AIT Lecture

YONSEI UNIVERSITY
Graduate school of International Studies

Deep De-carbonization Pathways: Korea as an example

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Current Position
- Professor, Yonsei University
- Director, Sustainable Development Program, Ban Ki-moon Foundation
- Coordinating Lead Author, WG3, IPCC
- Member, Presidential Council on Carbon Neutrality and Green Growth, Republic of Korea
- Board Member, World Wild Fund, Korea
- Director, Global Partnership, Education Commission Asia
- Finance Sector Advisory Panel, Asian Development Bank
- Editorial Board Member, Journal of Sustainable Development in AP, UN ESCAP

Work Experience
- Professor, KDI School of Public Policy & Management
- Principal Climate Change Specialist, Asian Development Bank
- Deputy Executive Director, Global Green Growth Institute
- Senior Energy Economist, World Bank
- Project Leader, Institute for Global Environmental Strategies
- Senior Fellow, Korea Energy Economics Institute

Education
- BA, Seoul National University, Republic of Korea
- MA, Ph. D, Rutgers University, USA

Others
- Member, International Cooperation Committee, National Council on Climate and Air Quality (Presidential Committee), Republic of Korea (2019. 5 – 2021. 4)
- Chair, Appeal Committee, Green Climate Fund (2019. 8 - 2021.10)

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01 INTRODUCTION

Net Zero Declaration of Korea

Background

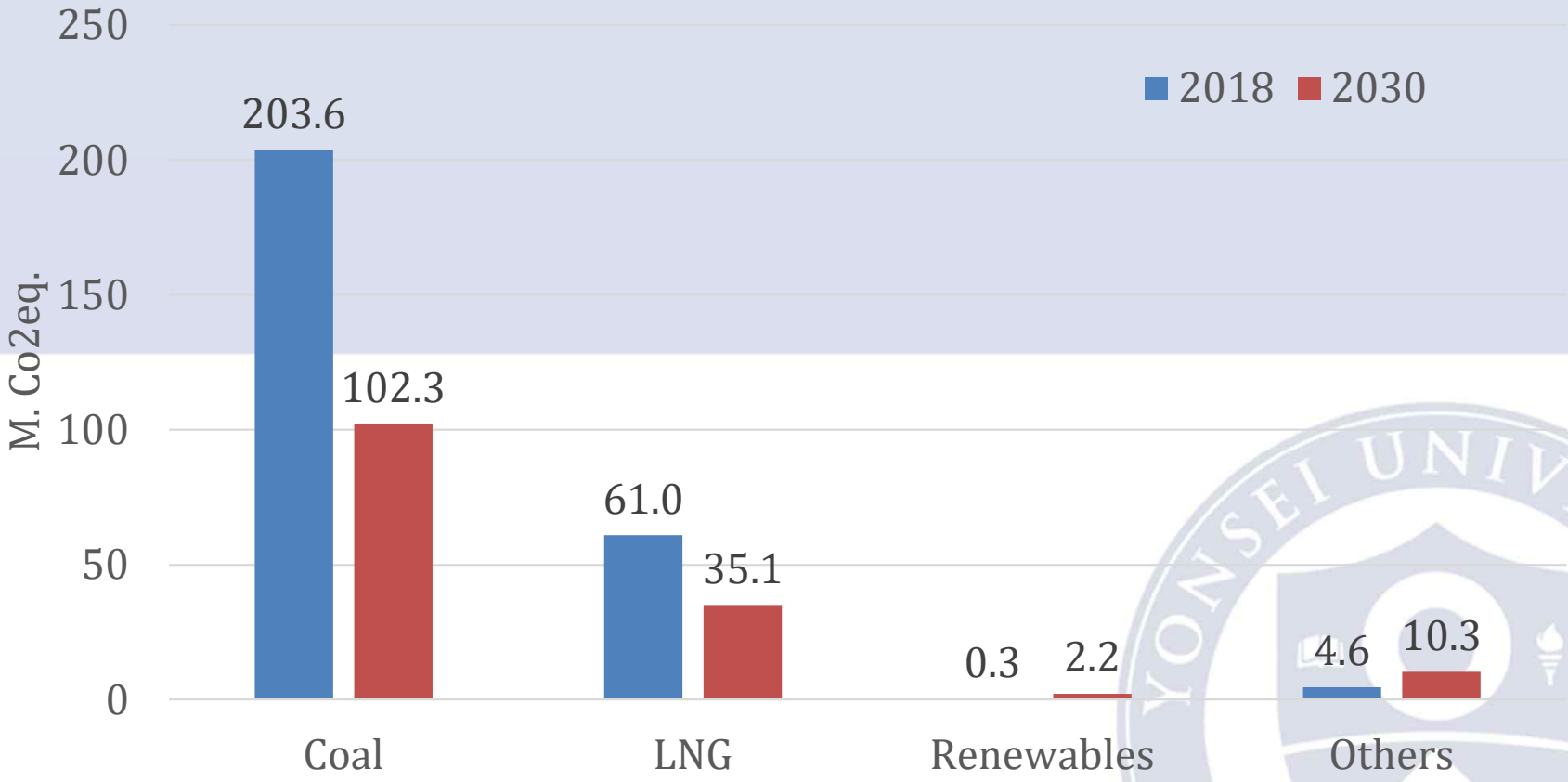
- On October 28, 2020, President Moon announced that Korea will commit to achieving carbon neutrality by 2050 at the speech to Parliament
- In general, it announced to promote 'net zero' in all sectors of industry, economy and society. It includes energy transition towards renewable energy sources and promotion of new energy businesses, which are renewable energy, hydrogen, and energy-related IT.
- Before Net Zero declaration, the Korean government announced Green New Deal of 37 billion USD to boost green infrastructure, clean energy and electric vehicle, etc.

Updated NDC of Korea

Summary

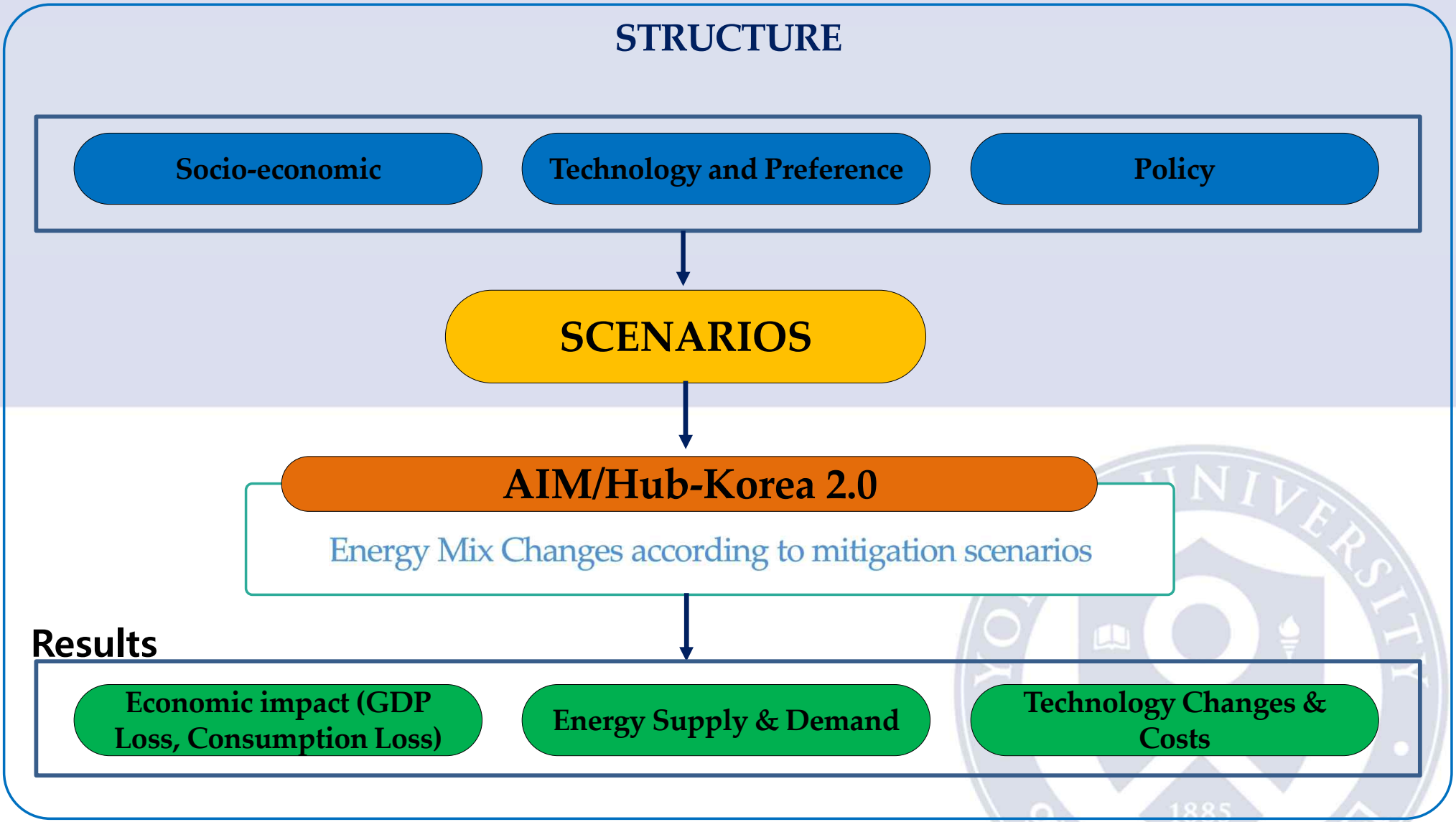
- The enhanced update of the first NDC of Republic of Kore (ROK) is set at the most ambitious level possible to achieve the goal of carbon neutrality by 2050 despite the country's manufacturing-based industrial structure.
- The updated and enhanced emission reduction target is to reduce total national GHG emissions by **40% from the 2018 level**, which is 727.6 MtCO2eq, by 2030.
- In September 2021, ROK enacted the Framework Act on Carbon Neutrality and Green Growth for Climate Crisis Response (or "the Carbon Neutrality Act"), enshrining the minimum level of a mid-term national GHG emission reduction target as well as a robust implementation mechanism in law to ensure a faithful implementation of its NDC.

