Analyzing the Economic Implications of GHG mitigation in Korea with the UNICON Framework

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YONSEI UNIVERSITY

Development of Global Integrated Assessment Model for GHG Mitigation

PROJECT OVERVIEW

Project Period	2022.06.01. ~ 2028.12.31.
Leading Institution	연세대학교 YONSEI UNIVERSITY
Participating Institutions	KEI 한국환경연구원 Korea Environment Institute / 서울대학교 SEOUL NATIONAL UNIVERSITY / 숙명여자대학교 SOOKMYUNG WOMEN'S UNIVERSITY

OBJECTIVES & TIMELINE

"Development of Global Integrated Assessment Model for GHG Mitigation" constructs an integrated assessment model consisting of bottom-up models that reflects the status of GHG reduction technologies by sector and a top-down model that analyzes the macroeconomic impact of mitigation policies. The project a ims to comprehensively assess the impact of global temperature changes and the effects of both domestic and international shifts in policy and technology.

ANALYZE national and international trends to set strategies for model development

DEVELOP sectoral bottom-up models and a top-down computable general equilibrium(CGE) model

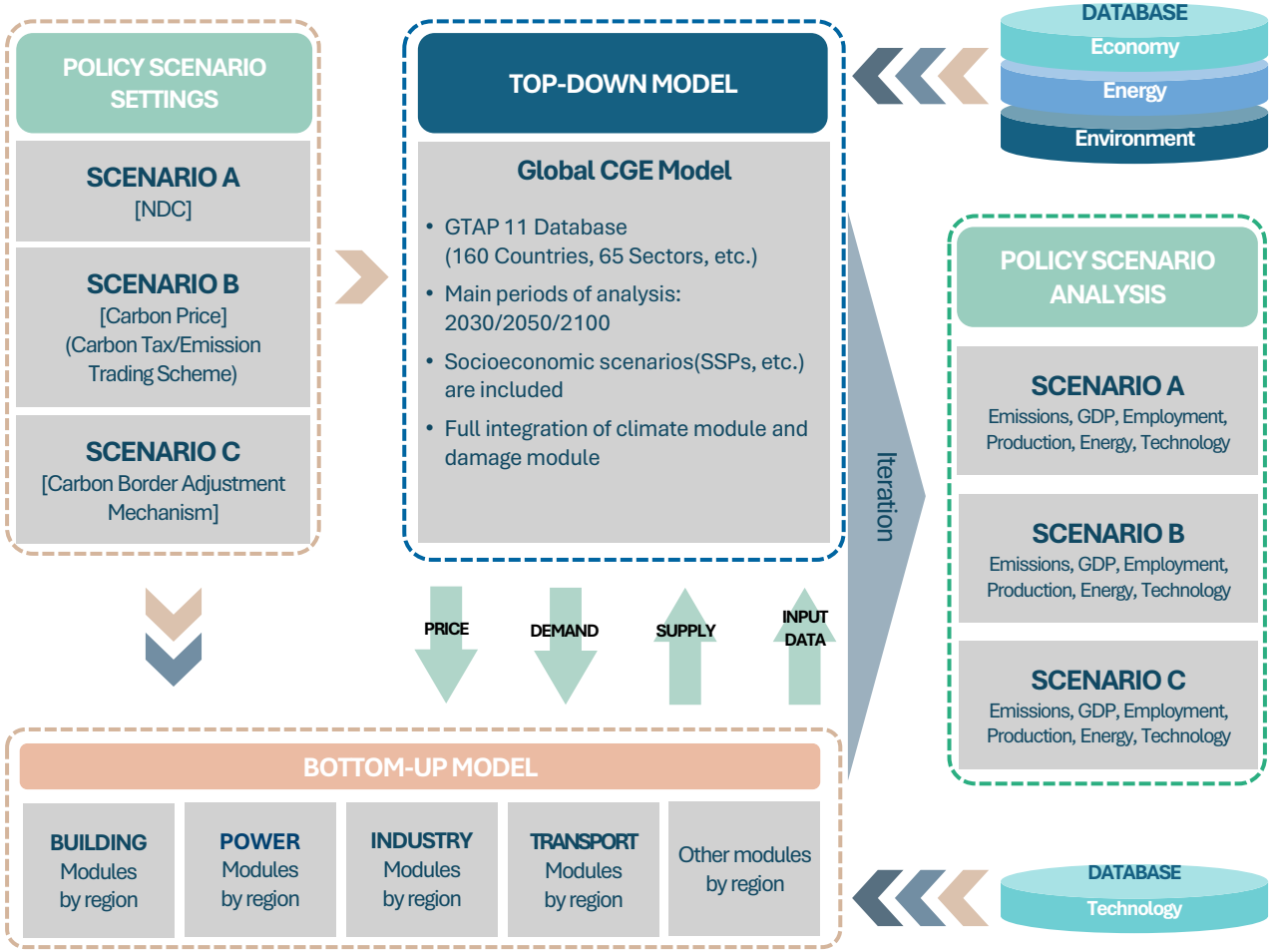
BUILD a global multi-regional and multi-sectoral top-down / bottom-up integrated model

