

# Environment and Resource Economics

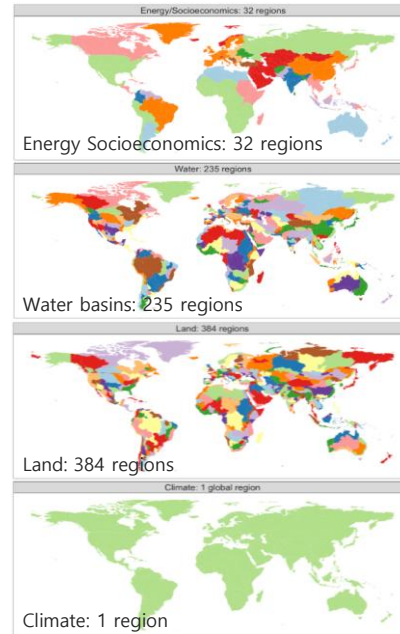
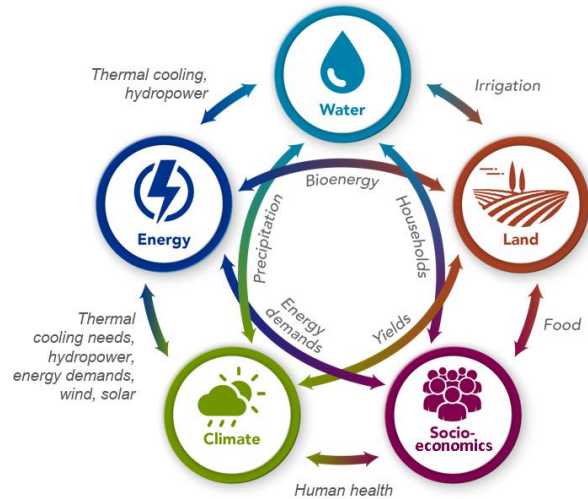
## Lecture – 1

Seungho Jeon



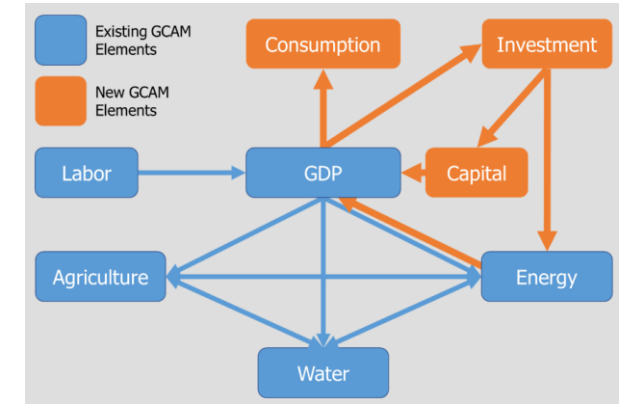
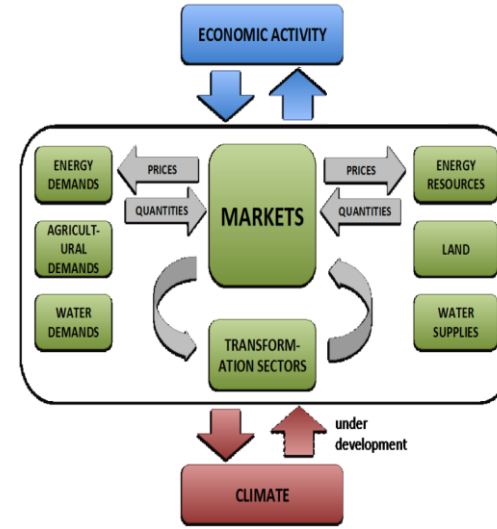
# : What is GCAM (Global Change Assessment Model)?

**GCAM** has been developed over the past 20 years at the PNNL<sup>1)</sup> in the United States



- **(IAM, Integrated assessment model)** The model integrates multiple sectors including socioeconomic, energy, land-use, water, and climate systems

- **(Spatial resolution)** It divides the world into 32 regions for socioeconomic and energy systems; South Korea is modeled as a single region
- **(Long-term projection)** GCAM simulates in 5-year time steps from the base year 2015 to 2100



- **(Bottom-up model)** It uses a bottom-up technology-rich structure to simulate systems at the technology level
- **(Equilibrium model)** GCAM calculates equilibrium prices by balancing the supply and demand of resources across sectors (energy, land, water, etc.)
- **(Macroeconomic model)** From version 7.0, GCAM incorporates GTAP<sup>2)</sup> databases to construct a Social Accounting Matrix (SAM<sup>3)</sup>), which is then used for CGE<sup>4)</sup>-based macroeconomic interactions. This enables two-way interaction between the energy system and GDP, allowing analysis of how climate change affects macroeconomic activity

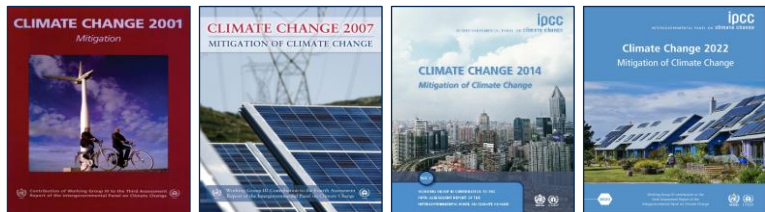
1) PNNL: Pacific Northwest National Laboratory  
2) GTAP: Global Trade Analysis Project  
3) SAM: Social Accounting Matrix  
4) CGE: Computable General Equilibrium



