The inspection of CO_2 emission targets of industry sector in Taiwan

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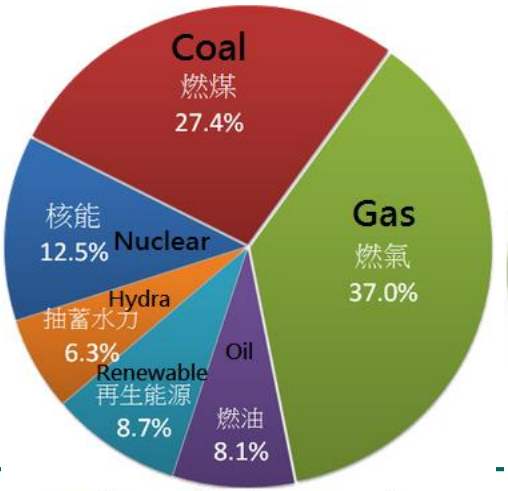
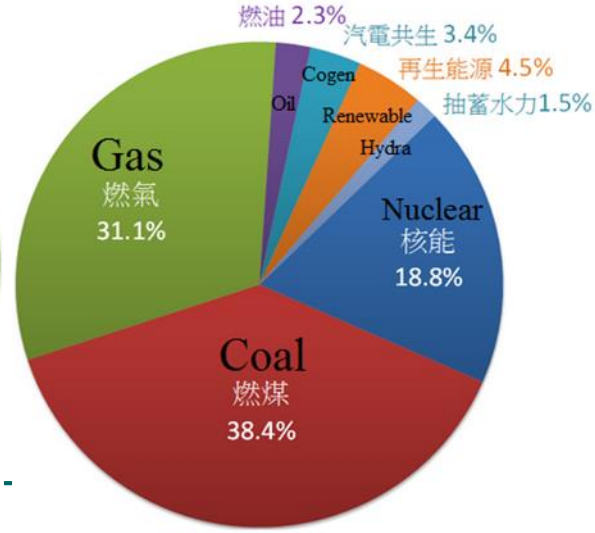
Formosa Island - Taiwan

- Capital：Taipei City
- Area：36,193 km^2
- Population：23 million
- GDP(nominal)：$517 billion
- Per capita：$22,002 (2014)
- Total installed capacity：48.86 GW
- Total generation：252.3 billion kWh



Installed capacity



Generation

Summary

- **Motivation:**
  - Most of the industry CO_2 emissions are from electricity usage .
  - Assume no life extension of existing nuclear plants & new nuclear plants will not operate.
  - **The research inspect the suitability of the proposed industry CO_2 emission targets under non-nuclear policy.**

- In order to inspect the CO_2 emission targets of industry sector in Taiwan, scenarios about the collocations of power generation and industry technologies are designed.

- The INER-MARKAL model are applied to estimate CO_2 emissions, electricity generation cost, abatement cost of industry sector in Taiwan.

- The results indicate that it is difficult to achieve the current emission targets, and adjustment of targets can be considered.

Outline

- Introduction
- Scenario Assumptions
- Results and Discussion
- Conclusion

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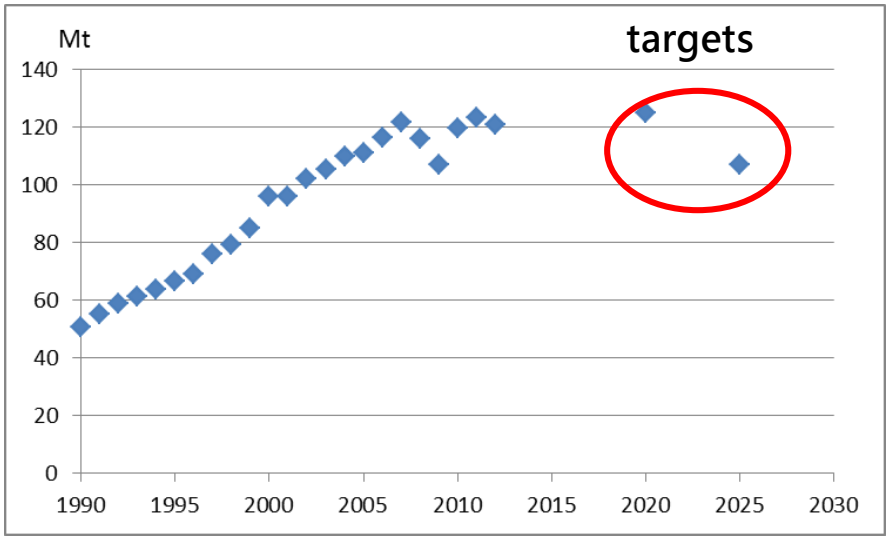
Introduction

