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Low Carbon Strategic Analysis of Taiwan's Industrial Sector

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Outline

- Background
- Motivation and Problem Statement
- Methods
- Low carbon industrial and power technologies
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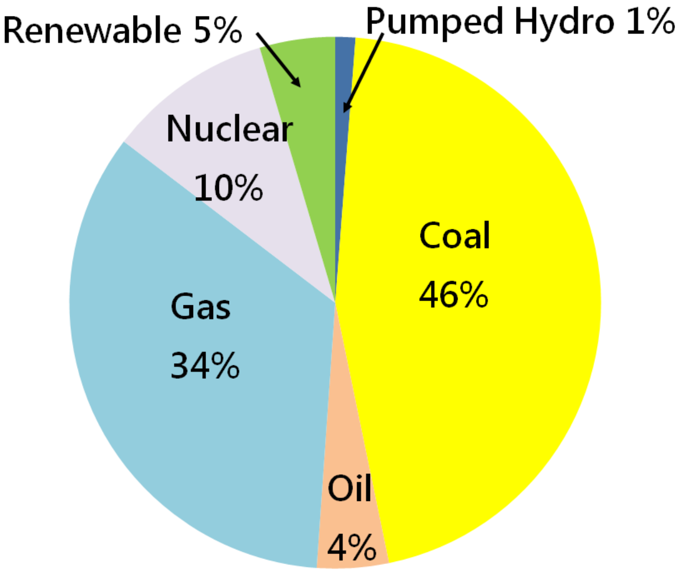
Background information about Taiwan

- 36 thousand km² (1.8 times of the size of Slovenia)
- Population density: 651 people per km² (6.4 times compared to Slovenia
- Highly dependent on international trade. Imported fuels currently account for around 98% of Taiwan's energy supply.
- 84% of our power generation comes from fossil fuels



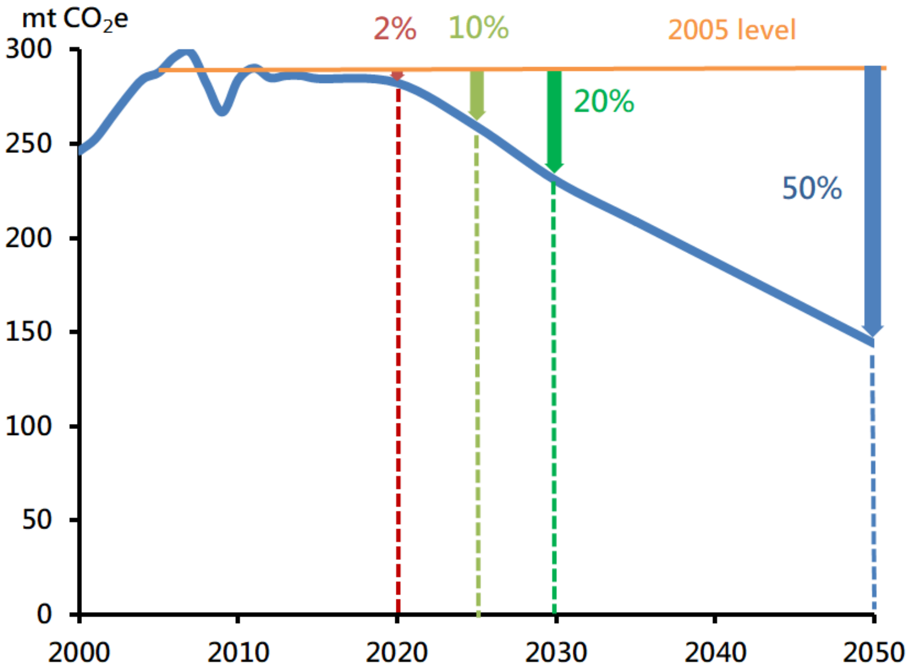
Total installed capacity：52.46 GW
Total generation：275.6 billion kWh

- **Power generation by fuel (2018)**

Background

- In July 2015, Taiwan promulgated the "Greenhouse Gas Emission Reduction and Management Act" and stipulated a GHG reduction target to reduce GHG emissions to lower than 50% of the 2005 level (288 mtCO2e) by 2050.

- Taiwan has submitted its NDC to reduce GHG emissions by 20% compared to the 2005 level by 2030 in August 2015.
- These are very ambitious carbon reduction goals for Taiwan, a developing country, to keep sustained economic growth.