GHG Emission Target for 2030



02 AIM Model - Korea

AIM/Hub-Korea 2.0



AIM/Hub-Korea 2.0

Characteristics

Emissions	CO2, CH4, N2O, NH3, SOx, NOx, BC, OC, …
Dynamics	Recursive Dynamic (1-year Step)
Base Year	2005
Base Data	Original Energy Balance and SAM
Program	GAMS/MCP

Four Scenarios

1 Ambitious Deployment of Renewable Energy

2 Re-utilization of Nuclear Power since 2035

3 Renewable Deployment and Forest Carbon Sink

4 Efficiency and CCS

Scenario

Ambitious Deployment of Renewable Energy

- Technology development makes the renewable technologies to be more affordable and efficient energy sources. In addition, the Korean government has been enthusiastically promoting the deployment of renewable energy sources, and the draft of the 9th Long-term Power Supply and Demand targets to expand the electricity generation from renewable sources to 26% and the capacity of renewable energy to 78GW by 2034
- This scenario considers to the ambitious deployment of renewable energy
- Assumption of no additional nuclear powerplants after 2034 and of strict restriction on coal-fired power generation

Scenario

Re-utilization of Nuclear Power since 2035

- The current administration plans to gradually exit nuclear power and to build no additional nuclear powerplants after the completion of reactors under construction. However, this policy direction is debatable that nuclear powerplants can contribute to achieving Net Zero target
- This scenario considers that the future administration determines to utilize nuclear powerplants again after stringent safety checks and thoughtful planning. Considering the time required for establishing new mid- and long-term energy policy and for designing and building additional nuclear powerplants, it considers the use of nuclear power after 2035.
- Nuclear power generation would be determined based on the competition with other technologies

Scenario

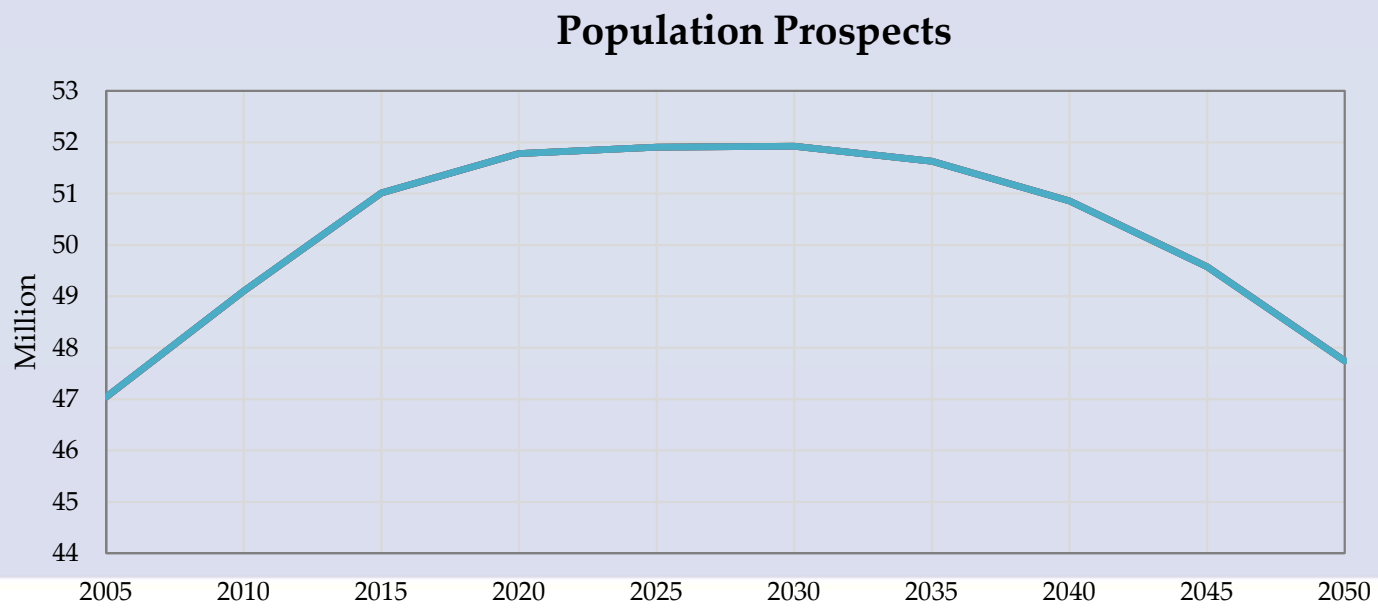
Renewable Deployment and Forest Carbon Sink

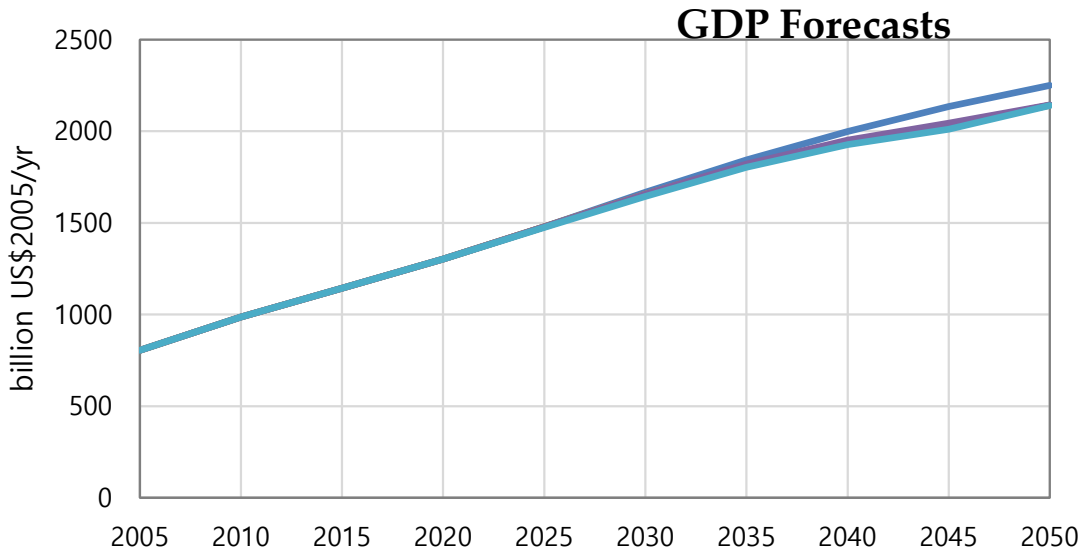
- In addition to Scenario 1, this scenario takes into account the carbon reductions from forest carbon sink

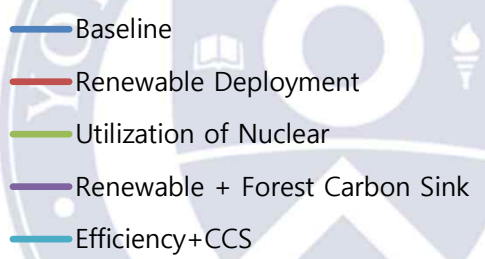
Technology Scenario: Energy Efficiency and CCS

- The deployment of Carbon Capture Storage (CCS) has been concentrated in some countries, especially in the US, today and some CCS, including CCUS, facilities have been commissioned in other regions and countries. However, the investment in this technology has not been reached enough compared to other low carbon technologies, and it is expected to have a more time to fully commercialize a larger scale deployment of CCS
- Technology development, including better energy efficiency, may lead to decrease in energy demand in the future
- This scenario considers the constraint on nuclear, the competition between coal/gas with CCS and renewable energy, and decrease in energy demand attributed to improvement of energy efficiency