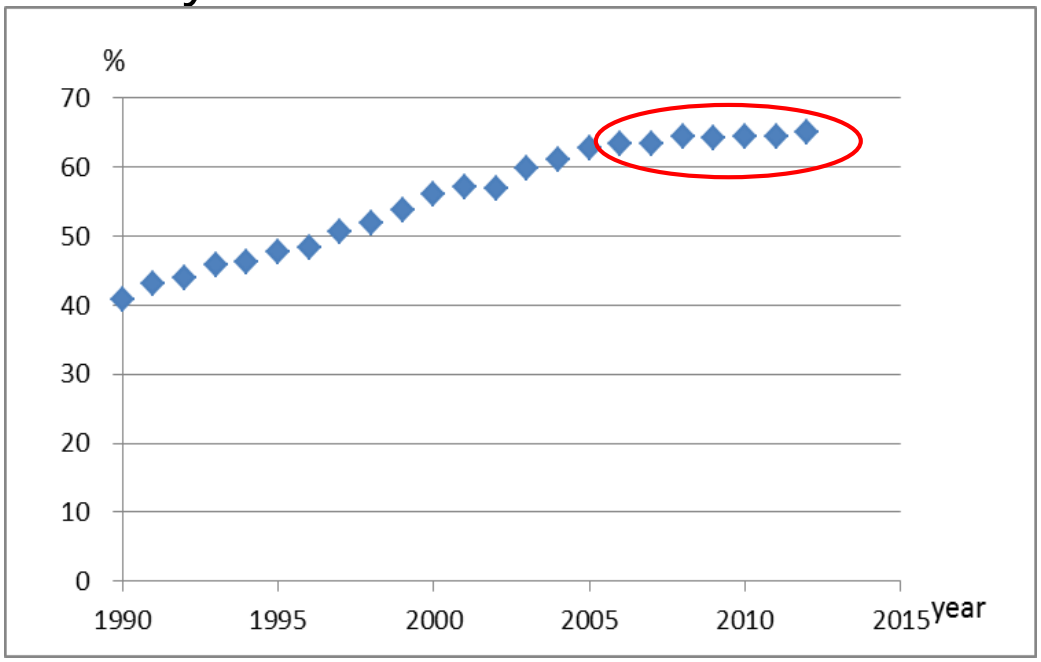
- The CO_2 emission from industry sector is larger than other sectors(industry sector:49%, transport sector:14%, commercial sector:13%, building sector:12%) in Taiwan, so it always plays an important role in national carbon reduction.
- The government makes a CO_2 emissions reduction targets in 2011:
  - 125 Mt in 2020, it close to the emission in 2011
  - 107 Mt in 2025 , it close to the emission in 2009



The history emissions and targets

Introduction

- The emissions of electricity usage accounted for more than 60% in recent years:



The proportion of electricity usage emissions of industry sector

The development of low carbon electricity technologies is an important method for CO_2 emission reduction for industry sector.

Introduction

- The main low-carbon electricity technologies before 2030:

➢ **Nuclear power plants:**

- The operation periods of three existing plants:

Nuke 1: 1978-2019

Nuke 2: 1981-2023

Nuke 3: 1984-2025

- New plant(Nuke 4) :

Reactor 1: It is mothballed.

Reactor 2: It is halted.

Due to the high anti-nuclear voice, the life extension of existing plants or operation of Nuke 4 are debate issues.

Introduction

- **Gas-fired power plants:**
  - Announced imported amount of LNG(more than 98% of NG usage is from LNG in 2014):

    2015: 1400 Mt

    2020: 1500 Mt

    2025: 2000 Mt
- **Renewable energy power plants:**

Policy Objectives of Renewables in Taiwan before July, 2014

unit：MW	2015	2020	2025	2030
Hydro Power	2,089	2,138	2,502	2,502
On-shore Wind	871	1,200	1,200	1,200
Off-shore Wind	15	600	1,800	3,000
Waste	848	925	1,369	1,369
Biogas	29	29	31	31
PV	747	1,622	3,052	3,100
Ocean Energy	1	30	200	600
Geothermal	4	66	150	200
H_2 and Fuel cells	7	60	200	500
Total	4,611	6,670	10,504	12,502
Comparison with current capacity (48.86 GW)	9%	13%	21%	25%