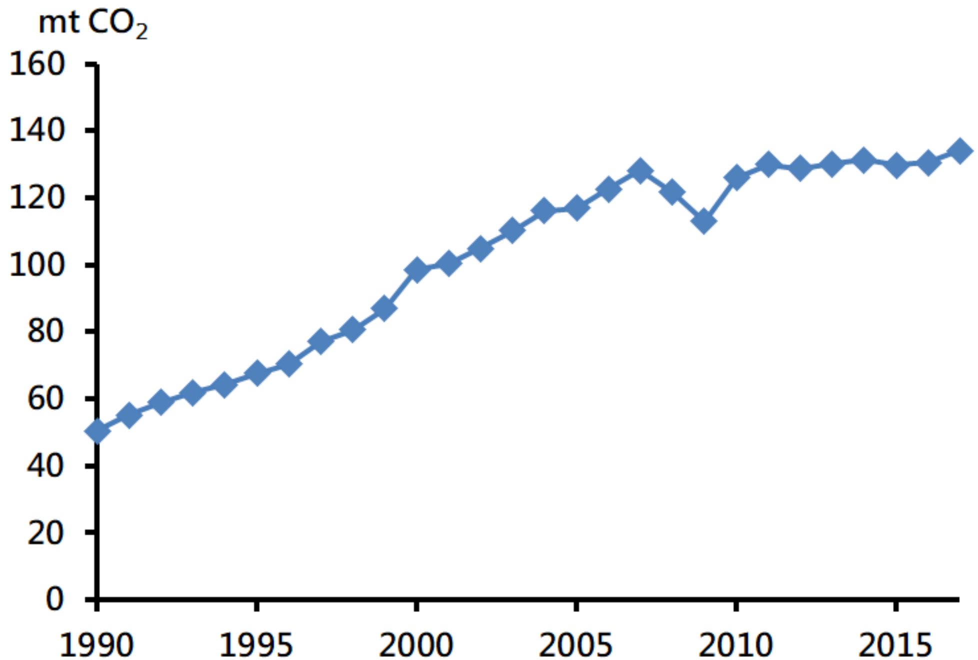


- GHG emissions in Taiwan

Source: Environmental Protection Administration Executive Yuan, 2017, ROC (Taiwan)

Background (cont.)

- Between 1990 and 2017, carbon emissions from fuel-combustion in the industrial sector increased by 165 % (3.7 % / y) in Taiwan.



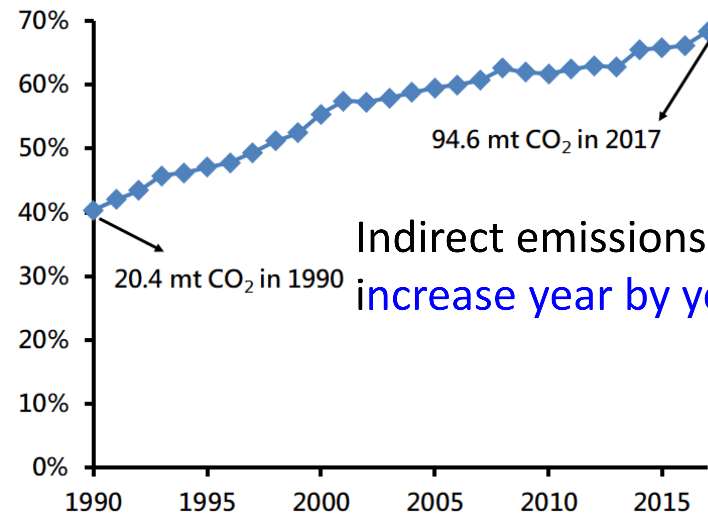
- Carbon emissions from fuel-combustion in the industrial sector

Source : The statistic of CO_2 emissions from fuel combustion, 2018, Bureau of Energy, ROC (Taiwan)

Background (cont.)

- About 70% of industry's fuel-combustion CO_2 emissions are indirect emissions from electricity use, and motor-driven systems account for 70% of that. And about 60 % of direct emissions come from the boilers.
- Therefore, development of low carbon electricity technologies, motor-driven systems and boilers are the main methods for reduction of CO_2 emissions of industrial sector in Taiwan.

share of indirect emissions in industrial sector



Indirect emissions share increase year by year

Source : The statistic of CO_2 emissions from fuel combustion, 2018, Bureau of Energy, ROC (Taiwan)

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Motivation and Problem Statement

- With "nuclear-free homeland by 2025" policy, Taiwan's six nuclear power reactors will be decommissioned as their 40-year operating licenses expire.

- Less innovation and cost reduction have taken place for industrial decarbonization technologies. This makes the pathways for reducing industrial CO_2 emissions less clear and higher cost than that for other sectors.

- That’ s why it is an important issue to analyze and propose low carbon strategies of Taiwan's industrial sector.

Motivation and Problem Statement (cont.)

- In Taiwan, about 90% of GHG emissions are from fuel-combustion CO_2 emissions, and industrial sector is responsible for about 50% among them, so the reduction of industrial fuel-combustion CO_2 emissions dominates national GHG emissions reduction action.

- This is the reason why this research focuses on the reduction of industrial fuel-combustion CO_2 emissions.