# Why GCAM?



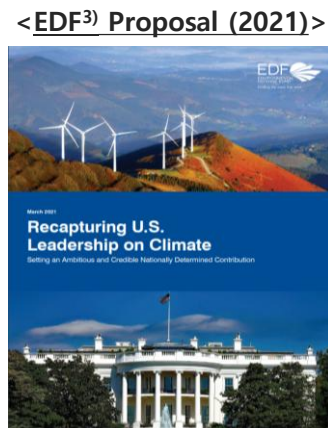
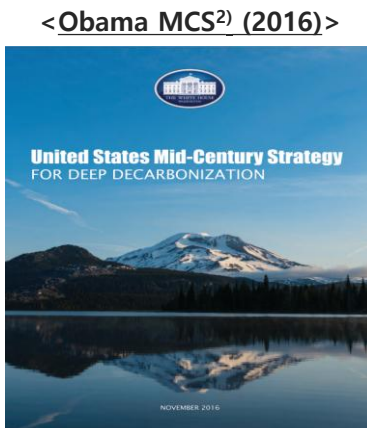
One of the main IAMs used in IPCC<sup>1)</sup> climate change scenario analyses



Source: IPCC, <https://www.ipcc.ch/reports/>



Used in U.S. national decarbonization strategies under the Obama administration



Source: White House. [https://unfccc.int/files/focus/long-term\\_strategies/application/pdf/mid\\_century\\_strategy\\_report-final\\_red.pdf](https://unfccc.int/files/focus/long-term_strategies/application/pdf/mid_century_strategy_report-final_red.pdf)

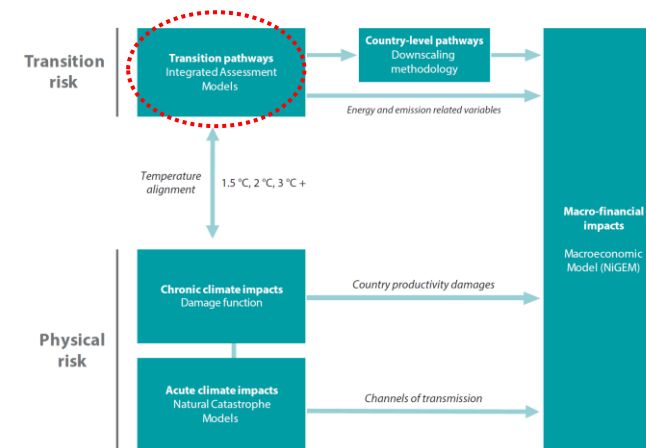


One of the three IAMs used in NGFS<sup>4)</sup> transition risk analysis.



Used by the Bank of Korea to analyze the economic impact of climate change

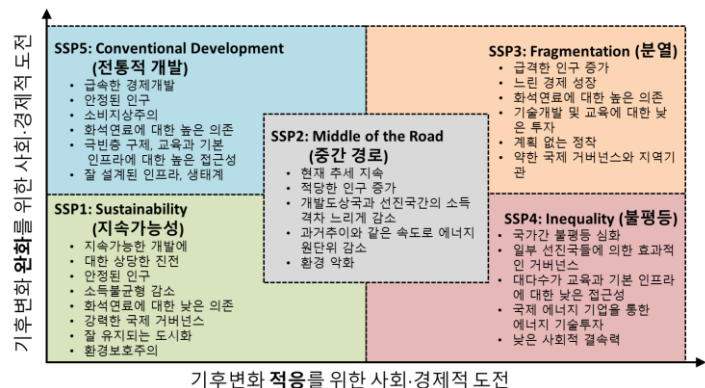
## <Impact of Climate Change on the Macroeconomy>



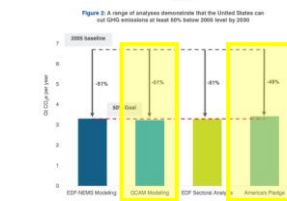
Source: NGFS, <https://www.ngfs.net/ngfs-scenarios-portal/>



Used to develop SSP<sup>5)</sup>-RCP<sup>6)</sup> scenarios GCAM is the marker model for SSP4



Source: Kate Calvin. The GCAM Shared Socioeconomic Pathways(SSPs) 발표자료를 재구성.



Source: Environmental Defense Fund (EDF). <https://www.edf.org/sites/default/files/documents/Recapturing%20U.S.%20Leadership%20on%20Climate.pdf>

Source: JGCRI/PNNL, [https://mobile.twitter.com/chris\\_r\\_vernon/status/1469435043068231688/photo/1](https://mobile.twitter.com/chris_r_vernon/status/1469435043068231688/photo/1)

Source: Adapted GCAM v.7.0 Documentation - GCAM Model Overview, <https://igcri.github.io/gcam-doc/overview.html>

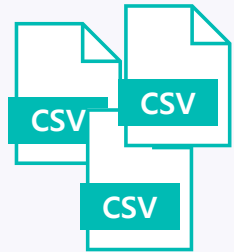


# : *Data Science in GCAM-Korea*

## Data System

Through a process that entails **330 R modules**, data gathered from diverse sources undergoes **preprocessing and transformation** into XML<sup>1)</sup> files

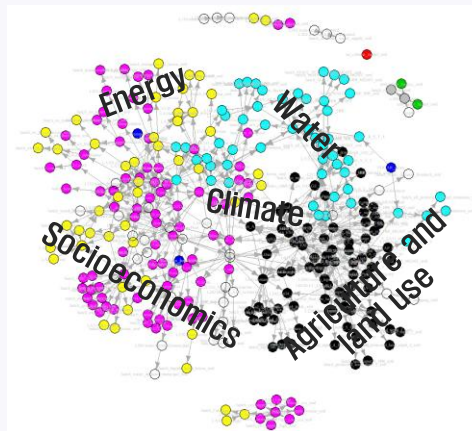
### Part A: Input Data Generation



#### Raw Data

Over **580 CSV<sup>2)</sup>** files including parameters and data sourced from international organizations such as **IEA<sup>3)</sup>**, **IMF<sup>4)</sup>**, **UN<sup>5)</sup>** and **others** are utilized in GCAM

