Taiwan 2050 Net-zero Pathway

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Outline

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1. Introduction
Climate Crisis and 2050 Net-zero Target

- Climate change has now become climate crisis
- 2018, IPCC indicated in the special report “Global Warming of 1.5°C”
  - To avoid irreversible changes in systems, global warming must not exceed 1.5°C
  - Therefore, global net anthropogenic CO2 emissions must reach net-zero around 2050
  - On longer time scales, sustained net-negative global anthropogenic CO2 emissions are required to prevent further warming
    ➢ Net-negative economy and society

FIGURE SPM.3B, IPCC, 2018, Special report Global Warming of 1.5°C.
Figure SPM.3B from IPCC, 2018, Special report Global Warming of 1.5°C.
This new assessment paints a devastating picture of a worsening global climate crisis that is now “inevitable, unprecedented, and irreversible.”

(Guardian newspaper headline 10 August 2021)

Immediate, rapid and large-scale reductions of all greenhouse gases are needed to limit global warming to 1.5 degrees.

(IPCC news release, August 9, 2021)
Climate Crisis and 2050 Net-zero Target

• Net Emissions: GHG emissions released by humans minus GHG removal from the atmosphere within a period of time

• Three groups of GHG removal (GGR) methods (UK Royal Society, 2018, Greenhouse Gas Removal)
  1. Increased biological uptake
     Afforestation, reforestation and forest management; Habitat restorations; Soil carbon sequestration; Biochar; BECCS; Ocean fertilization; Building with biomass
  2. Natural inorganic reactions
     Enhanced terrestrial weathering; Mineral carbonation at surface; Ocean alkalinity
  3. Engineered removal
     DACCS; Low-carbon concrete; and others
Net-zero GHG or CO2 Emissions Target Declarations

• At the end of July 2021, over 130 countries have announced net-zero GHG or CO2 emissions target around 2050
  • June 2019, United Kingdom was the first country legislated for 2050 net-zero GHG emissions
  • December 2019, European Union, as the leader of global GHG reduction, published “European Green Deal”, announced the target to become the first climate-neutral continent by 2050
  • September 2020, China announced to reach carbon neutral by 2060
  • October 26, 2020, Japanese Prime Minister Yoshihide Suga declared that Japan would reach net-zero GHG emissions by 2050
  • October 28, 2020, President Moon Jae-in of South Korea announced that South Korea would reach net-zero CO2 emissions by 2050
  • April 22-23, 2021, President Joe Biden of US held Leaders Summit on Climate and announced goal of net-zero GHG emissions by 2050
At the end of July 2021, over 130 countries have announced net-zero GHG or CO2 emissions target around 2050.

Net-zero Emissions Race (by March 2021)
Source: Painted according to the data from Net Zero Tracker, The Energy & Climate Intelligence Unit (https://eciu.net/netzerotracker)
Net-zero in Taiwan

- **Net-zero Pathway Task Force**, November 2020- November 2021
  - Executive Yuan organizes the net-zero pathway task force
  - There are five working groups. Each one is joined by various responsible ministries, agencies, experts, and think tanks
    - Clean energy
    - Energy efficiency
    - Clean transportation
    - Negative emissions technology
    - Policies/Economic instruments
  - Executive Yuan is expected to finalize the net zero pathway by **November 2021**
Net-zero in Taiwan

• On April 22, 2021, Earth Day, President Ing-Wen Tsai announced that “The 2050 net-zero transformation is the goal of the whole world, and it is also the goal of Taiwan!”

• Taiwan is under pressure
  • Over 130 countries have announced net-zero GHG or CO2 emissions target around 2050 including our neighbors in East Asia,
  • A huge gap between the international target and Taiwan’s current target
    • Current GHG reduction target is written in “Greenhouse Gas Reduction and Management Act” since 2015
    • “Long-term national GHG emission reduction goal shall be to reduce GHG emissions to no more than 50% of 2005 GHG emission by 2050”

• Another critical pressure
  • EU CBAM (carbon border adjustment mechanism) from 2026.
  • The government and industries in Taiwan all face serious pressure and incentives. Start to change their mind gradually
Net-zero in Taiwan