VALIDATE the global integrated assessment model and conduct policy scenario analysis

Phase 1	Year 1	Analysis of trends in national and international IAMs & DB construction
	Year 2	
Phase 2	Year 3	**Development of bottom-up models by sector & top-down CGE model**
	Year 4	**Development of multi-regional and multi-sectoral IAM**
	Year 5	
Phase 3	Year 6	Validation of integrated model, policy scenario analysis
	Year 7	

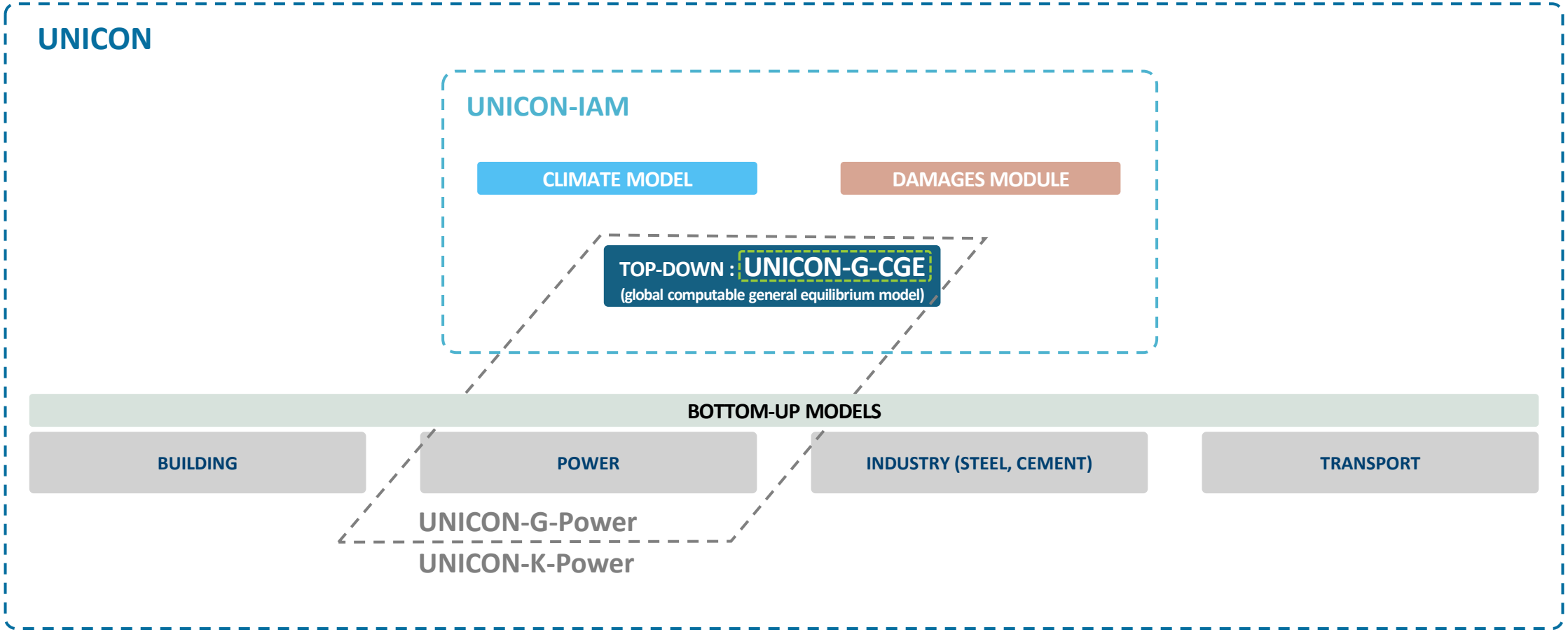
UNified Integrated Climate Options Nexus [UNICON]