Language: R



#### Input Data

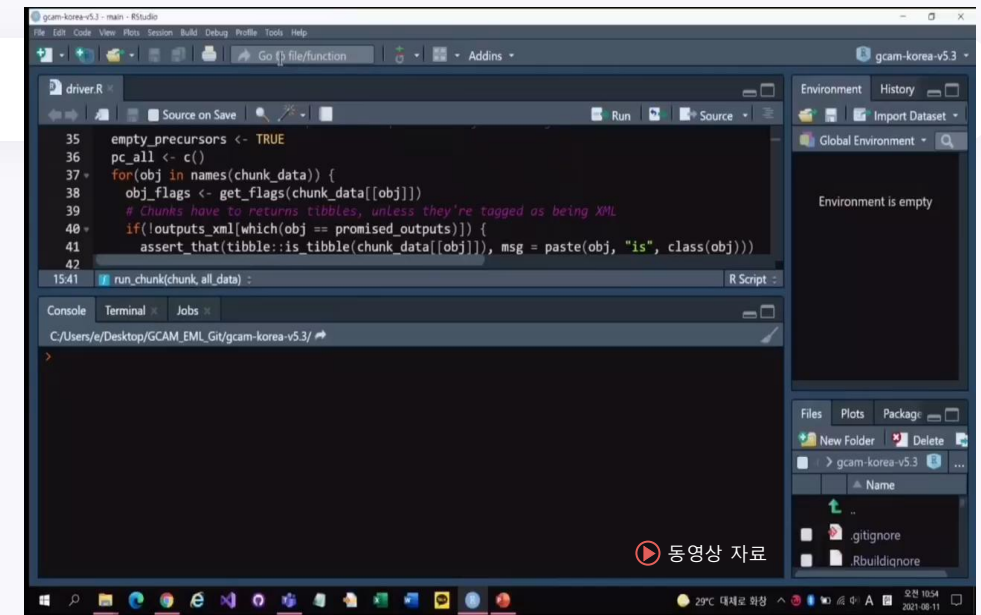
Input data(\*.xml) follows a consistent set of rules and has a **hierarchical structure**. It is structured into around **130 XML files**

Language: C++



#### Output Data

Simulation results is stored in the **baseX file** (or **XML**). The results could be extracted by using either R or Model Interface.



### Part B: GCAM simulation

#### Core System

Model runs, finding **international equilibrium prices** that balance supply and demand in all markets

- 1) XML: eXtensible Markup Language
- 2) CSV : Comma Separated Values
- 3) IEA: International Energy Agency
- 4) IMF: International Monetary Fund
- 5) UN: United Nations



# : Novelty of GCAM-Korea

## Official Introduction of GCAM Subregional Model

### Subregional Models

The table below shows the versions of GCAM with subregions along with the POC and institution at which it is hosted.

Subregional Breakouts

name	gcam_version	new_subregions	POC	Institution	Link
GCAM-USA	core	50 states + DC	Matthew Binsed - matthew.binsed@pnlnl.gov, Gokul Iyer - gokul.iyer@pnlnl.gov	PNLN	<a href="https://github.com/core">https://github.com/core</a>
GCAM-Canada	v5.3	10 provinces + 3 territories	Matthew Binsed - matthew.binsed@pnlnl.gov, Evan Davies - evan.davies@ualberta.ca	University of Alberta / PNLN	Private repo
GCAM-Korea	v5.3	17 Provinces	Sunguk Kim - sunguk.kim@ajou.ac.kr, SeungHo Jeon - sidus44@naver.com, MinYoung Roh - rohmin9122@gmail.com	Ajou University	None

### Subregional GCAM Models

Source: <https://gcri.github.io/gcambreakout/artides/regional.html>

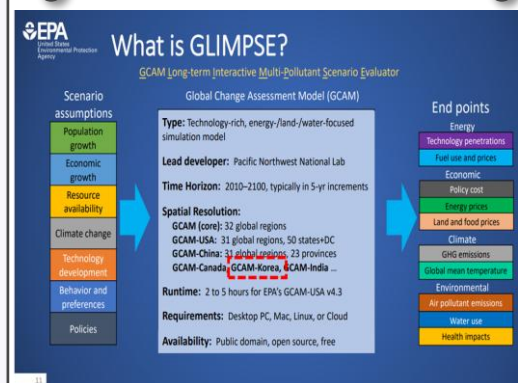
## PARIS REINFORCE

Evidently, the most widely used model throughout the reviewed literature is GCAM: an open source fully integrated assessment model (Calvin et al., 2019) supported by a dedicated and active community, with global coverage and significant geographic detail. Some of the instances in the literature include modified versions of GCAM, focusing on the biggest economies, such as GCAM-USA (Shi et al., 2017), GCAM-China (Yu et al., 2014) and GCAM-Korea (Jeon et al., 2020). GCAM has also been one of the main models used for the projection of the Shared Socioeconomic Pathways (SSP) scenarios of the IPCC reports (O'Neill et al., 2017), namely SSP4 (Calvin et al., 2017).

