

Taiwan's Roadmaps Towards a Low Carbon Development: an Evaluation with the MARKAL Model

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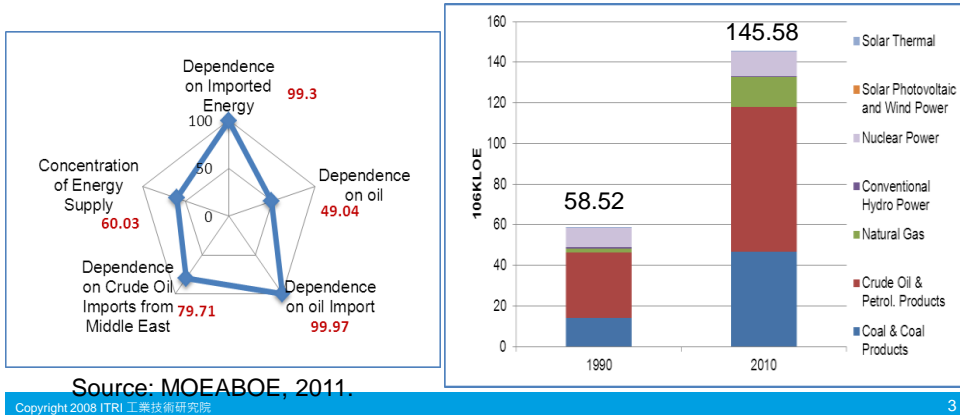
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Outline

- Introduction
- Objective & Scenario Definition
- MARKAL-Taiwan Model
- Scenario Assumption
- Simulation Results
- Discussions
- Conclusion

Introduction

- Taiwan is an island that lacks natural energy resources. It relied on imported energy for 99.30% of its total supply, which comprises 91% fossil fuels and only 0.25% of renewable energy (MOEABOE, 2011).
- Taiwan ranked 23rd in the world for countries with the highest CO₂ emission countries (IEA, 2011).



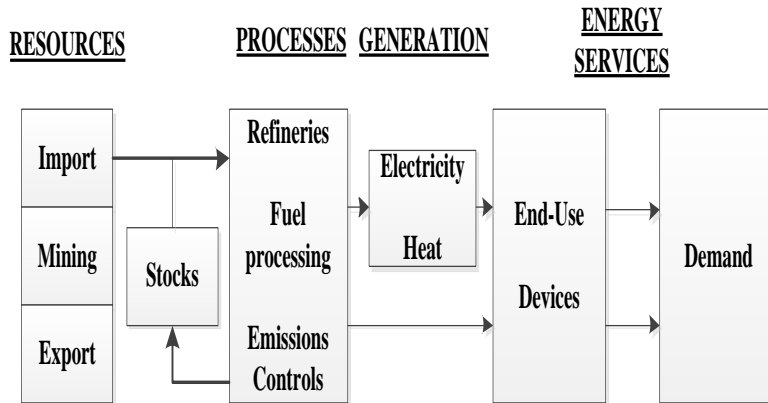
Objective & Scenario Definition

- Objective
 - Explore the roadmap of Taiwan's development of low-carbon economy by 2050
 - Assess the reduction of carbon emission in the electricity supply, industry, buildings, and transportation sectors.
- Low Carbon Development scenario (LCDS)
 - Carbon emission levels remain unchanged from 2025 to 2050
 - Carbon emission level returns to 70% of the 2000 level by 2050
 - Carbon emission level returns to 50% of the 2000 level by 2050.

