NSTC 國家科學及技術委員會 National Science and Technology Council

中華民國經濟部 Ministry of Economic Affairs, R.O.C.

行政院環境保護署 Environmental Protection Administration Executive Yuan, R.O.C.(Taiwan)

Net Zero Transition: 12 Key Strategies

2050 Net Zero Transition Key Strategies 「Carbon Capture, Utilization and Storage, CCUS」Action Plan(Draft)

Ministry of Economic Affairs (MOEA)
Environmental Protection Administration (EPA), Executive Yuan
National Science and Technology Council (NSTC)

Dec. 2022

Outline

1. The Analysis of Current Situation
2. Plan Targets and Timeline
3. Division of Authority and Responsibilities
4. Execution Strategies and Measures
5. Just Transition
6. Expected Benefits
7. Budget Planning

1. The Analysis of Current Situation

Broader policy approaches and technologies are required to achieve the goal of decarbonizing the global energy system

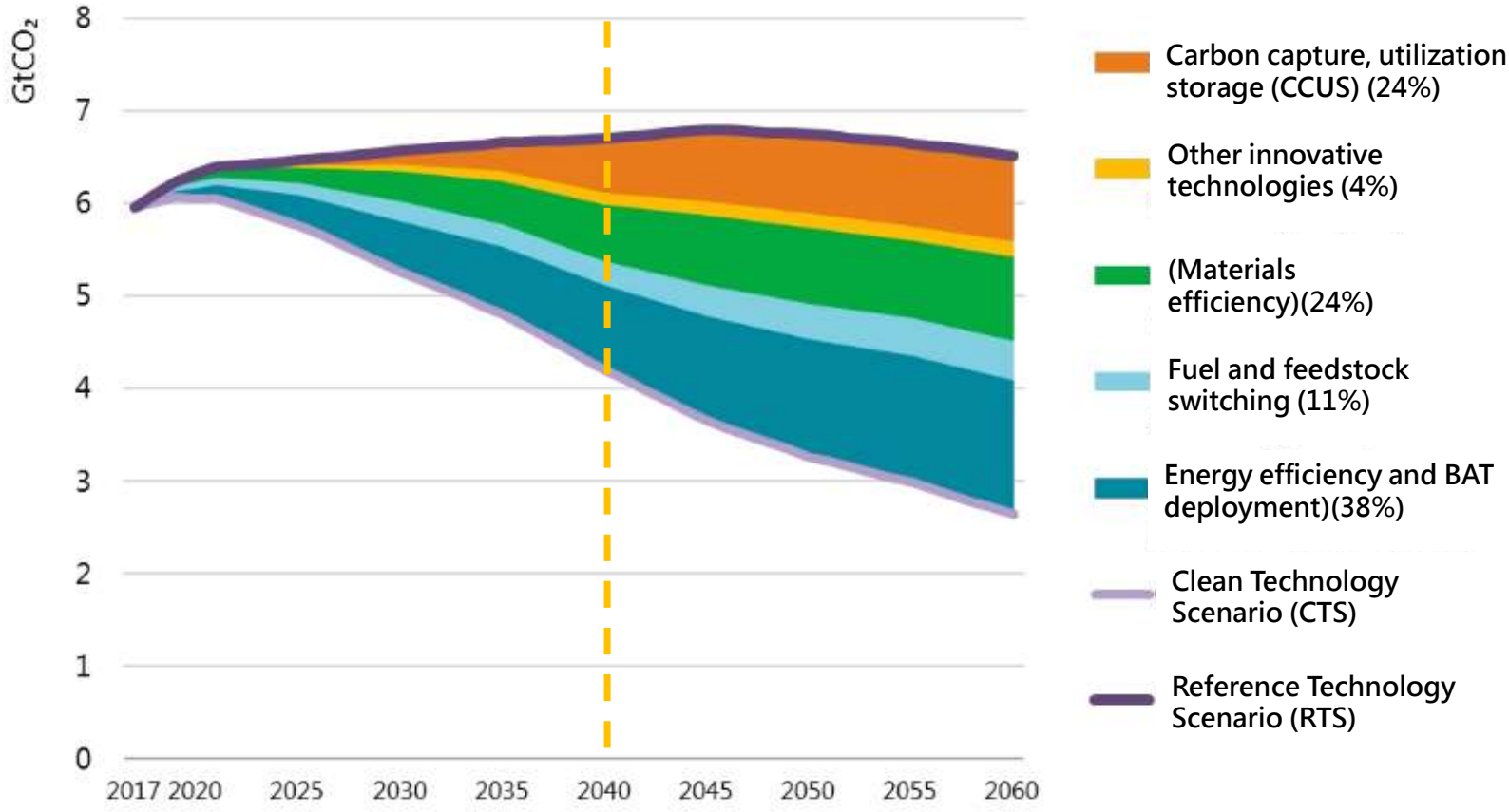
In order to halt the intensification of climate change and to reach the Paris Agreement goal to limit global warming to below 1.5 ° C, countries are actively setting reduction targets and commitments to net zero emissions. According to the International Energy Agency (IEA), electricity will be the most affected sector in the net-zero transition.