### Literature review of modeling

Source: [https://paris-reinforce.eu/sites/default/files/2021-07/D7.3%20-%20Report%20on%20stakeholder%20needs%20and%20research%20capacity%20needed\\_v1.10R\\_REVISIED.pdf](https://paris-reinforce.eu/sites/default/files/2021-07/D7.3%20-%20Report%20on%20stakeholder%20needs%20and%20research%20capacity%20needed_v1.10R_REVISIED.pdf)

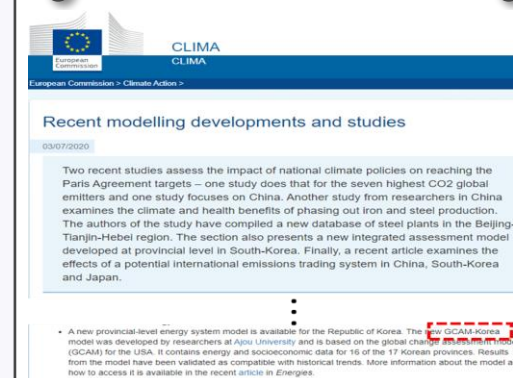
## U.S. Environmental Protection Agency



### High spatial resolution model

Source: [https://www.cmascenter.org/conference/2020/slides/Loughlin\\_GLIMPSE\\_CMAS2020.pdf](https://www.cmascenter.org/conference/2020/slides/Loughlin_GLIMPSE_CMAS2020.pdf)

## European Commission



### Literature review of modeling

Source: <https://ec.europa.eu/newsroom/clima/items/682256>



# : *Power grid implications of electrification (2025)*

## Research Question

## How does electric vehicle (EV) adoption affect the national grid?

### Background

Spatial mismatch between power supply and demand

- Expansion of EVs raises concerns over insufficient transmission infrastructure

### Scenario

- (Reference) No mitigation policies are implemented (business as usual)
- (NetZero) Mitigation policies in place to achieve net-zero emissions by 2050

### Main findings

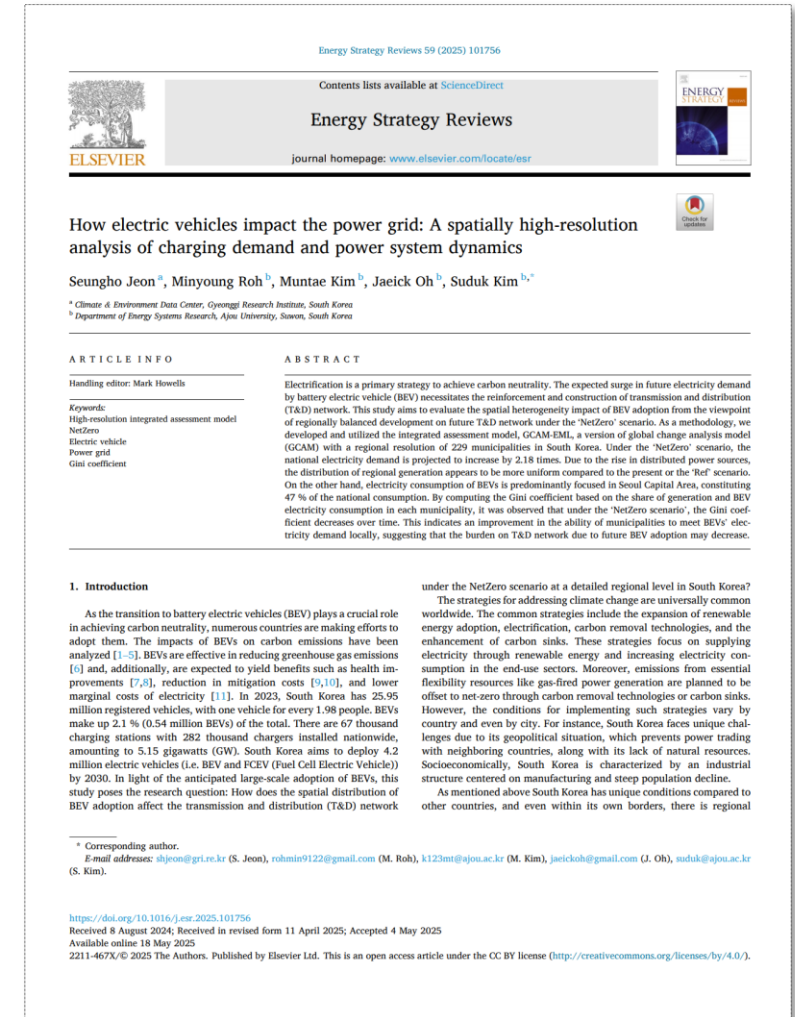
Spatial mismatch is reduced as supply becomes more balanced

Power Supply	Power Demand
<ul style="list-style-type: none"><li>① Retirement of coal-fired power plants</li><li>② Nationwide expansion of solar PV</li><li>③ Power supply becomes spatially balanced</li></ul>	<ul style="list-style-type: none"><li>① Population is assumed to remain concentrated in the capital region</li><li>② EV adoption is concentrated in the capital region.</li><li>③ Power demand from EVs remains spatially concentrated.</li></ul>

### Implications

Spatial coordination of power supply-demand

- Electrification does not necessarily worsen grid stress if supply becomes spatially distributed.



The background features a large, light blue watermark of the Hanbat University logo. It is a circular seal with the university's name in Korean, English, and Chinese, and the text "SINCE 1927".

# **R**esearch achievement: **Empirical and Applied Research**



# : *Spatial Analysis of solar PV (Jeon, 2025)*

## Research Question

How much solar PV potential is economically usable and utilized?