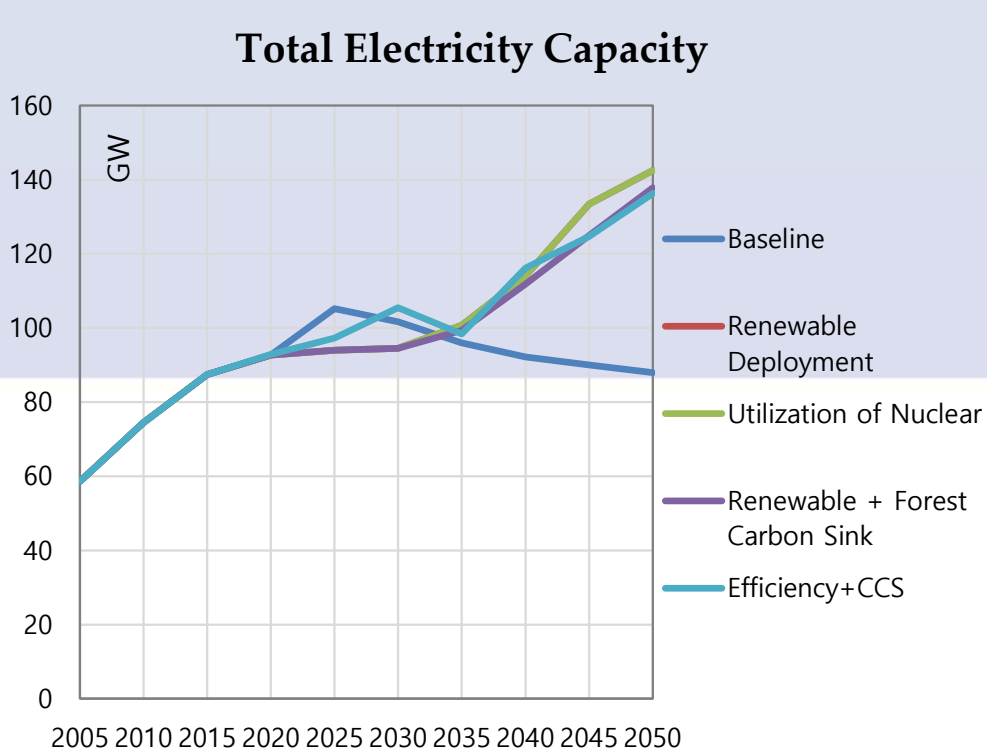
Socio-economic Status by Scenario

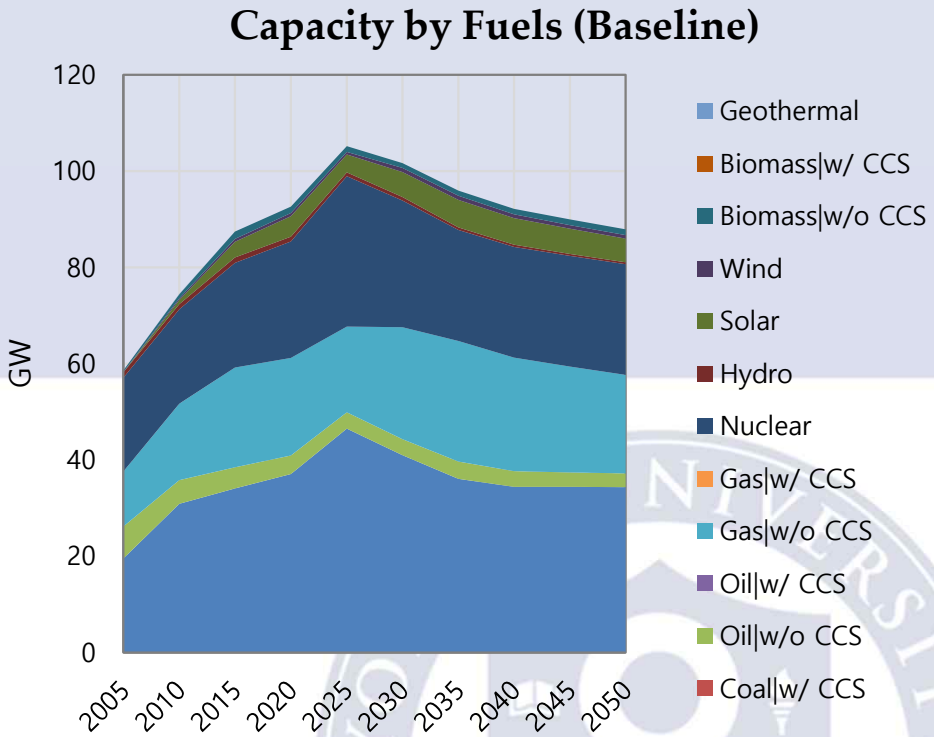






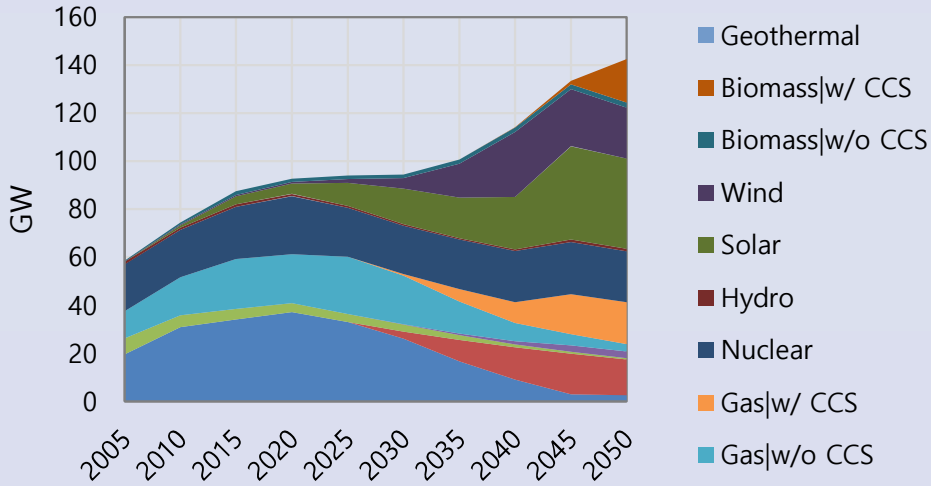
Electricity Capacity (Baseline)



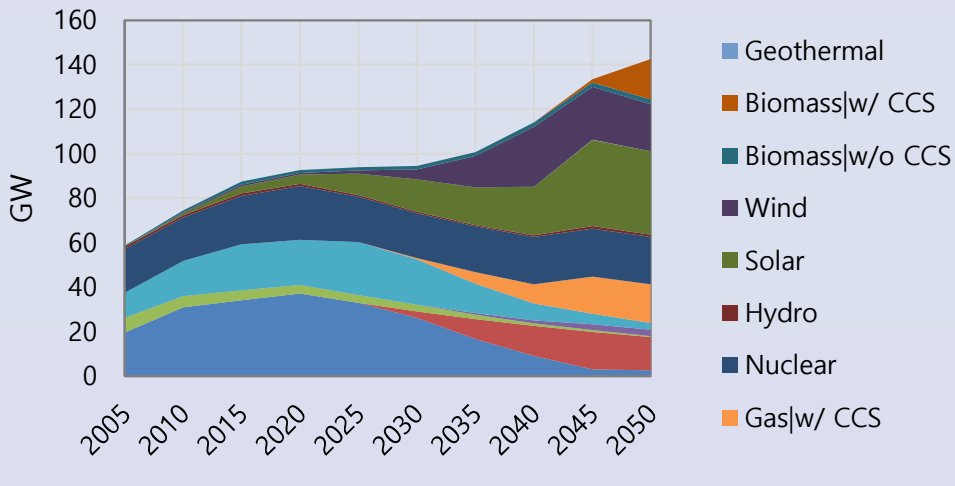


Electricity Capacity

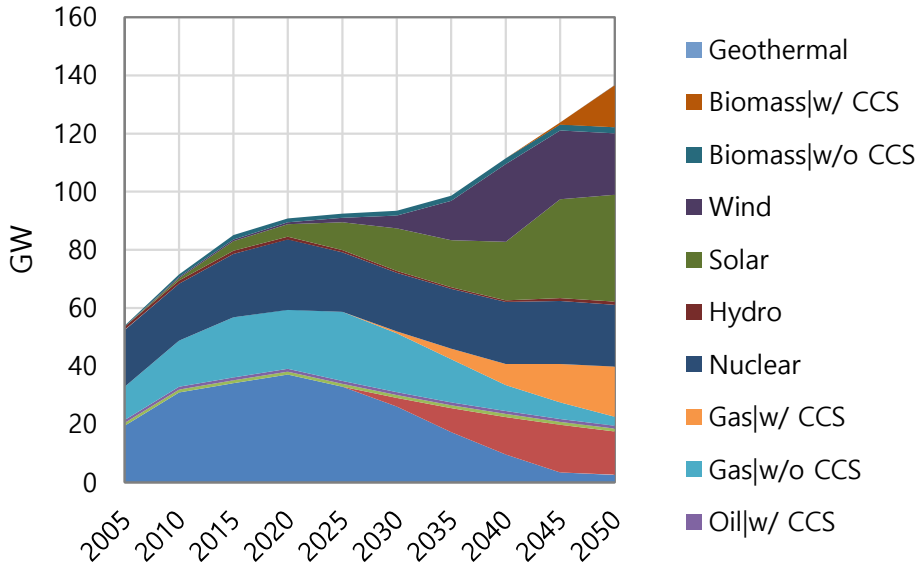
Capacity by Fuels (Scenario 1: Renewable)