- Renewable Energy
- CCUS
- Behavior Change
- Energy Efficiency
- Hydrogen Energy
- Electrification
- Biomass Energy
- Just Transition

Note: CCUS is a carbon capture, utilization and storage technology (Carbon Capture, Utilization and Storage, CCUS), mainly to solve the carbon dioxide emissions generated from the production of industrial products and the conversion of fossil fuels into energy, and to capture carbon dioxide through different technologies and then to use or to archive.

Reference: Net Zero by 2050 A Roadmap for the Global Energy Sector, IEA, July 2021.

IEA scenario shows that CCUS will be a key carbon reduction technology at the later stage



Source: IEA 2019. All rights reserved. Notes: The Reference Technology Scenario (RTS) includes current country commitments to limit emissions and improve energy efficiency, including Nationally Determined Contributions (NDCs).

CCUS summary

The CO_2 is separated from flue gas of power plants, industrial sites emission or directly from the air. The CO_2 captured will be then transformed into useful chemicals of commercial importance or injected underground for permanent storage.

Note: BAT: Best Available Technology; CTS: Clean Technology Scenario; RTS: Reference Technology Scenario
Reference: IEA(2019), Transforming Industry Through CCUS

2050 Net-Zero Pathway (Key Milestones)

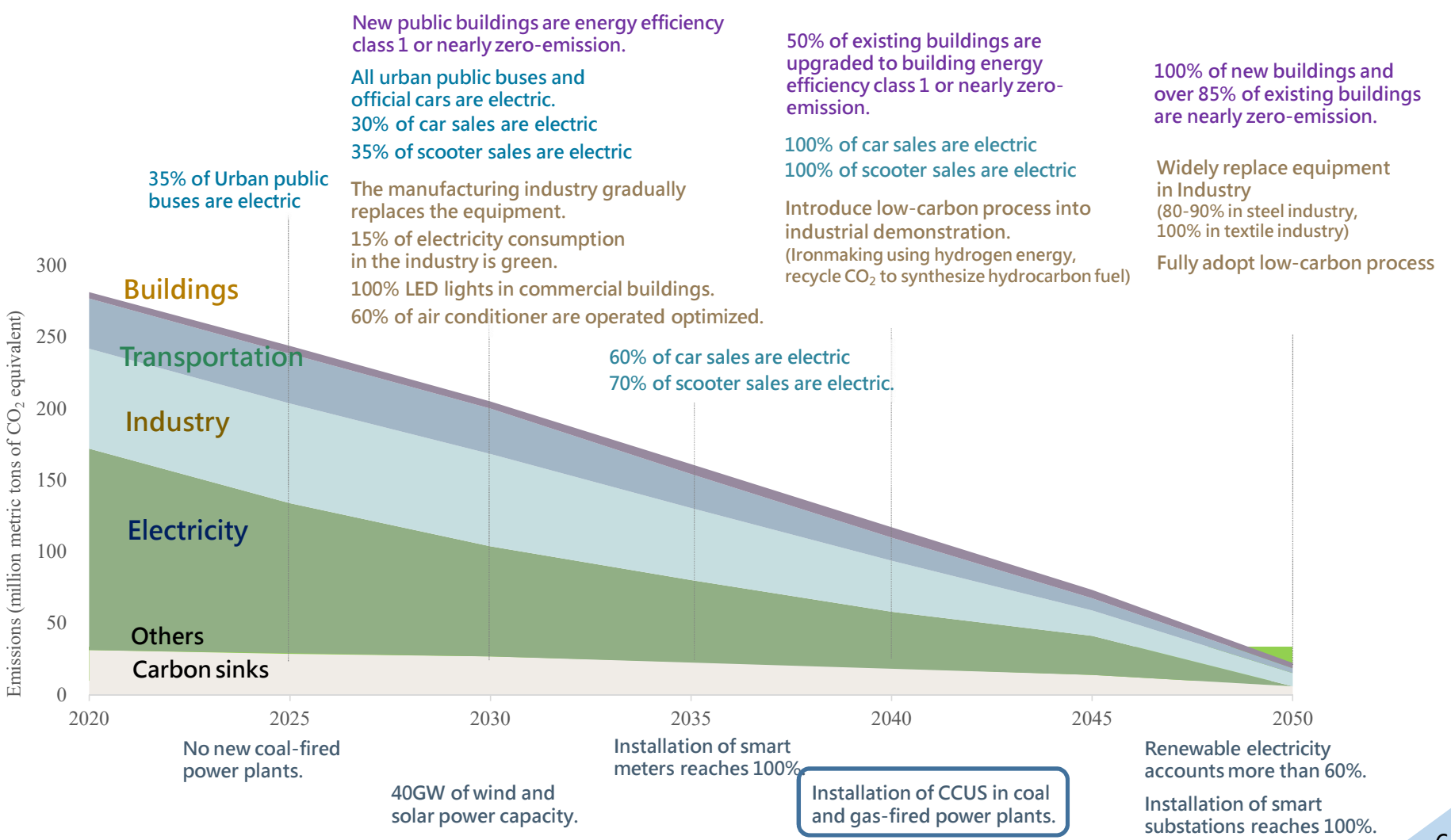
Buildings
Improving in exterior design, energy efficiency and appliance energy efficiency standards.