MARKAL-Taiwan Model

- The Reference Energy System

75 processes technologies 63 generation technologies 256 demand technologies



Scenario Assumptions (1/4)

| Year | GDP Grow Rate (%/year) | Industry Structure (%) | | |
|-----------|------------------------|------------------------|-----------|----------|
| | | First | Secondary | Tertiary |
| 2011~2020 | 4.19 | 1.35 | 29.30 | 69.35 |
| 2021~2030 | 3.09 | 1.19 | 26.86 | 71.95 |
| 2031~2040 | 2.73 | 0.90 | 25.00 | 74.10 |
| 2041~2050 | 2.40 | 0.69 | 23.08 | 76.23 |
| 2051~2055 | 2.20 | 0.71 | 21.63 | 77.66 |

| Year | Population (thousand) | Household (thousand) | Crude oil (US2008/b) | Coal (US2008/t) | Coke (US2008/t) | LNG (US2008/t) |
|------|-----------------------|----------------------|----------------------|-----------------|-----------------|----------------|
| 2010 | 23,165 | 7,821 | 76.66 | 102.58 | 193.18 | 509.40 |
| 2015 | 23,354 | 8,250 | 87.52 | 103.69 | 220.70 | 327.84 |
| 2020 | 23,437 | 8,591 | 99.43 | 105.76 | 223.32 | 361.64 |
| 2025 | 23,427 | 8,847 | 108.25 | 107.33 | 227.68 | 428.47 |
| 2030 | 23,301 | 9,013 | 113.27 | 107.46 | 232.92 | 466.21 |
| 2035 | 23,003 | 9,070 | 114.60 | 108.05 | 234.67 | 518.88 |
| 2040 | 22,506 | 9,010 | 123.21 | 109.20 | 236.42 | 572.40 |
| 2045 | 21,813 | 8,839 | 132.46 | 109.49 | 238.16 | 631.45 |
| 2050 | 20,935 | 8,565 | 142.41 | 109.83 | 239.91 | 696.58 |
| 2055 | 19,924 | 8,144 | 153.10 | 110.30 | 240.78 | 768.43 |

Scenario Assumptions (2/4)

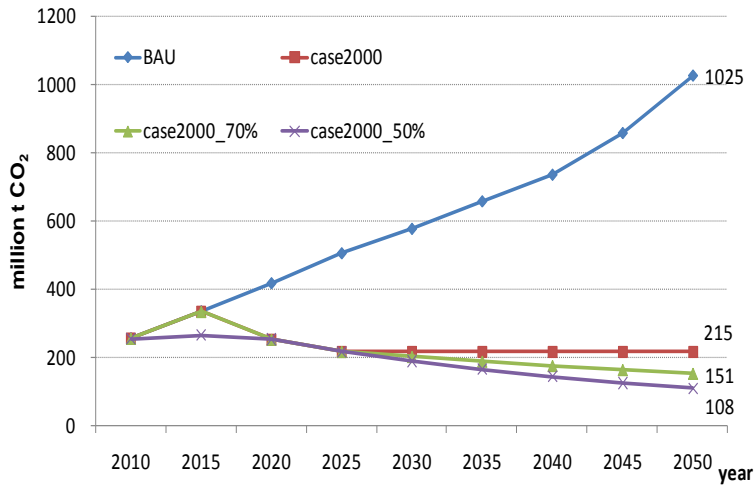
| | | BAU | Case2000 | Case2000_70 % | Case2000_50 % |
|---------------------------------------|---|-----|----------|------------------|------------------|
| CO ₂ emission target | 2020 Return to 2005 emission level (252 Mt) | | ⊙ | ⊙ | ⊙ |
| | 2025 Return to 2000 emission level (214 Mt) in 2025 | | ⊙ | ⊙ | ⊙ |
| | 2050 Return to 2000 emission level (214 Mt) | | ⊙ | | |
| | 2050 low than 30% of 2000 emission level | | | ⊙ | |
| | 2050 low than 50% of 2000 emission level | | | | ⊙ |
| LNG | maintain at 2008's level(822 Mt) | ⊙ | | | |
| | up to 1400 Mt in 2020 up to 2000 Mt in 2025-2050 | | ⊙ | ⊙ | ⊙ |
| Renewable energy | Maintain at 2008's level: total 2934.9 MW | ⊙ | | | |
| | Accumulated installed capacity is 6,388MW in 2020 8,921MW in 2025-2050 | | ⊙ | ⊙ | ⊙ |