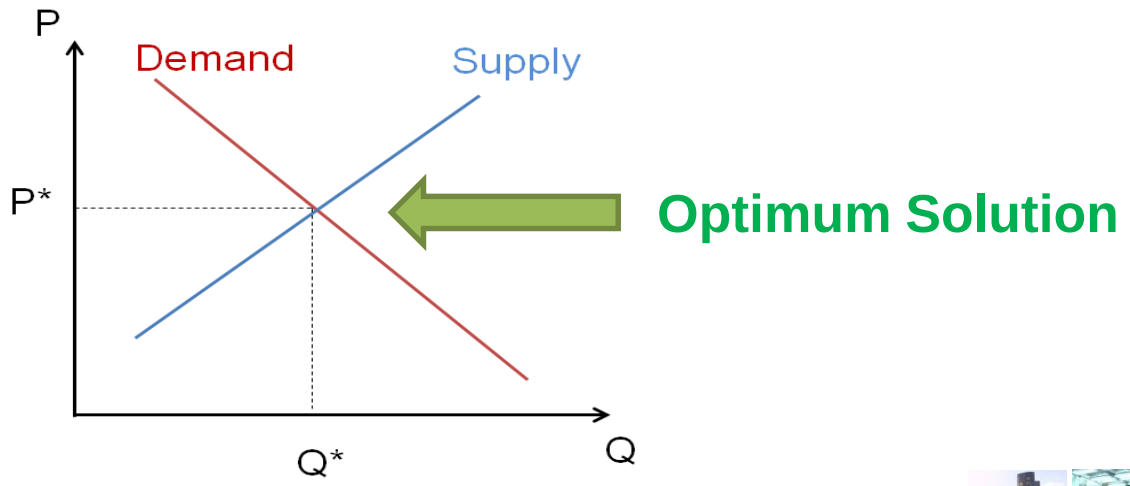
Introduction

- The main energy saving and carbon reduction source for industry sector in Taiwan:
  - Petrochemical raw material manufacturer
  - Electrical and electronic manufacturer
  - Blast furnace iron and steel
  - Electric arc furnace iron and steel
  - Cement

The study applied the MARKAL model to provide collocations of electricity and industry technologies achieving the CO_2 emissions targets of industry sector in Taiwan, beside, in order to check the suitability of reduction targets, electricity generation costs, abatement costs of industry sector were calculated.

MARKAL Model

- MARKet ALlocation - Elastic Demand : It is a linear programming tool supported by IEA-ETSAP (Energy Technology Systems Analysis Program).
- MARKAL provides a technology-rich basis for estimating energy dynamics over a period.
- The model will arrange appropriate technologies to satisfy the endogenous energy service demands under minimizing total cost (or maximizing net total surplus).



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Scenario Assumptions

- This study provided different scenarios about the collocations of electricity and industry technologies:
- Electricity technologies (assume no life extension of existing plants & new nuclear plant will not operate):
  - Chosen by the MARKAL model through the least-cost combinations. **(E1)**
  - According to the announced development objective about renewable energy and the imported LNG. **(E2)**
  - Expanded LNG and renewable energy usage to reduce the coal-fired electricity generation. **(E3)**
- Industry technologies:
  - Energy efficiencies are maintained as 2010 level. **(I0)**
  - Voluntary energy efficiency improvements (average 0.5%/year). **(IN)**
  - Larger energy efficiency improvements (1, 2, 2.5, 4, 5%/year). **(I1, I2, I2.5, I4, I5)**

Scenario Design

Electricity technologies

- Chosen by the MARKAL model through the least-cost combinations. (E1)
- Announced renewable energy and imported LNG policy. (E2)
- Enlargement of renewable energy and imported LNG . (E3)

Industry technologies

- Energy efficiencies maintained as 2010 level. (I0)
- Voluntary energy efficiency improvement. (IN)
- Larger energy efficiency improvement. (I1, I2, I2.5, I4, I5)

19 scenarios about collocations of low-carbon electricity and industry technologies

MARKAL model

Each scenario's CO_2 emissions, electricity generation cost, abatement cost of industry sector

Provide the collocations achieving current CO_2 reduction targets and suggest suitable targets

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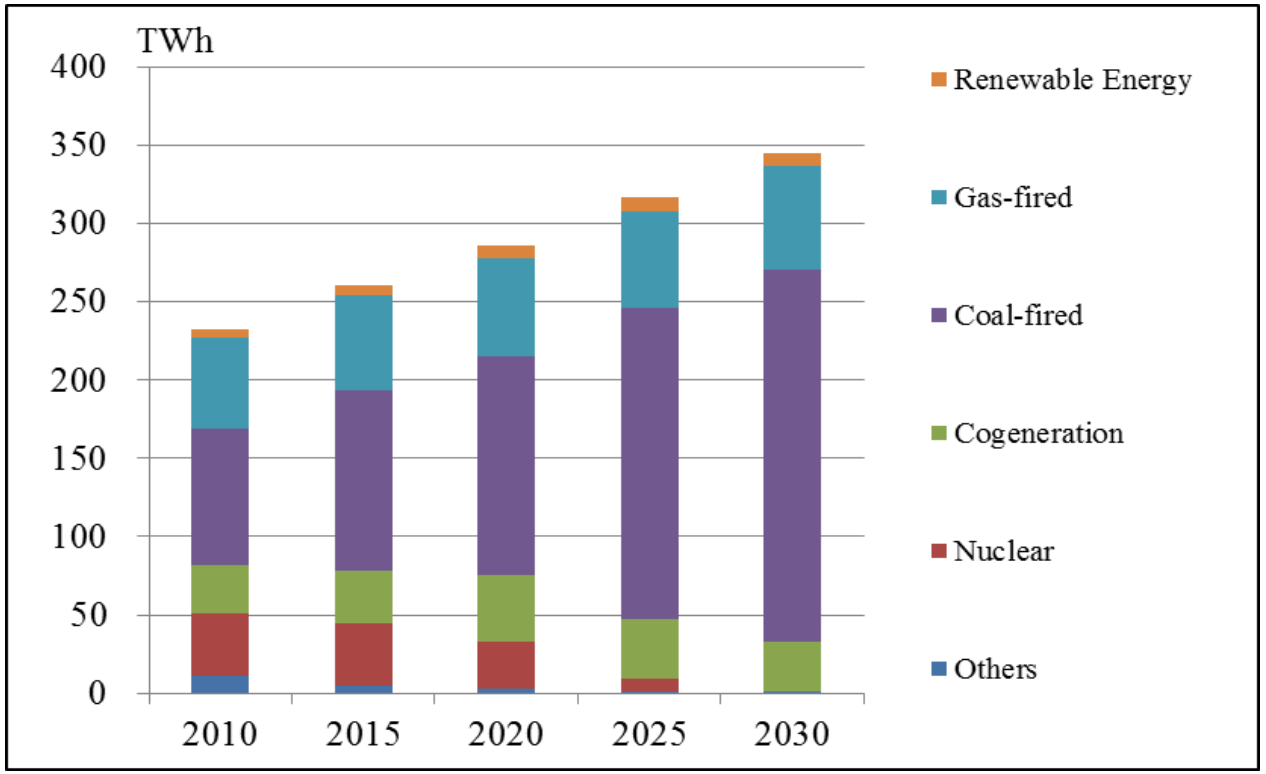
Power generation mix of BAU

