final energy consumption reduction in industry sector

- 1. Energy efficiency improvement-> 2. expansion of electrification-> 3. Heat transition
 - Efficiency increased by 5% every five years
 - Increase of electricity share by 4% every five years (2020- 48.7%, 2050- 72.7%)
 - Replace fuel with electricity in low temp. heat demand(2020: 33.7TWh, 2050: 57.4TWh)

Phase	2020	2025	2030	2035	2040	2045	2050
1. Energy efficiency improvement	562.6	534.5	507.7	482.4	458.2	435.3	413.6
2. Additional Electrification	562.6	526.6	492.8	461.1	431.3	403.3	377.1
3. Heat transition	562.6	525.6	490.7	458.0	427.3	398.5	371.7

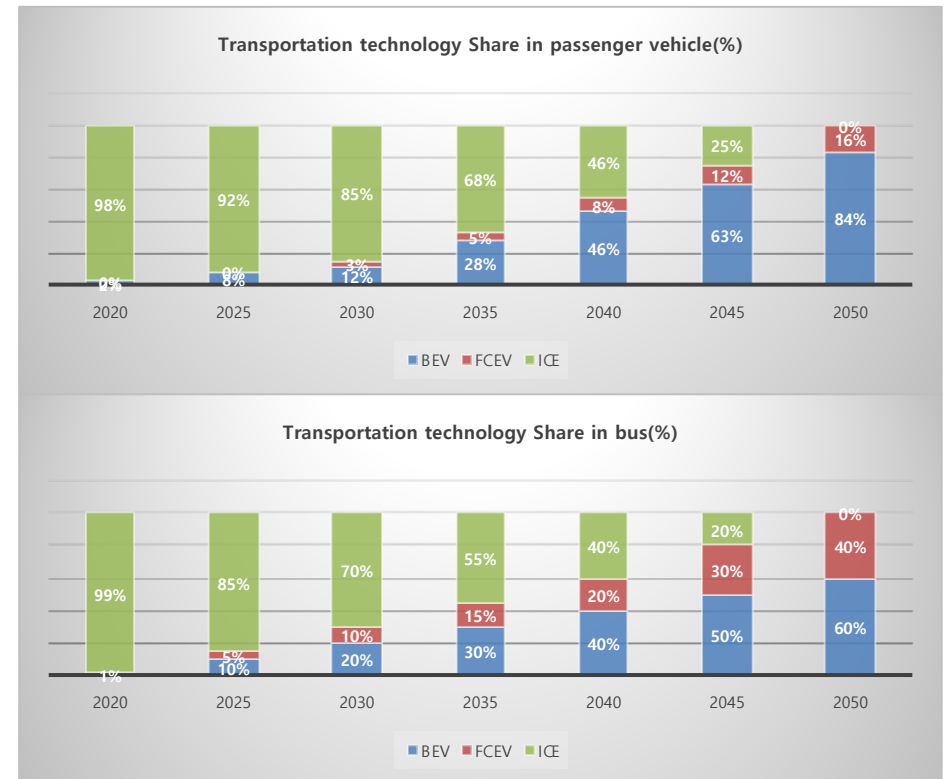
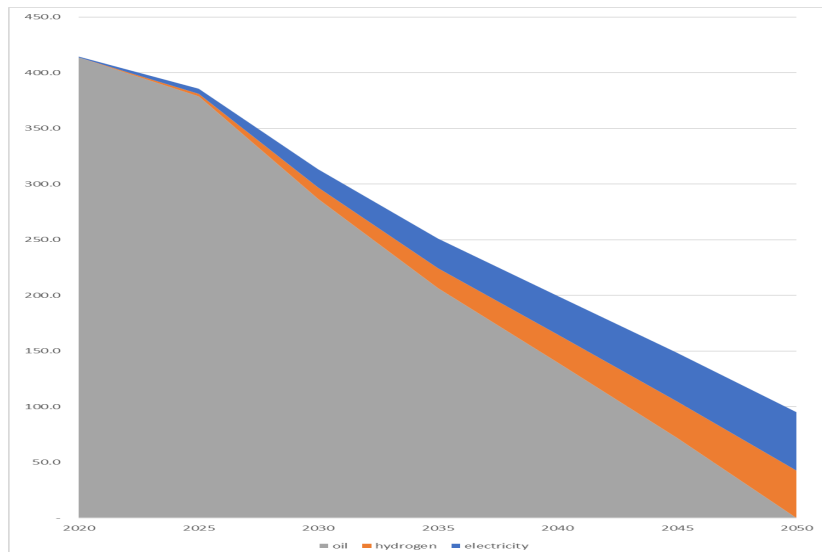
Of 371.7 TWh
 Electricity 300TWh
 Heat and Hydrogen : rest

