FONDAZIONE ENI ENRICO MATTEI

Economia dello Sviluppo – Seminar:

Integrated Assessment Models: Theory and Applications

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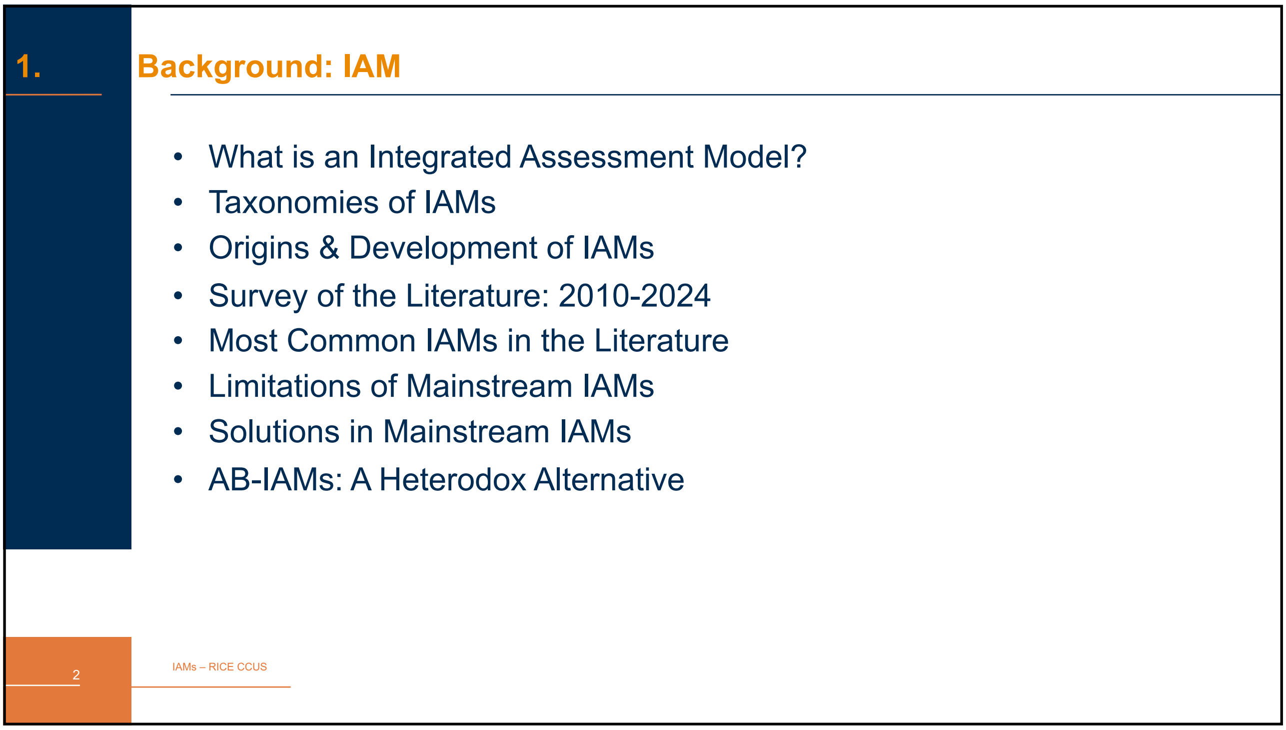
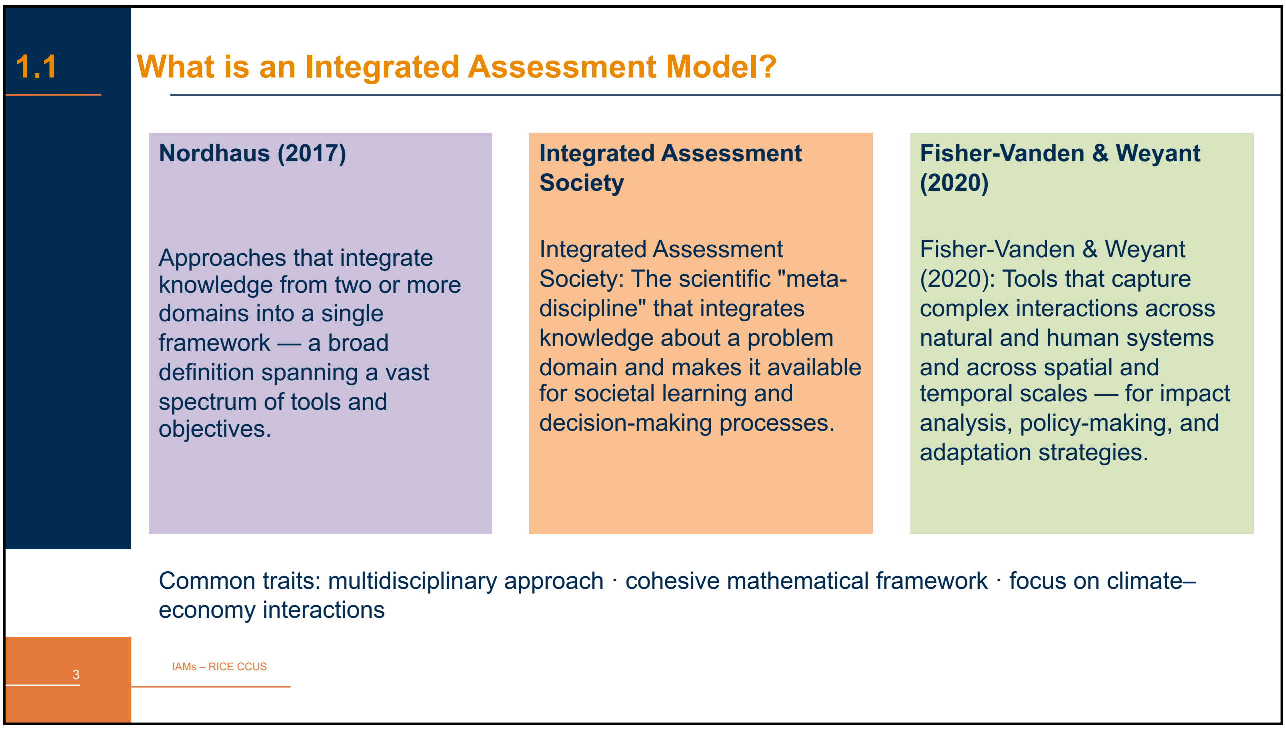
Lecture Structure

1. Background: IAM
2. Modeling: RICE
3. Original contribution: CCUS
4. An application: FEEM-RICE with CCUS



1. Background: IAM

- What is an Integrated Assessment Model?
- Taxonomies of IAMs
- Origins & Development of IAMs
- Survey of the Literature: 2010-2024
- Most Common IAMs in the Literature
- Limitations of Mainstream IAMs
- Solutions in Mainstream IAMs
- AB-IAMs: A Heterodox Alternative



1.1 What is an Integrated Assessment Model?

Nordhaus (2017)

Approaches that integrate knowledge from two or more domains into a single framework — a broad definition spanning a vast spectrum of tools and objectives.