- Coal fired: The major source of electricity supply due to it's lower cost
- Gas fired: The electricity generation almost maintains as 2010 level
- Nuclear: The existing plants will be phased out from 2020 onwards (10% in 2020, 2% in 2025)
- Renewable Energy: The share of electricity generation are close to 2% from 2010 to 2030.



The allocation of electricity generation for BAU

CO_2 emissions in BAU

The CO_2 emissions in BAU

	unit	2010	2015	2020	2025	2030
Total emission	Mt	251	276	319	373	407
Emission of industry sector	Mt	130	150	178	210	226
Percentage of emission from industry sector	%	52	54	55	55	55

- **The emissions of industry sector in 2020 and 2025 are 178 and 210 Mt, they are 42% and 96% larger than the target values(125 and 107 Mt).**
- **Industry sector is still the main CO_2 emission resource in the future**

The CO_2 emissions of industry sector in BAU

	unit	2010	2015	2020	2025	2030
Emission from fuel-fired	Mt	47	53	55	58	61
Emission from electricity consumption	Mt	83	97	123	152	165
Percentage of emission from electricity consumption	%	64	65	69	72	73

- **More than 60% of CO_2 are released from electricity usage in the future.**

Industry energy efficiency scenario analysis

Discussion about the influence of industry energy efficiency on CO_2 emission reductions

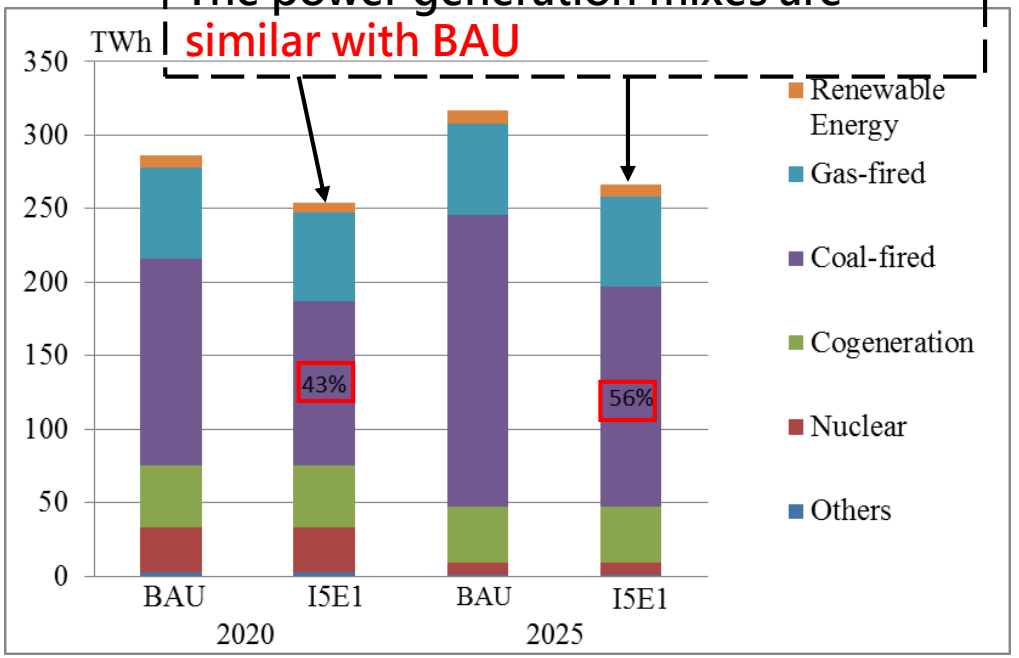
Industry energy efficiency scenario analysis