- UNICON is an IAM framework that links sectoral bottom-up models (buildings, power, industry, transport, etc.) with a top-down global CGE model that is fully integrated with a climate module and damage module.



Various Modalities of UNICON

- The **UNICON** framework supports various modalities of application tailored to the analytical context.



- Currently in development: UNICON-G-Building, UNICON-G-Industry, …

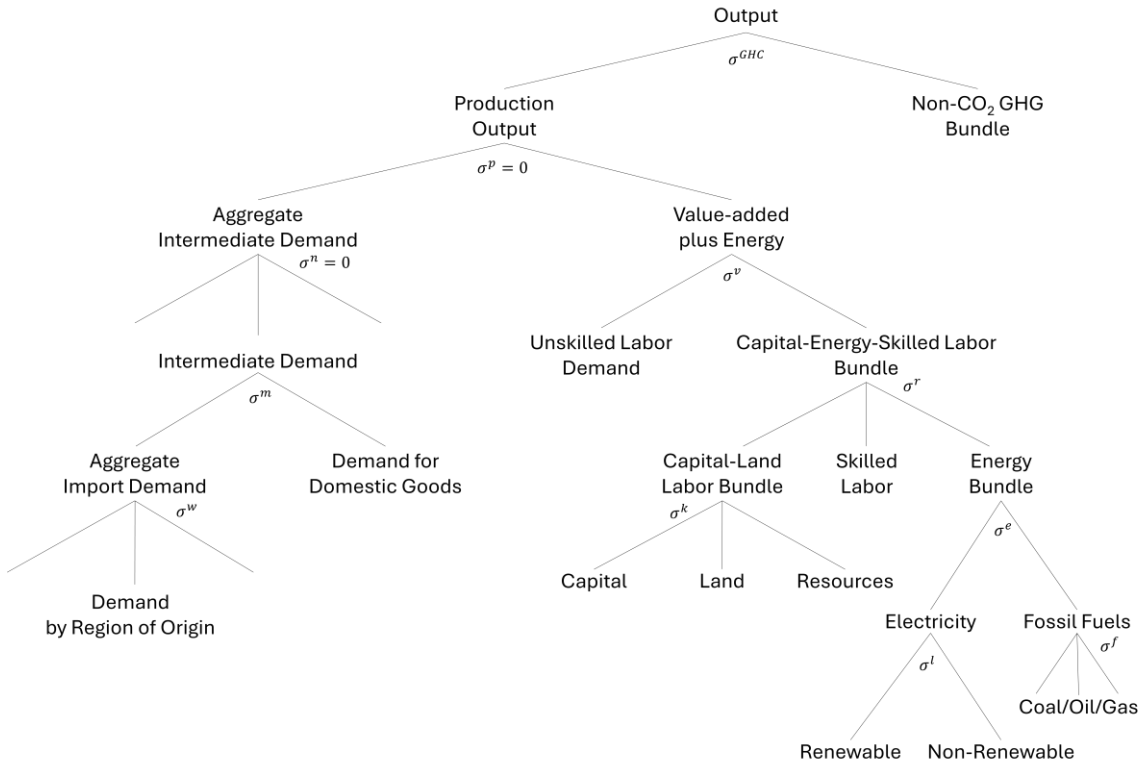
UNICON-G-CGE

- The economy model of the UNICON framework is a dynamic-recursive global computable general equilibrium (CGE) model that builds on the model developed by Kim et al. (2023) and Jung et al. (2021)
- The model is solved for the set of equilibrium conditions for all regions and commodities in (a) market equilibrium conditions, (b) consumption demand functions, (c) current account balance conditions, budget constraints, and capital stock dynamic equations, (d) zero-profit conditions, and (e) factor supply function
  - Calibrated share form of the CES production function:

$$Q = \bar{Q}\left[\sum_i \theta_i \left(\frac{X_i}{\bar{X}_i}\right)^{\rho}\right]^{\frac{1}{\rho}}, \qquad \rho = \frac{\sigma - 1}{\sigma}$$