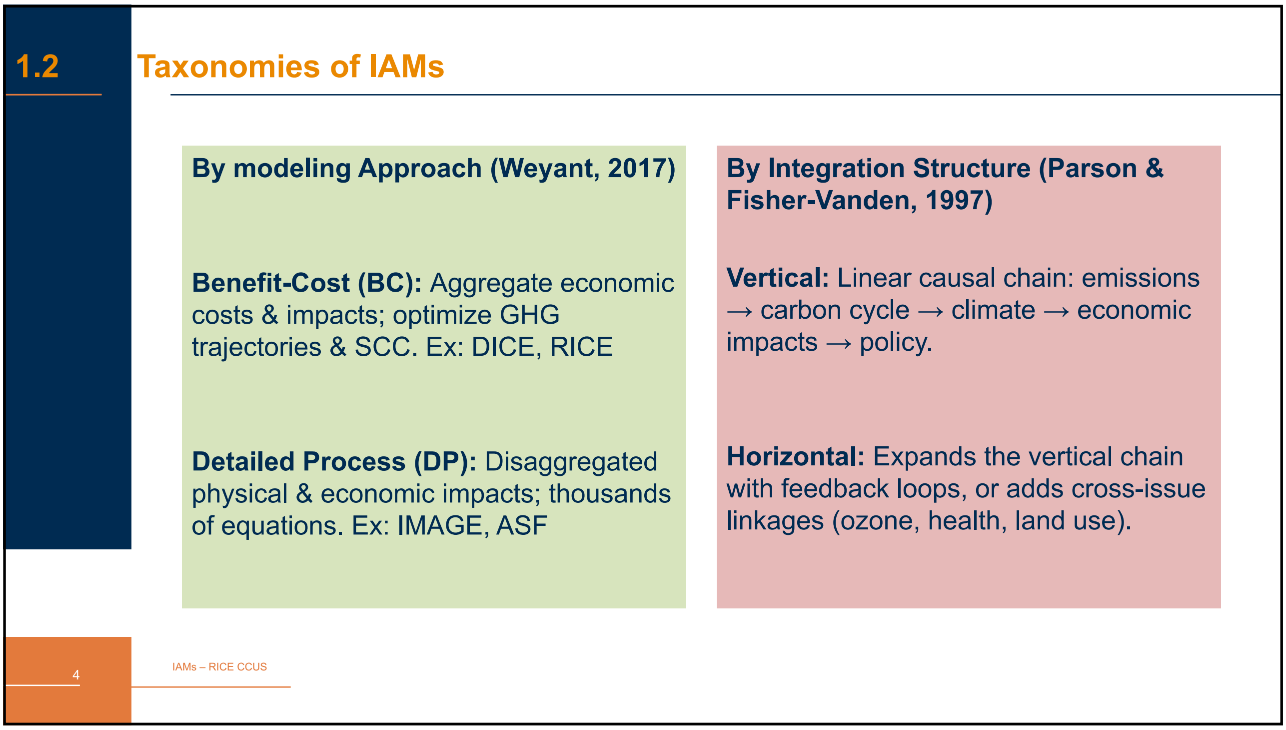
Integrated Assessment Society

Integrated Assessment Society: The scientific "meta-discipline" that integrates knowledge about a problem domain and makes it available for societal learning and decision-making processes.

Fisher-Vanden & Weyant (2020)

Fisher-Vanden & Weyant (2020): Tools that capture complex interactions across natural and human systems and across spatial and temporal scales — for impact analysis, policy-making, and adaptation strategies.

Common traits: multidisciplinary approach · cohesive mathematical framework · focus on climate–economy interactions



1.2 Taxonomies of IAMs

By modeling Approach (Weyant, 2017)

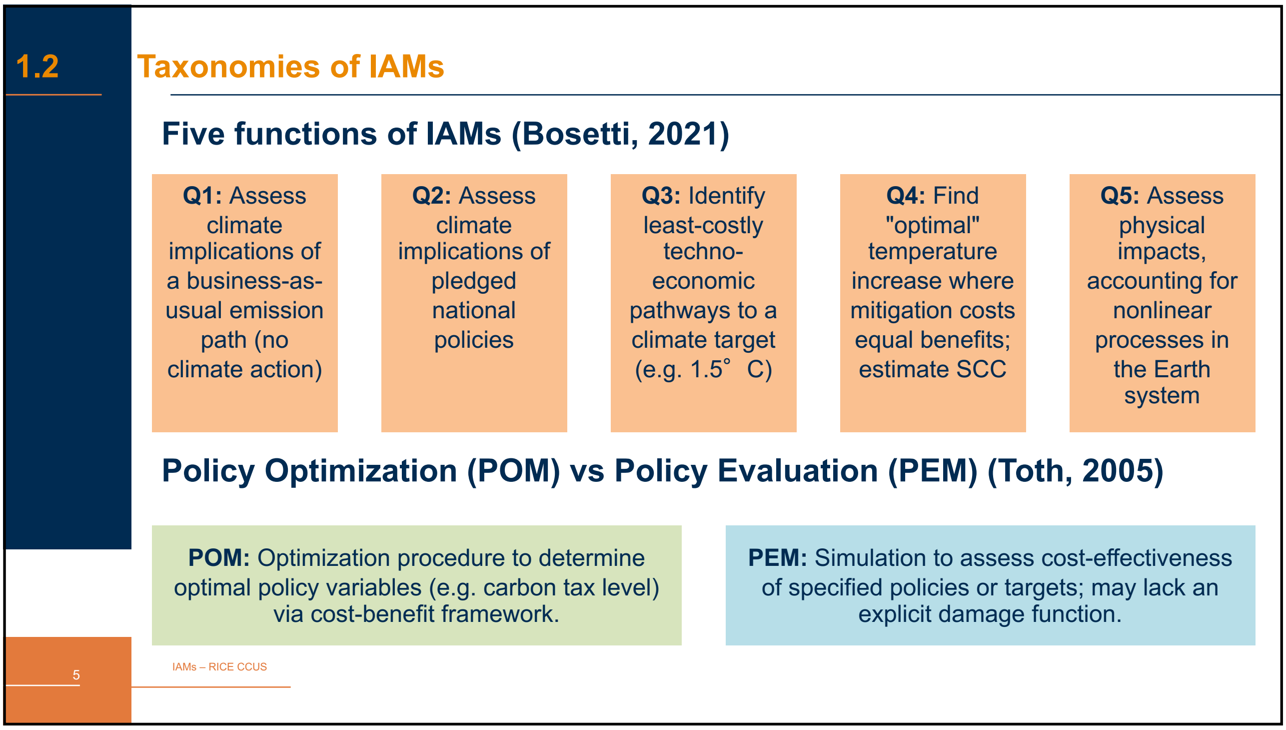
Benefit-Cost (BC): Aggregate economic costs & impacts; optimize GHG trajectories & SCC. Ex: DICE, RICE

Detailed Process (DP): Disaggregated physical & economic impacts; thousands of equations. Ex: IMAGE, ASF

By Integration Structure (Parson & Fisher-Vanden, 1997)

Vertical: Linear causal chain: emissions → carbon cycle → climate → economic impacts → policy.

Horizontal: Expands the vertical chain with feedback loops, or adds cross-issue linkages (ozone, health, land use).



1.2 Taxonomies of IAMs

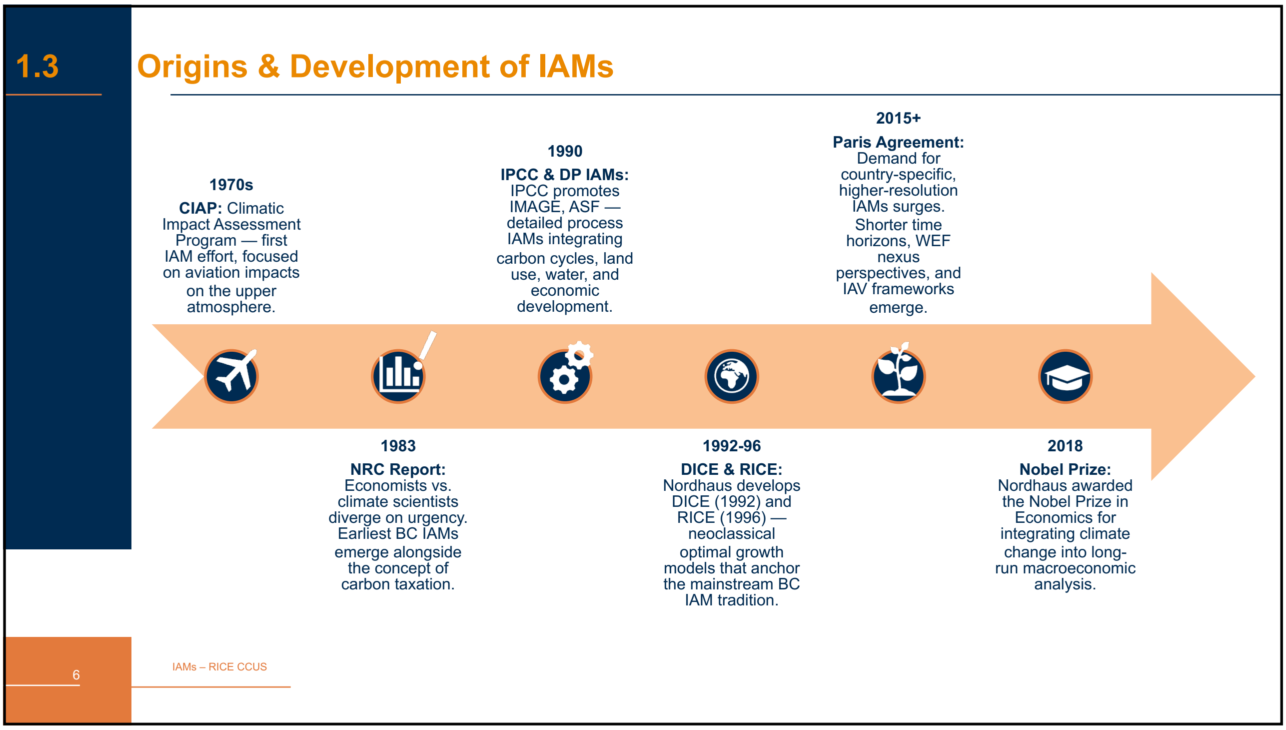
Five functions of IAMs (Bosetti, 2021)