Scenario assumptions: (Industry energy efficiency improvements → CO_2 emission reduction)
- Industry energy efficiency improvements :0.5%, 1%~5% /year (IN, I1~I5)
- Electricity technologies: Least-cost combination

Scenarios	Emissions in 2020 (Mt)	Emissions in 2025 (Mt)
INE1	166(+32.8%)	190(+77.6%)
I1E1	163(+30.4%)	183(+71%)
I2E1	151(+20.8%)	167(+56.1%)
I2.5E1	149(+19.2%)	161(+50.5%)
I4E1	136(+8.8%)	143(+33.6%)
I5E1	128(+2.4%)	132(+23.4%)
Target values	125	107

(%): comparison with target values

The power generation mixes are similar with BAU



The allocation of electricity generation for BAU and I5E1 in 2020 and 2025

The high shares of coal-fired release large amounts of CO_2 emissions, it results in that only the industry energy improvement is not enough to achieve reduction targets

Low carbon electricity technology scenario analysis

Discussion about the influence of low carbon electricity technology on CO_2 emission reductions

Low carbon electricity technology scenario analysis

Scenario assumptions:(Low carbon electricity technology → CO_2 emission reduction)

•Electricity technologies:

1. Announced amount of LNG and renewable energy(E2)
2. Enlargement of LNG and renewable energy (E3)

•Industry technologies:

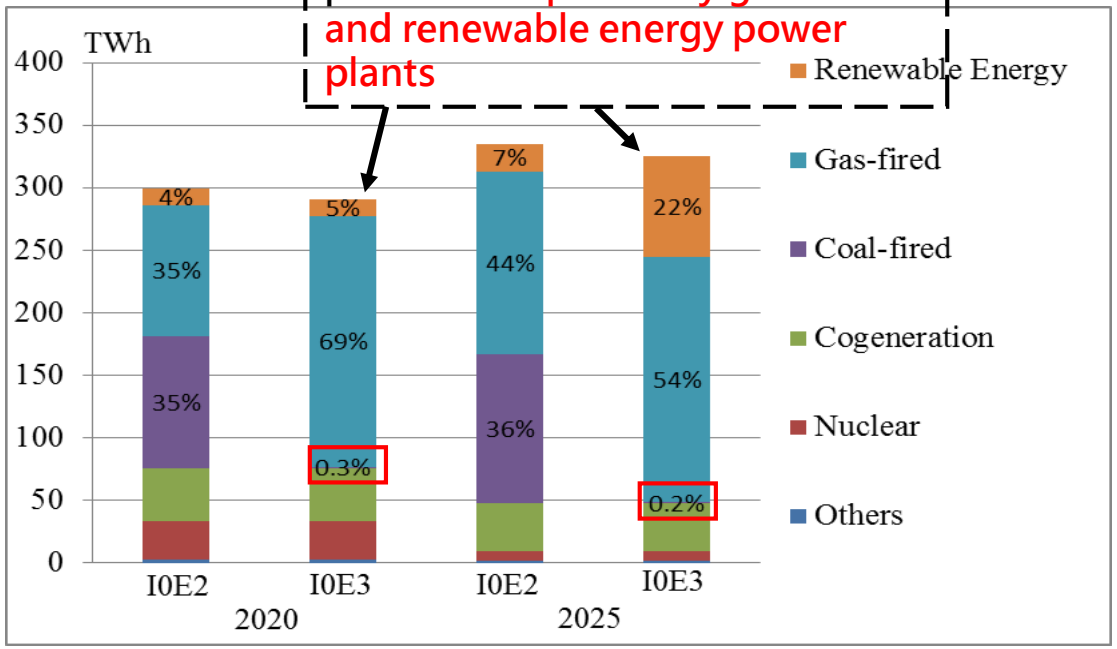
Energy efficiencies are maintained as 2010 level. (I0)

Almost all coal-fired power plants are replaced by gas-fired and renewable energy power plants

Scenarios	Emissions in 2020 (Mt)	Emissions in 2025 (Mt)
I0E2	162(+29.6%)	178(+66.4%)
I0E3	129(+3.2%)	128(+19.6%)
Target values	125	107

(%): comparison with target values

Only the dependence on low carbon electricity technologies can't achieved the targets, even all coal-fired electricity generations are replaced.



The allocation of electricity generation for I0E2 and I0E3 in 2020 and 2025

Low carbon industry and electricity technology scenario analysis

The targets can't be achieved only rely on low carbon industry or electricity technologies, therefore, the collocation of low carbon industry and electricity technologies should be considered.