Transportation
Changing in travel behavior, reducing demand for transportation, and electro-mobility.

Industry
Improving in energy efficiency, fuel switching, circular economy, and innovative technologies.

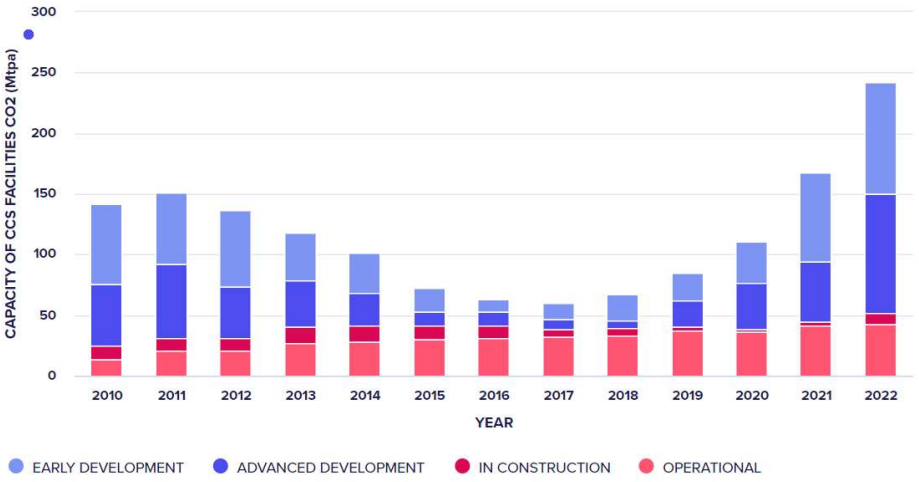
Electricity
Scaling up renewable energy, developing new energy technologies, energy storage, and power grid upgrade.

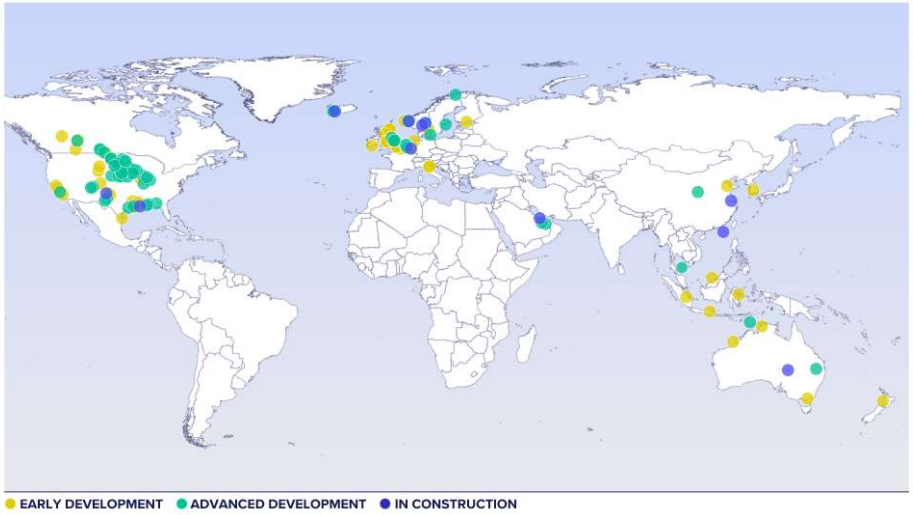
Negative emissions technologies
Demonstration by 2030.
At scale by 2050.



Reference: National Development Council,「Taiwan' s Pathway to Net Zero Emissions in 2050」, 2022.03.30

Whilst several CCUS demonstration projects are running globally, further research is needed to scale up the technology





■ International Demonstration Project

Boundary Dam, Canada

In 2014, CCS technology was applied to coal-fired power plants. By 2022, the accumulated carbon capture capacity had reached 4,370,715 metric tons. The captured CO_2 is mainly used for Enhanced Oil Recovery (EOR) and storage.

Tomakomai, Japan

From 2016 to 2019, CO_2 was injected into the underground layers of nearly 1,000m and 2,400m below the seabed, and a total of 300,000 tons of CO_2 was injected.

Reference: MOEA(2022); IEA (2020); IEA, CO_2 emissions; Global CCS Institute

Amplifying the use of carbon capture technology domestically will depend on a proactive carbon utilization and storage planning

Formosa Petrochemical Mailiao CO_2 Capture testing plant

Developed by the National Tsing Hua University(NTHU), the capture capacity reaches **1.6t CO_2 daily** (67kg/h), with energy consumption < 3.0 GJ/ton of CO_2.