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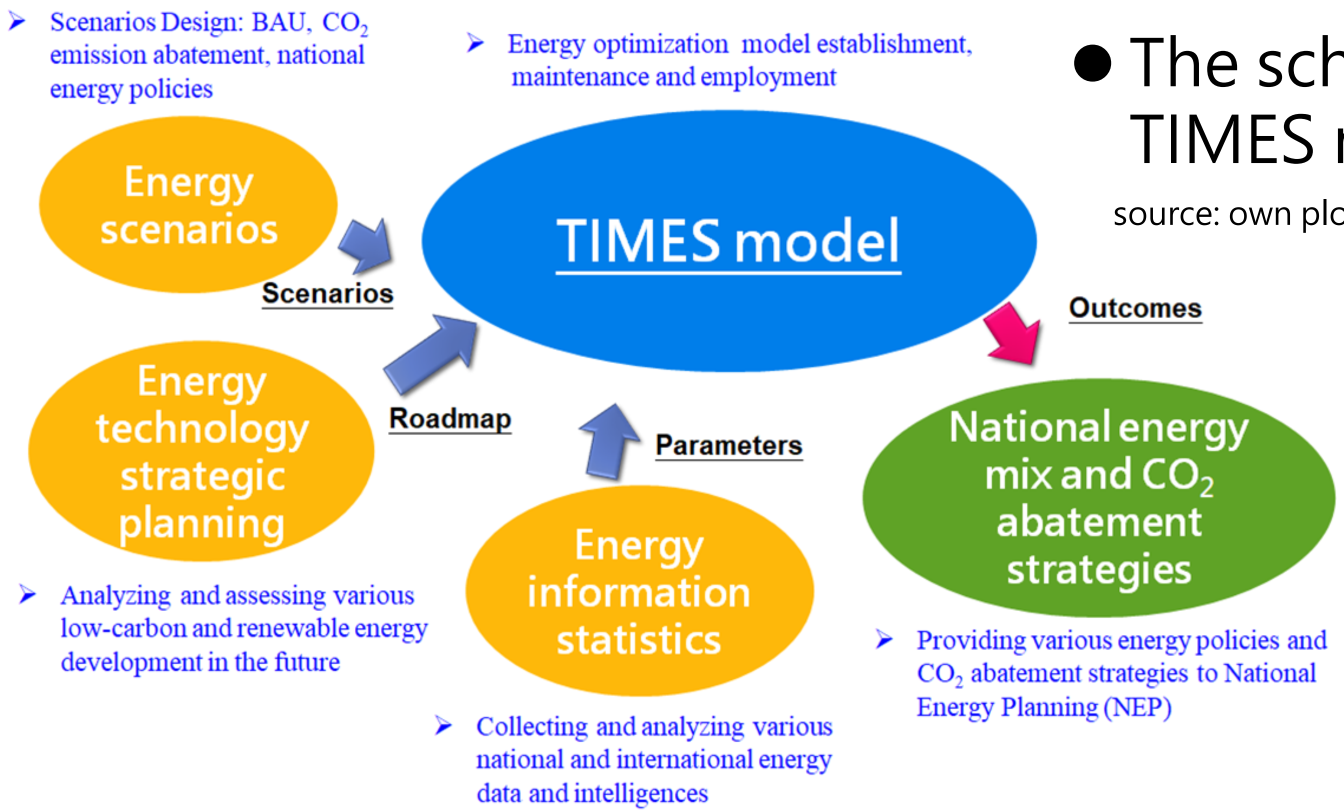
Methods

- This research first inventoried the main low-carbon technologies in Taiwan's industrial and power sectors. And all these technologies are built into the TIMES model.

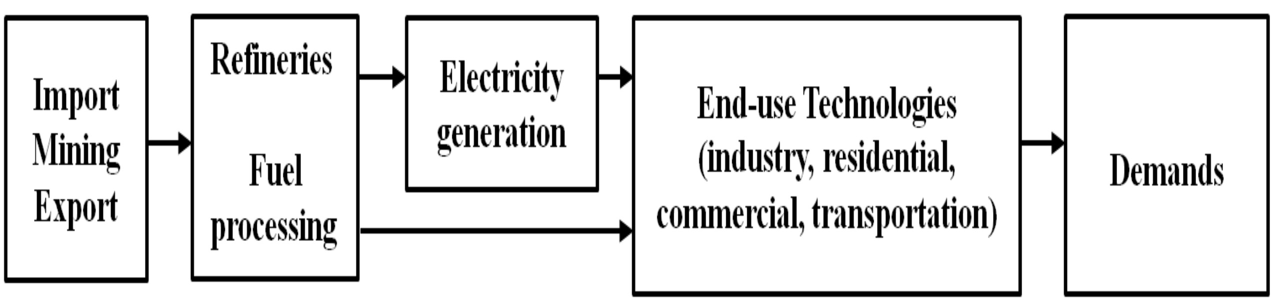
- TIMES (The Integrated MARKAL-EFOM System) model generator was established by IEA, which uses linear-programming to produce a least-cost energy system, it simulates energy system optimization plans for global, regional or single countries in the next 20 to 50 years. TIMES can be adopted to evaluate optimal energy deployment for CO_2 emissions reduction scenarios.

Methods



- The scheme diagram of TIMES model

source: own plot



- The flowchart of TIMES model

source: own plot

Methods (cont.)

- Assumptions of scenarios

Technologies	Time	Reference scenario	Carbon reduction scenario
Coal-fired, Gas-fired[1,2], Oil-fired power plants	2017-2028	Upper bound set as 10610 TPC planning	
	2029-2050	Upper bound of coal-, gas-, and oil-fired annual growth rate set as 1.5%/y, 5.5%/y and 0%/y, respectively	
Renewable[1] power plants	2017-2030	Upper bound set as the government planning	
	2031-2050	Upper bound set as our own estimation	
Nuclear Plants	from 2015	Nuke 1-3 decommission as scheduled / Nuke 4 halt	
Cogeneration	2020-2050	Upper bound referred to reports of Bureau of Energy	
Pump storage	2020-2050	Existing capacity is 2.6 GW, but there is still 705MW potential in the future	
Industrial boilers	from 2017	1. Upper bound of gas replacing coal:20% in 2030, 40% in 2050 2. Upper bound of bio-charcoal replacing coal:10% in 2030, 30% in 2050	
Motor driven systems[3]	from 2017	Without electricity saving	Electricity saving compared with reference scenario:10% in 2030, 20% in 2050
National CO_2 reduction targets	2020	N/A	98% of emission amounts in 2005
	2025		90% of emission amounts in 2005
	2030		80% of emission amounts in 2005 (NDC)
	2050		50% of emission amounts in 2005 (Mandated target)