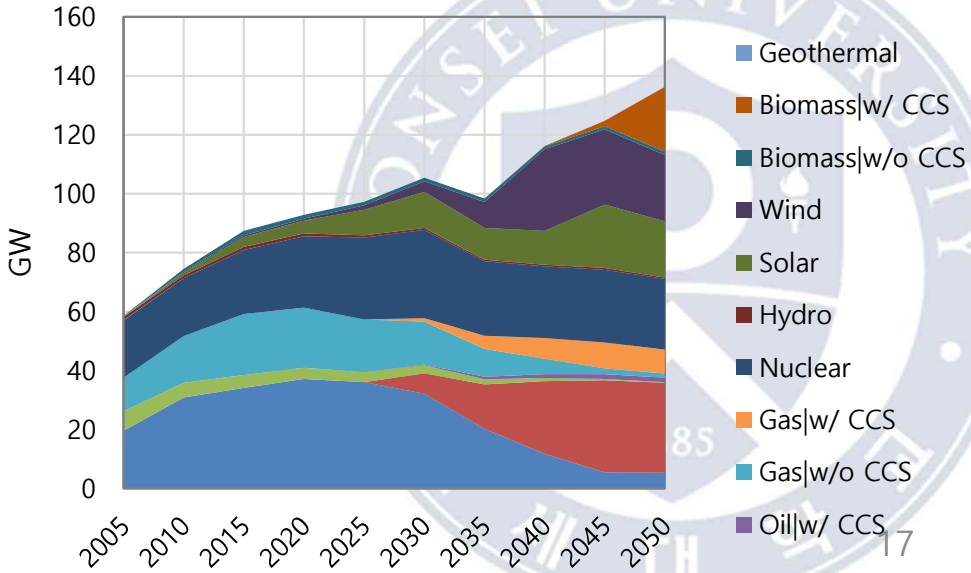
Capacity by Fuels (Scenario 2: Nuclear)



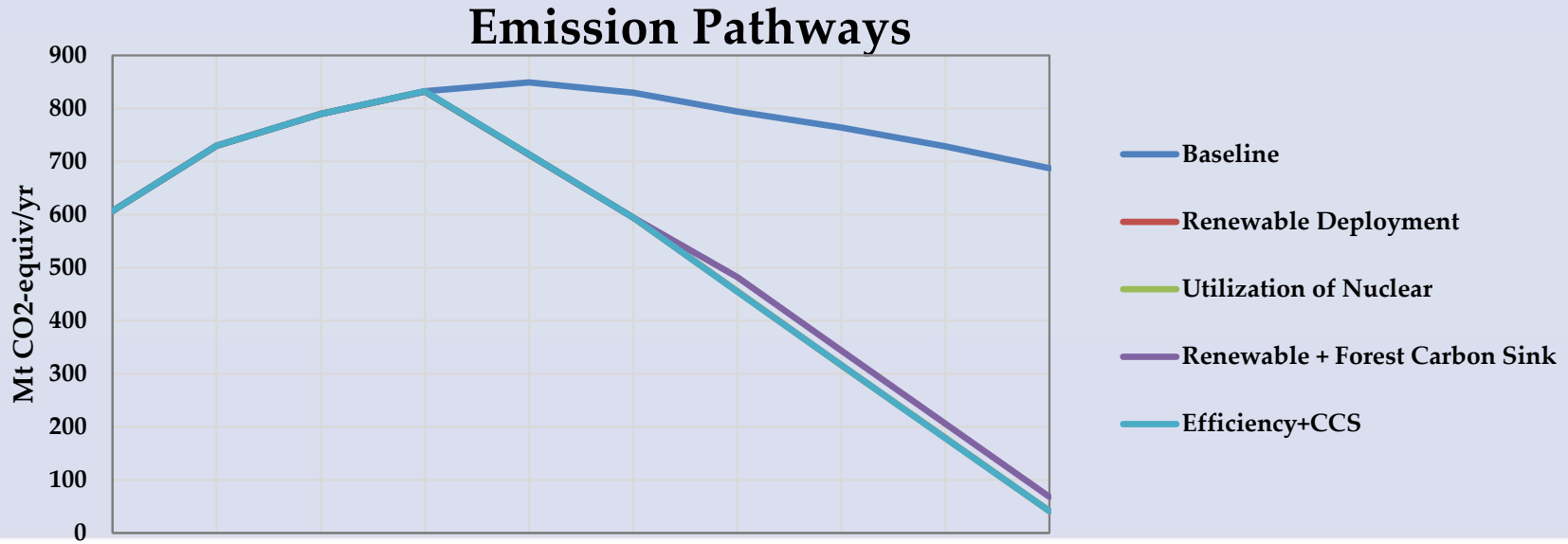
Capacity by Fuels (Scenario 3: Renewable & Forest Carbon Sink)

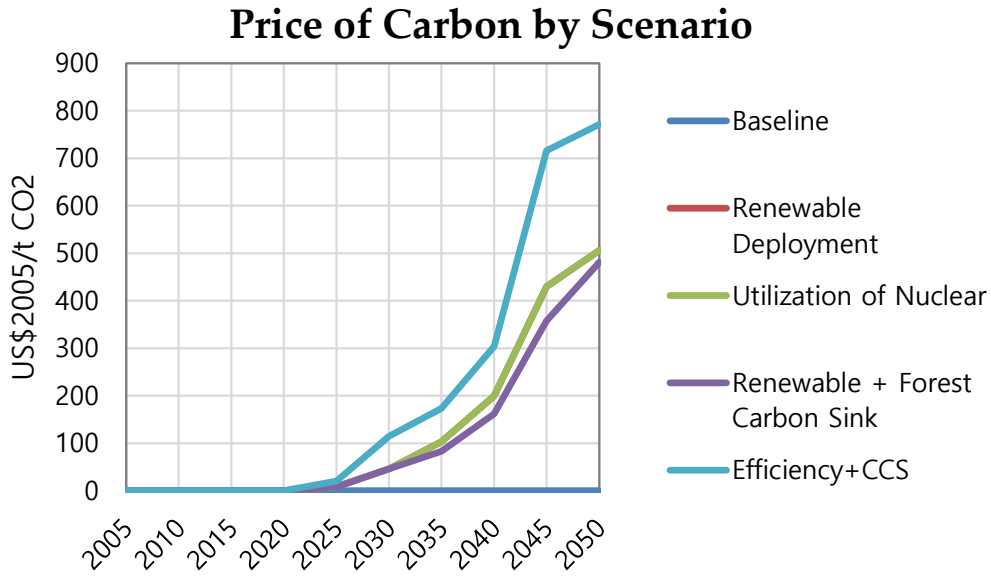


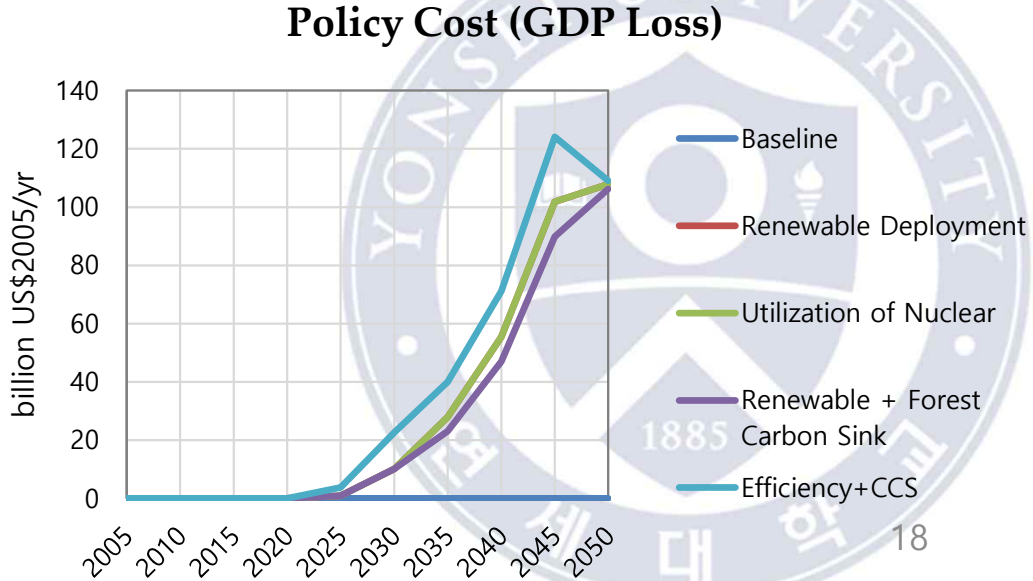
Capacity by Fuels (Scenario 4: Efficiency + CCS)