Scenario Assumptions (3/4)

| | | BAU | Case2000 | Case2000_70 % | Case2000_50 % |
|---|--|-----|----------|------------------|------------------|
| Energy saving | Energy tech. efficiency improve 0.4%/yr from 2009 ~ 2050 | ⊙ | | | |
| | high efficiency technology | | ⊙ | ⊙ | ⊙ |
| Nuclear energy | NPP1~ NPP3 normal decommissioning | ⊙ | | | |
| | NPP 1~ NPP3 extend service | | ⊙ | ⊙ | ⊙ |
| | NPP4 is deemed as the reduction measure | ⊙ | | | |
| | NPP4 operation | | ⊙ | ⊙ | ⊙ |
| Coal-fired unit installed with CCS device from 2025 | | ⊙ | ⊙ | ⊙ | |
| Steel and Iron ind. installed with CCS device from 2025 | | ⊙ | ⊙ | ⊙ | |
| Cement ind. installed with CCS device from 2020 | | ⊙ | ⊙ | ⊙ | |

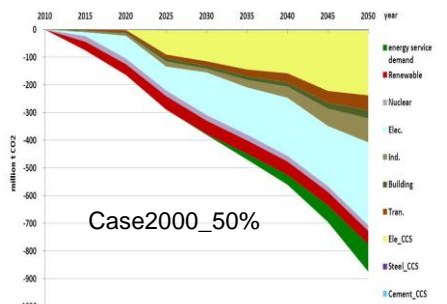
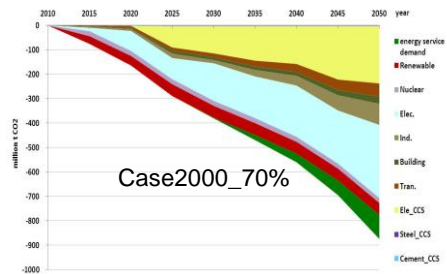
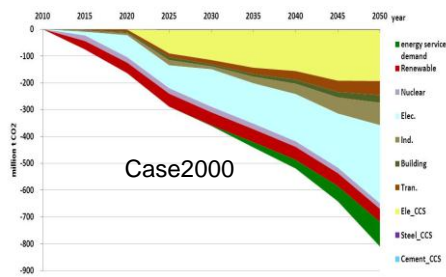
Simulation Results (1/10)

- CO₂ emission:



Simulation Results (2/10)

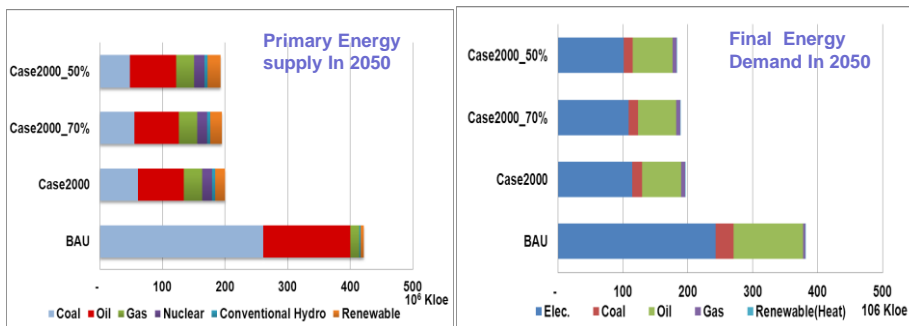
- **Low carbon pathway**
 - In LCDS electricity sector contributes to carbon reduction from 36 to 37%
 - CCS technologies by the electricity from 23 to 27%,
 - lower demand for energy services from 11 to 12%.