1.:Electricity generation from gas-fired and renewable power plants are 50% and 20% in 2025, respectively

2:Importing amount of LNG is 3270 Mton in 2025, capacity of gas-fired power plant is determined by TIMES model

3:The electricity saving rates in carbon reduction scenario are based on New Policy Scenario in World Energy Outlook (2016)

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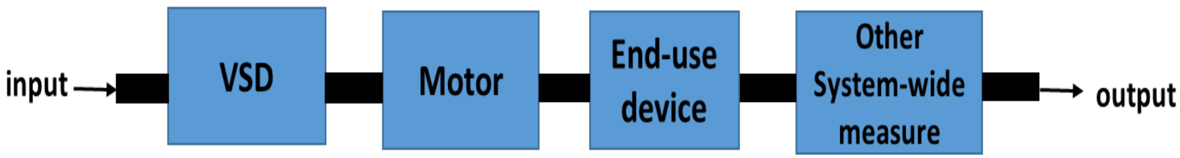
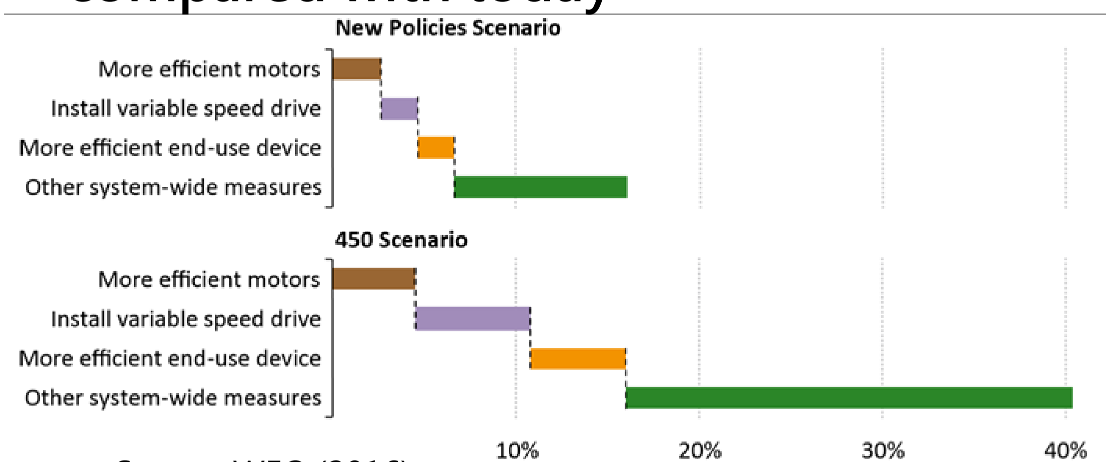
Motor driven system

- Motor-driven system



Source : Own plot

- Electricity saving in global industrial motor-driven systems in 2040 compared with today



Source: WEO (2016)

- The majority of electricity savings in electric motor systems can often be found not in the motor itself but elsewhere in the system, including system-wide measures, end-use device, and variable speed drive.

- The ranking of benefit-cost ratios are: other system measures > end use equipment > variable speed drive > motor unit.

Industrial boilers

- At present, industrial boilers are mainly coal-fired boilers, which have large carbon emissions but they are cheaper, and energy efficiency improvement is the main carbon reduction method.

- Gas-fired and bio-charcoal boilers are used to replace coal-fired one in the future

Low carbon industrial technologies inventory

Technologies \ Items	Abatement cost(NT/ton) 2030	Abatement cost(NT/ton) 2050	Category
Chemical material MDS	446.26	383.67	Motor-driven-system
Steel and iron MDS	426.53	371.14	
Other MDS	351.63	320.96	
Air conditioning in EE MDS	229.20	162.19	
Compressed air system in EE MDS	163.42	120.40	
Process in EE MDS	294.97	245.77	
Efficiency improvement of blast furnace	-2,279.28	-2,765.88	Process
Steel and iron direct casting	-2,081.88	-2,120.36	
Top gas recycle for blast furnace	-1,540.96	-1,561.75	
Efficiency improvement of electric arc furnace	-1,886.42	-2,486.20	
Process control and energy management in clinker making	-376.83	-386.69	
Efficient clinker cooler	-130.31	-140.17	
Chemi-thermo mechanical pulp	-1,144.22	-578.91	
Efficiency improvement of coal-fried boiler	-1,036.33	-1,137.21	Boiler
Gas-fried boiler	3195.9	3516.99	
Bio-charcoal boilers	3,430.85	1,501.20	

Source: INER (2017)

MDS : Motor-driven system
EE : electrical and electronic machinery

- Three categories:
  motor driven system,
  process,
  boiler
- Technologies have negative abatement costs naturally arise in the reference scenario due to cost-effective
- The central focus of carbon reduction contribution, in this research, is on the motor driven systems, gas and bio-charcoal fired boilers

Low carbon power

- With "nuclear-free homeland by 2025" policy, Taiwan government has set a target of power generation by 2025： gas-fired power generation is 50%, coal-fired power generation is 30%, renewable is 20%. Therefore, gas-fried and renewable power plants will be the main low-carbon power technologies in Taiwan in the future.