Taiwan Cement Corporation: The Calcium Looping Carbon Capture Pilot Plant

TCC cooperated with ITRI established capture **1 ton CO_2/hr** of pilot plant and **0.25 ton CO_2/hr** of new generation test facility, respectively. Next step will scale up the oxyfuel calcination system to capture **100,000 tons CO_2/year** in 2030.

Changchun Petrochemical: CO_2 conversion to acetic acid

Transport high-concentration CO_2 exhaust from Dairen Chemical Cooperation and Nanya Plant to Changchun Petrochemical, which is converted into CO, and synthesized with methanol to make acetic acid. The annual production capacity is **600,000 tons**, **removing 160,000 tons CO_2/year.**

Reference: Chung Sung Tan (2022),「CO2 Capture, Storage and Utilization (CCSU)」, Department of Chemical Engineering, National Tsing Hua University, https://reurl.cc/X5O0GE ; ITRI ; MOEA(2022),「Taiwan' s Pathway to Net Zero Emissions in 2050 - CCUS」; Government Science and Technology Development Plan (2018), the second-phase performance report-carbon reduction and coal elimination group ; MOEA(2019), Low-carbon manufacturing processes in energy-intensive industries : cases compilation

Problems to be solved for CCUS technology implementation

Carbon Capture

1) The costs of CO_2 capture remain too high (US$50-70/ton) to be widely deployed, with the capture efficiency needing to be ameliorated.
2) The feasibility of the technology shall be tested based in a step-by-step manner.
3) Relevant infrastructure is not yet provided for.
4) There is currently no existing storage site, which discourages companies from scaling up the capture capacity.

Carbon Utilization

1) High costs and a lack of catalysts with low reaction temperature and high conversion efficiency.
2) The development of catalyst technology for CO_2/hydrocarbons conversion is necessary to reproduce high value-added petrochemical or other raw materials.
3) Stable supply sources of hydrogen is needed to expand CO_2 utilization planning in future.

Carbon Sequestration

1) Storage sites shall be addressed with issues related to environmental protection and safety.
2) Lack of relevant regulations and standards.
3) The success of carbon sequestration in deep saline aquifers in marine environments requires the development and implementation of technologies for geological exploration, marine engineering, and monitoring, operation & maintenance from domestic perspectives.

Reference: MOEA(2022),「Taiwan' s Pathway to Net Zero Emissions in 2050 - CCUS」

Formulating effective strategies and measures based on past CCUS research achievements and bottlenecks

Technology still needs to be refined

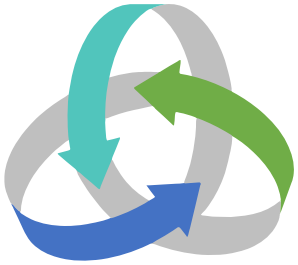
1. Continue to subsidize forward-looking technology R&D
2. Cooperate with the industry to improve existing technology

Geological data is fragmentary and remains to be integrated

1. Promote cross-departmental ministry cooperation to acquire and integrate geological data.
2. Prioritize and develop the technologies required to explore and acquire regional geological information such as shoreline and marine environment.

There is currently no carbon storage related technology and site verification data

1. Promote demonstration projects with state-owned enterprises
2. Cooperate with academic research institutes to conduct long-term monitoring and tracking, and safety risk assessment



Lack of policy research and methodology to address just transition

1. Continuedly assess possible impacts of CCUS implementation on industry, labor, people's livelihood and regional development
2. Promote relevant social science research

National regulations shall be kept consistent with international norms

Establish carbon capture and storage assessment guidelines and management mechanisms

Taiwan's 2050 Net-Zero Transition

12 Key Strategies

2. Plan Targets and Timeline

CCUS carbon reduction target in 2030 is optimistically estimated at 4.6 million tons

Based on the IEA estimated global carbon capture level and our national conditions, the positive goal for 2030 is set as following:

2030 Target

Baseline Goal

Promoting the demonstration project, the estimated carbon reduction benefit of CCUS is **1.74-1.79 million tons**[1*]

Positive Goal

If relevant regulations and supporting facilities are in place by 2025, it is estimated that the CCUS will contribute to **4.6 million tons** reduction[2**]

2050 Target

Committed to reducing carbon emissions by **40.2 million tons** through advanced methods such as improving regulations, strengthening social communication, promoting industrial applications, and continuously researching and developing cutting-edge technologies for ocean and soil carbon sinks.