TRANSPORTATION

► Main assumptions

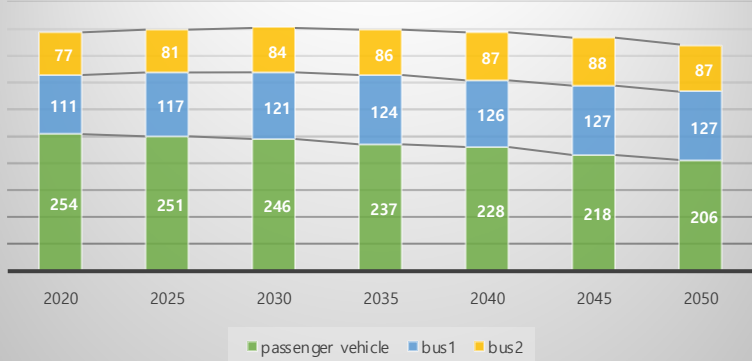
- Focusing on road transportation
 - 98% of energy consumption and 96% of GHG emission in transportation sector is focused on road transportation
 - Rail is already achieve high level of electrification
- Less ICE and more Evs and FCEVs
- Compared to EV efficiency (passenger vehicle) relative efficiency of FCEV (67.4%) and ICE (13.7%)

[Energy consumption by fuel]

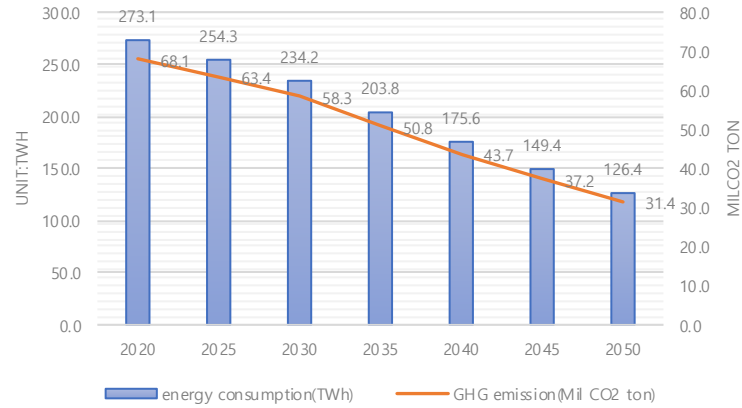


TRANSPORTATION

Travel transportation demand (unit: bil.pkm)