Emission Pathway







03 UNICORN Model - Global

Research Objectives

❑ Objective of Research

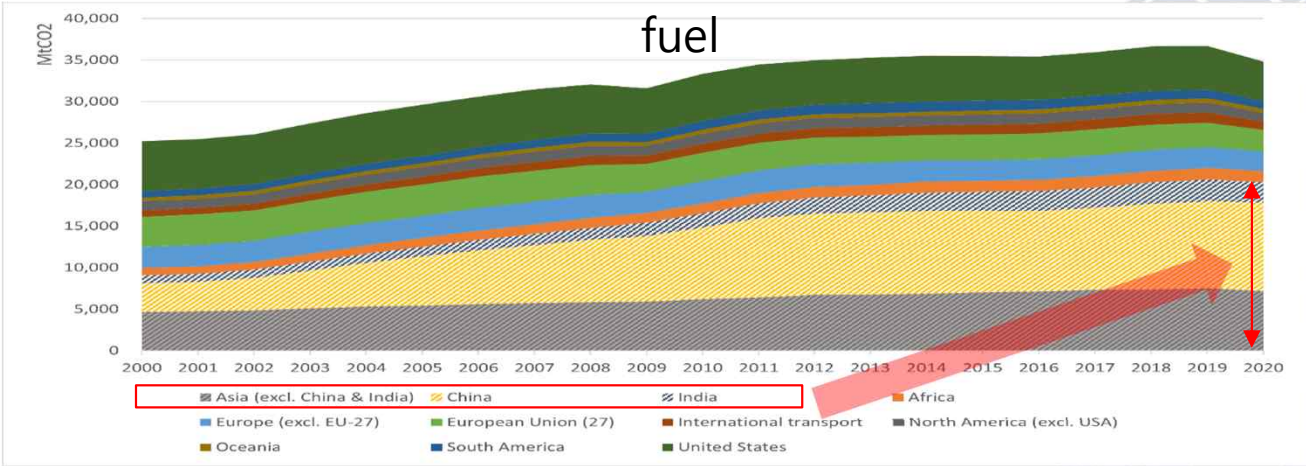
➢Understanding the quantitative costs and benefits of Net Zero transitions and analyzing the economic impacts of the Net Zero transition in developing Asian countries by applying a global CGE model

❑ Background

➢(Developing Asian Countries) Fastest growing economies & Rapidly increasing GHG emissions

➔**Net Zero Transition** for decoupling economic growth and GHG emissions and for achieving national Net Zero goals and the global 1.5-degree target.

Global Annual CO2 emissions from fossil fuel



Source: Our World in Data, 2022

Research Objectives

❑ Scope of the Research

- ➢ Establish a **global dynamic recursive CGE model** with GTAP (Global Trade Analysis Project) 10 DB and other available data
  - ❖ GTAP POWER database: 121 countries and 20 aggregated regions, 76 products and services with 12 power technologies (Aguiar et al, 2019)
  - ❖ 7 aggregated regions: OECD, CCA, East Asia, South Asia, Southeast Asia, Pacific, and Developing Countries
  - ❖ Aggregation of industries into 19 sectors, focusing on green industries
- ➢ Four different pathways (BAU, NDC Extension, Net Zero Transition, Orderly Net Zero Transition)
- ➢ The economic impacts (real GDP, real GDI, employment, investment, price index) of low-carbon transition, including Net Zero Transition, of Asian developing regions

Low-carbon Transition Scenarios

❑ Transition Scenarios

➢ Four Transition Scenarios with different policy mixes

Baseline	• Continuation of the current policies
NDC Extension Scenario	• Reaching countries' NDC targets and continuing their mitigation actions but not achieving Net Zero by the targeted year • Incorporating the NDC targets of individual countries in OECD and Asia regions
Net Zero Transition Scenario	• Applying Global Carbon Prices provided by IEA Net Zero Emission (NZE) scenario • Economy-wide carbon pricing with revenue recycling towards distortionary taxes
Orderly Net Zero Transition	• Applying Global Carbon Prices provided by IEA Net Zero Emission (NZE) scenario • Economy-wide carbon pricing with revenue recycling towards distortionary taxes • Coordination of policies via linking carbon markets in Asia

* **Orderly Net Zero Transition** is based on the effective coordination of regional policies, which encourage mutual actions among countries instead of uncoordinated actions of individual countries. This study identifies the Asian international carbon market as a representative coordinated policy among Asian countries.

Low-carbon Transition Scenarios

❑ Transition Scenarios: Carbon Prices for achieving Net Zero

Classification	2030	2050
Advanced economies	130	250
Selected emerging market and developing economies	90	200
Other emerging market and developing economies	15	55
Source: (IEA, 2021)		

(Note) Country Classification

- **Advanced economies**: OECD countries and European countries
- **Selected emerging economies**: Selected emerging economies classified by IEA (China, Russia, Brazil, South Africa) + Singapore, Taipei,China, Malaysia, Indonesia, Kazakhstan, Argentina, Costa Rica, Brunei Darussalam
- **Other emerging economies**: Remaining countries not classified as advanced or selected emerging economies

	2030	2050
OECD	129.11	248.48
Caucasus and Central Asia	56.22	134.69
East Asia	92.07	202.40
South Asia	15.00	55.00
Southeast Asia	56.40	135.05
Pacific	15.00	55.00
Other Developing Countries	57.83	134.90
Source: Author's calculation		

Data and Methodology

❑ Computable General Equilibrium (CGE) model

- Key Equations
  - Global multi-regional dynamic recursive computable general equilibrium (CGE) model
  - Constant Elasticity of Substitution (CES) production function and factor demand (Calibrated share form)

- $\boldsymbol{Q = \bar{Q}\left[\sum_i \theta_i \left(\frac{X_i}{\bar{X}_i}\right)^{\rho}\right]^{1/\rho}, \rho = \frac{\sigma-1}{\sigma}}$,
  - ❖ Q: amount of output , X_i: i-th input, σ: constant elasticity of substitution, θ_i: value share of i-th input

- $\boldsymbol{X_i = \lambda_i^{\sigma-1}\theta_i\left(\frac{\bar{\beta}}{\bar{P}_i}\right)^{1-\sigma}\left(\frac{\beta}{P_i}\right)^{\sigma} Q, \beta = \bar{\beta}\left[\sum_i \theta_i \left(\frac{P_i}{\bar{P}_i}\right)^{1-\sigma}\right]^{1/(1-\sigma)}}$,
  - ❖ P_i: price of i-th input, β is the output price

Data and Methodology

- Key Equations
  - Capital Stock Dynamics: $K_t = (1-\delta)^k K_{t-k} + \frac{(1+g_I)^k-(1-\delta)^k}{g_I+\delta} I_{t-k}$
  - Current Account Balance: $\sum_{(r',i)} Pfob_{r,r',i} Qtrade_{r,r',i} + \sum_i Ptrnserv_{r,i} Qtrnserv_{r,i} + ForegnSaving_r = \sum_{(r',i)} Pcif_{r',r,i} Qtrade_{r',r,i}$
  - Budget Balance (household, government, investment)
    - $(1-ti) \cdot \sum_f PF_f QF_f = \sum_i P_i \cdot (1+tc_i) \cdot QC_i + HSaving$
    - $\sum_f tf_f PF_f QF_f + ti \sum_f PF_f QF_f + \sum_i (tc_i P_i QC_i + tp_i PP_i QP_i + \sum_j t_{ij} P_i QAP_{ij}) + \sum_{(r',i)} tariff_{r',r,i} Qtrade_{r',r,i} = \sum_i P_i QG_i + GovSaving$
    - $\sum_i P_i QINV_i = HSaving + GovSaving + ForeignSaving$