### Background

Gyeonggi-do has the highest electricity demand but a relatively low level of renewable generation

### Method

- **GIS (Geographic Information System) spatial analysis**  
based on satellite imagery irradiance data (1.5km raster)
- Three-tier PV potential assessment  
(Theoretical > Technical > **Market potential**)
- **Economic viability** based on LCOE vs. SMP (System Marginal Price)+REC (Renewable Energy Certificate) threshold using land prices at grid-level
- Municipality-level utilization rates assessed (Actual generation ÷ market potential)

### Main findings

Large spatial disparities in utilization rates

- Gwangju : 147.1%, Paju : 2.2%

### Implications

Policy attention is needed for underutilized but high-potential areas (e.g. Yeonchoen)

<Theoretical potential>

$$G^{th} = \sum_i^n g_i^{th} = \sum_i^n irr_i$$

<Technical potential>

$$G^{tc} = \sum_i^n g_i^{tc} = \sum_i^n g_i^{th} \times AreaRatio_{i,j} \times eff$$

where,  $i \notin geo\_restricted$

<Market potential>

$$G^{mk} = \sum_i^n g_i^{tc}$$

where,  $i \notin policy\_restricted$ ,  
 $LCOE_i < SMP + (w_{i,j} \times REC)$

$G^{th}$  : theoretical potential in Gyeonggi-do (MWh)

$g_i^{th}$  : theoretical potential of each grid cell ( $i$ ) (MWh)

$irr$  : irradiance (MWh/year/100m<sup>2</sup>)

$G^{tc}$  : technical potential in Gyeonggi (MWh)

$g_i^{tc}$  : technical potential of each grid cell ( $i$ ) (MWh)

$AreaRatio$  : panel coverage ratio (%)

$eff$  : module efficiency (%)

$geo\_restricted$  : geographically restricted area

$policy\_restricted$  : politically restricted area

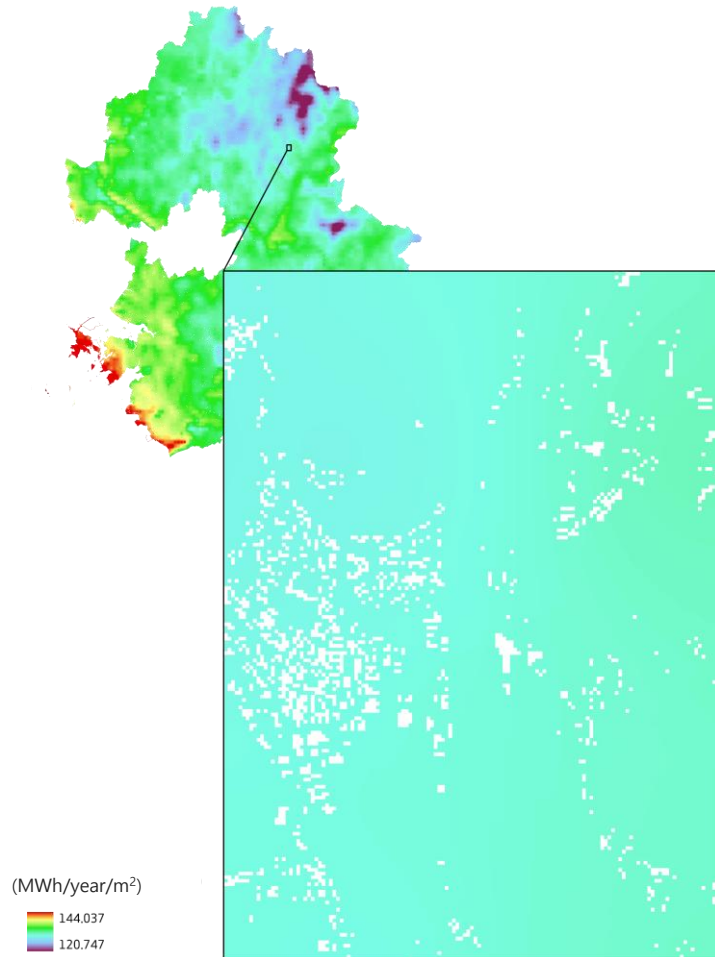
$LCOE_i$  : levelized cost of electricity of each grid cell ( $i$ ) (MWh)

$SMP$  : system marginal price (won/kWh)

$REC$  : renewable energy certificate (won/kWh)

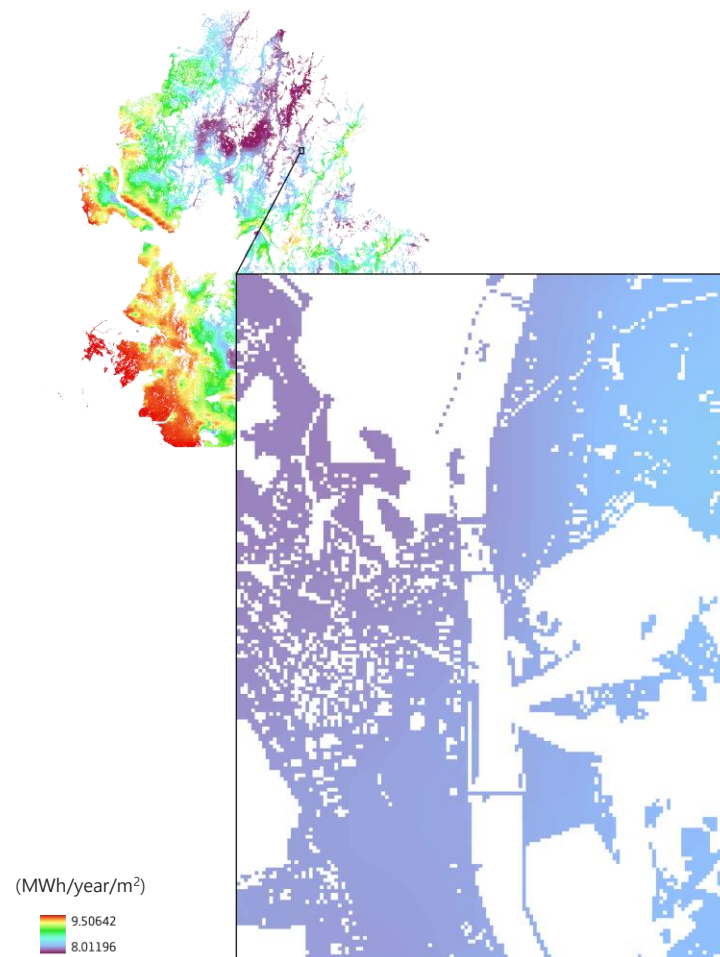
$w$  : REC weight (unitless)