• Aug. 30, 2021, in a meeting of the National Council for Sustainable Development
  • Prime Minister Su made two important decisions concerning the revision of the Greenhouse Gas Reduction and Management Act
    • The target of 2050 net-zero should be specified in the ACT
    • EPA should consult with the Ministry of Economic Affairs about the carbon pricing policy to be adopted in the Act
      • In addition to the ETS in the Act, a carbon fee system earmarked for mitigating and adapting climate change is expected
        • The ETS has not been implemented yet
        • Interest groups (businesses, environmentalists) are lobbying hard against each other on the fee rate and the usage of revenue
2. Policy choices for net-zero pathways
Approaches to mitigate climate crisis

• To avoid irreversible changes in systems, global warming must not exceed 1.5°C
  • Therefore, global net anthropogenic CO2 emissions must reach net-zero around 2050
  • On longer time scales, sustained net-negative global anthropogenic CO2 emissions are required to prevent further warming
    ➢ Net-negative economy and society

• Two major approaches to mitigate the climate crisis
  1. To reduce GHG emissions
     • Emission reduction
  2. To remove GHG stocks in the atmosphere, GHG removal (GGR)
     • Using negative emissions technologies (NETs) to remove GHG from the atmosphere
       • Natural: forestry, agriculture
       • Technological: energy, industry
       • Combined: BECCS
All available Strategies and Policies

• To reach net zero by 2050, we need all available and correct strategies and policies
  • Proactive GHG reduction and removal policies
  • R&D of low-carbon and GGR technologies
  • Transforming to become a net-negative economy and society
Economic Strategies and Policies

- Economic incentives
  - To reduce GHG emissions
    - Carbon pricing (carbon tax and ETS) and energy tax based on GHG emissions or fossil fuels
      - Tax-fund system: Tax revenue to be disbursed to citizens and to form a GGR fund
  - To remove GHG stocks
    - Using the interests of the GGR fund
      - To pay the carbon removal price based on GGR
        - Reverse auction of GGR
        - To invest in GGR R&D
    - Dynamic cap-and-trade system with banking and borrowing
      - Emission allowances
      - Carbon removal obligations
Economic Strategies and Policies

• To overcome free-riding in international climate agreements and to encourage other countries to join a climate club, such as EU
  • Tariff
  • Carbon border adjustment mechanism (CBAM)
  • Green carbon fund
    • See Shaw and Fu. "Climate clubs with tax revenue recycling, tariffs, and transfers." Climate Change Economics (2020)
Economic Strategies and Policies

• Sustainable consumption and production policies
  • Huge investments for transforming the system of consumption and production are needed
    • Government investments in infrastructure
    • Private investments: households and industries
  • Related policies
    • Greening government budgeting and procurement
    • Greening finance
      • Loans, bonds, investment, financing
    • Green financing: Green carbon fund
    • Systems of green consumption and production
      • Green value chain
      • Extended producer responsibility to cover the whole value chain
3. Methodology
Cambridge Econometrics

• Cambridge Econometrics founded in 1978
• A commercial spin-off from the University of Cambridge
• Take forward the pioneering work of Professor Sir Richard Stone
  • 1984 Nobel Laureate in Economics
• Research fields: applied economic analysis
• Models: E3ME, MDM-E3, LEFM, CHELMER
• Projects
  • New Climate Economy – unlocking the inclusive growth story of the 21st Century
  • Modelling global renewables targets
  • Fueling Europe’s Future: How the transition from oil strengthens the economy
E3ME: Global Macro-econometric Model

• To analyze the short-, medium- and long-term impacts of Energy-Environment-Economy (E3) policies

• E3ME is a dynamic, computer-based, global macroeconomic model. The econometric approach, which provides a strong empirical basis for the model and means it is not reliant on some of the restrictive assumptions common to CGE models

• The first version of the E3ME model was built by an international European team under a succession of European Commission research projects, which were completed in 1999

• E3ME’s origins lie in post-Keynesian economic theory. E3ME includes a realistic representation of the financial system and pays particular attention to unemployment and the labor market

• Features
  • Covers 59 global regions and 43 economic sectors in each region, with additional detail in Europe
  • Its econometric specification addresses concerns about conventional macroeconomic models and provides a strong empirical basis for analysis. It can fully assess both short and long-term impacts and is not limited by many of the restrictive assumptions common to Computable General Equilibrium (CGE) models
  • Integrated treatment of the world’s economies, energy systems, emissions and material demands. To capture two-way linkages and feedbacks between these components.