- According to the recently announced renewable energy development target, solar photovoltaic and offshore wind power are the most actively developed renewable energy technologies of the government. The solar photovoltaic target is 20GW, and the offshore wind power is 5.5 GW in 2025.

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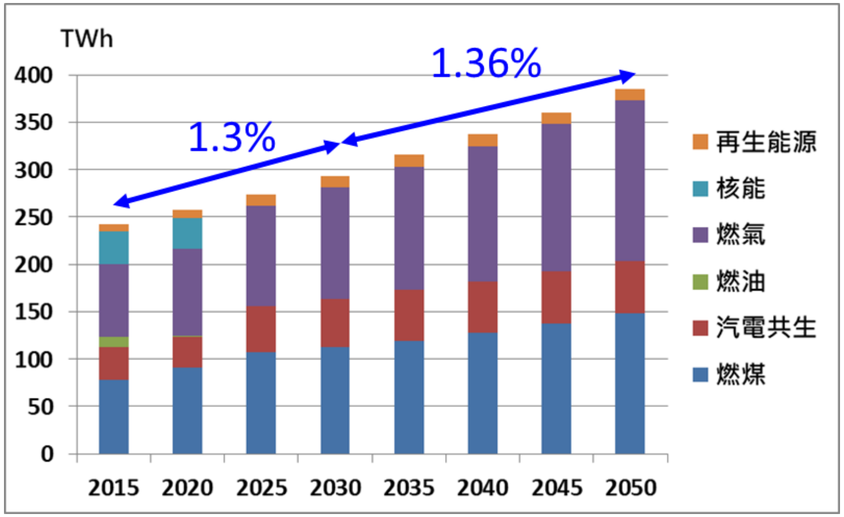
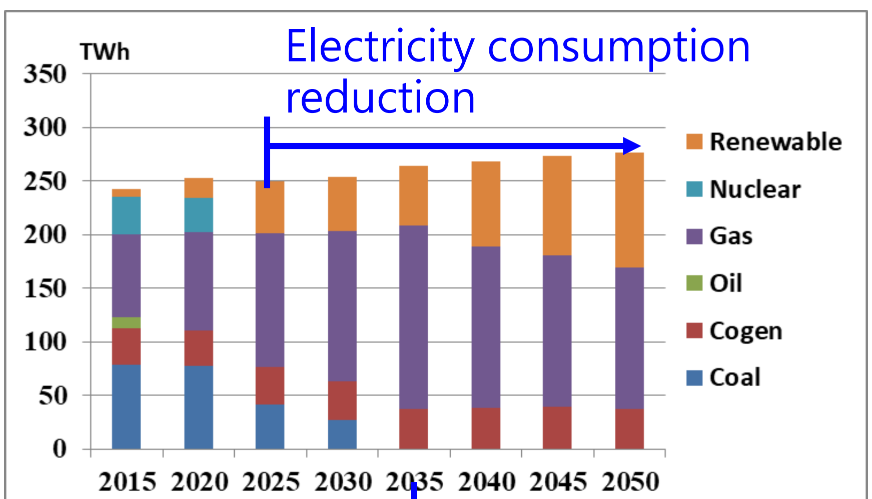
Power generation structure

- Reference scenario



- Carbon reduction scenario



Coal-fired is completely phased-out

- For carbon reduction scenario, after 2025, it begins to reduce electricity consumption to meet the carbon reduction target.
- Coal-fired power generation is gradually reduced. It has been completely replaced by renewable energy and gas-fired power generation by 2035. It leads to lower electricity emission coefficients but higher power generation costs than the reference situation.

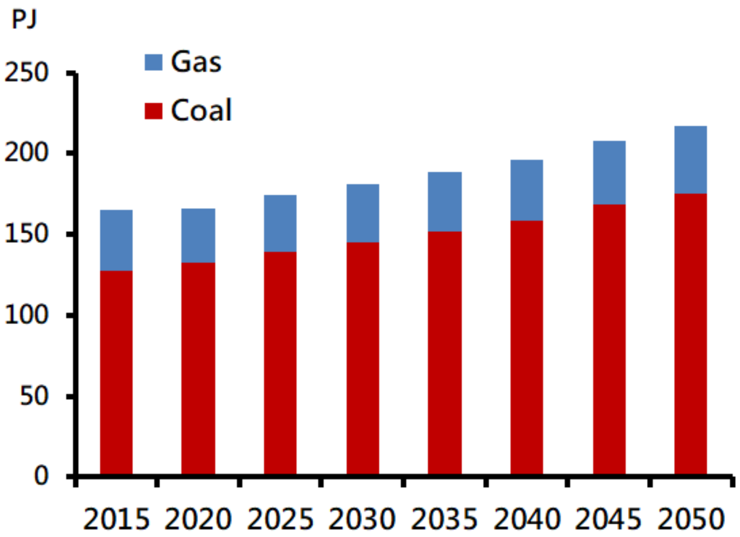
Electricity Generation costs and emission coefficients