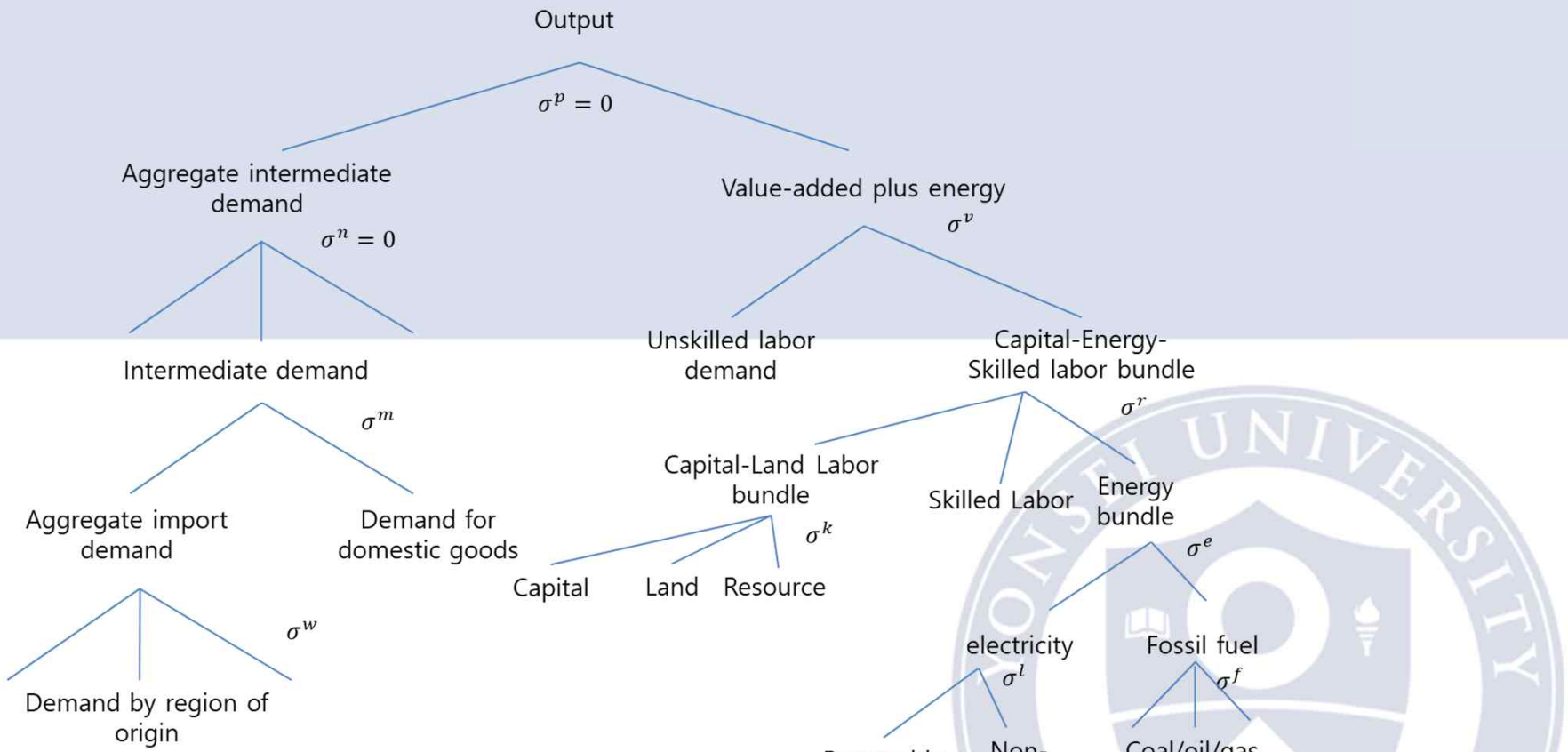
Data and Methodology

- Regional Classification

Label	Description	GTAP regions code
OECD	OECD (except the Republic of Korea): Europe Region (EU member countries, Rest of Europe, Rest of European Free Trade Association, and United Kingdom) + Australia, New Zealand, Japan, Canada, and United States	ALB, AUS, AUT, BEL, BGR, CAN, CHE, CYP, CZE, DEU, DNK, ESP, EST, FIN, FRA, GBR, GRC, HRV, HUN, IRL, ITA, JPN, LTU, LUX, LVA, MLT, NLD, NOR, NZL, POL, PRI, PRT, ROU, SVK, SVN, SWE, TUR, USA, XEF, XER
CCA	Caucasus and Central Asia	KAZ, KGZ, TJK, XSU, ARM, AZE, GEO
EAsia	East Asia: China, the Republic of Korea, Hong Kong China, Taipei,China, and Mongolia	CHN, HKG, KOR, MNG, TWN, XEA
SAsia	South Asia: India, Pakistan, Nepal, Bangladesh and nearby countries (Maldives, Afghanistan, Bhutan, Sri Lanka)	BGD, IND, NPL, PAK, LKA, XSA
SEAsia	Southeast Asia: 10 ASEAN member countries and Timor-Leste	BRN, KHM, IDN, LAO, MYS, PHL, SGP, THA, VNM, XSE
Pacif	The Pacific: Mostly small island countries	XOC
DC	The other developing countries: Countries not included in OECD and five Asian sub-regions	MEX, XNA, ARG, BOL, BRA, CHL, COL, ECU, PRY, PER, URY, VEN, XSM, CRI, GTM, HND, NIC, PAN, SLV, XCA, COM, JAM, TTO, XCB, BLR, RUS, UKR, XEE, BHR, IRN, ISR, JOR ,KWT, OMN, QAT, SAU, ARE, XWS, EGY, MAR, TUN, XNF, BEN, BFA, CMR, CIV, GHA, GIN, NGA, SEN, TGO, XWF, XCF, XAC, ETH, KEN, MDG, MWI, MUS, MOZ, RWA, TZA, UGA, ZMB, ZWE, XEC, BWA, NAM, ZAF, XSC, XTW

Data and Methodology

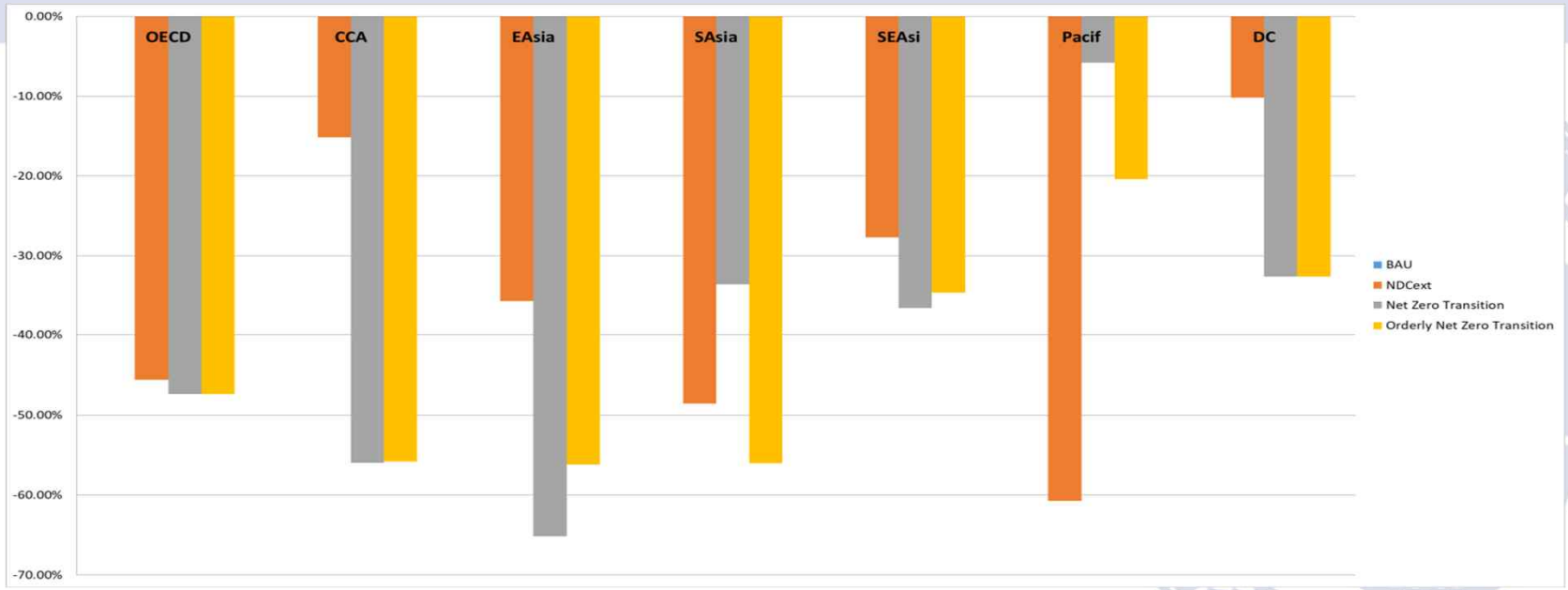
- Nesting Structure



Analysis

- Changes in GHG Emissions (2022-2050)
  - A significant emission reduction in the OECD region (~50% relative to BAU)
  - Global but differentiated carbon prices (Net Zero Transition) ➔ Further decrease in CCA, East Asia, and Developing Countries (Compared to NDC)
  - With carbon pricing only, relatively less emissions reductions in South Asia ➔ With both carbon pricing and the international carbon market in Asia, a noticeable emission reduction in South Asia

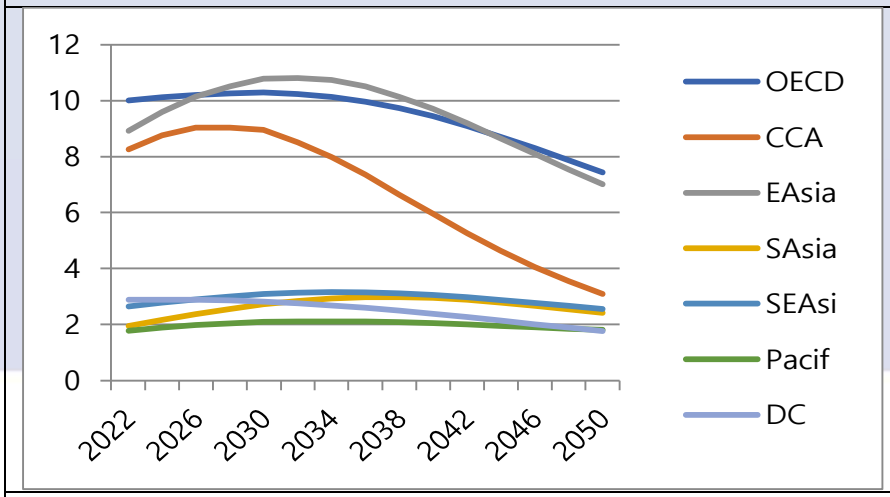
Changes in GHG Emissions (2022-2050) (% difference from BAU level)