Note 1* According to the data from the Ministry of Economic Affairs: (1) Power industry: The carbon capture and sequestration test of Taipower Taichung Plant and the carbon sequestration test of CPC cooperation Miaoli Tiezhenshan, the total amount of CO_2e capture and store is 1 million tons/year. (2) Small scale demonstration of CCUS is implemented in the petrochemical industry, steel industry and cement industry introduce, about 0.7-0.8 million tons of CO_2e. Among them, 210,000 tons of petrochemicals, 480,000 tons of steel, and 50,000 to 100,000 tons of cement, with a total negative carbon emission of 1.74-1.79 million tons of CO_2e.

Note 2** Reference: MOST(2021)

Keep supporting forward-looking carbon capture research, training future-proof talents, and improving existing technologies to scale up capture capacity yearly

R&D Stage | Demonstration Stage | Widespread Stage

Carbon Capture Technology Research and Development Plan

NSTC

- Chemical absorption process and calcium looping carbon capture technologies demonstrations → Scale-up and commercialization
- Biomass or waste gasification power generation applications → Scale-up and commercialization
- Forward-looking carbon capture technologies and relevant talents cultivation → Demonstration & Verification → Scale-up
- Direct air carbon capture technology and relevant talents cultivation → Demonstration & Verification

2022 — 2025 — 2030 — 2040 — 2050

Carbon Capture Technology Development /Application Plan

MOEA

Development of CO_2 Capture Technology with Low-Cost

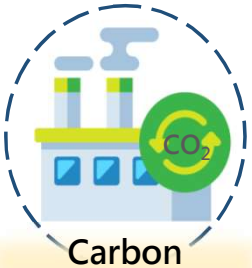
- Enhance existing industrial technology, such as low-temperature desorption/long-duration capture scavenger
- Cooperate with high-carbon emissions and state-owned enterprises to conduct CO_2 capture field verification
- Assist the industry in maximizing the system integration efficiency and gradually scaling up to million-ton capture capacity

Application scale-up

Reference: NSTC(2022); MOEA (2022),「Taiwan’s Pathway to Net Zero Emissions in 2050 - CCUS」

Develop forward-looking carbon utilization technology to improve existing conversion efficiency, and develop new biomass chemical and energy products to enhance product added value

R&D Stage | Demonstration Stage | Widespread Stage



Carbon Utilization Technology R&D Plan

NSTC

- Develop high-efficient/new catalysts to convert CO_2 into high value-added chemicals
- Develop biomass crops into biochemical and energy products

Demonstration & Verification

Industrial application

2022 — 2025 — 2030 — 2040 — 2050

Carbon Utilization Technology Development /Application Plan

MOEA

Innovative Technologies to Promote the Transformation of CO2 Utilization into Low-Carbon Chemicals

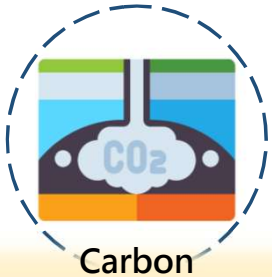
- R&D of low-temperature and high-efficiency catalysts required for CO_2 conversion
- Assist the industry in developing innovative technologies for the synthesis of chemicals, such as ethane/propane, and their conversion into bulk petrochemical raw materials, such as ethylene/propylene
- Combine CO_2 with hydrogen or hydrogen-related production technology to expand CO_2 utilization domestically

Application scale-up

Reference: NSTC(2022); MOEA (2022),「Taiwan’s Pathway to Net Zero Emissions in 2050 - CCUS」

Collect geological exploration data, identify key areas for exploration and develop related technologies, and promote demonstration experiments to obtain critical local parameters for analysis

R&D Stage | Demonstration Stage | Widespread Stage



Carbon Sequestration Technology Research and Development Plan

NSTC

1. Ameliorate simulation and assessment of the rate of geological carbon sequestration mechanisms
2. Geological exploration and potential storage capacity assessment
3. Technology for storage monitoring and maintenance

2022 — 2025 — 2030 — 2040 — 2050

Carbon Sequestration Technology Development /application Plan

MOEA

Establish an Operational CO_2 Storage Field

- Establish the technologies for geological storage safety monitoring, risk assessment, site operation and maintenance, and import maritime engineering technologies abroad
- Complete the legislation and gradually expand the investment in the development of saline aquifer storage sites from the coast to the sea areas

Carry out field verification and demonstrate the feasibility of storage to obtain critical parameters and experiences

Scale-up and gradual commercialization

Reference: NSTC(2022); MOEA (2022),「Taiwan’ s Pathway to Net Zero Emissions in 2050 - CCUS」

3. Division of Authority and Responsibilities

Technology R&D

Forward-looking Technology Development

- Before 2030, unmature concepts and prototype technologies still need to developed to meet 2050 net zero emissions target
- Continuously enhance the research and development capacity of science and technology

Technology R&D: NSTC, Academia Sinica

Advance Implementation of Industrial Technology

- Develop innovative technologies for low-cost CO2 capture
- Innovative technologies for the conversion of CO2 capture and utilization into low-carbon chemicals
- Establish an operational CO2 storage field
- Promote the replication and diffusion of CCUS based on successful cases