  - Equilibrium conditions for CES technology:

$$X_i = \lambda_i{}^{\sigma-1}\left(\frac{\bar{\beta}}{\bar{P}_i}\right)^{1-\sigma}\left(\frac{\beta}{P_i}\right)^{\sigma} Q, \qquad \beta = \bar{\beta}\left[\sum_i \theta_i \left(\frac{P_i}{\bar{P}_i}\right)^{1-\sigma}\right]^{\frac{1}{(1-\sigma)}}$$



Production Nesting Structure of Global CGE Model in UNICON-IAM

- UNICON-G-CGE is calibrated to GTAP11 and GDP and population projections for SSP2 (ver 3.1)

GHG Mitigation in Korea

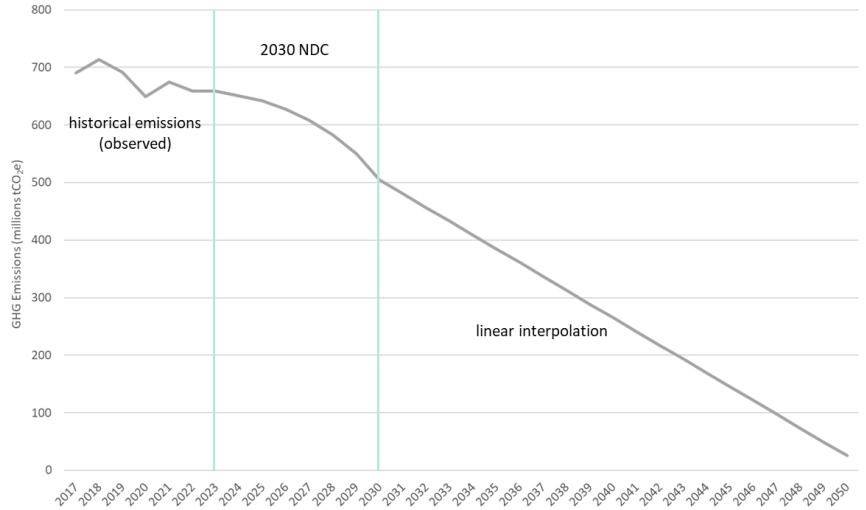
- Using **UNICON-G-CGE**, we hypothesize a net-zero emissions pathway for Korea to assess the macroeconomic implications of GHG mitigation in Korea (Scenarios: BAU vs NZ).
- A hypothetical net-zero emissions pathway is constructed:
  - 2017 to 2022: Historical emissions from the National Greenhouse Gas Inventory (Source: Greenhouse Gas Inventory & Research Center of Korea)
  - 2023 to 2030: Emissions target pathway from Korea's 2030 NDC

Table 1. National Emissions Reduction Targets in Korea's 2030 NDC (million tCO_2e)

2018	2023	2024	2025	2026	2027	2028	2029	2030
686.3	633.9	625.1	617.6	602.9	585.0	560.6	529.5	436.6