- **Q1:** Assess climate implications of a business-as-usual emission path (no climate action)
- **Q2:** Assess climate implications of pledged national policies
- **Q3:** Identify least-costly techno-economic pathways to a climate target (e.g. 1.5° C)
- **Q4:** Find "optimal" temperature increase where mitigation costs equal benefits; estimate SCC
- **Q5:** Assess physical impacts, accounting for nonlinear processes in the Earth system

Policy Optimization (POM) vs Policy Evaluation (PEM) (Toth, 2005)

POM: Optimization procedure to determine optimal policy variables (e.g. carbon tax level) via cost-benefit framework.

PEM: Simulation to assess cost-effectiveness of specified policies or targets; may lack an explicit damage function.



1.3 Origins & Development of IAMs

1970s
CIAP: Climatic Impact Assessment Program — first IAM effort, focused on aviation impacts on the upper atmosphere.

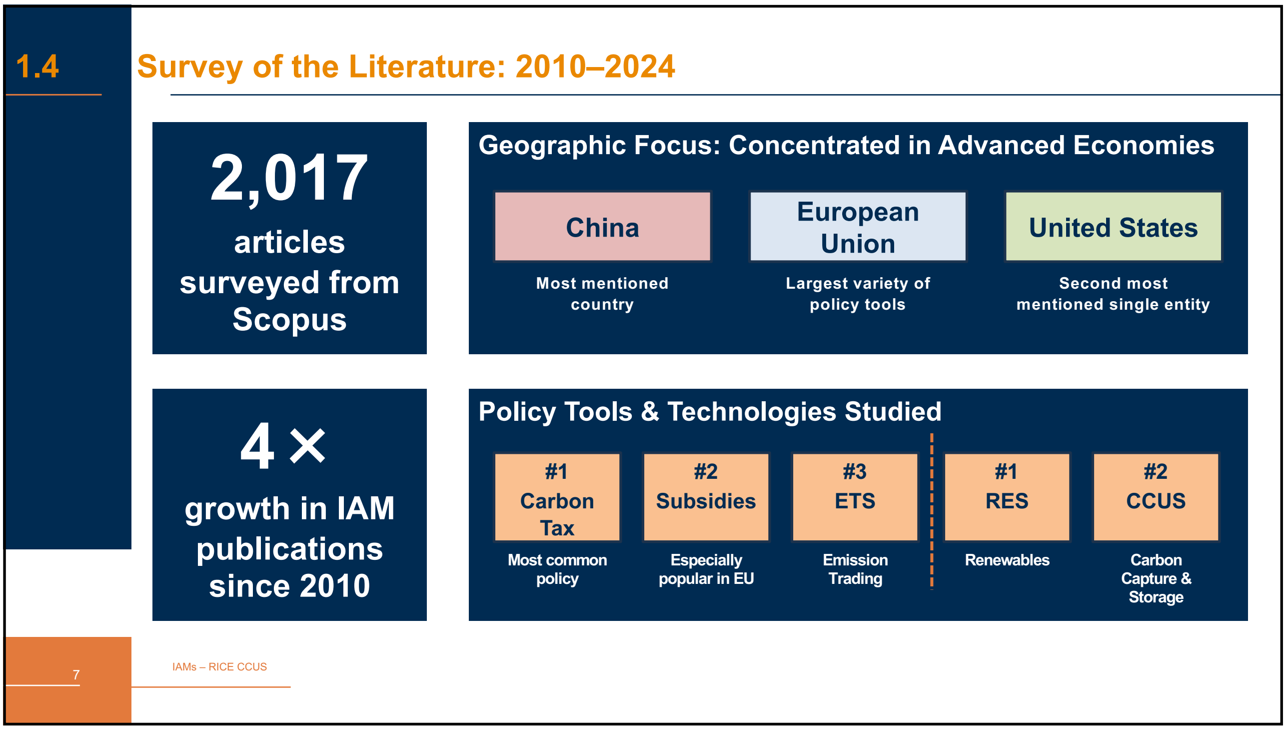
1983
NRC Report: Economists vs. climate scientists diverge on urgency. Earliest BC IAMs emerge alongside the concept of carbon taxation.

1990
IPCC & DP IAMs: IPCC promotes IMAGE, ASF — detailed process IAMs integrating carbon cycles, land use, water, and economic development.

1992-96
DICE & RICE: Nordhaus develops DICE (1992) and RICE (1996) — neoclassical optimal growth models that anchor the mainstream BC IAM tradition.

2015+
Paris Agreement: Demand for country-specific, higher-resolution IAMs surges. Shorter time horizons, WEF nexus perspectives, and IAV frameworks emerge.

2018
Nobel Prize: Nordhaus awarded the Nobel Prize in Economics for integrating climate change into long-run macroeconomic analysis.



1.4 Survey of the Literature: 2010–2024

2,017
articles surveyed from Scopus

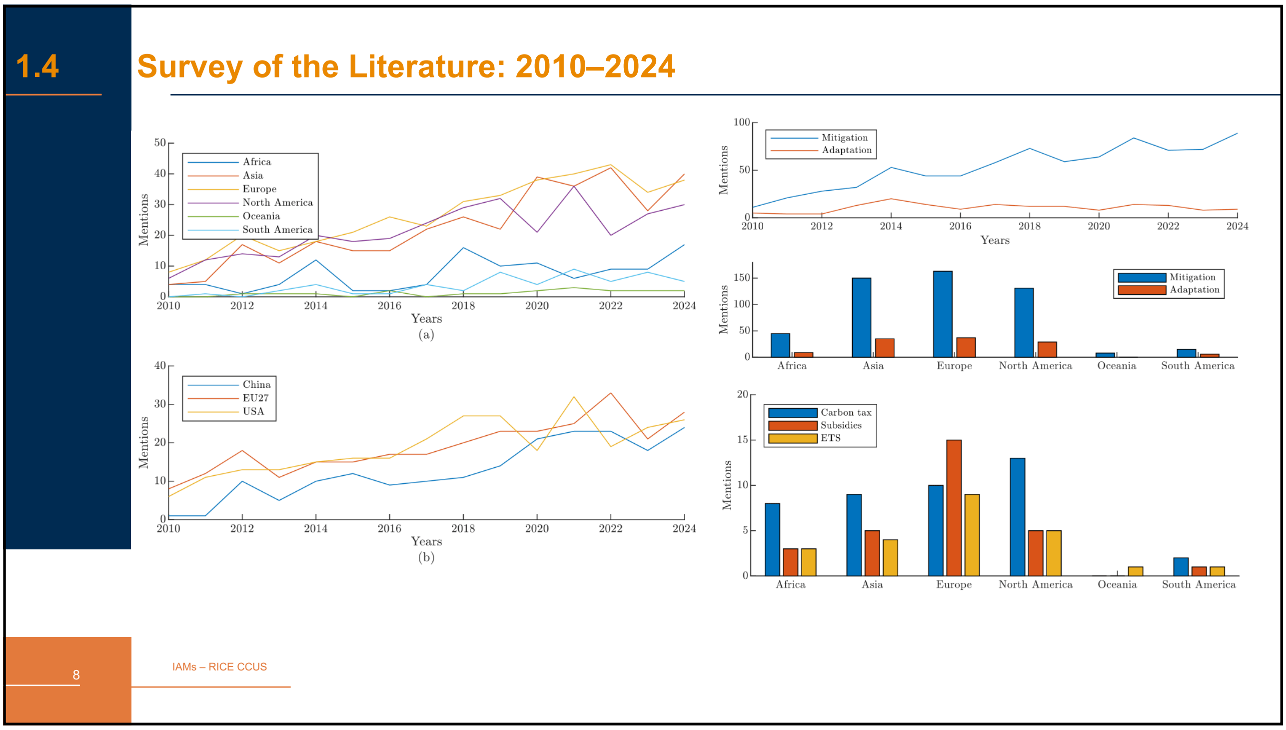
4×
growth in IAM publications since 2010