Simulation Results (3/10)

- Energy Structure**

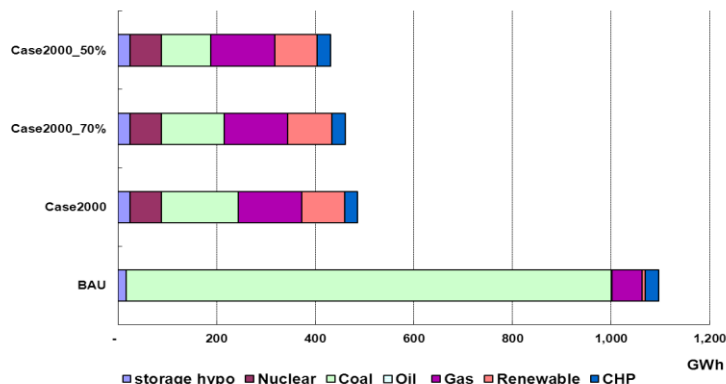
- The total energy supply for LCDS in 2050 is reduced to 50% of the reference scenario, and as the target of carbon reduction increase, the share of coal uses is largely reduced.
- Renewable energy(including thermo energy) are 8~ 11% in LCDS.
- The demand for electricity is the highest (55 ~ 58% of the total demand) with coal comes to the lowest (8%).



Simulation Results (4/10)

- Electricity Demand Structure**

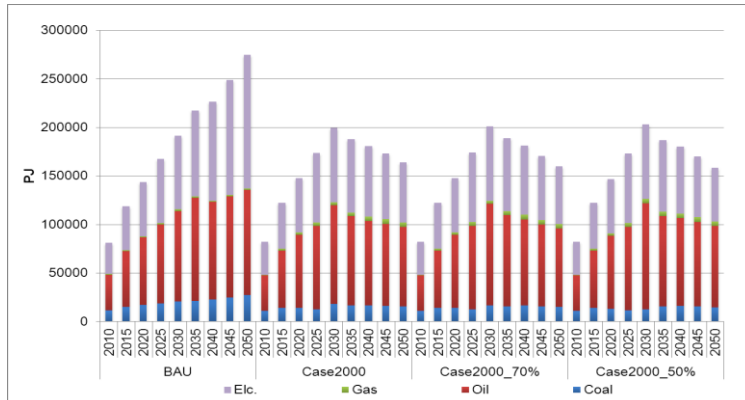
- The demand for electricity in every LCDS in 2050 is reduced by 39 to 44% compared to the reference scenario.
- Power generation by coal is lowered from 90% in the reference scenario to 23-32%, and power generation by low/non carbon energy is increased from 6% in the reference scenario to 57-65%.



Simulation Results (5/10)

- Industry Energy Demand

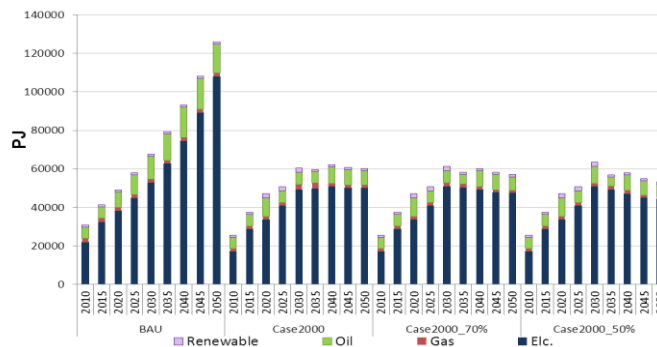
- The total energy demand in each LCDS is lower than BAU scenario by 20%. This demand peaks at 2030 and declines thereafter along with the increasingly harsher demand for CO₂ reduction.
- In 2050, the demand for oil in all LCDS falls lower than the ratio in the BAU scenario by 23% to 25%.



Simulation Results (6/10)

- Building Energy Demand

- The total energy demand in each LCDS is lower than the BAU scenario by 50%.
- In 2050, the demand for electricity in each LCDS falls lower than the BAU scenario by 44 to 59%. The ratio of renewable energy in each LCDS remains between 2%~4% throughout the years, higher than the BAU scenario by 96%.
- In 2050, the demand for oil in each LCDS falls below the BAU scenario by 50% to 60%.