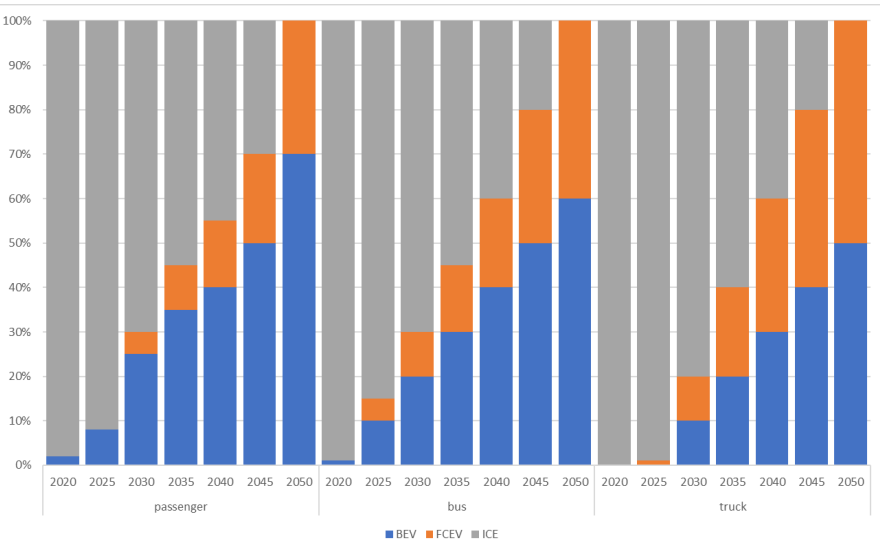


Energy consumption and CO2 emission

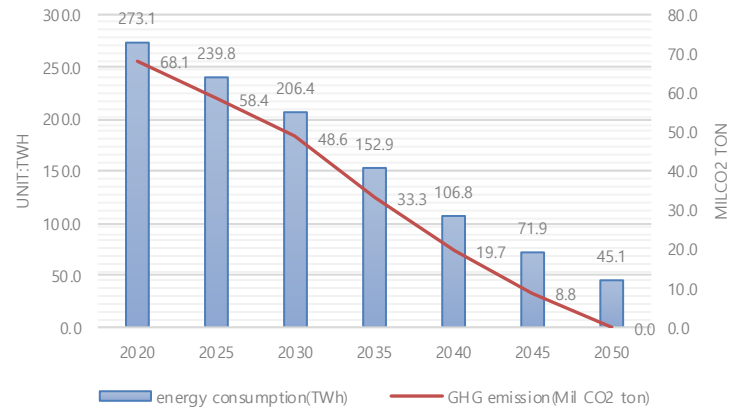


Travel transportation demand

- Modal change (passenger vehicles to public transportation)
- ICE Passenger vehicles efficiency increase by 50%
- Passenger occupancy is assumed to increase (1.14 to 1.3 person)