Demonstration/Verification: MOEA, Public/Private enterprises

Legislation, Policy, Governance

Complete Legal Support

- Integral assessment of carbon reductions of Net Zero Pathway strategies
- Adjustment of CCS regulatory structure and establishment of reduction counting methodology and verification mechanism

Policy Promotion: Environmental Protection Administration

International Cooperation

- Work with international institutions and enterprises to level up CCUS research and development capabilities and international talents cultivation in Taiwan
- Evaluate cooperation opportunities with international partners to introduce related technologies and experiences in Taiwan

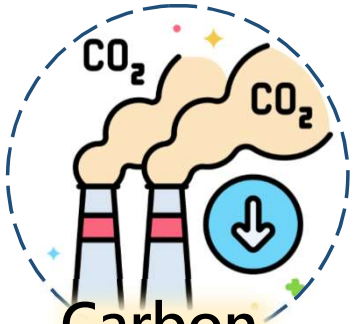
Inter-ministerial Collaboration: NSTC, MOEA, EPA, Academia Sinica

Just Transition

National Development Council (collaboration with other ministries)

4. Execution Strategies and Measures

Technical and geological aspects: The NSTC is responsible for CCUS forward-looking technology development and geological exploration, while the MOEA assists in industrial connection and refinement of existing industrial technologies



Carbon Capture

1. Enhance carbon capture mature technologies: such as chemical absorption and calcium loop
2. R&D on forward-looking carbon capture technologies: such as physical absorption, solid adsorption, membrane, chemical cycle, algae carbon fixation, etc.

Carbon Utilization

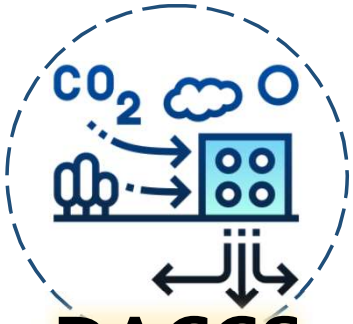
1. Enhance carbon capture and direct utilization technologies: such as supercritical carbon dioxide solvent application technology, marine ranch, plant/algae factory, etc.
2. R&D on CO_2 conversion technologies: such as conversion technology of CO_2 into chemicals or energy products

Carbon Sequestration

1. Develop and import technologies for geological exploration through and international cooperation: innovative technologies such as geological carbon storage and mineralization.
2. Geological structure investigation and simulation evaluation: such as field simulation of storage mechanism rate, etc.

BECCS

1. Develop biomass energy combined with carbon capture, storage and utilization (BECCS/U) : such as high-efficient biomass green energy combined with carbon capture/biomass material utilization technology
2. Develop technology to reuse and add high-value to agricultural residual materials: such as agricultural and industrial residual materials and sludge/biogas residue circular economic system combined with negative carbon technology, etc.



DACCS

1. Development of high-efficient carbon-fixation technology and adsorption materials for direct air capture: such as the development of high-efficient carbon-fixation algae/carbon-fixation microorganisms, etc.
2. R&D on carbon footprint calculation and methodology: such as the development of negative carbon footprint technology , environmental footprint, carbon sink calculation, and related methodology, etc.