Simulation Results (9/10)

- **CO₂ index (in 2050)**
 - total CO₂ emission decreases from 1,025 Mt to 108~215 Mt.
 - per capita emission decreases from 49 t/per capita to 5.1 ~ 10.3 t/per capita.

| Year | Energy CO ₂ Total Amount (Mt) | | | | Per Capita Emission of CO ₂ (tons/ per capita) | | | |
|------|--|--------|------------|------------|---|--------|------------|------------|
| | BAU | CO2000 | CO2000_70% | CO2000_50% | BAU | CO2000 | CO2000_70% | CO2000_50% |
| 2010 | 254 | 254 | 254 | 254 | 11.0 | 11.0 | 11.0 | 11.0 |
| 2015 | 334 | 258 | 258 | 334 | 14.3 | 11.1 | 11.1 | 11.1 |
| 2020 | 416 | 252 | 252 | 416 | 17.8 | 10.7 | 10.7 | 10.7 |
| 2025 | 504 | 215 | 215 | 215 | 11.4 | 9.2 | 9.2 | 9.2 |
| 2030 | 576 | 215 | 201 | 188 | 24.7 | 9.2 | 8.6 | 8.0 |
| 2035 | 656 | 215 | 187 | 163 | 28.5 | 9.4 | 8.1 | 7.1 |
| 2040 | 734 | 215 | 174 | 142 | 32.6 | 9.6 | 7.7 | 6.3 |
| 2045 | 857 | 215 | 162 | 124 | 39.3 | 9.9 | 7.4 | 5.7 |
| 2050 | 1,025 | 215 | 151 | 108 | 49.0 | 10.3 | 7.2 | 5.1 |

Simulation Results (10/10)

- Emission intensity drops from 0.73 g/US\$ to 0.15~0.08 g/US\$.
- Energy intensity also drops from 0.27 toe/US\$ to 0.13 ~ 0.14 toe/US\$.
- All CO₂ emission indicators in the LCDS drop below the level in the BAU scenario by 10%.

| Year | Emission Intensity (g/US\$) | | | | Energy Intensity (toe/US\$) | | | |
|------|-----------------------------|--------|------------|------------|-----------------------------|--------|------------|------------|
| | BAU | CO2000 | CO2000_70% | CO2000_50% | BAU | CO2000 | CO2000_70% | CO2000_50% |
| 2010 | 0.60 | 0.60 | 0.60 | 0.60 | 0.282 | 0.282 | 0.282 | 0.282 |
| 2015 | 0.64 | 0.50 | 0.50 | 0.50 | 0.282 | 0.281 | 0.281 | 0.281 |
| 2020 | 0.66 | 0.40 | 0.40 | 0.40 | 0.278 | 0.270 | 0.270 | 0.268 |
| 2025 | 0.69 | 0.29 | 0.29 | 0.29 | 0.277 | 0.267 | 0.267 | 0.266 |
| 2030 | 0.68 | 0.25 | 0.24 | 0.22 | 0.272 | 0.268 | 0.268 | 0.267 |
| 2035 | 0.67 | 0.22 | 0.19 | 0.17 | 0.270 | 0.225 | 0.225 | 0.222 |
| 2040 | 0.66 | 0.19 | 0.16 | 0.13 | 0.263 | 0.193 | 0.192 | 0.188 |
| 2045 | 0.68 | 0.17 | 0.13 | 0.10 | 0.265 | 0.164 | 0.159 | 0.156 |
| 2050 | 0.73 | 0.15 | 0.11 | 0.08 | 0.270 | 0.139 | 0.134 | 0.130 |

Discussion (1/3)

- Compared to the emission levels at 2007
 - Taiwan's scale of CO₂ reductions is lower than the developed countries (e.g. OECD Europe, OECD North America, and Japan), but higher than the developing countries (e.g., China, India, and Latin America) and the average global reduction.
- The average mitigation cost for Taiwan is between the two low-carbon development scenarios described in the IEA report (2006).