Reference scenario								
	2015	2020	2025	2030	2035	2040	2045	2050
Generation cost (NTD/kWh)	2.1	2.15	2.32	2.43	2.50	2.55	2.65	2.69
Electricity emission coefficient (kg/kWh)	0.62	0.59	0.63	0.61	0.58	0.56	0.55	0.54
Carbon reduction scenario								
Generation cost (NTD/kWh)	2.1 0.06 €/kWh	2.27	3.04	3.30	3.64	4.02	4.03	4.20 0.12 €/kWh
Electricity emission coefficient (kg/kWh)	0.62	0.54	0.46	0.38	0.32	0.28	0.25	0.22

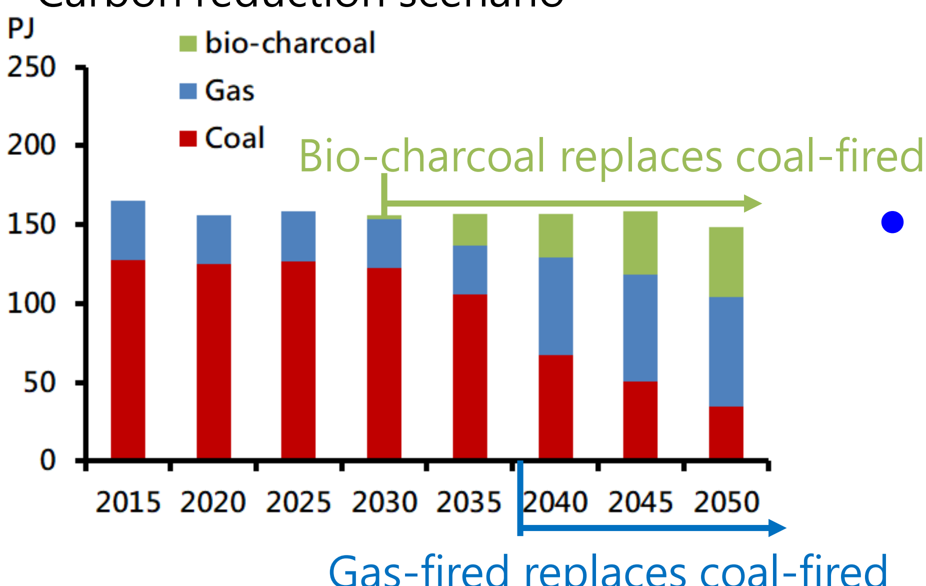
Note: The generation cost in 2015 is based on historical data from Taiwan Power Company, and those between 2020 and 2050 are calculated from TIMES model

Industrial boiler structure

- Reference scenario



- Carbon reduction scenario

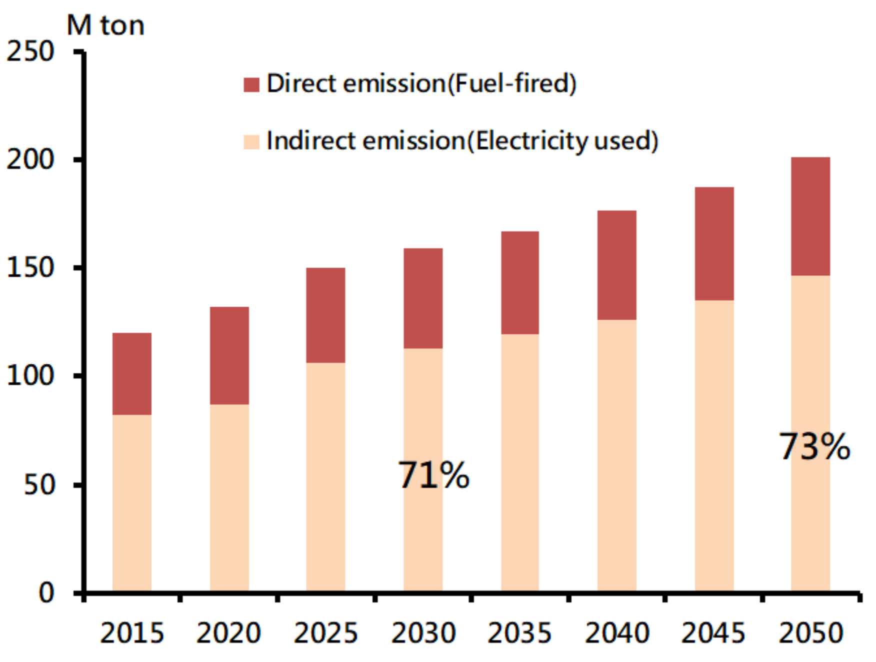


- For carbon reduction scenario, there is no technical replacement by 2030, the national carbon reduction targets are reached by the cost-effective technologies of other sectors.