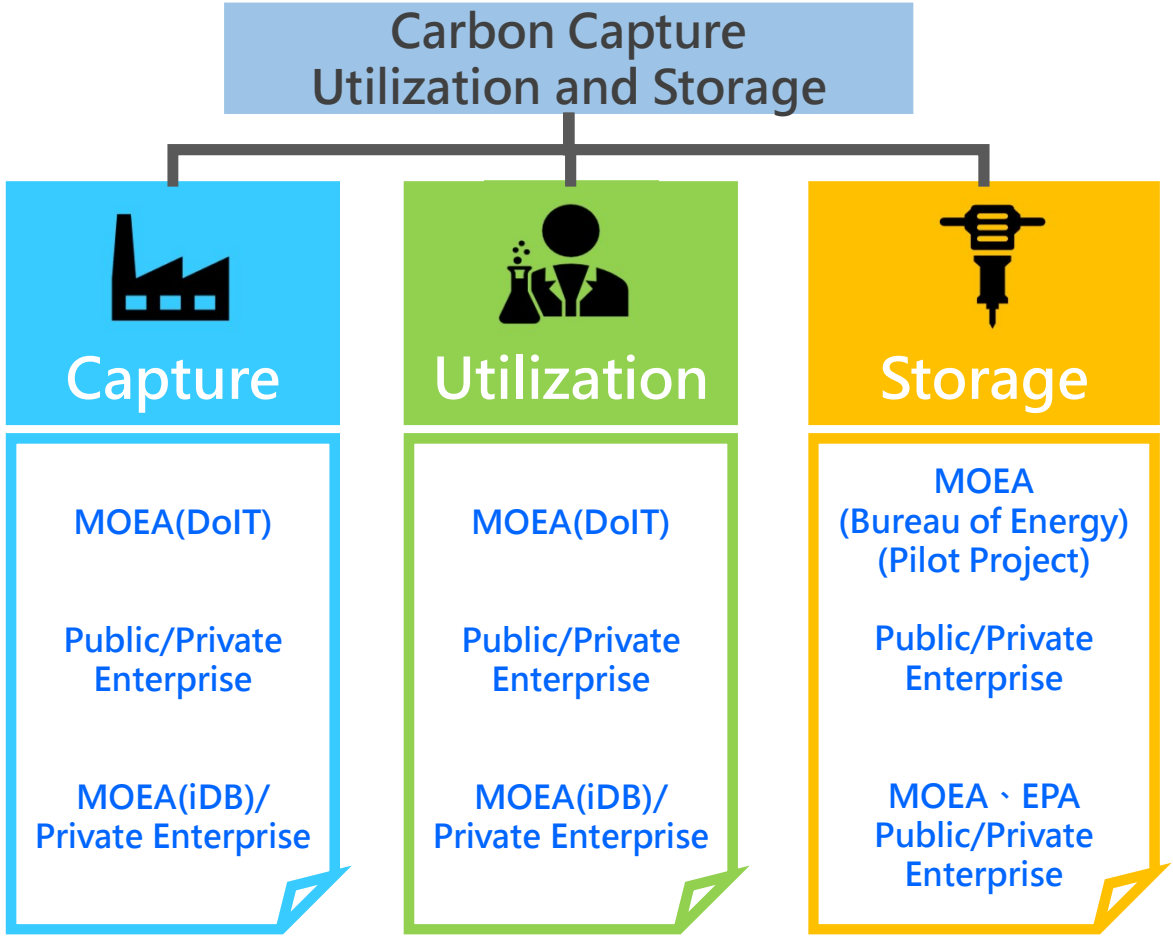
Domestic Technology Development and Refinement

International Cooperation and Technology Introduction

Industry-Academy Cooperation and Talent Cultivation

Cross-ministerial Technology Application and Verification

Field demonstration: The MOEA cooperates with public/private enterprises to expand the demonstration scale of carbon utilization and promote field experiments of carbon sequestration



Diffuse Carbon Utilization Experience

- Guide other industry players to establish CCUS facility
- Assist the industry to convert various hydrocarbon products through the utilization of CO_2, and increase the amount of CO_2 for reuse purpose
- Public enterprises continue to increase carbon sequestration capacity and establish the industry of carbon sequestration and maintenance services

Promote Carbon Sequestration Demonstration

Public enterprises take the lead in demonstrating carbon reduction and will trigger investment from other public/private enterprises

Reference: NSTC(2022); MOEA (2022),「Taiwan’ s Pathway to Net Zero Emissions in 2050 - CCUS」

Regulations: EPA will complete CCUS-related regulations to support and promote work planning

Climate Change Act authorizes the establishment of the carbon capture and storage management system and clarifies the authority and responsibility of the competent authorities

➲Core Work Planning

- ➢ Licensing Regime and Monitoring Guidelines/Planning
- ➢ Site Suitability Assessment Guidelines or Specifications
- ➢ Technical Promotion and Regulatory incentive for Test Plans
- ➢ Negative Carbon Technology Regulation Strategy and Industry Incentive Measures
- ➢ Public consultation (NGO and local supervisors, information platform promotion, consultation and discussion)
- ➢ Cooperate with international units to promote carbon reduction performance in line with international standards
- ➢ Improve domestic carbon sequestration regulations

Plan Goals

Research and develop carbon capture and storage (CCS) environmental management mechanism, including carbon capture and storage assessment guidelines, permission management regulations, environmental and ecological impact, and environmental monitoring strategies ect

Working Items

- ■ Regulatory framework for permission and carbon reduction performance
- ■ Management mechanism for testing plan
- ■ Incentive mechanisms for reduction benefits
- ■ Survey and monitoring methods for carbon sequestration research and development in ecological sea areas

Expected Results

Establish the assessment guidelines and management mechanisms of carbon capture and storage, combined with reduction benefits, as well as (Carbon credit) incentive measures to facilitate the promotion and implementation of this key strategy.

Reference: Environmental Protection Administration (2022)

5. Just Transition

Identify and address key issues by holding social dialogue and strengthening communication with stakeholders

Labor Aspect

- If CCUS is implemented in the existing carbon emission industry in the future, it will help trigger industrial transformation, create job opportunities, and provide opportunities for current employees to learn new job skills.
- If some companies fail to transform smoothly during the industrial transition process, it may cause unemployment.
- The process of learning new skills may lead to stress accumulation, physical and mental adjustment problems for labors.

Industry/Livelihood Aspect

- In addition to the use of green energy, the introduction of CCUS will effectively reduce the pressure of carbon border tax imposed by European countries and American on high-carbon-emission industries.
- The costs of CCUS equipment and technology will also increase operating costs for companies, which may pass them onto consumers and affect people's livelihood.