Low carbon industry and electricity technology scenario analysis(According to announced amount imported LNG and renewable energy policies)

Scenario assumptions: (Announced amount imported LNG and renewable energy policies+ Industry energy efficiency improvements ⟶ CO_2 emission reduction)

- Electricity technologies:
  Announced amount of LNG and renewable energy (E2)
- Industry energy efficiency improvements :
  0.5%, 1%~5% /year (IN, I1~I5)

Scenarios	Emissions in 2020 (Mt)	Emissions in 2025 (Mt)
INE2	153(+22.4%)	161(+50.5%)
I1E2	149(+19.2%)	155(+44.9%)
I2E2	138(+10.4%)	140(+30.8%)
I2.5E2	135(+8%)	134(+25.2%)
I4E2	123(-1.6%)	118(+10.3%)
I5E2	115(-8%)	106(-0.9%)
Target values	125	107

(%): comparison with target values

While industry efficiency improvement is less than 2.5%/ year ,the targets can't be achieved, maybe they need more amount of LNG and renewable energy.

- To achieve the target in 2020:
  Industry efficiency improvement >4%/year
- To achieve the target in 2025:
  Industry efficiency improvement>5%/year

Low carbon industry and electricity technology scenario analysis (Enlargement of LNG and renewable energy)

Scenario assumptions:(Enlargement of imported amount of LNG and renewable energy+ Industry energy efficiency improvements ⟶ CO_2 emission reduction)

- Industry energy efficiency improvements : less than 2.5% /year (0.5%, 1%~2.5% /year (IN, I1~I2.5))
- Electricity technologies: Expanded LNG and renewable energy to reduce coal-fired electricity generation (E3)

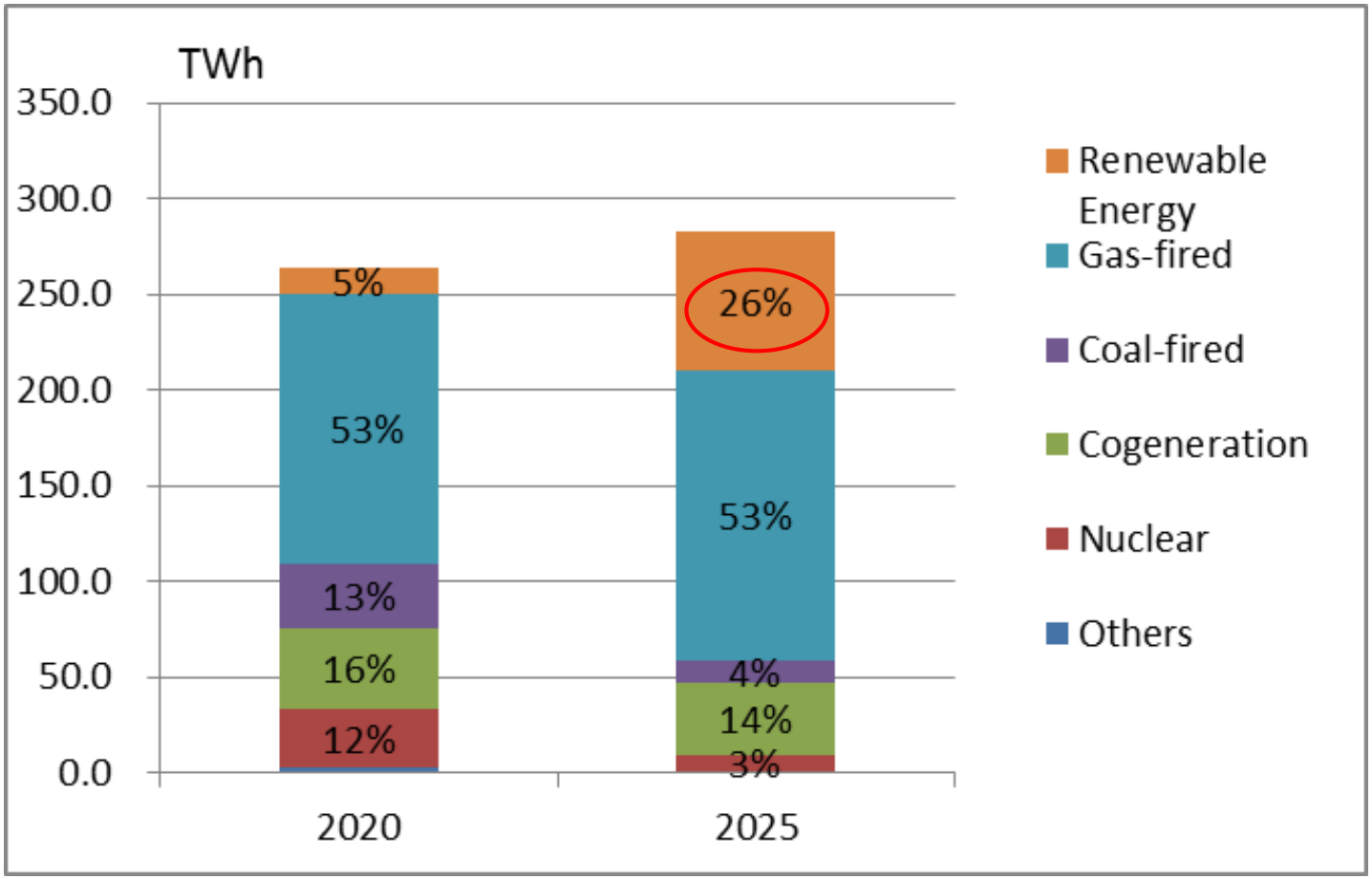
Scenarios	Emissions in 2020 (Mt)	Amount of imported LNG in 2020 (Mt)	Emissions in 2025 (Mt)	Amount of imported LNG in 2025 (Mt)
INE3	125(0%)	2532(+69%)	116(8.41%)	2396
I1E3	122(-2.4%)	2452(+63%)	112(4.61%)	2314
I2E3	121(-3.2%)	1978(+32%)	106(-0.93%)	2012(+6%)
I2.5E3	119(-4.8%)	1940(+29%)	104(-2.8%)	2002(+1%)
Target value	125	1500	107	2000