| | | 2050 to Baseline | 2050 to 2007 |
|-------------------------|------------|------------------|--------------|
| China | | -44% | -25% |
| India | | -47% | 100% |
| OECD Europe | | -51% | -66% |
| OECD North America | | -54% | -55% |
| OECD Pacific | | -52% | -64% |
| Economies in transition | | -49% | -32% |
| Other developing Asia | | -51% | 2% |
| Africa and Middle East | | -49% | 33% |
| Latin America | | -44% | -13% |
| World | | -48% | -24% |
| Japan | scenario A | | -74% |
| | scenario B | | -74% |
| Taiwan | CO2000 | -9.51 | -59% |
| | CO2000_70% | -13.71 | -43% |
| | CO2000_50% | -20.02 | -18% |

Discussion (2/3)

- The annual growth rates for energy and electricity demand in all three LCDS are above 1%, which is higher than the developed countries but lower than developing countries.
- A similar trend can be observed for the carbon intensity, but a greater reduction in energy intensity than OECD Europe is also found.

| growth rate % (2050 to 2000) | IEA ETP ¹ | | | | Japan ² | | Taiwan | | |
|--|----------------------|-------|-------|-------|--------------------|---------------|--------|----------------|----------------|
| | OECD Europe | US | China | India | scenario A | scenario B | CO2000 | CO2000_70 % | CO2000_50 % |
| TPES (Mtoe) | -0.24 | -0.34 | 2.46 | 2.38 | -1.0 | -1.2 | 1.33 | 1.27 | 1.25 |
| Electricity consumption (TWh) | 0.73 | 0.38 | 3.87 | 4.36 | | | 1.95 | 1.85 | 1.71 |
| CO2 emissions (Gt) | -2.64 | -3.21 | 0.69 | 0.81 | -2.6 | -2.6 | 0.00 | -0.71 | -1.38 |
| GDP (billion USD using exch. rates) | 1.28 | 1.80 | 5.39 | 5.28 | 1.4 | 0.5 | 3.20 | 3.20 | 3.20 |
| GDP (billion USD using PPP) | 1.30 | - | 5.59 | 5.28 | | | | | |
| Population (millions) | 0.19 | 0.72 | 0.23 | 0.93 | | | -0.11 | -0.11 | -0.11 |
| TPES/GDP (toe per thousand USD 2000 PPP) | -1.52 | -2.11 | -2.92 | -2.63 | -2.4 | -1.7 | -1.82 | -1.87 | -1.89 |
| TPES/population (toe per capita) | -0.43 | -1.10 | 2.24 | 1.46 | -0.4 | -0.8 | 1.44 | 1.38 | 1.36 |
| Electricity consumption /population (kWh per capita) | 0.53 | -0.33 | 3.98 | 3.40 | | | 2.07 | 1.96 | 1.82 |
| CO ₂ /GDP | -3.87 | -4.92 | -4.45 | -4.24 | -1.3 | -1.4 | -3.10 | -3.79 | -4.43 |

Discussion (3/3)

- This indicates:
 - Taiwan's economy is still growing continuously
 - Low/no carbon energy development is limited
 - Carbon-reduction incentives (e.g., carbon tax) have not been implemented
 - The draft Greenhouse Gas Reduction Act has not been adopted
- all sectors need to implement strict energy saving measures and incur high costs.

Conclusions

- Taiwan is not a party to the UNFCCC, it is not eligible to participate in the flexible mechanisms laid out in the Kyoto Protocol.
- UNFCCC is not offered Taiwan the equitable treatment accorded to parties of the UNFCCC, which is against the principle of Article 3 of the UNFCCC.
- In order maximize the effects of global climate mitigation efforts, it is pertinent for Taiwan to be eligible to take part in the flexible mechanisms as a member of the international community.

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Thank you for your attention !

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