Geographic Focus: Concentrated in Advanced Economies

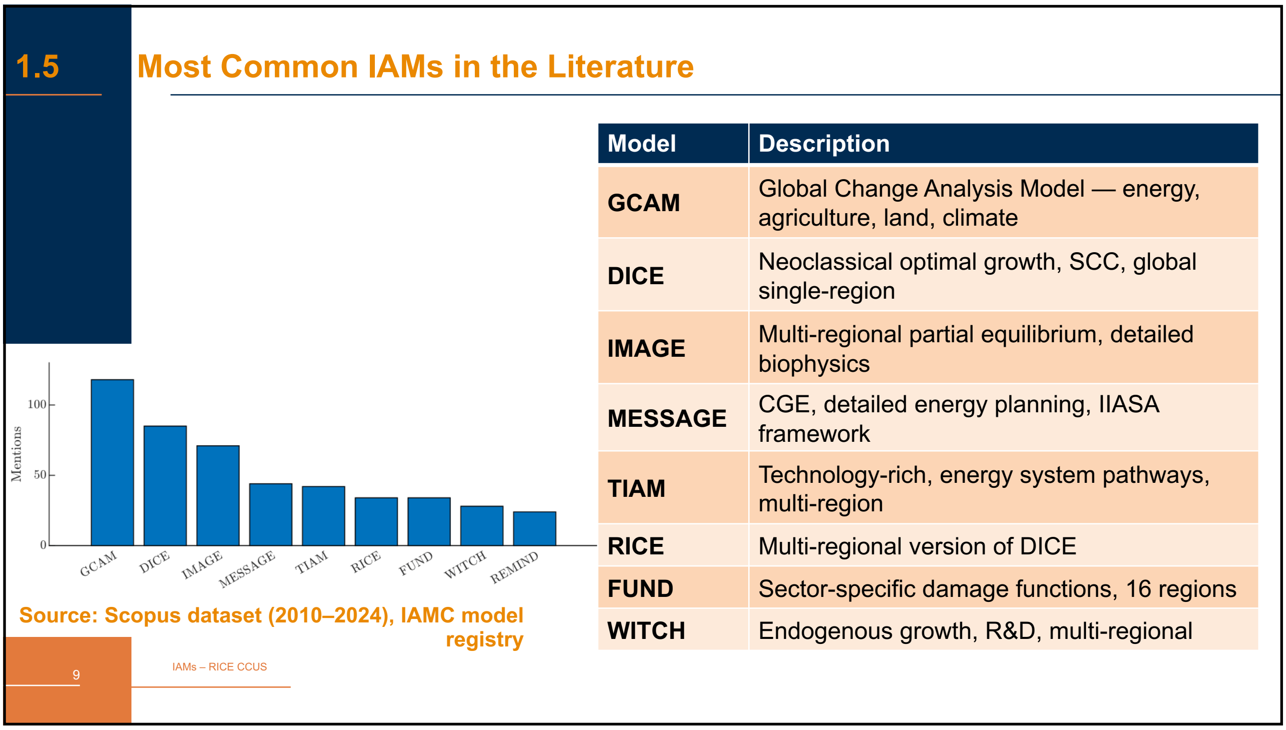
China	European Union	United States
Most mentioned country	Largest variety of policy tools	Second most mentioned single entity

Policy Tools & Technologies Studied

#1 Carbon Tax	#2 Subsidies	#3 ETS	#1 RES	#2 CCUS
Most common policy	Especially popular in EU	Emission Trading	Renewables	Carbon Capture & Storage



1.4 Survey of the Literature: 2010–2024



1.5 Most Common IAMs in the Literature

Source: Scopus dataset (2010–2024), IAMC model registry

Model	Description
GCAM	Global Change Analysis Model — energy, agriculture, land, climate
DICE	Neoclassical optimal growth, SCC, global single-region
IMAGE	Multi-regional partial equilibrium, detailed biophysics
MESSAGE	CGE, detailed energy planning, IIASA framework
TIAM	Technology-rich, energy system pathways, multi-region
RICE	Multi-regional version of DICE
FUND	Sector-specific damage functions, 16 regions
WITCH	Endogenous growth, R&D, multi-regional

1.6 Limitations of Mainstream IAMs

Discounting & Equity:

Discount rates derived from market data give negligible weight to future generations. Intergenerational and international equity are poorly captured by a representative consumer.

Tipping Points:

Catastrophic, nonlinear climate events are largely absent. Including tipping points raises SCC estimates by 25%–100%+ (Cai et al., 2015; Dietz et al., 2021).

Climate Sensitivity & Uncertainty:

Damage functions lack strong empirical grounding. A single discount rate cannot reflect the diverse risk-return structure of real investments.

Heterogeneity & Equilibrium:

Representative-agent assumption ignores distributional impacts. Equilibrium frameworks smooth over multiple equilibria, unemployment persistence, and social conflict.

Missing Financial System:

No banking sector, no endogenous credit cycles. Climate shocks cannot propagate through financial markets. Mitigation is treated as a cost, not as someone's income.

Arbitrary Parameters:

Key choices (social welfare function form, climate sensitivity, damage functions) are subject to modeler discretion and can dramatically shift SCC estimates and policy conclusions.

1.7 Solutions in Mainstream IAMs

Narrowing Scope & Time Horizon

- Growing focus on shorter-run policy evaluations, driven by urgency of near-term climate impacts and demand from national/regional actors following the Paris Agreement (2015)
- Country-specific and sub-national models with higher resolution damage functions and inter-sectoral feedbacks