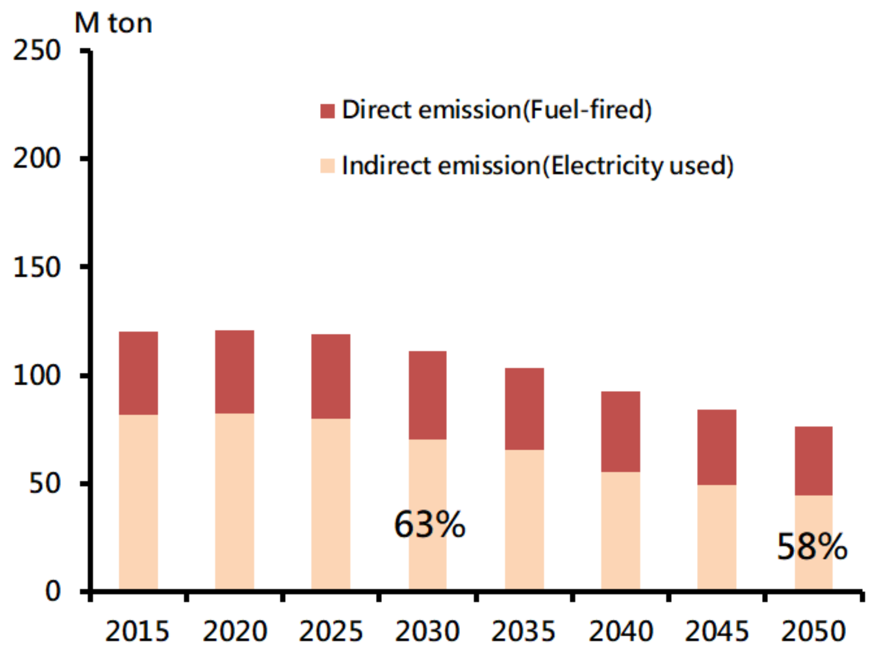
- Bio-charcoal boilers replace coal-fired boiler by 2030 ; Gas-fired boilers replace coal-fired boiler by 2040.

CO_2 emission amount for industrial sector

- Reference scenario



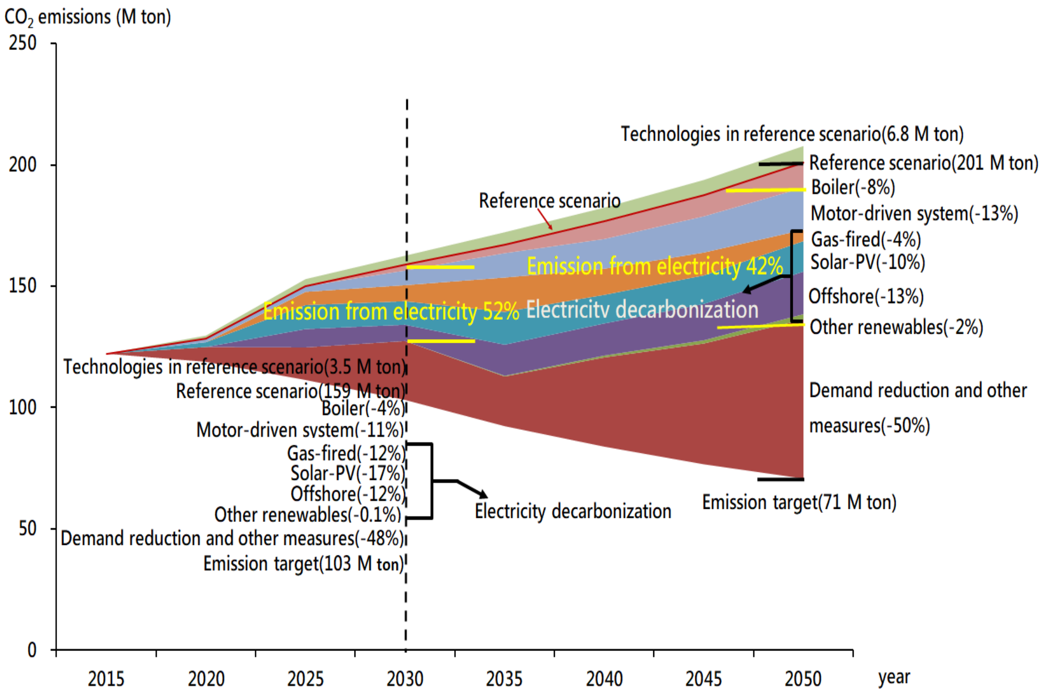
- Carbon reduction scenario



- Compared with reference scenario, indirect emission(electricity used) emissions are much less for carbon reduction scenario, therefore, reduction of indirect emission is important for CO_2 reduction action for industrial sector.

- We can explain the transition from reference scenario to carbon reduction scenario by means of CO_2 reduction prism plot.

The industrial CO_2 emissions reductions by technology



- Technologies in reference and carbon reduction amount M ton

1.The amount of carbon reduction from electricity use(motor-driven system and low carbon power contribution) is much greater than the carbon reduction of fuel combustion emissions (boiler contribution)

2.The carbon reduction from the main low-carbon industrial technologies (motor-driven system and boiler) is limited(<20%). It must be combined with electricity decarbonization, demand reduction and other measures, such as material efficiency, fuel replacement, and CCS.

3. By 2050, the carbon reduction target is ambitious, If it is impossible to reduce the demand too much, it is recommended to plan for industry structure adjustment from high energy intensity industries toward high value-add ones, more energy-saving technologies and low-carbon electricity such as enhanced geothermal and CCS.

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Conclusions

- With TIMES model, the low-carbon analysis for Taiwan's industrial sector has been performed in this study.

- Carbon emissions from electricity use account for a high proportion in Taiwan's industrial sector.