Source: National Framework Plan for Carbon Neutrality and Green Growth (April 2023)

  - 2030 to 2050: Linear interpolation of emissions to reach net-zero in 2050



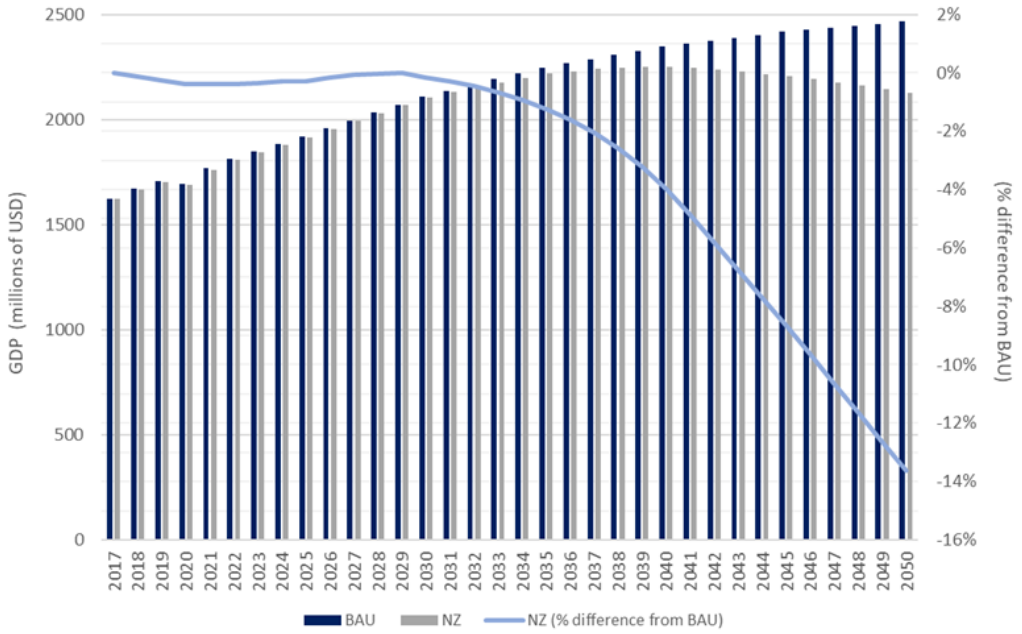
Hypothetical Net-zero Emissions Pathway

GHG Mitigation in Korea

- Economy-wide negative impacts are expected to arise with GHG mitigation, with the magnitude of these effects intensifying closer to the target year of 2050.

Economic Implications of Net-Zero (% difference from BAU)

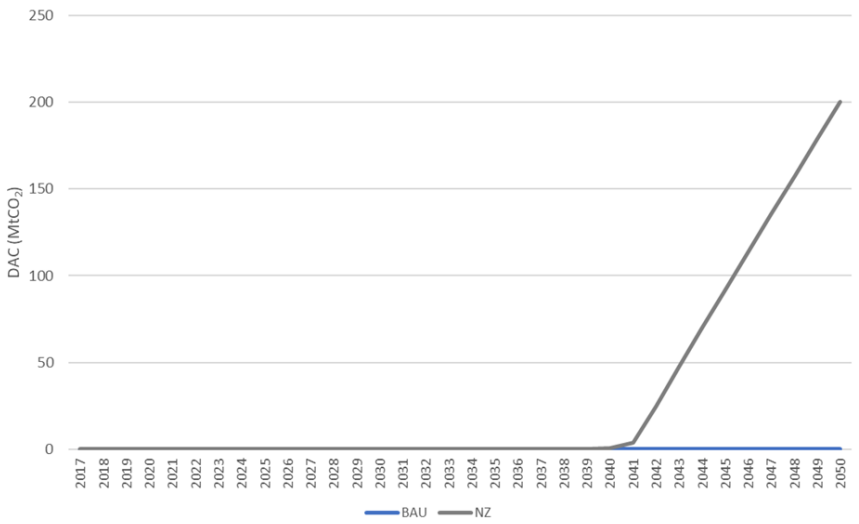
	2025	2030	2035	2040	2045	2050
GDP	-0.28%	-0.34%	-1.90%	-5.13%	-7.86%	-10.48%
Output	-0.22%	-0.18%	-1.67%	-4.85%	-6.33%	-7.58%
Consumption	-0.46%	-0.35%	-1.15%	-3.72%	-8.50%	-13.51%
Imports	-0.48%	-1.28%	-4.41%	-9.29%	-11.93%	-14.00%
Exports	-0.26%	-0.91%	-3.96%	-8.52%	-11.24%	-13.52%
Employment	-0.35%	-0.16%	-0.84%	-2.77%	-3.50%	-3.89%