Increasing Model Detail

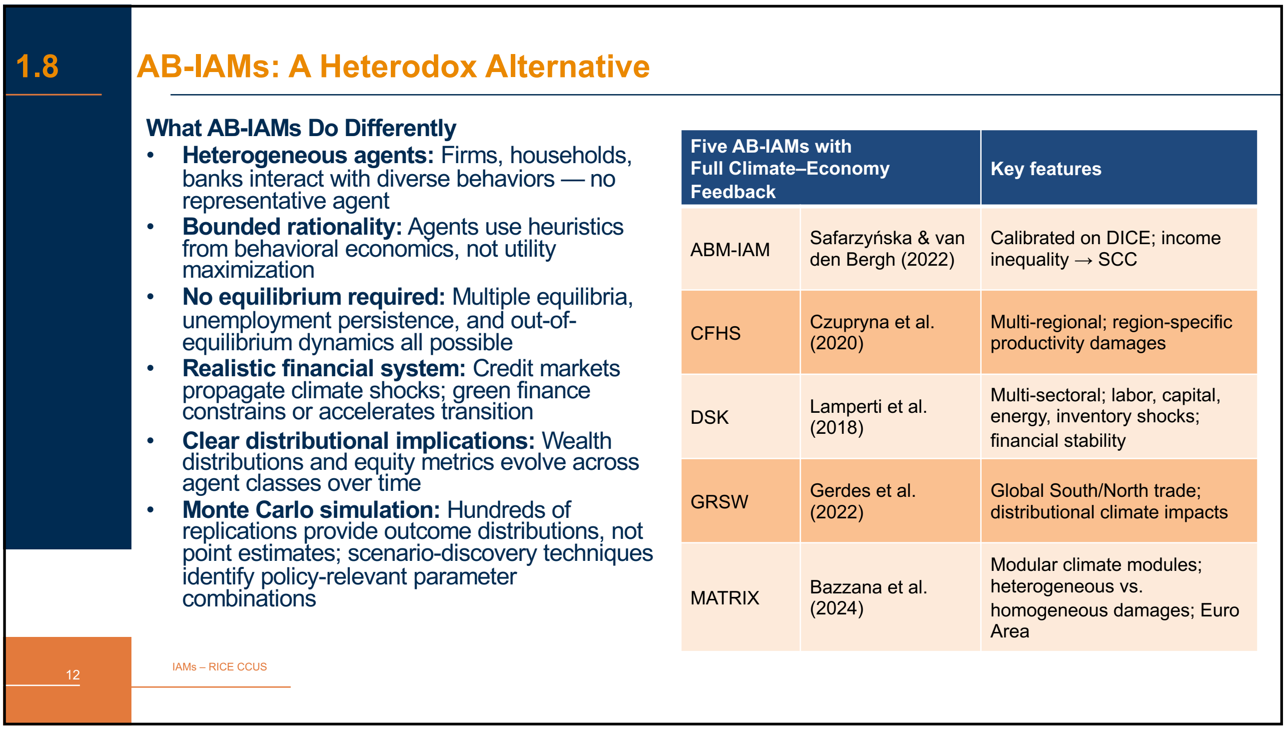
- IAV (Impact, Adaptation, Vulnerability) frameworks: coupled detailed system models allowing feedback between large- and fine-scale earth systems, physical systems, and socioeconomic systems
- WEF nexus perspective: explicit recognition of water–energy–food sector interactions and coordination
- Improved energy system characterization and endogenous technological change in several models (e.g. REMIND, WITCH)

Addressing Uncertainty

- Sensitivity analysis on free parameters as standard practice; numerical results not to be taken at face value (US IWG on SCC, 2010)
- Hindcasting exercises to test model performance against historical data
- Cross-model comparison under identical scenarios to identify sources of uncertainty and bound outcomes

Limits of These Solutions (Gambhir et al., 2019)

- Increased detail brings greater computational and data burdens
- Aggregation across resolutions may still interfere with reliability of physical systems and distributional capture
- Fundamental structural issues — representative agent, equilibrium assumption, missing financial system — remain largely unaddressed



1.8 AB-IAMs: A Heterodox Alternative

What AB-IAMs Do Differently

- **Heterogeneous agents:** Firms, households, banks interact with diverse behaviors — no representative agent
- **Bounded rationality:** Agents use heuristics from behavioral economics, not utility maximization
- **No equilibrium required:** Multiple equilibria, unemployment persistence, and out-of-equilibrium dynamics all possible
- **Realistic financial system:** Credit markets propagate climate shocks; green finance constrains or accelerates transition
- **Clear distributional implications:** Wealth distributions and equity metrics evolve across agent classes over time
- **Monte Carlo simulation:** Hundreds of replications provide outcome distributions, not point estimates; scenario-discovery techniques identify policy-relevant parameter combinations

Five AB-IAMs with Full Climate–Economy Feedback		Key features
ABM-IAM	Safarzyńska & van den Bergh (2022)	Calibrated on DICE; income inequality → SCC
CFHS	Czupryna et al. (2020)	Multi-regional; region-specific productivity damages
DSK	Lamperti et al. (2018)	Multi-sectoral; labor, capital, energy, inventory shocks; financial stability
GRSW	Gerdes et al. (2022)	Global South/North trade; distributional climate impacts
MATRIX	Bazzana et al. (2024)	Modular climate modules; heterogeneous vs. homogeneous damages; Euro Area

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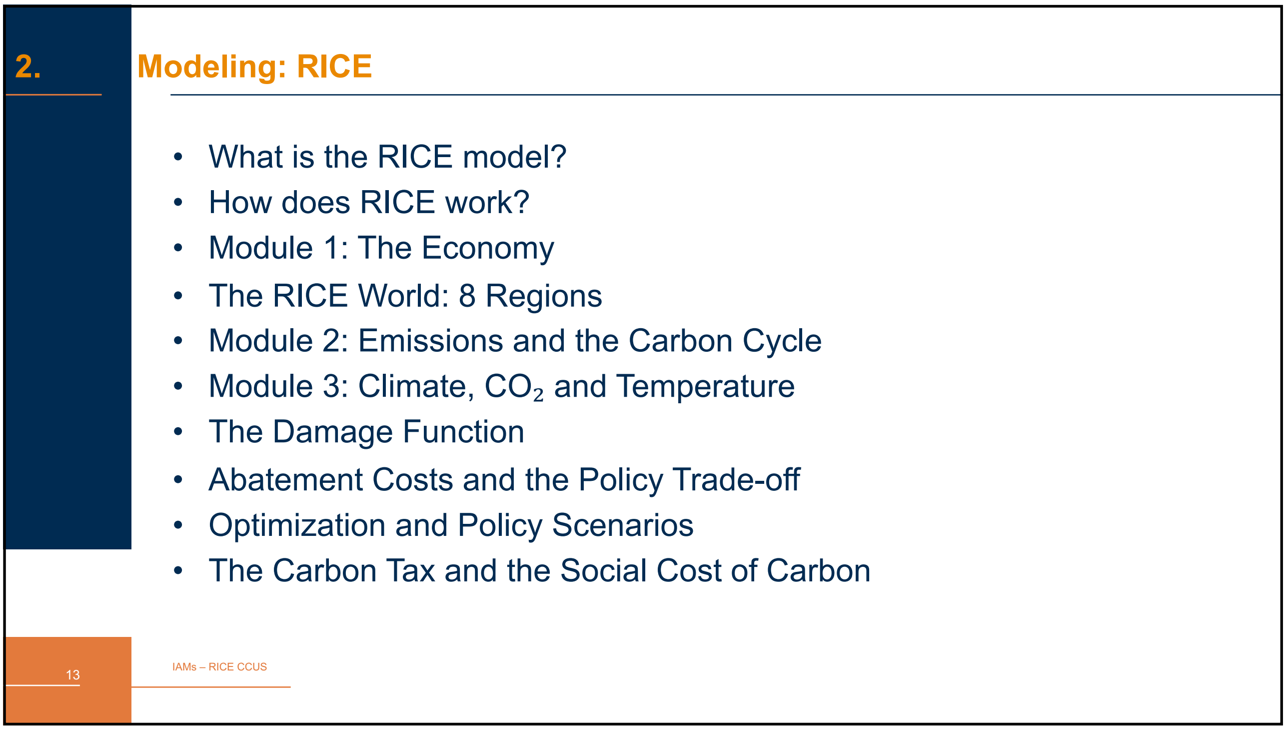

2. Modeling: RICE

- What is the RICE model?
- How does RICE work?
- Module 1: The Economy
- The RICE World: 8 Regions
- Module 2: Emissions and the Carbon Cycle
- Module 3: Climate, CO_2 and Temperature
- The Damage Function
- Abatement Costs and the Policy Trade-off
- Optimization and Policy Scenarios
- The Carbon Tax and the Social Cost of Carbon

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2.1 What is the RICE model?

RICE stands for Regional Integrated model of Climate and the Economy. Developed by William Nordhaus & Joseph Boyer (Yale University, 2000).