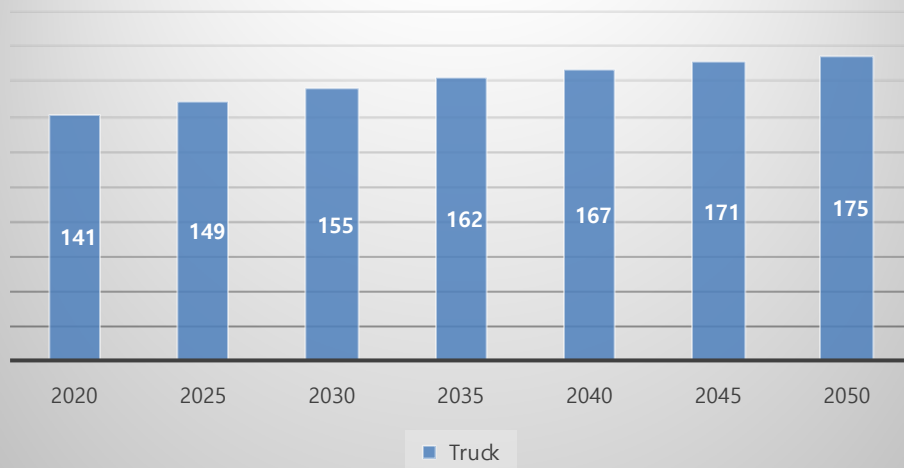
Energy consumption and CO2 emission



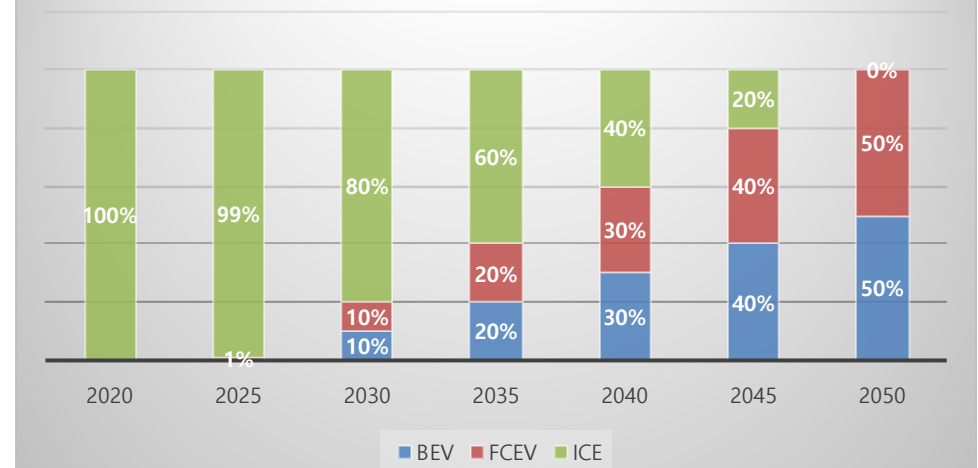
Modal change + transportation technology change

TRANSPORTATION

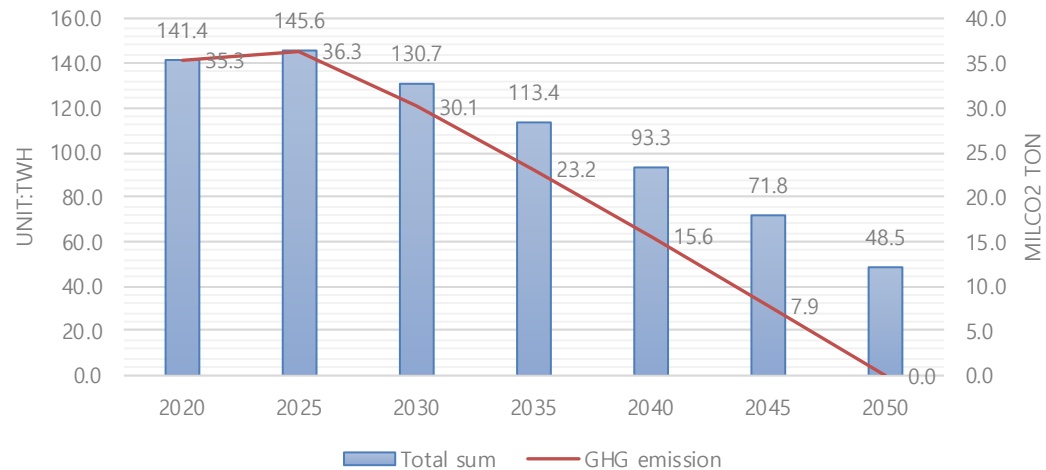
Freight transportation demand (unit: bil.tkm)



Share of truck(%)