## Theoretical potential



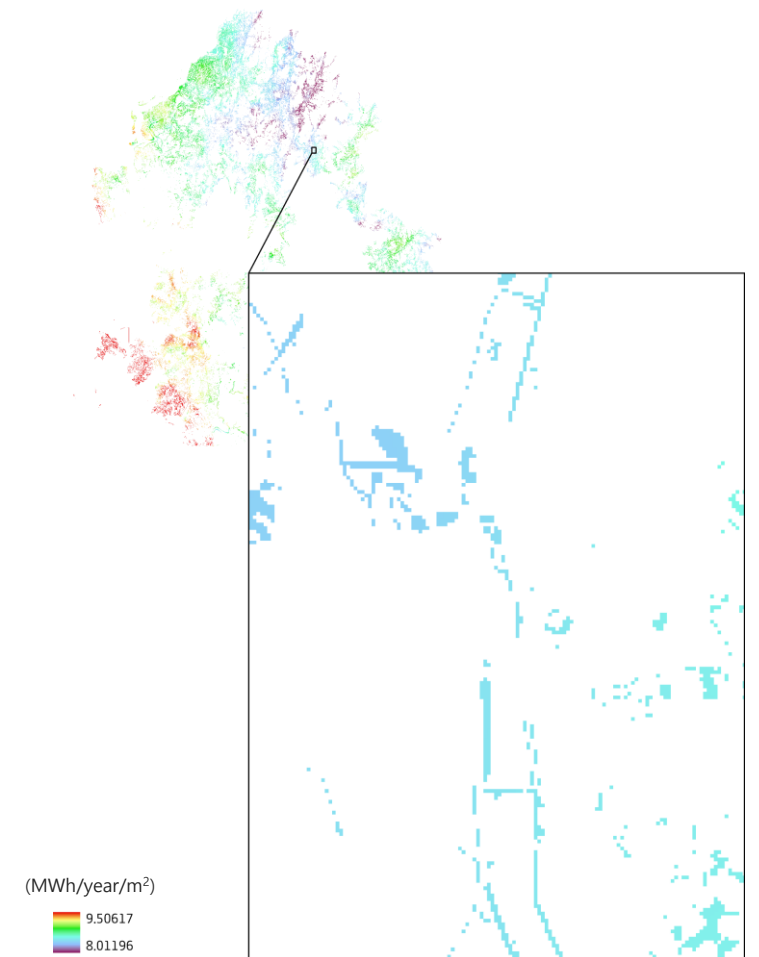
Source: Author

## Technical potential



Source: Author

## Market potential



Source: Author



# : Bridging environment and energy

## Research Question

How much electricity can we save by greening our cities?

Green space ↑

Heat ↓

Electricity use for cooling ↓

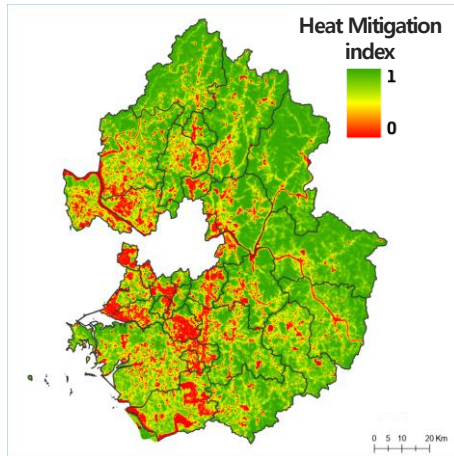
## Research Design

- **(Background)** An extended study on the monetary valuation of ecosystem regulating services
- **(Objective)** To estimate the cooling effect of green space and the resulting change in electricity demand for cooling under temperature variation
- **(Data)**

① Hourly temperature data (2004-2024, 77 stations nationwide) from ASOS<sup>1)</sup> provided by KMA<sup>2)</sup> retrieved via API<sup>3)</sup>

② Monthly electricity consumption by cities and contract type provided by KEPCO<sup>4)</sup>

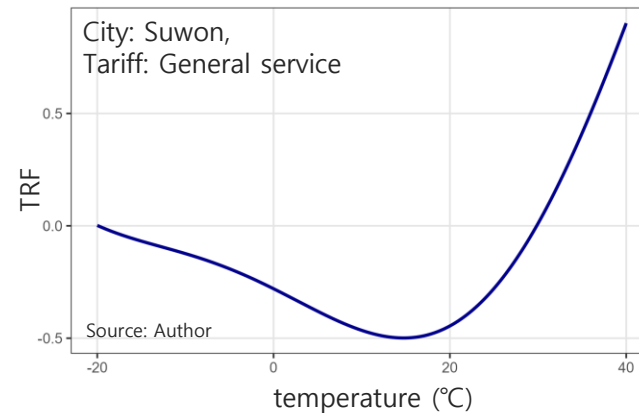
Heat Mitigation impact  
using InVEST model



Source: Gyeonggi research institute and National Institute of ecology

\* InVEST model: Integrated Valuation of Ecosystem Services and Tradeoffs

Temperature response function  
(TRF)



$$y_t^s = \int f_t(s) \left[ k^{(1)} + \frac{t}{T} k^{(2)}(s) \right] ds + \epsilon_t$$

Electricity demand function

$$y_t = \log \left( \frac{MPS_t}{MED_t} \right) = \alpha + \beta_t \log(MGDP_t) + \gamma \log(PRC_t) + \delta TE_t + \epsilon_t$$

$$MPS_t \text{ Monthly electricity sales} \quad \text{where } TE_t = \int f_t(s) \hat{k}_t(s) ds$$

$$MED_t \text{ Monthly effective days} \quad = TE_t^c + TE_t^h + \hat{k}_t(\bar{s}_t)$$