Region/Livelihood Aspect

- The implementation and application of CCUS technology can reduce the carbon emissions impact of industrial parks or factories on the neighboring environment and residents. Low-carbon communities may even boost the development of regional economy.
- The security management of carbon storage sites and its impact on the local environment are also issues of concern to the people living around.

6. Expected Benefits

Technical Aspect

- Increase the capture and utilization capacity to increase carbon reduction benefits
- Develop new technologies to improve the performance
- Reduce the costs of practical application

Academic Aspect

- Establish domestic carbon storage database
- Build research teams
- Assess potential carbon storage sites
- Develop technologies for exploration and monitoring

Economic Aspect

- Incentivize at least 4 demonstration sites in the industrial process
- Drive more than 9 manufacturers and more than 2 billion R&D resources for investment in related areas

Legal Aspect

- Establish carbon capture and storage assessment guidelines and management mechanisms
- Improve CCUS-related regulations
- Create incentives and subsidies

Just Transition Aspect

- Formulate policy supporting measures for just transition
- Establish the platform for communication
- Information transparency

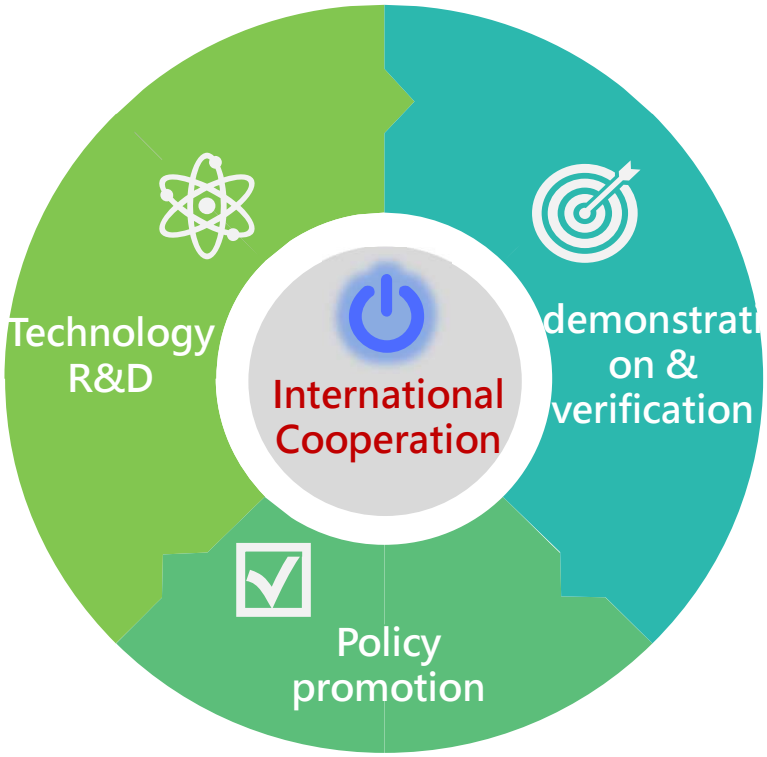
7. Budget Planning

Subsequent budget planning will be adjusted on a rolling basis, depending on the effectiveness of the initial demonstration and verification and the maturity of technology development

An estimated budget of 3.723 billion NTD is ring-fenced for CCUS in 2023-2024

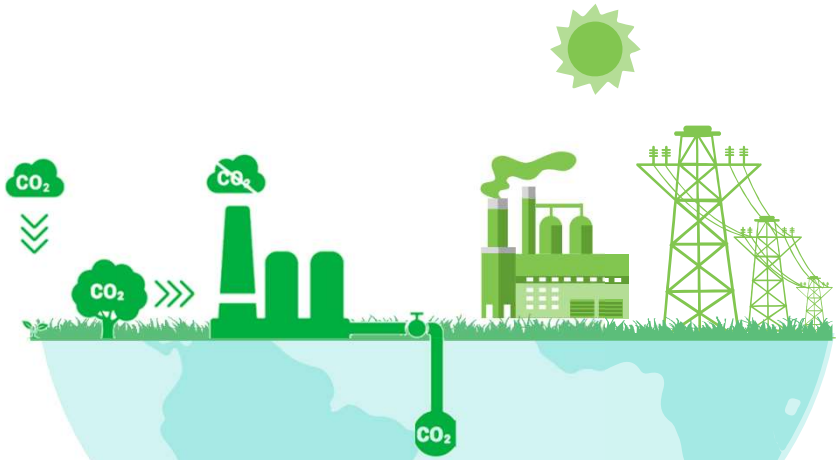
Development of Forward-looking Technology
NSTC
443 million NTD

Improvement of Legislation Support
EPA
43 million NTD



Application of Existing Technology
MOEA
3.237 billion NTD

Reference: NSTC(2022); MOEA (2022),「Taiwan' s Pathway to Net Zero Emissions in 2050 - CCUS」; Environmental Protection Administration (2022)



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