Energy consumption and CO2 emission



1. Assessment of heating demand in building energy consumption

Phase 1; 5% energy efficiency increase by five years

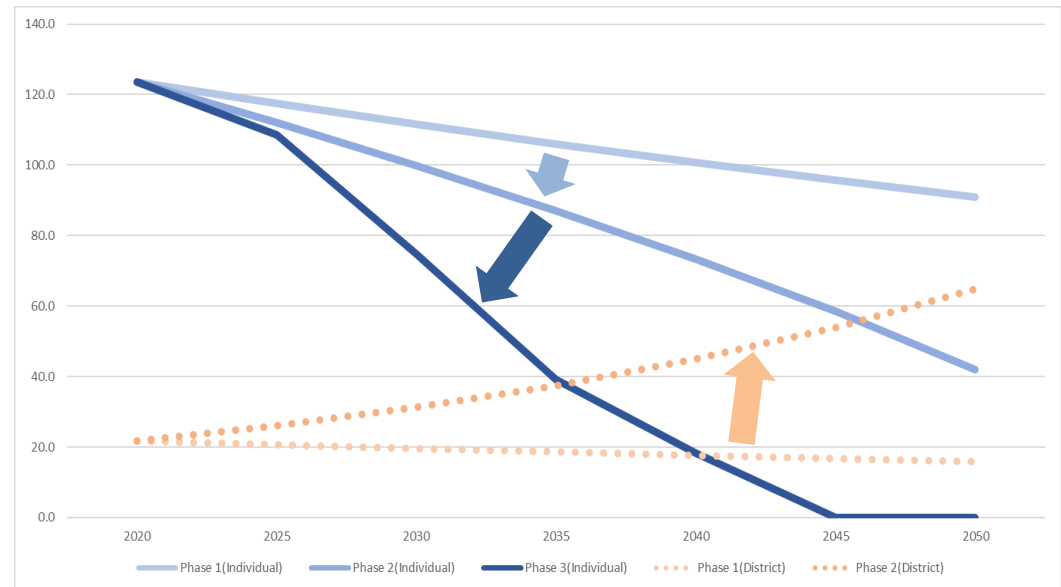
	2020	2025	2030	2035	2040	2045	2050
individual	123.6	117.4	111.5	106.0	100.7	95.6	90.9
district	21.7	20.6	19.6	18.6	17.7	16.8	16.0

Phase 2; expansion of DH 20% by five years

	2020	2025	2030	2035	2040	2045	2050
individual	123.6	112.0	99.9	87.1	73.3	58.4	42.0
district	21.7	26.0	31.3	37.5	45.0	54.0	64.8