$PRC_t$  Real electricity tariff index

$MGDP_t$  Monthly GRDP

$TE_t$  Monthly temperature effect

1) ASOS: Automated Synoptic Observing System

2) KMA: Korea Meteorological administration

3) API: Application Programming Interface

4) KEPCO: Korea Electric Power Corporation



## ∴ 수업개요

### 수업 운영 방식

- ✓ 강의 중심의 수업
- ✓ 수업 중 언제든지 어떤 주제도 질문 가능
- ✓ 취식 가능 (냄새만 심하게 안나면)

### 성적 평가 방법: 상대평가

- ✓ 출석: 10%, 중간고사: 45%, 기말고사 45%
- ✓ 문제풀이 (OX, 객관식, 주관식 포함)

### 개별 면담

- ✓ 703호 노크해서 내가 자리에 있으면 언제든지 환영
- ✓ 미리 이메일 통해서 약속 잡는 것도 환영
- ✓ 면담내용은 어떤 내용도 환영

# Introduction





## : *Positive vs. normative economics*

### **Positive economics**

The study of explaining and predicting economic phenomena. It identifies causes and effects without making value judgments.

Example: If a carbon tax is set at 10,000KRW/tCO<sub>2</sub>, how much will greenhouse gas emissions be reduced?

### **Normative economics**

The study of discussing what is desirable regarding economic policies or situations. It proposes policy directions based on value judgments.

Example: How high should the carbon tax be raised?

**Positive → Normative**: Constructive discussions are possible only when empirical results exist, which can then serve as a basis for value judgments.

### **Environmental economics in my class**

In this course, we will study environmental economics within the scope of empirical economics.



## : *What is environment economics?*

### **Microeconomics**

The study of how economic agents make decisions—such as production and consumption—based on their motivations.

### **Macroeconomics**

The study of how macroeconomic variables such as GDP, growth rate, unemployment rate, and interest rate are formed and interact.

### **Environmental economics**

The study of how to develop and manage the natural environment or environmental resources by applying economic principles.

- ✓ How do economic agents affect the natural environment?
- ✓ How should government policies or economic institutions be designed to balance human consumption needs with the preservation of natural ecosystems?

## 농어촌공사, '멸종위기 야생생물 모니터링' 시행

✎ 박예진 기자 | ⌚ 입력 2025.08.27 09:53 | ⌚ 수정 2025.08.27 17:47 | 💬 댓글 0

환경보전·생물다양성 확보 위한 지속 가능 개발 실천



금개구리 이주를 위한 포획 /사진제공=한국농어촌공사

<https://www.hkbs.co.kr/news/articleView.html?idxno=804644>

## 녹조 라떼 그만... 조류경보제 손질

✎ 김인성 기자 | ⌚ 입력 2025.08.19 14:48 | 💬 댓글 0

환경부 '녹조 수질검사·정보공개' 전면 개편, 종합 대책 마련  
당일 경보 발령, 조류독소 기준 도입... 먹는물 안전관리 강화



낙동강 지점별 채수위치 변경 계획(안) /자료제공=환경부

<https://www.hkbs.co.kr/news/articleView.html?idxno=804038>

## 국내 보험사, 여전히 '화석연료' 지원 몰입

✎ 박예진 기자 | ⌚ 입력 2025.08.27 13:39 | 📄 댓글 0

기후리스크 관리 낙제점... 석탄 예외 조항, 재생E 지원 뒷전  
"최근 20년간 6000억 달러 손실에도 탈석탄 로드맵 전무"

<https://www.hkbs.co.kr/news/articleView.html?idxno=804655>

기간별 화석연료 보험 잔액 추이



기간별 화석연료 보험 잔액 추이 / 자료제공=한국사회책임투자포럼

## 환경부-유엔, '2035 국가온실가스 감축목표' 협력 논의

✎ 박준영 기자 | ⌚ 입력 2025.08.27 12:00 | ⌚ 수정 2025.08.27 18:21 | 📄 댓글 0

금한승 차관, 셀윈 하트 유엔 특보와 회동... 재생에너지 전환·탄소중립 달성 전략 공유



금한승 환경부 차관이 27일 서울 국회 인근에서 유엔사무총장 기후행동특별보좌관 셀윈 하트(Selwin Hart)와 기념촬영을 하고 있다. /사진제공=환경부

<https://www.hkbs.co.kr/news/articleView.html?idxno=804652>



## ***: Environmental economics in everyday life***

### **Volume-based Waste Fee System**

- Before 1995, waste collection fees were charged based on building size or property tax
  - ✓ No economic incentive to reduce waste generation
- After 1995, a volume-based waste system was introduced. General waste must be disposed of using designated bags
  - ✓ Since the cost of waste disposal (the price of the designated bags) is proportional to the amount of waste generated, households have an economic incentive to reduce waste.

### **Extended Producer Responsibility**

- A system in which producers of products or packaging are required to recycle a certain amount of waste. If they fail to do so, they must pay a recycling fee higher than the actual cost of recycling.

### **Congestion Pricing**

- An increase in automobile use raises road congestion, leading to time loss for travelers and higher fuel consumption.