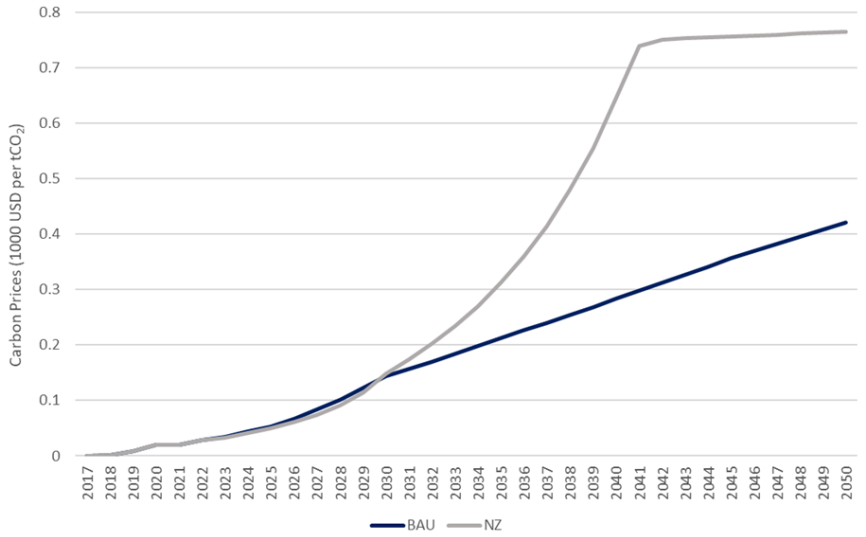
Annual Impact on Real GDP (2017 – 2050)

GHG Mitigation in Korea

- Significant increase in carbon prices may be necessary to be able to achieve net-zero emissions.
  - The steep increase after 2035 in the NZ scenario reflects the rising marginal abatement cost, with costly DAC deployment potentially driving up the carbon price to over 700 USD/tCO2 by 2050.