Phase 3; 100% electrification of individual heating by 2045

	2020	2025	2030	2035	2040	2045	2050
individual	123.6	108.6	74.9	39.2	18.3	0.0	0.0

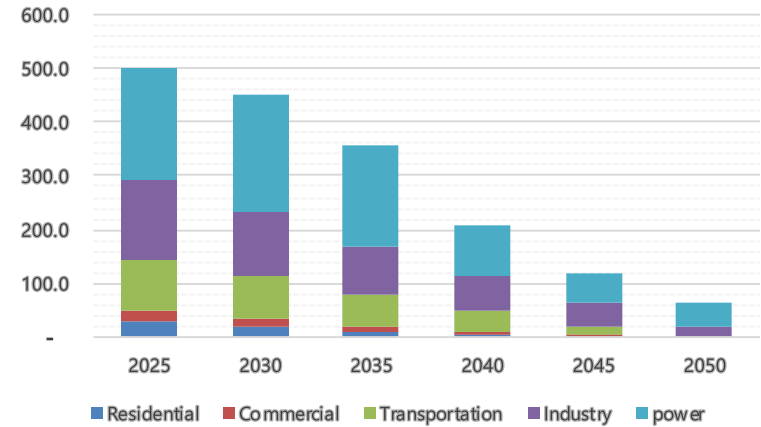


SUMMARY

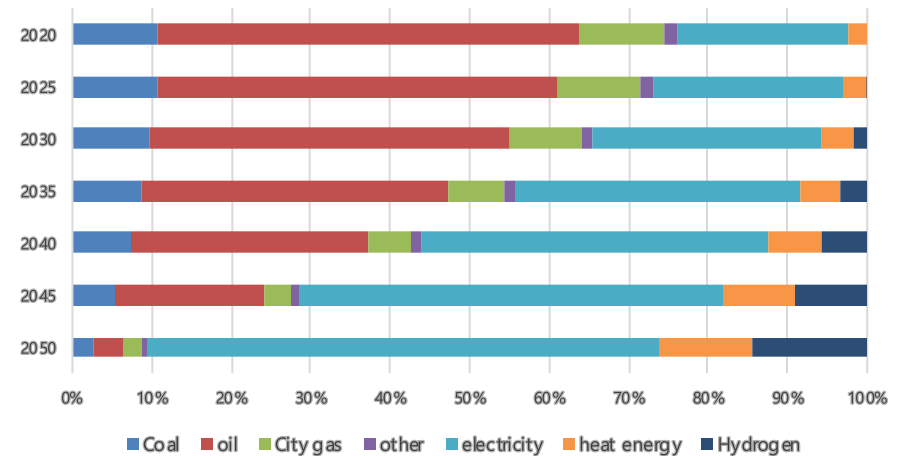
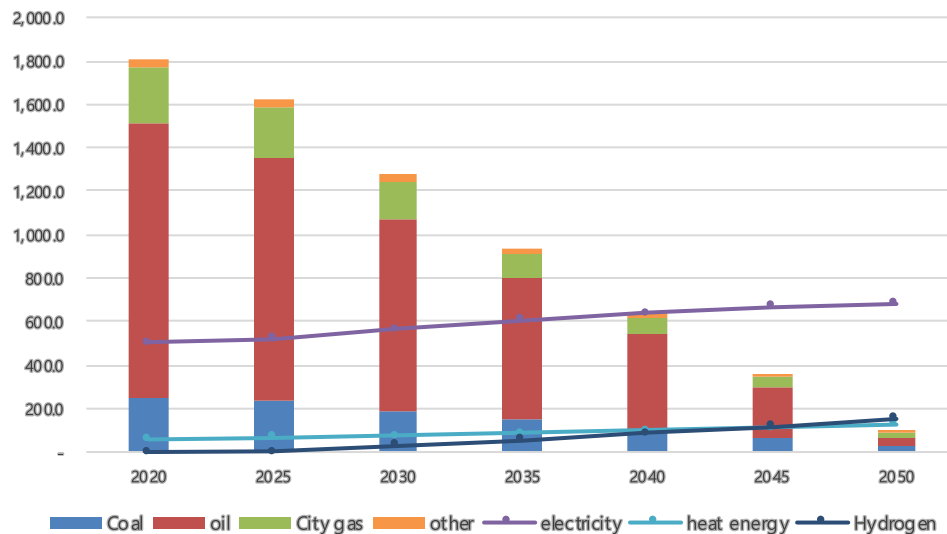
▶ Research objectives

- Net zero (90% reduction from current emission level)
- Sector coupling
- Time horizon : 2020~2050(five year interval)
- Methodology: Demand- Excel, Supply- optimization model