• Timeframe: 1970-2050 on an annual basis. Version 6
Future Technology Transformations (FTT)

• FTT is a group of sectoral models of technological change
  • power, road transport, household heating and steel
• Dynamic selection and diffusion of innovations
  • Lotka-Volterra equation
4. Policy Scenarios
To reach the 2050 net-zero target, need all possible and correct strategies to induce transformation of all sectors.

Total CO2 emissions: 283 MtCO2 (2018), 289 MtCO2 (2019)

- Removal by LULUCF: 22 MtCO2 CO2

Emissions by sectors in 2018:
- **Energy sector (94% of total CO2 emissions)**
  - Energy Industry (71% of CO2 emissions from energy sectors)
  - Transportation (13% of CO2 emissions from energy sectors)
- **Manufacturing Industry and Construction** (12% of CO2 emissions from energy sectors)
  - Chemicals
  - Iron & Steel
  - Non-metallic mineral products
Taiwan CO2 emissions in 2018 from energy sector

- **Energy Industry**: 71%
- **Manufacturing Industry and Construction**: 13%
- **Transportation**: 12%
- **Service Industry**: 2%
- **Residential**: 1%
- **Agriculture, Forestry, Fishery, and Husbandry**: 1%
- **Others**: 1%

**CO2 emissions from the energy sector are 267 MtCO₂**

**CO2 emissions from Manufacturing Industry and Construction**

- **Iron & Steel**: 26%
- **Non-ferrous metal industry**: 15%
- **Chemicals**: 18%
- **Pulp, Paper and Printing**: 30%
- **Food, Beverage and Tobacco**: 7%
- **Non metallic mineral products**: 3%
- **Others**: 1%

**Note:** Total CO2 emissions in 2018 are 283 MtCO₂, removal from LULUCF are 22 MtCO₂
Four emission intensive industries in Taiwan

GHG Emissions from Manufacturing Industry in 2019

GHG emissions from manufacturing industry are 150 MtCO2e

Note: Total GHG emissions in 2019 are 289 MtCO2e
Carbon tax rate rises yearly. Lump-sum transfer tax revenues to citizens after paying GGR or investment.

Increase solar PV and off-shore wind power's capacity.

R&D in fossil fuels + CCS.

Phase out oil, coal and gas in power generation.

Fossil fuels alone can't be used.

Fossil fuels + CCS.

Increase EV market share.

Phase in CCS.

90% by 2036.

Increase rapidly.

Keep increasing.

Phase out coal or gas for power. Use green energy or hydrogen.

Raise energy efficiency, R&D in CCS and Hydrogen.

Phase in BECCS.

R&D in NETs.

Phase in CCS.

99% by 2047.

Increase rapidly.

Keep increasing.

Policy Scenarios:

1. Carbon Tax
2. Renewables
3. Regulation on fossil fuels
4. EVs
5. Transformation of Energy Intensity Industries
6. NETs
1. Real Carbon Tax Rate in 2050 is equal to the unit cost of NETs in 2050 (Royal Society, 2018).

2. Nominal Carbon Tax Rate rises at a nominal interest rate of 4.88% (real interest rate 3.8% + inflation rate 1.08%).

- Apply the Hotelling rule (QJE, 1931)
- Backstop technology: NETs
- Calculate the shadow price of carbon
- Rises at a real interest rate of 3.8%, to reach the unit cost of the backstop technology in 2050
5. Taiwan 2050 Net-zero Pathway
(Preliminary Results)
Power Structure in 2050

- **Baseline**
  - Coal: 66.94%
  - Gas: 23.73%
  - Renewables: 4.1%

- **1 Carbon Tax**
  - Coal: 1.54%
  - Gas: 45.75%
  - Renewables: 22.0%
  - Coal + CCS: 1.42%
  - Gas + CCS: 24.68%

- **1 + 2 Carbon Tax + Renewables**
  - Coal: 6.3%
  - Gas: 5.2%
  - Renewables: 87.8%
  - Coal + CCS: 0.1%
  - Gas + CCS: 0.1%