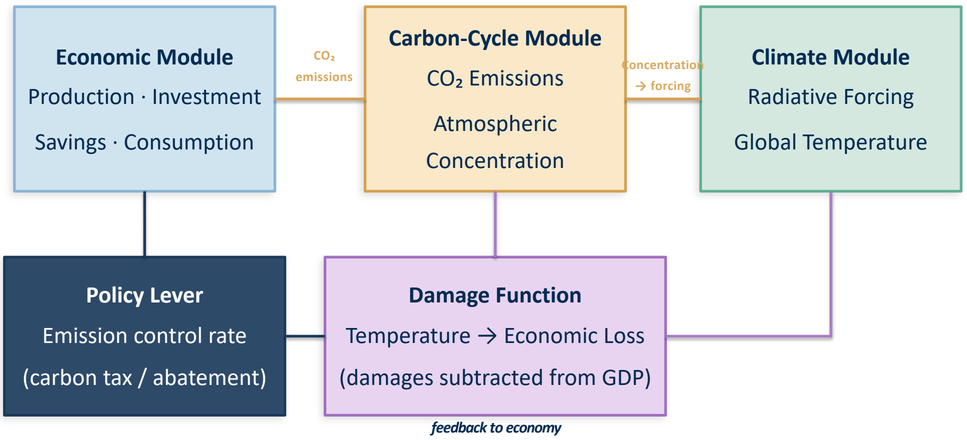
REGIONAL: Splits the world into 8–13 regions (USA, Europe, China, etc.) so each area has its own economy, emissions, and climate impact.

INTEGRATED: Connects the economy with the carbon cycle and the climate, all in one coherent model.

DYNAMIC: Runs forward in time (decade by decade up to 2100+), tracking how variables evolve.

Core question: How should society balance the cost of cutting emissions today against the damages of climate change in the future?

2.1 How does RICE work?



Economic Module
Production · Investment
Savings · Consumption

CO_2 emissions

Carbon-Cycle Module
CO_2 Emissions
Atmospheric Concentration

Concentration → forcing

Climate Module
Radiative Forcing
Global Temperature

Policy Lever
Emission control rate
(carbon tax / abatement)

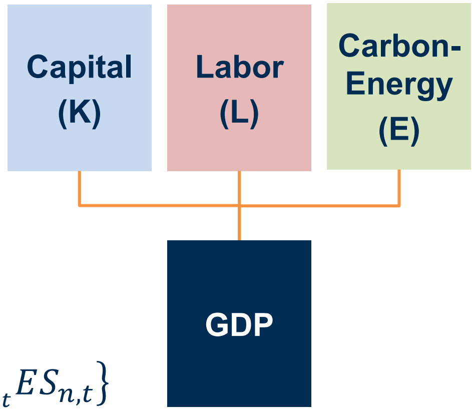
Damage Function
Temperature → Economic Loss
(damages subtracted from GDP)

feedback to economy

2.2 Module 1: The Economy

How does the economy produce output?

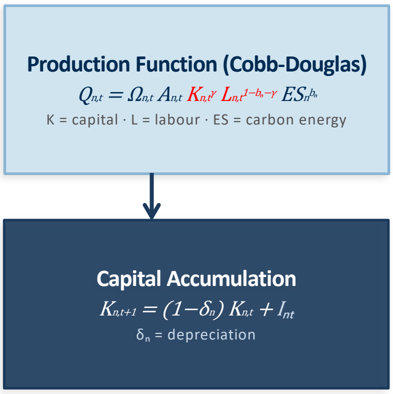
- Each region produces GDP using Capital (K), Labour (L), and Carbon-Energy (E).
- But burning fossil fuels emits CO_2, which causes future climate damages.
- Regions invest part of their income to build new capital (factories, infrastructure).
- Population and technology grow over time → economy grows even without new policy.



$$Q_{n,t} = \Omega_{n,t}\{A_{n,t}K_{n,t}^{\gamma}L_{n,t}^{1-b_n-\gamma}ES_n^{b_n} - c_{E_{n,t}}ES_{n,t}\}$$

with $$ES_{n,t} = \zeta_{n,t}E_{n,t}$$

2.2 Capital Accumulation



Production Function (Cobb-Douglas)

$$Q_{n,t} = \Omega_{n,t}\, A_{n,t}\, K_{n,t}^{\gamma}\, L_{n,t}^{1-b_n-\gamma}\, ES_n^{b_n}$$

K = capital · L = labour · ES = carbon energy

Capital Accumulation

$$K_{n,t+1} = (1-\delta_n)\, K_{n,t} + I_{nt}$$

δ_n = depreciation

What are the elasticities?

γ = capital elasticity of output

- A 1% increase in K raises output by exactly γ%
- Equals capital's share of income — calibrated around $\gamma \approx 0.3$
- Constant and identical across all RICE regions

b_n = carbon-energy elasticity of output

- A 1% increase in carbon energy raises output by b_n%
- Region-specific: reflects each region's energy intensity
- Labour exponent = $1 - b_n - \gamma$ (exponents sum to 1 → Constant Returns to Scale)

$\gamma + (1-b_n-\gamma) + b_n = 1$ → Constant Returns to Scale (CRS)

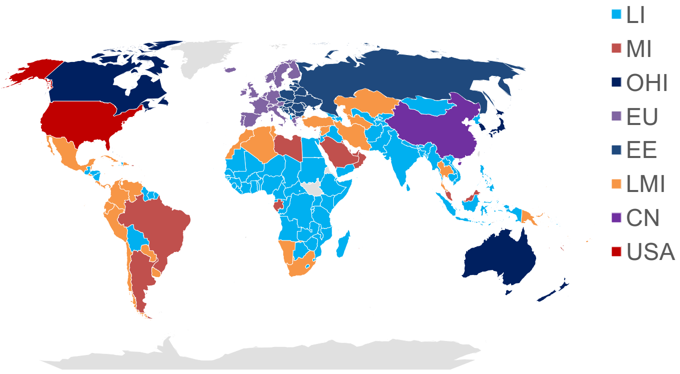
Doubling all inputs exactly doubles output — no scale advantage or disadvantage.

2.3 The RICE World

Regions:

- USA
- China (CN)
- Europe (EU)
- Other High Income (OHI)
- Easter Europe (EE)
- Middle Income (MI)
- Lower-Middle Income (LMI)
- Lower Income (LI)

RICE-99 Regions



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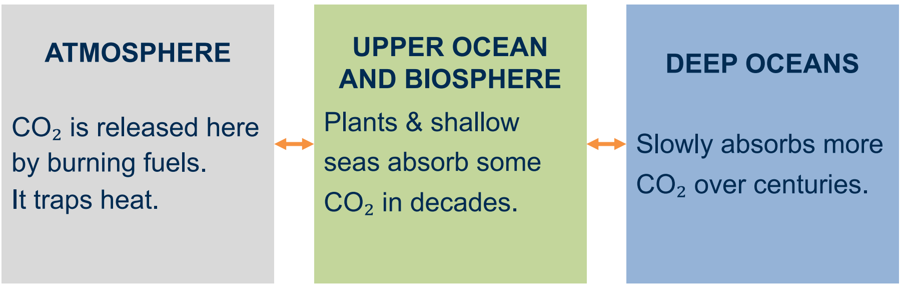
Each region optimizes its own economy, but CO_2 emissions mix globally → one region's pollution affects everyone's climate.

2.4 Module 2: Emissions and the Carbon Cycle

Burning fossil fuels emits CO_2. That CO_2 it moves between three 'boxes':



ATMOSPHERE

CO_2 is released here by burning fuels. It traps heat.

UPPER OCEAN AND BIOSPHERE

Plants & shallow seas absorb some CO_2 in decades.

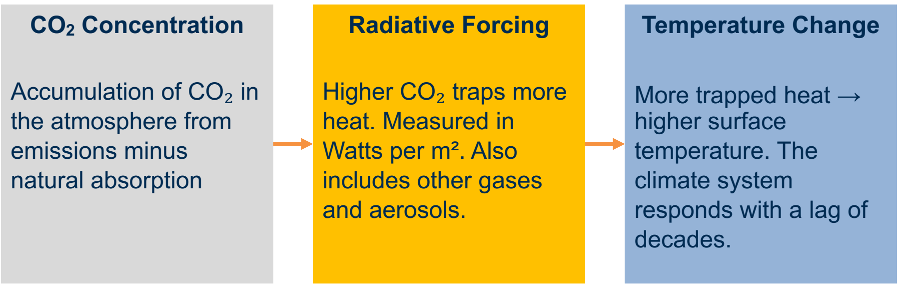
DEEP OCEANS

Slowly absorbs more CO_2 over centuries.