GHG emission by energy sectors

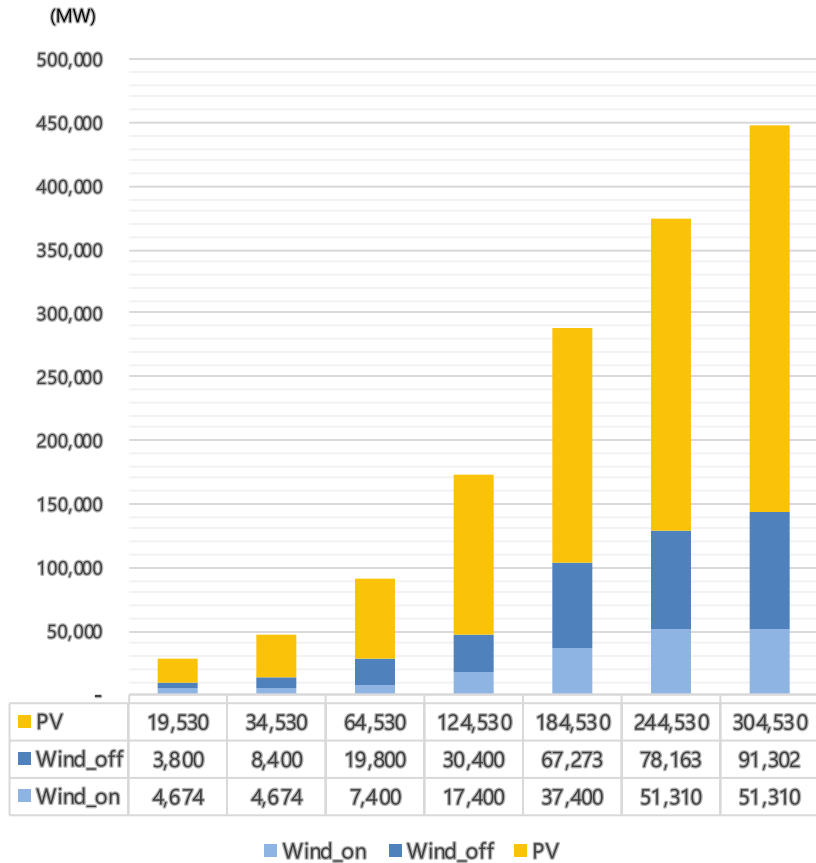


Future energy supply change

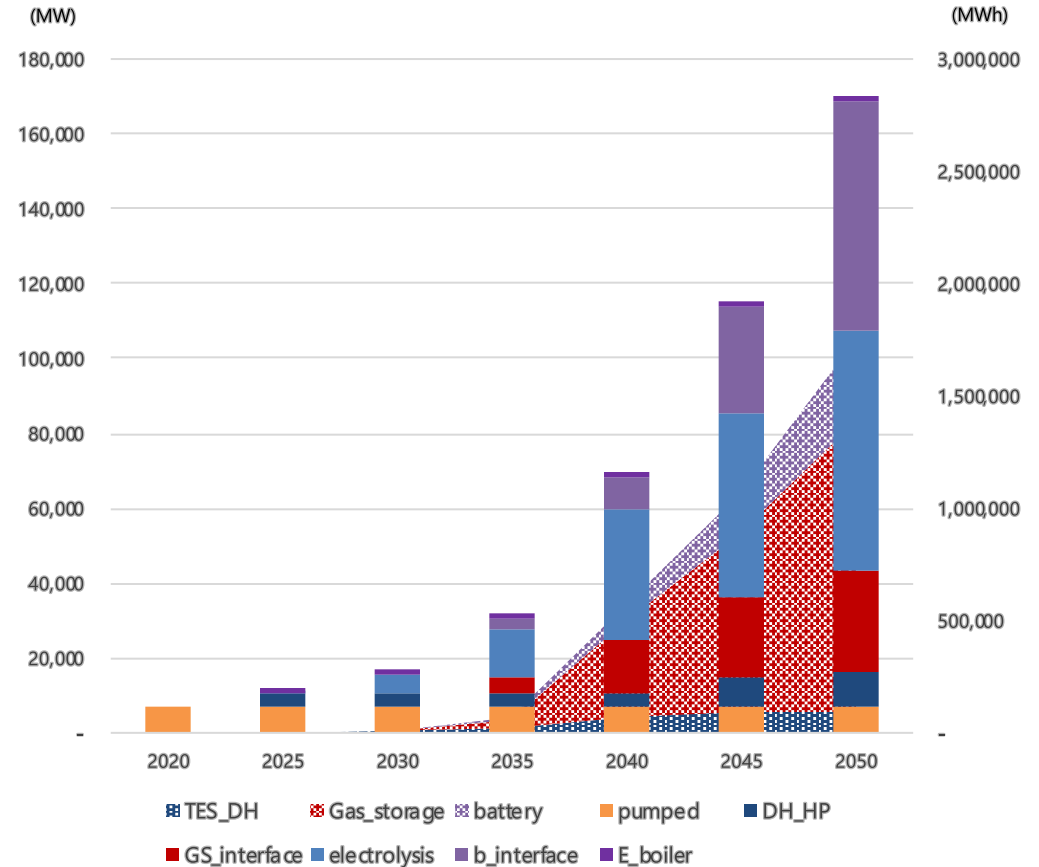


RE AND FLEXIBLE TECHNOLOGIES DEPLOYED

[RE installation change (2020~2050)]



[Flexible technologies installation (2020~2050)]