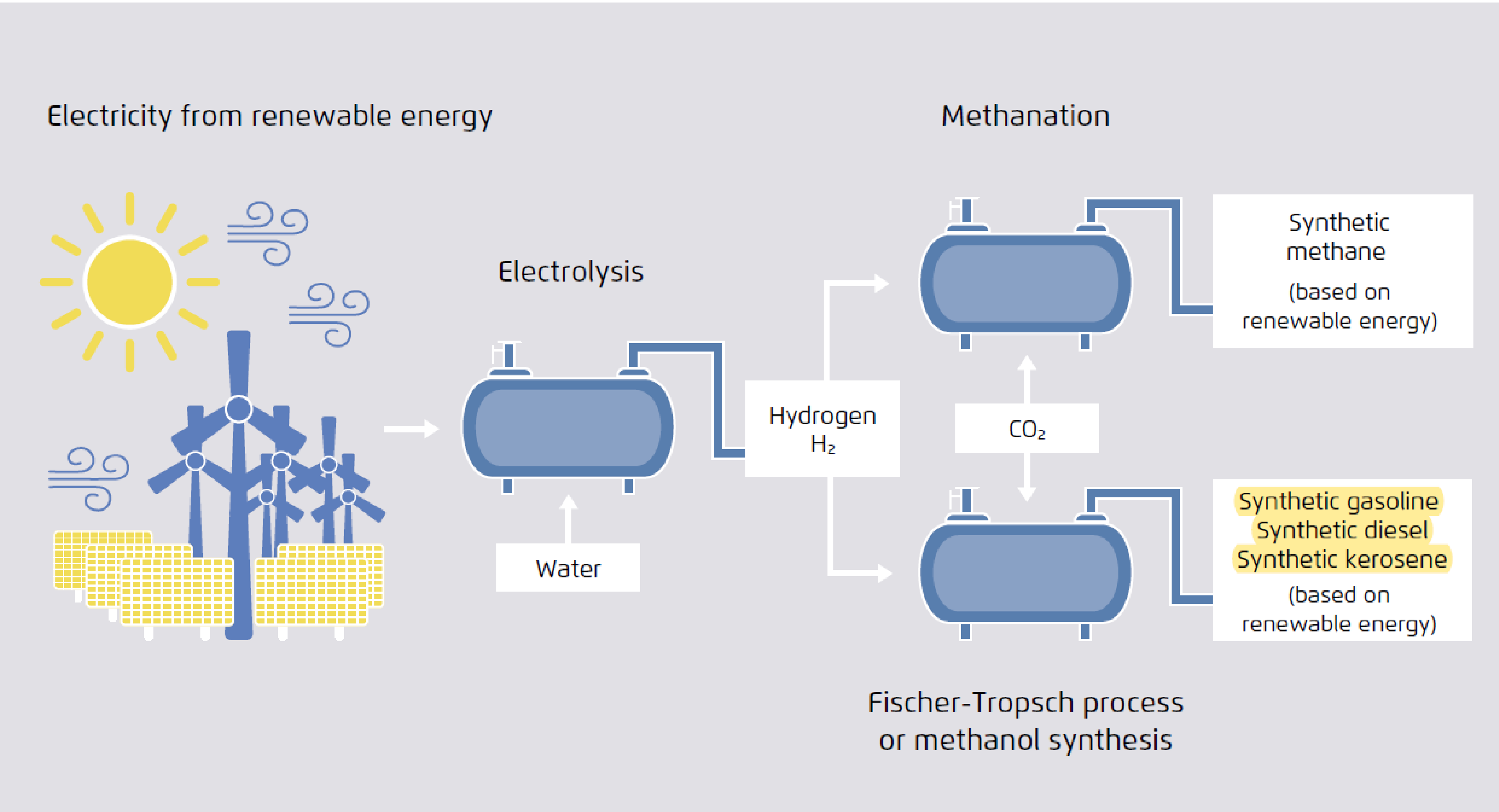
- Therefore, carbon reduction focuses on efficiency (especially on system-wide measures), power decarbonisation (renewable power, CCS, and nuclear power), others such as boilers and demand reduction by industry structure adjustment, consumption pattern change and price signal.

Conclusions (cont.)

- Industrial companies can reduce CO_2 emissions in various ways, with the optimal local mix depending on the availability of biomass, carbon-storage capacity and low-cost zero-carbon electricity and **hydrogen**, as well as production changes due to demand reduction and other measures.

Conclusions (cont.)

- Production process for electrofuels (hydrogen, power-to-gas methane and power-to-liquid fuels) from sun and wind



Agora Verkehrswende (2018)

Conclusions (cont.)

- In the harder-to-abate industrial sectors such as steel, cement, and chemicals, bioenergy and carbon capture will also be required.

- If carbon-storage sites are available, CCS is the lowest-cost decarbonization option for now. However, the local availability of carbon storage capacity and public acceptance and regulatory support for carbon storage determine whether CCS is a feasible option.

Conclusions (cont.)

- In the long run, the cost of zero-carbon electricity, also for producing heat and hydrogen, will be more economical than the technologies with CCS. But this depends on the availability of renewables and will differ on a country-by-country basis.

- And for isolated and densely populated Taiwan, how to exploit and harness more reliable renewable energy such as photovoltaics, off-shore wind power, biomass, and enhanced geothermal power is a difficult challenge to face in the future.

Thank you for your attention.

Forest of lives—Smangus, Hsinchu, Taiwan
These photos were taken by Ko.