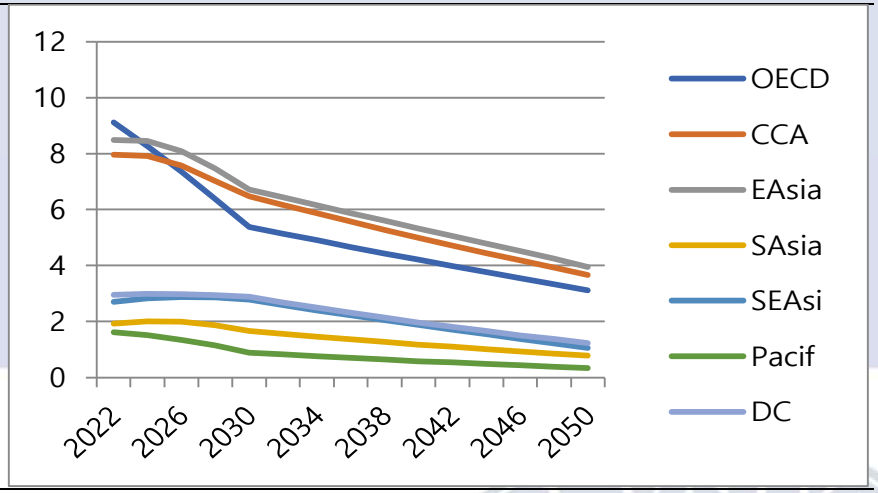
Analysis

- GHG Emissions per capita by region (Unit: tCO_2eq)