- **1 + 2 + 3 Carbon Tax + Renewables + Regulations on Fossil Fuels**
  - Coal + CCS: 2.0%
  - Gas + CCS: 7.1%
  - Renewables: 71.3%
  - BECCS: 19.6%

- **Current Policy: 20%-30%-50%**
  - Coal: 28.9%
  - Gas: 44.3%
  - Renewables: 23.5%

Emissions from power generation:
- **Baseline**: 201.52 MtCO2
- **1 Carbon Tax**: 43.68 MtCO2
- **1 + 2 Carbon Tax + Renewables**: 14.30 MtCO2
- **1 + 2 + 3 Carbon Tax + Renewables + Regulations on Fossil Fuels**: 1.35 MtCO2
- **1 + 2 + 3 + 4 + 5 + 6**: -41.73 MtCO2

Current policy: 20%-30%-50% Emissions from power generation 101.23 MtCO2

Note: Because EV and Transformation of energy intensive (EI) industries do not make much difference on power mix, we did not present power mix of those scenarios.
2030s
Mostly Gas and Renewables
Coal 22.8%
Gas 33.1%
Renewables 40.2%
Coal + CCS 0.2%
Gas + CCS 0.9%

2040s
Mostly Renewables, with some Gas + CCS
Renewables 65.4%
Coal + CCS 6.9%
Gas + CCS 27.7%

2050s
Mostly Renewables, with some BECCS
Renewables 71.3%
Coal + CCS 2.0%
Gas + CCS 7.1%
BECCS 19.6%
Note:
1. We use total CO2 emissions minus CO2 removals to get the historical data from 2005 to 2018.
2. Net CO2 emissions after 2019 are the difference between the total CO2 emissions simulated by E3ME and 21 MtCO2 from LULUCF.
3. We only present the results of carbon tax with revenue recycling in this graph. The results without revenue recycling are a little bit smaller. Because the two curves almost coincide, thus we do not present in the graph.
4. We calculate the Target in Law using total GHG emissions reduction percentage as total CO2 emission reduction percentage, and then subtract 21 MtCO2 of LULUCF.
CO2 emissions from Iron & Steel in 2050 (MtCO2)

- 5.1+6.1
- 5.2+6.1
- 5.3+6.1

CO2 emissions from Chemicals in 2050 (MtCO2)

- 5.1+6.1
- 5.2+6.1
- 5.3+6.1

100% investment paid by industry will have the least emissions.

100% investment subsidized by carbon tax revenue will have the highest emissions because of rebound effect.
1.R+2+3+4 Invest in EV will have positive impacts on GDP

(1+2) Renewables policy invest more from 2021 to 2045 than current policy, and will have positive impact on GDP

1.R+2+3 Invest in Fossil Fuels + CCS

(1.0) Without revenue recycling will have negative effects on GDP

Current Policy: 20%-30%-50% will need to invest in Renewables before 2025, and will have positive effects on GDP

(1+2+3) Invest in Fossil Fuels + CCS

(1.R) Carbon tax with lump-sum revenue recycling will increase consumption and investment, and have positive effects on GDP
GDP relative to baseline (part 2)

(5.1 or 5.2 or 5.3 +6.1)
Carbon Removal Price paid by carbon tax revenue is better for GDP

Among the scenarios, investments in transforming the EI industry 100% paid by firms will increase GDP the most

(5.1 or 5.2 or 5.3 +6.2)
Carbon Removal Price paid by government has smaller positive effects on GDP because it will crowd out other government expenditures
Income Redistribution (2050)

Real disposable income relative to baseline will decrease if Carbon Removal Price paid by carbon tax revenue. Lower income group decreases less than higher income group.

Real disposable income will increase relative to baseline if Carbon Removal Price paid by government budget. Lower income group increases more than higher income group.
6. Conclusions
Taiwan 2050 Net Zero Pathway

- Taiwan can meet the target of 2050 net-zero, and result in a win-win solution in terms of net-zero emissions, economic growth, and social equity
  - Need to adopt all possible and economically correct policies and strategies
    - Polluter pays principle
    - And avoid those unsound policies
      - Subsidize polluters
Thank you for your attention!