(%): comparison with target values

There are some challenges must be overcome

The amounts of imported LNG are close to policy target

Power generation mix of I2.5E3:

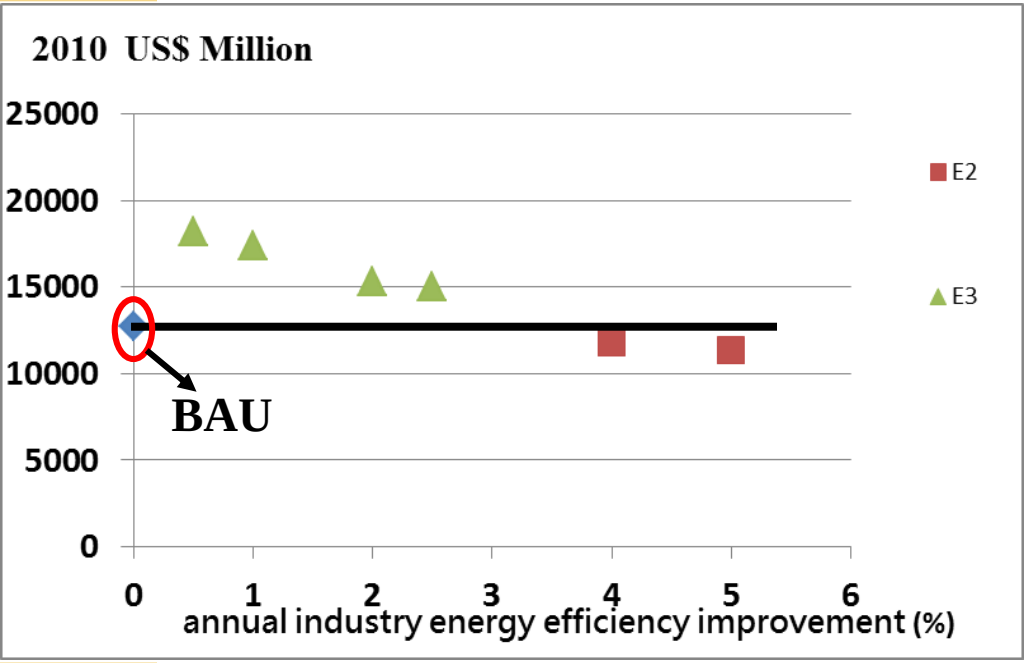


Although the amount of imported LNG is close to policy target (2000 Mt), the capacity of renewable energy is 47GW, which is much larger than the policy target: 9 GW, and therefore it is a challenge .