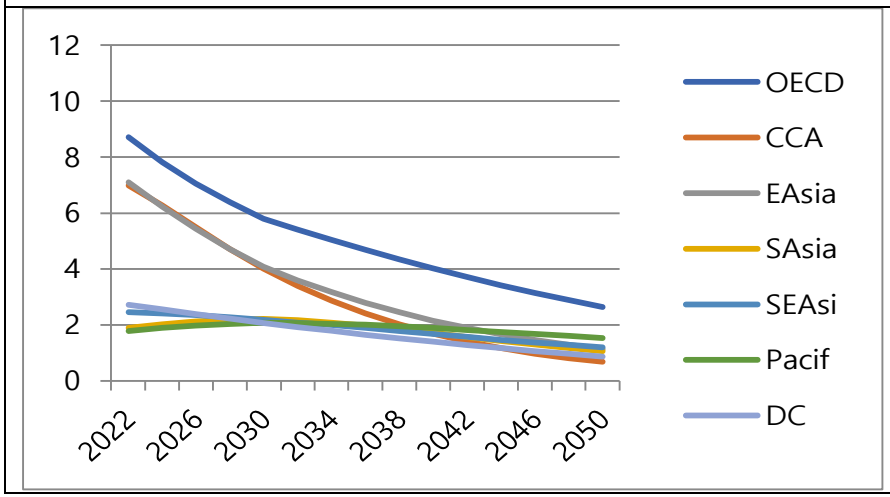
BAU Scenario



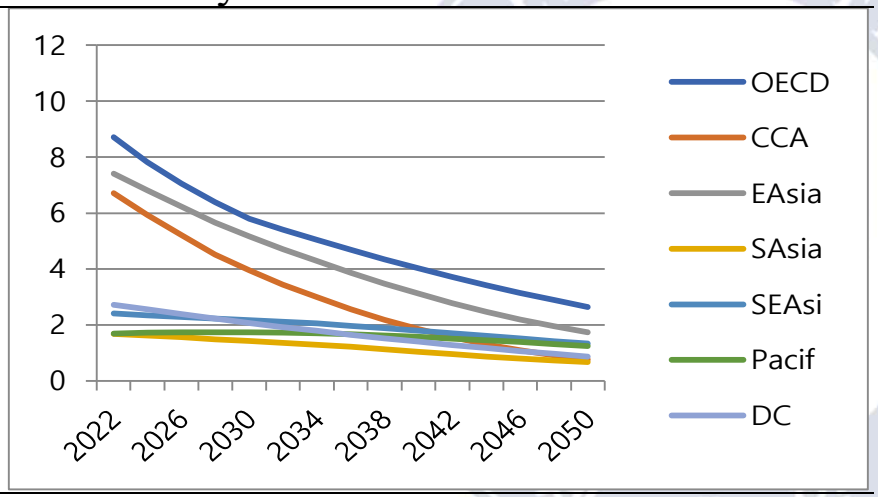
NDC Extension Scenario



Net Zero Transition Scenario

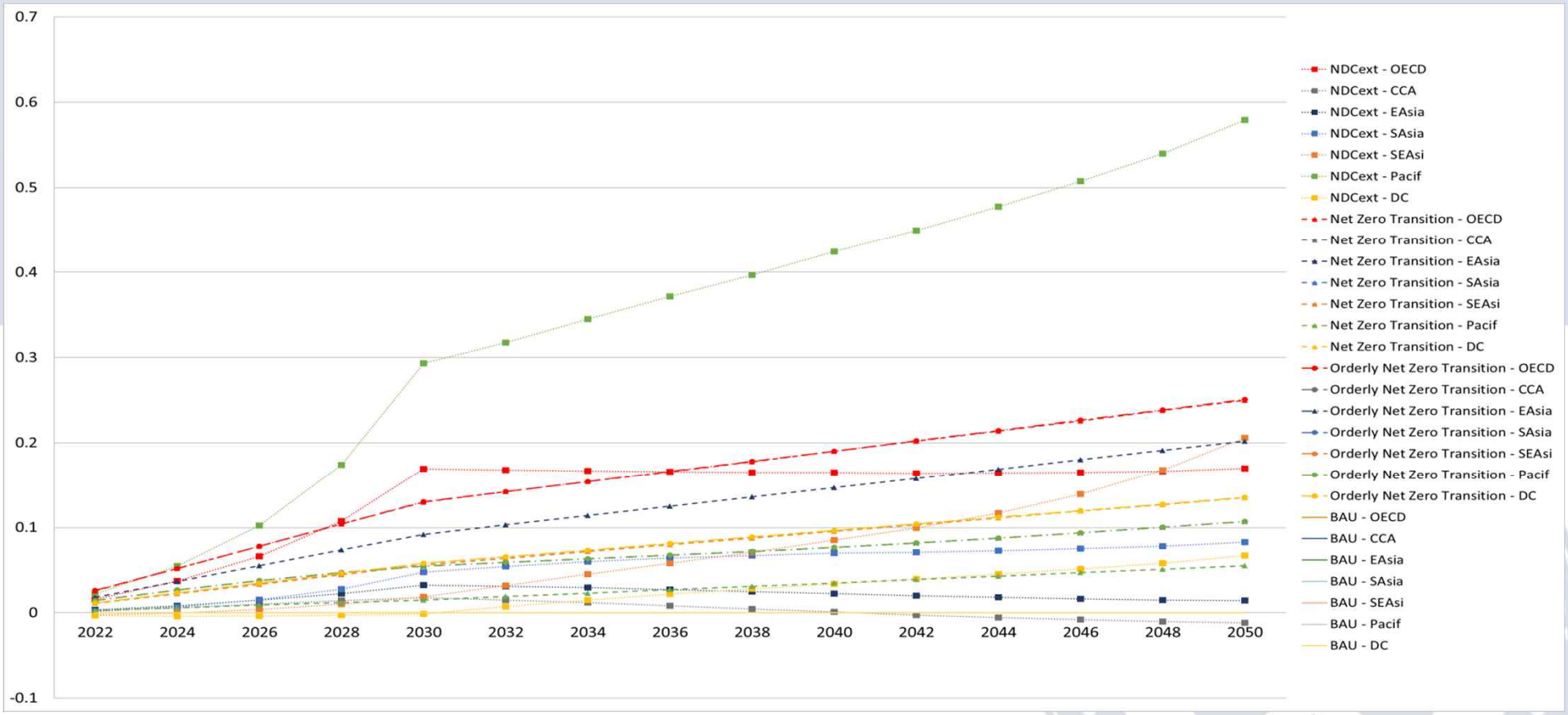


Orderly Net Zero Transition Scenario



Analysis

- Trajectories of Regional Carbon Prices by Scenario

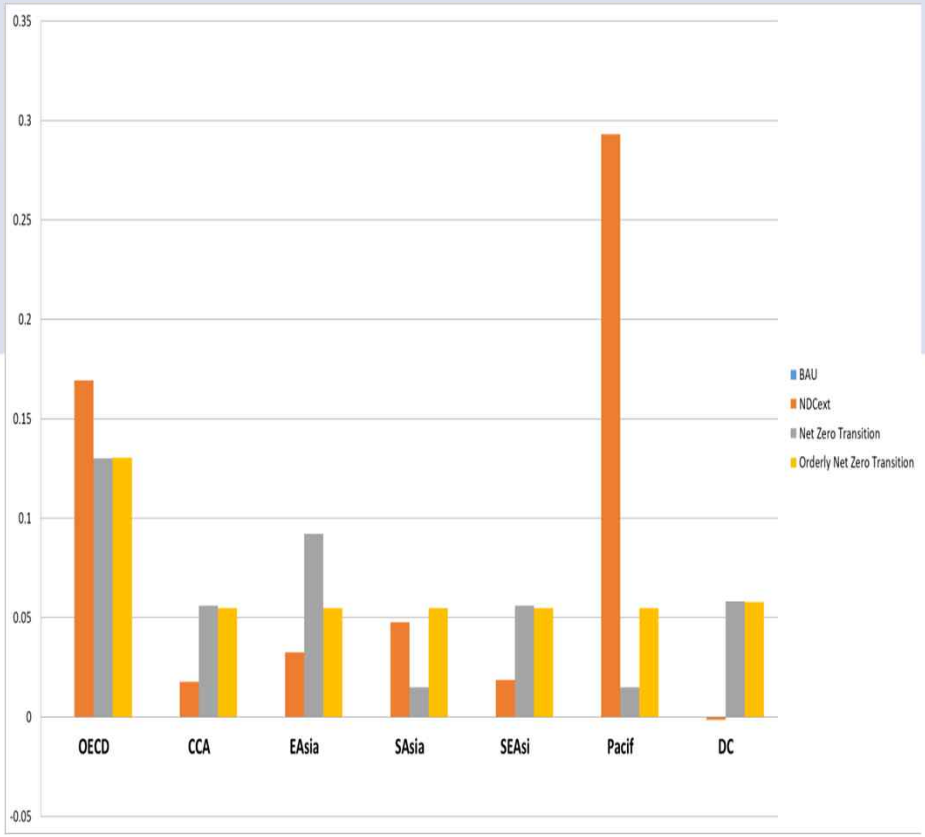


- Line (BAU), Dot (NDC Extension), Dash (Net Zero Transition), Long Dash Dot (Orderly Net Zero Transition)

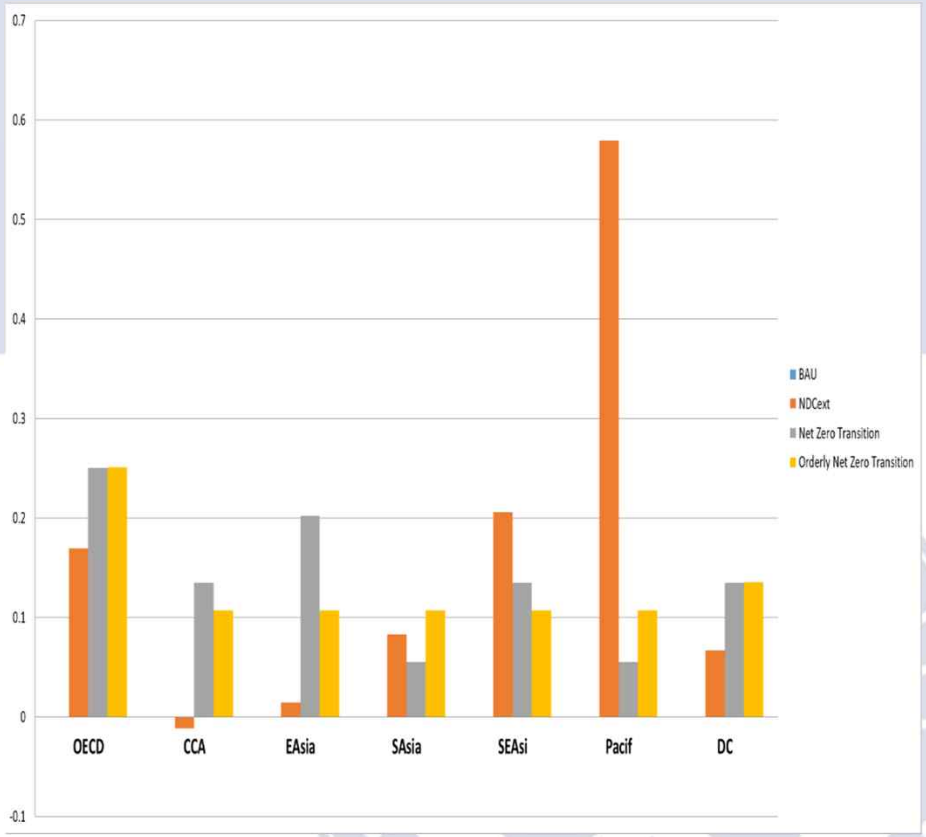
Analysis

- Carbon Prices in 2030 and in 2050 by region

Carbon Price in 2030



Carbon Price in 2050

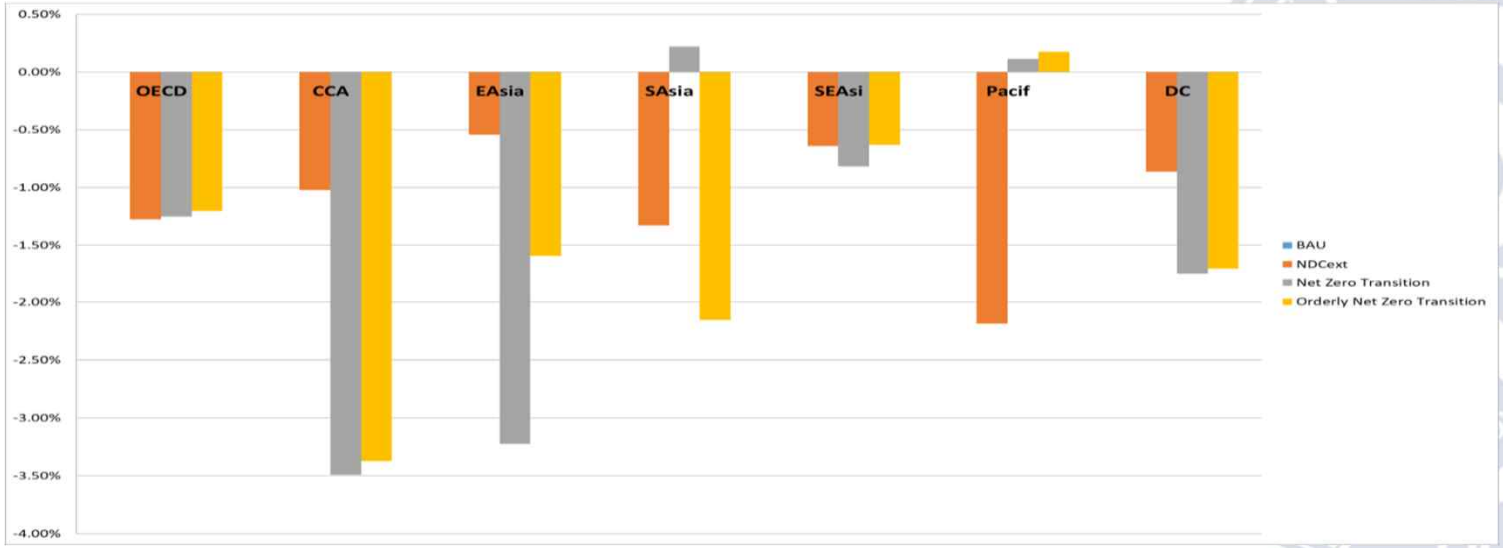


- Orange (NDC Extension), Grey (Net Zero Transition), Yellow (Orderly Net Zero Transition)

Analysis

- Changes in Real GDP (2022-2050)
  - A mild decrease in real GDP relative to the BAU level under all transition scenarios
  - Net Zero Scenario relative to BAU level
    - [**Deeper GDP losses**] CCA, East Asia, Southeast Asia, and other Developing Country regions
      ⇔ [**Positive GDP Impact**] South Asia, Pacific
  - Orderly Net Zero Scenario relative to Net Zero Scenario
    - Positive impacts of carbon trading on all regions except South Asia

Changes in Real GDP (2022-2050) by Scenario (% difference from BAU)



Key Findings

- Achieving Net Zero, requiring higher emission reductions, would incur slightly larger GDP losses relative to BAU level, but the size of losses would be much smaller than emissions reductions
- **The low-carbon transition would bring a general but slight decrease in production**.
- Necessary to consider and support Just Transition, which reduces the potential social and economic challenges, such as inequality, poverty and, job losses, under low-carbon transition pathways
  - Various policy measures, including financial and technological supports, for industries likely to receive damages from low-carbon transition, particularly fossil-fuel-related industries, and their employment
  - Consider Stranded assets being vulnerable to low-carbon transition and Net Zero transition
- A wide range of supportive measures, including transfer of technology and finance, within and among countries
- Necessity of understanding potential co-benefits, such as health benefits, reducing greenhouse gas emissions and low-carbon transition

Thank you