DAC Deployment



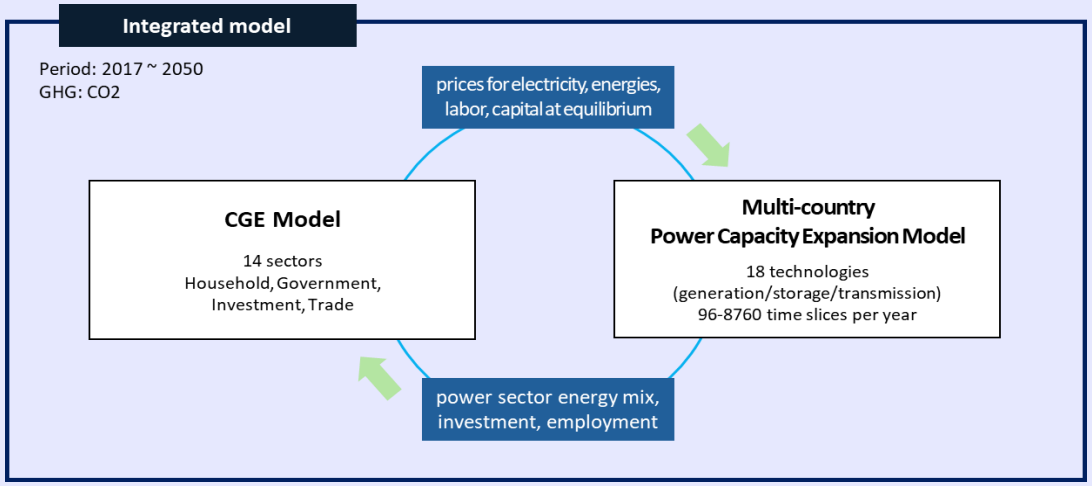
Carbon Prices to Achieve Net-zero

- Early and gradual mitigation is critical to avoid steep economic shocks after 2035.
- Complementary policies (e.g. clean energy investment, efficiency improvement) can reduce reliance on high carbon prices.
- International carbon pricing cooperation or offsets could reduce domestic burden and cost spikes.

Ongoing Research

UNICON-G-Power: "Linking Top-down and Bottom-up Models for a Macroeconomic Analysis of Decarbonization in Northeast Asia"

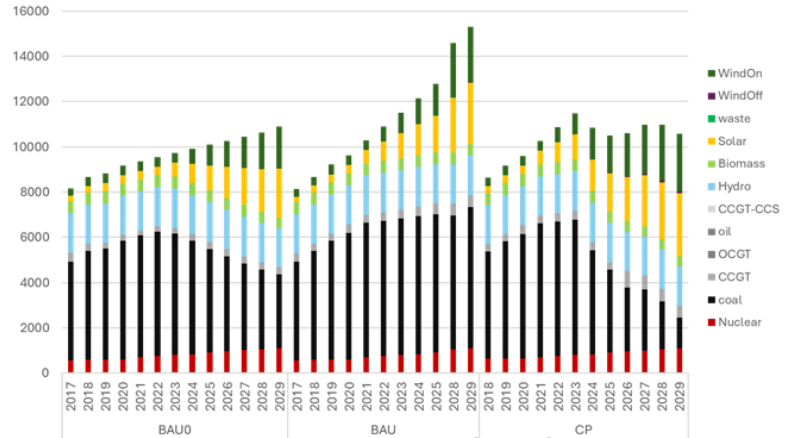
- A more detailed analysis of the power sector operations, carbon pricing, grid interconnections in Northeast Asia within a combined TD-BU framework



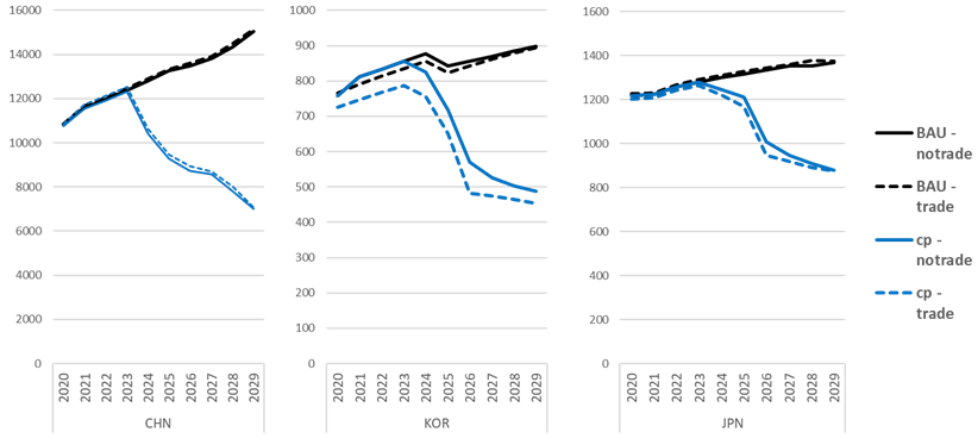
The BU model uses exogenous assumptions on technology costs and policies to optimize generation, fuel consumption, capital, and labor needs.

Price Feedback : The TD model takes these physical quantities and computes **market equilibrium prices** for electricity, fuels, capital, and labor, then passes them back to the BU model.