TES_DH : Thermal energy storage in DH network

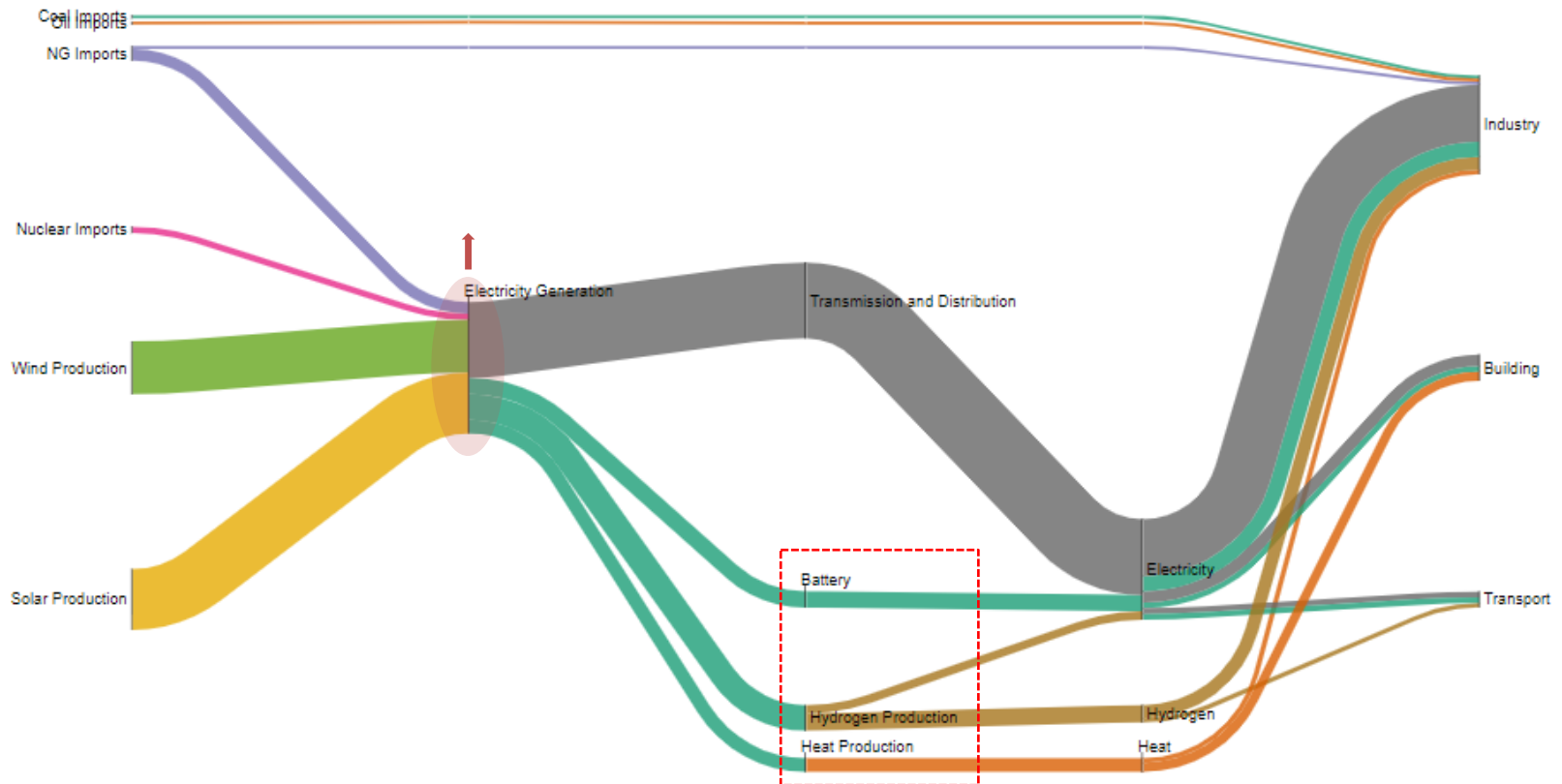
DH_HP : Heat Pump in DH network

E_boiler : Electric boiler in DH network

RESULTS

► Sankey diagram

- 2050 energy flow from primary energy sources to final energy consumption
- NG will be still used for power generation (tiny amount), however decarbonization of power sector is almost done(43 mil CO2 ton in power sector)



RESULTS(HOURLY)