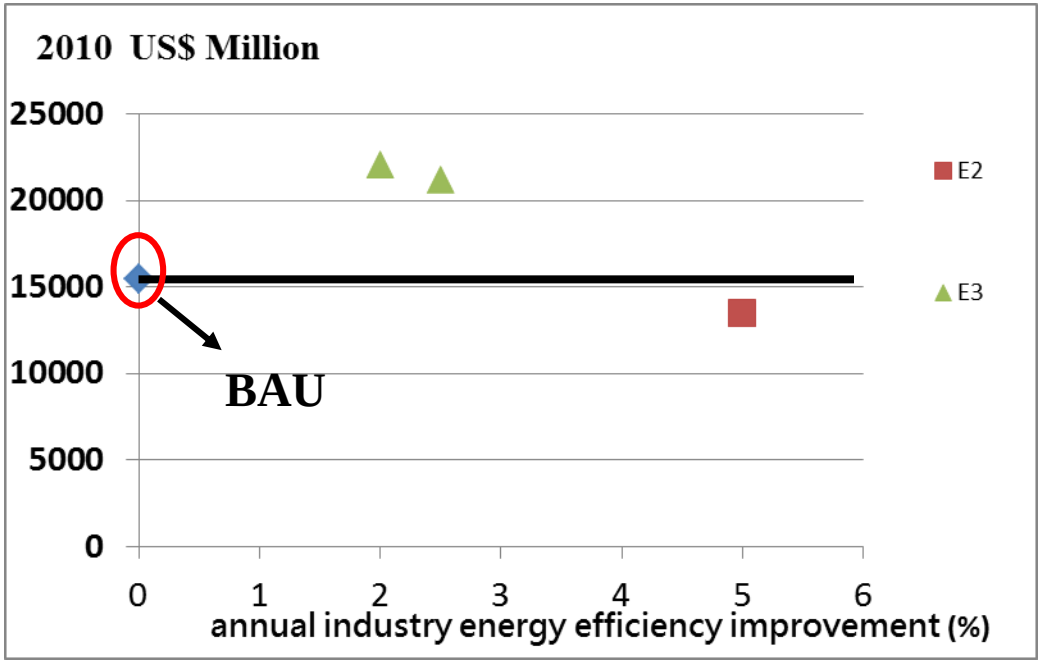
The electricity generation costs

The electricity generation costs for industry sector

Costs in 2020:



Costs in 2025:



The electricity generation costs for the scenarios achieving CO_2 reduction targets:

- E3: Larger than BAU, the extra costs are 14% to 40% of the expenditure of social welfare in 2012, it will impact the government expenditure.
- E2: Although the electricity generation costs are lower than BAU, but the investment on 4%/year or more industry energy efficiency improvement must be expensive. In addition, there are some challenges to be overcome.

Suggested Targets

From the analysis before, the CO_2 emissions reduction targets are too high under nuclear-free homeland target, and the research suggests to face the reality and raise the target values such like Japan:

Electricity technologies	Announced development objective about renewable energy and the imported LNG
Industry technologies	2%/year* energy efficiency improvements
CO_2 emissions	138Mt (2020), 140 Mt (2025) (10.4% and 30.8% larger than original targets)

*: government's objective of energy efficiency improvement per year

The comparison of CO_2 emission of industry sector between the suggested scenario and BAU

	unit	scenario	2020	2025
Emission from fuel-fired	million ton	BAU	55	58
		Suggested scenario	48	47
Electricity consumption	TWh	BAU	166	186
		Suggested scenario	143	150
Emission coefficient of electricity consumption	kg/kWh	BAU	0.74	0.82
		Suggested scenario	0.63	0.61
Emission from electricity consumption	million ton	BAU	123	152
		Suggested scenario	90	93
Total emission of industry sector	million ton	BAU	178	210
		Suggested scenario	138	140

The suggested target values are 138 million tons (2020) and 140 million tons (2025), which are 29% and 50% larger than BAU

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Conclusions (I)

- To achieve the CO_2 reduction target for industry sector in Taiwan under the nuclear-free homeland target, it must develop low-carbon electricity and industry technologies simultaneously.

- For the scenarios achieving the targets :

Under the announced development objectives about imported LNG and renewable energy:

1. Although the electricity generation costs are lower than BAU, but the investment on 4%/year or more industry energy efficiency improvement may be expensive. In addition, there are some challenges to be overcome.

Enlargement of imported LNG and renewable energy :

1. The amounts of imported LNG or renewable energy are much larger than policy targets, and it is a challenge.
2. The electricity generation costs will impact the government expenditure.

Conclusions (II)

- Under the nuclear-free homeland target, the CO_2 emissions reduction targets are too high, the research suggests to face the reality and raise the target values such like Japan:
- Collocation:
  - Electricity technologies:
    Announced development objective about renewable energy and the imported LNG
  - Industry technologies:
    2%/year energy efficiency improvements
- Emissions of industry sector:
  138 Mt (2020), 140 Mt (2025), they are 10.4% and 30.8% larger than original targets

Thanks for your attention

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Voluntary energy saving and carbon reduction plans of industry in Taiwan

- Petrochemical raw material manufacturer: Manufacture procedure improvement of raw material, such as ethylene, ethylene glycol, chloroethene monomer, etc.. Catalyst reaction technology improvement, renewal of compressor. The average energy efficiency improvement rate is 0.34% per year.
- Electrical and electronic manufacturer: Manufacture procedure improvement of DRAM, liquid crystal display, wafer. The usage of high efficiency chiller and compressor. The average annual energy efficiency improvement rate is 0.67%.
- Blast furnace iron and steel: Pulverized coal injection, blast furnace control system, internal energy saving and carbon reduction, biomass replacement for steam coal, optimal utilization of self-produced furnace gas, renewal of compressors. These are the main energy saving and carbon reduction methods carried out by China Steel Corporation, and they can result 0.83% average energy efficiency improvement rate per year.
- Electric arc furnace iron and steel: The use of direct current electric arc furnace, pre-heat of waste steel. The average energy efficiency improvement rate is 0.5% per year.
- Cement: The manufacturers are taking steps to improve energy efficiency on three parts: rotary kins, clinker system, grind system. The average energy efficiency improvement rate is 0.31% per year.

Power generation mix of I2E2