Iteration & Adjustment → until convergence : The BU model updates its decisions and dispatch to align with the new price signals and the electricity demand from the TD model.



NEA Power Generation Mix

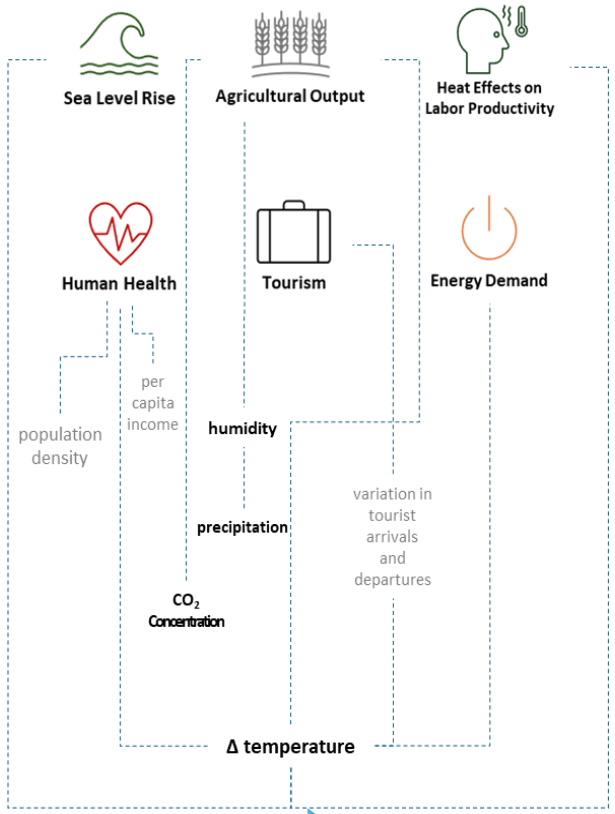


Grid Interconnection Impact on CO2

Ongoing Research

UNICON-IAM: "Assessing Climate Impacts Through Integration of a Global CGE Model with Regional- & Sector-Specific Damage Functions"

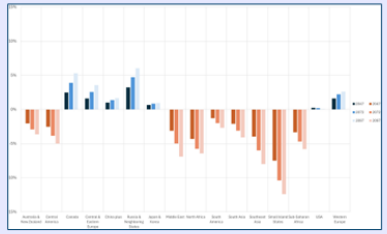
DAMAGES MODULE
(currently under improvement)

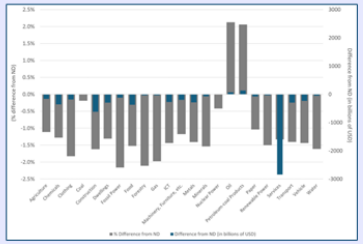


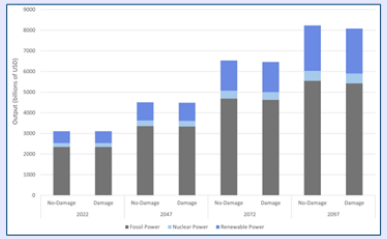
ECONOMY MODEL: UNICON-G-CGE
(model in improvement, preliminary results)

Utilizing **UNICON-IAM**, we analyze global/regional economic impacts, sectoral production changes, etc.


Regional Temperature Changes


Climate Impacts on Regional GDP


Changes in Sectoral Production


Energy Production with Climate Damage

- Preliminary analysis and results signal significant regional disparities in climate damages, as well as widespread but uneven output losses by industry sector.
- Findings the urgency of equity-focused climate policies, sector-specific resilience planning, and international cooperation to mitigate climate damages and promote sustainable economic trajectories

CLIMATE MODEL

Emissions

Carbon Cycle
4-reservoir Impulse Response Model

Radiative Forcing

Two-Box Energy Balance Model
- Atmosphere Layer
- Ocean Layer

Global Mean Surface Temperature

Thank You

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