CO_2 is a 'stock pollutant': it accumulates over decades and centuries. Even if we stop all emissions today, the CO_2 already in the atmosphere keeps warming the planet. This is why early action matters, the damage is hard to undo.

2.5

Module 3: Climate, CO_2 and Temperature



CO_2 Concentration

Accumulation of CO_2 in the atmosphere from emissions minus natural absorption

Radiative Forcing

Higher CO_2 traps more heat. Measured in Watts per m². Also includes other gases and aerosols.

Temperature Change

More trapped heat → higher surface temperature. The climate system responds with a lag of decades.

Two climate parameters:

- **Climate Sensitivity**: How much warming from doubling CO_2 concentration. Estimates range from 1.5 to 4.5°C.
- **Climate Lag**: The ocean absorbs heat slowly, so temperature catches up to forcing over time. Past emissions still causing future warming.

2.6

The Damage Function

Temperature → Economic Loss

$$\Omega_{n,t} = 1 - \frac{1}{1 + \alpha_{1_n}\Delta T_t + \alpha_{2_n}\Delta T_t^2}$$

- Once temperature rises, the economy suffers losses. The damage function converts °C of warming into % of GDP lost.
- **Agriculture**: Crop yields fall in hotter, drier regions
- **Coastal flooding**: Sea level rise threatens cities & infrastructure
- **Human health**: Spread of heat-related and tropical diseases
- **Catastrophic risk**: Low-probability, very large ('tail') events
- **Non-market impacts**: Ecosystem loss, biodiversity, cultural value

Damages are non-linear!!! doubling temperature more than doubles the damage. Small differences in warming matter a lot at high temperatures.

2.7

The Cost of Cutting Emissions → Abatement Cost

- Reducing CO_2 emissions is not free. Using less fossil fuel means less energy available for the economy → lower output.
- The emission control rate (μ) represents how much of potential emissions are cut.
- **Trade-off:**

Cut emissions now		**Do nothing now**
• Less CO_2 in atmosphere • Lower future temperature • GDP lost today to abatement costs	**VS**	• No GDP loss today • More CO_2 and higher temperature • Higher future GDP loss

Cost rises quickly as you try to cut more and more emissions. Cutting 10% of emissions is cheap; cutting 90% is very expensive. → Curved, convex cost relationship.

2.8

What does RICE optimize?

- The RICE model finds the policy that maximizes total welfare across all regions and all future generations.
- **Consumption** = each region's GDP net of investment and abatement costs
- **Discount rate**: future welfare counts less than current welfare (VERY CONTROVERSIAL AND CAN DRIVE RESULTS)
- **Sum over time and regions**
- **Goal: choose the emission control rate (in each region, each decade) to maximize total discounted welfare → Optimal policy**

2.9 Policy scenarios

RICE can simulate different policy choices and compare their outcomes:

- **BAU:** no climate policy. Emissions grow freely. Used as Baseline to compare policy results.
- **Optimal:** The best policy found by the model by maximizing global welfare.
- **Kyoto Protocol:** The same but constrained by emission targets for rich countries only.
- **Global Carbon tax:** All regions pay the same tax per ton of CO_2.

2.10 Carbon tax

In the optimal policy, the model computes a **"carbon shadow price"**, equivalent to a tax on CO_2 emissions.

How does it work?

- A price is placed on each tonne of CO_2 emitted (e.g. $20 per tonne).
- Firms and households respond by switching to cleaner energy or using less energy, because fossil fuels become more expensive.
- CO_2 emissions fall. Less CO_2 → slower concentration rise → lower future temperature.
- The optimal tax equals the 'Social Cost of Carbon' (SCC): the monetary value of damage caused by one extra tonne of CO_2.

3. Original contribution: CCUS

1. What is CCUS? Why do we need it?
2. Technologies
   - Capture
   - Utilization
   - Transport
   - Storage

3.1 What is CCUS?

Carbon Capture Utilization and Storage

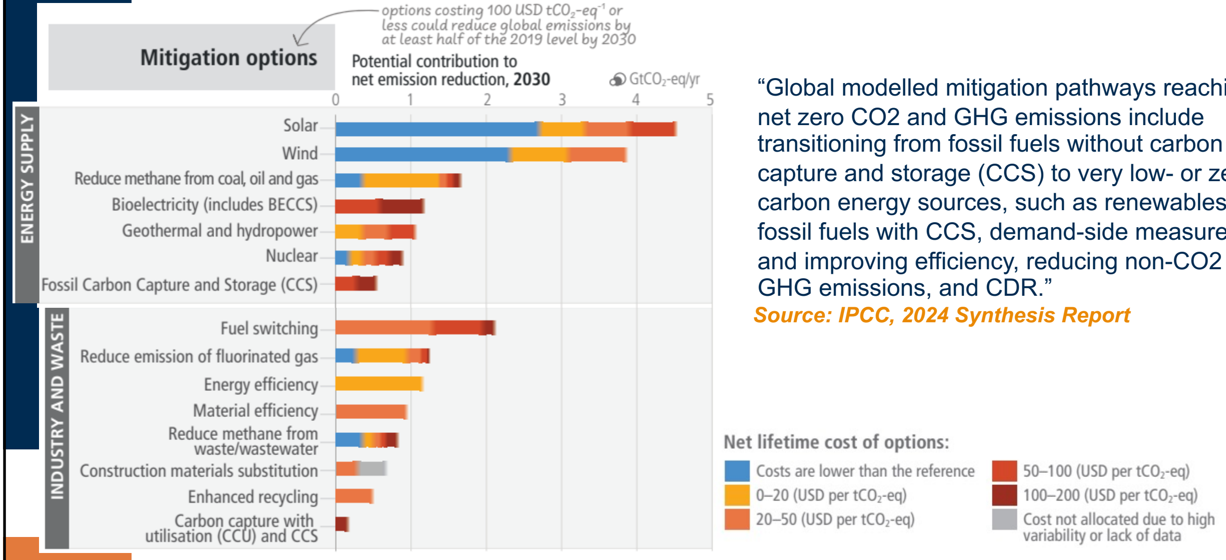
- CCUS involves the capture of CO2, from power generation or industrial facilities using fossil fuels or biomass as fuel.
- If not being used on-site, captured CO2 is compressed and transported by pipeline, ship, rail or truck.
- CO2 can be used in a range of applications, or injected into deep geological formations such as depleted oil and gas reservoirs or saline aquifers.

3.1 What is CCUS?

Carbon Capture Utilization and Storage

- Carbon capture can be retrofitted to existing power and industrial plants.
- It can tackle emissions in *hard-to-abate sectors*, particularly heavy industries like cement, steel or chemicals.
- Capture technologies can remove CO2 from the air (DAC) to balance emissions that are unavoidable or technically difficult to abate.

3.2 Why do we need CCUS?



"Global modelled mitigation pathways reaching net zero CO2 and GHG emissions include transitioning from fossil fuels without carbon capture and storage (CCS) to very low- or zero-carbon energy sources, such as renewables or fossil fuels with CCS, demand-side measures and improving efficiency, reducing non-CO2 GHG emissions, and CDR."

Source: IPCC, 2024 Synthesis Report

3.3

Technologies: Capture

- **Precombustion capture**. Breaking down hydrocarbons in natural gas or coal into hydrogen and CO2. Typically carried out by the reforming of natural gas or gasification of coal or petroleum coke. The resulting CO2 is then compressed and transported for storage.
- **Post-combustion capture**. CO2 is stripped from flue gases and then compressed and transported for storage.
- **Oxy-fuel processes**. Fuel is combusted using almost pure oxygen instead of air. Thus, burning fuel produces water and pure CO2 exhaust gas that can be captured at relatively low cost for transportation and storage.