## *Features in environmental economics*

### **Market failure and externalities**

- **(Public goods)** Many goods and services in environmental economics have strong public good characteristics.
  - ✓ Environmental resources often lack private property rights or are owned collectively.
- **(Externalities)** Actions of an economic agent may unintentionally cause benefits or damages to third parties, but such effects are not reflected in market prices.
  - ✓ Bees kept by a beekeeper pollinate nearby orchards, increasing fruit production
  - ✓ A factory discharges wastewater into a river, harming downstream fisheries

### **Environmental policy**

- Leaving environmental resource use entirely to market forces can increase environmental damage
- To ensure efficient use of environmental resources, economic incentives should be considered
  - ✓ Levying emission charges on pollutants
  - ✓ Setting caps on pollutant emissions



## ***: Features in environmental economics***

### **Cost-benefit analysis of environmental policy**

- When implementing environmental policy, both costs and benefits must be evaluated to provide a basis for policymaking
  - ✓ Unlike market goods, environmental goods often lack explicit prices, making this analysis difficult.

### **Economic development and environmental preservation**

- Economic development and environmental preservation were once viewed as conflicting goals.
- However, evidence shows that environmental problems are more severe in less-developed countries than in advanced economies.

# **E**conomics and natural environment





## : *Interrelationship between economy and environment*

### Material Balance Approach (Kneese et al., 1970)

- Households directly consume services from nature
  - ✓ Enjoyment from beautiful landscapes, clean air
- Households also extract various materials and energy from Earth's natural resources and supply them to the factor market
  - ✓ A farmer provides labor and land to a food company
- Firms purchase production factors from the factor market, use them as inputs for final products, and supply outputs to the goods market
  - ✓ A food company uses labor and land to produce flour, which is then supplied back to households
- Economic activities generate residuals that are released into nature
  - ✓ Some are absorbed by nature's assimilative capacity (e.g., composting food waste).
  - ✓ Others remain in the environment as pollutants (e.g., greenhouse gases)
- Types of resources supplied by nature
  - ✓ Renewable resources: Flora and fauna, solar energy, wind energy
  - ✓ Non-renewable resources: Oil, coal, metals



## ∴ ***Laws of Thermodynamics***

### **First Law of Thermodynamics: Law of Conservation of Energy**

- Energy can change its form, but its total amount does not change.
  - ✓ Materials or energy extracted from nature can be temporarily delayed through recycling or reuse, but they are ultimately converted into the same amount of waste and returned to nature.

### **Second Law of Thermodynamics: Law of Increase of Entropy**

- Entropy always increases or is maintained. Heat flows from a high temperature to a low temperature.
  - ✓ Hot coffee cools down on its own, but cold coffee does not get hot on its own.
- (Types of resources) Resources supplied by nature can be classified into two types.
  - ✓ Renewable resources: animals and plants, solar, wind
  - ✓ Non-renewable resources: oil, coal, metals



## ∴ *Basic Terminology Related to Environmental Pollution*

### **Environmental quality**

- Expresses the qualitative state of the natural environment. It is a very broad concept that includes pollution levels, natural scenery, etc.

### **Residuals**

- Materials remaining after the production or consumption process of an output. (Industrial waste: materials remaining from the production process, household waste: materials remaining from the consumption process)

### **Pollutant**

- A substance or energy that degrades environmental quality when released into nature.

### **Emission**

- The amount of pollutants among residuals that have been released into nature.

### **Sources**

- The location where pollutants are emitted (e.g., factories, automobiles, landfills)

### **Damages**

- The negative effects of environmental pollution on people and ecosystems (deterioration of human health, extinction of flora and fauna (animals and plants)).

### **Environmental medium**

- Elements that constitute the natural environment (e.g., land, water, air).



## : *Types of Pollutants*

### **Accumulative and Non-accumulative Pollutants**

- Classified according to whether they remain and accumulate for a long time after being released into nature, or disappear.
  - ✓ Accumulative pollutants: carbon dioxide, methane, lead, heavy metals
  - ✓ Non-accumulative pollutants: noise, bad smell, light pollution

### **Self-regulating ability of Ecosystems**

- Nature has the ability to absorb and break down a certain amount of pollutants
- When pollutants are emitted beyond the self-regulating ability of the ecosystem, they accumulate in nature.
  - ✓ Climate change is caused by carbon emissions consistently exceeding carbon absorption.
  - ✓ The situation where carbon emissions and carbon absorption are equal is called carbon neutrality.



## ∴ *Types of Pollutants*

### Local, Regional, and Transboundary Pollutants

- (Local) Pollutants that affect only the vicinity of a specific area.
  - ✓ carbon monoxide (CO) from cars and heating boilers shows high concentrations only nearby
- (Regional) Pollutants that affect urban or metropolitan areas
  - ✓ Acid rain is mainly caused by substances like SO<sub>2</sub> and NO<sub>x</sub>, and it travels more than several hundred kilometers
  - ✓ A case where acid rain falls in Daejeon due to pollutants emitted by vehicles driving in Seoul.
- (Transboundary) Pollutants that cross borders and affect other countries
  - ✓ the case of yellow dust originating from the Gobi Desert in Mongolia and affecting Korea and Japan
  - ✓ Greenhouse gases are causing climate change across the entire planet.



## ***: Types of Pollutants***

### **Land pollutants and Global pollutants**

- (Land) Pollutants that accumulate on the surface and destroy the environment.
- (Global) Pollutants that accumulate in the atmosphere and destroy the environment of the entire planet.

### **Point source and Nonpoint source Pollutants**

- (Point source) Cases where pollutants are emitted through a single point
  - ✓ air pollutants from factory smokestacks
  - ✓ discharge of cooling water from power plants
- (Nonpoint Source Pollutants) Cases where pollutants are emitted from a wide area
  - ✓ nitrogen and phosphorus washed away by rainwater from farmland (components of fertilizers and pesticides)
  - ✓ soil runoff from forests

### **Continuous and Intermittent Pollution**

- (Continuous) Cases where pollutants are emitted steadily (power plant operation, car traffic)
- (Intermittent) Cases where pollutants are emitted irregularly and intermittently (radioactive leakage due to an accident, oil tanker accident)

**Thank you**