3.3

Technologies: Capture

- **DACCS.** Large fans to pull in atmospheric air and pass it through a liquid solvent or solid sorbent, which extracts the CO2 from it. The solvent or sorbent is then heated to remove the CO2 for compression, transportation and storage.
- **BECCS.** Bioenergy with Carbon Capture and Storage. Cropland area absorbs CO2 and supplies biomass for bioenergy. Biofuel is converted into energy while applying other CCS technologies → net reduction is atmospheric CO2.

3.4 Technologies: Utilization

- CO2 used for production of fuels and chemicals
  - Electrocatalytic conversion to produce CO, methane, methanol and hydrocarbons
  - Plastics, reducing consumption of petrolchemical products
  - Urea for agriculture
- **Mineralization** (accelerated carbonation) for construction material
- **Beverage and food processing** (decaffeinated tea/coffee, vitamin additives, defatted/fat-free processed foods)
- Biological utilization (carbohydrate conversion in algae)
- **Enhanced Oil Recovery** (EOR) and CO2 fracking

3.5 Technologies: Transport

- Ships
- Pipelines
  - New infrastructure
  - Convert old infrastructure
- Different cost profiles, best option depends on currently available infrastructure and distance to repository

3.6 Technologies: Storage

- Depleted oil and gas reservoirs or saline aquifers (EOR)
- Deep ocean or sea bed (pumped to a suitable depth for storage)
- Crushed rock on the surface (mineralization)
- Injection into reactive rock formations (mineralization)
- Coal-bed methane (fracking)
- Methane hydrates (fracking)

4. An application: FEEM-RICE with CCUS

- What is FEEM-RICE?

RICE 99: $Q_{n,t} = \Omega_{n,t}\{A_{n,t}K_{n,t}^{\gamma}L_{n,t}^{1-b_n-\gamma}ES_n^{b_n} - c_{E_{n,t}}ES_{n,t}\}$

Endogenous technical change

FEEM-RICE: $Q_{n,t} = \Omega_{n,t}\left\{A_{n,t}K_{n,t}^{1-\alpha_n(ETCI)-\gamma}L_{n,t}^{\gamma}ES_{n,t}^{\alpha_n(ETCI)} - c_{E_{n,t}}ES_{n,t}\right\}$

with $\alpha_n = \alpha_n(ETCI_{n,t}) = \dfrac{\beta_{1n}}{2-\exp[\beta_{0n}ETCI_{n,t}]}$

and $ETCI_{n,t} = K_{Rn,t}^{c}ABAT_{n,t}^{1-c}$

4.1 Production function and factors

- Production

$$Q_{n,t} = \underbrace{\boxed{\Omega_{n,t}}}_{\text{Climate damage}} A_{n,t} \left[\underbrace{\boxed{K_{n,t}^{1-\alpha_n(ETCI)-\gamma}}}_{\text{Capital}} \underbrace{\boxed{L_{n,t}^{\gamma}}}_{\text{Labor}} \underbrace{\boxed{ES_{n,t}^{\alpha_n(ETCI)}}}_{\text{Carbon energy}} \right] - \underbrace{\boxed{c_{E_{n,t}} ES_{n,t}}}_{\text{Energy expenses}}$$

- Labor and TFP on an exogenous path accounting for region-specific population growth trends

4.2 Endogenous technical change

Endogenous Technological Change Index

composite index combining two stocks

$$ETCI_{n,t} = \underbrace{\boxed{K_{Rn,t}^{a}}}_{\text{Stock of knowledge}} \underbrace{\boxed{ABAT_{Sn,t}^{b}}}_{\text{Stock of cumulated emission abatement}}$$

$$K_{Rn,t+1} = R\&D_{n,t} + (1-\delta_R)K_{Rn,t}$$
$$ABAT_{Sn,t+1} = \delta_A ABAT_{Fn,t} + (1-\delta_B)ABAT_{Sn,t}$$

- The stock of knowledge grows with current R&D spending each period and depreciates at rate δ_R
- The stock of cumulated emission abatement incorporates current abatement flows weighted by a learning factor δ_A , and depreciate at rate δ_B — it captures *learning-by-doing*: the more a region has abated in the past, the more technologically efficient it becomes today

4.3

CCUS Technical Change

CCUS Technological Change Index

$$CTCI(n,t) = \boxed{CCUS(n,t)^c}\boxed{ABAT_{CCUS}(n,t)^d}$$

Stock of CCUS investment

Stock of cumulated emission abatement with CCUS

$$CCUS_{n,t+1} = CCUS_{f n,t} + (1-\delta_{CCUS})CCUS_{n,t}$$

$$ABAT_{CCUS}(n,t+1) = \delta_{CCUS}ABAT_f(n,t) + (1-\delta_{CCUS})ABAT_{CCUS}(n,t)$$

Carbon emissions

$$E_{n,t} = \varsigma_{n,t}\left(\frac{1}{2 - e^{\psi_n ETCI_{n,t} - \omega_n CTCI_{n,t}}}\right)ES_{n,t}$$

4.4

Capital

Capital accumulation

$$K_{n,t+1} = K_{n,t}(1-\delta) + I_{n,t} - \lambda R\&D_{n,t} - (1-\boxed{U})(1 + CCUS_{cost\ n,t})CCUS_{f\ n,t} - \mu CCUS_{n,t}$$

Utilization

In other words:

New Capital = Depreciated Old Capital + Investments – Resources dedicated to CCUS and R&D

4.5 Modeling CCUS costs

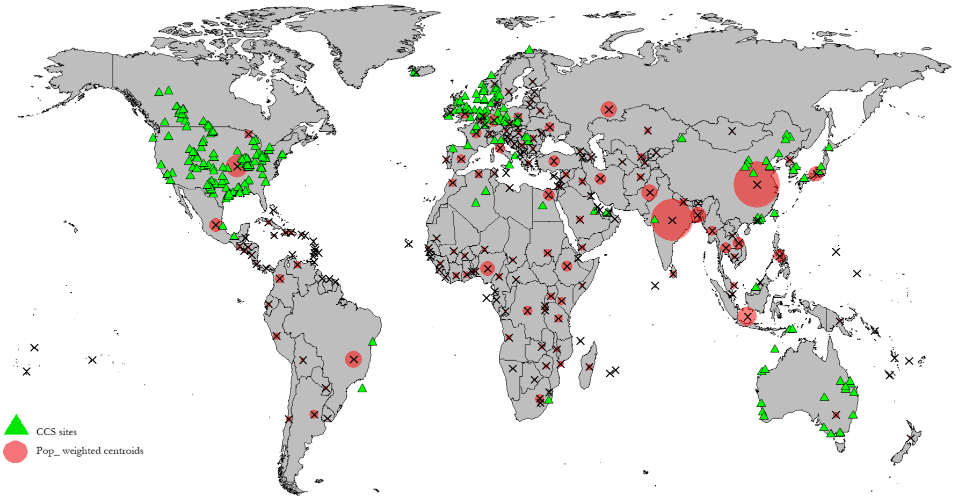
With cost of CCUS

$$CCUS_{cost}(n,t) = \bar{D}(n) + \left(1 - \frac{ABAT_{CCUS}(n,t)}{E(n,t)}\right)$$

How do we estimate the transport cost parameter $\bar{D}(n)$?

- $\bar{D}(n)$ is the normalized regional GDP-weighted average distance between each country’s population centroid and its closest CO2 storage site

4.7 Emission centers and carbon sinks

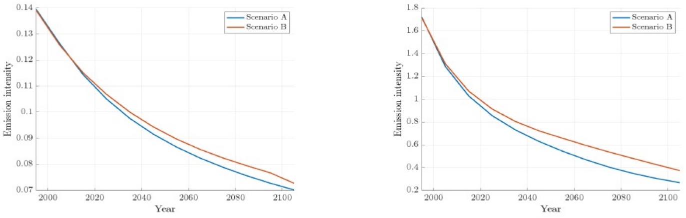


4.8 Calibrating CCUS costs

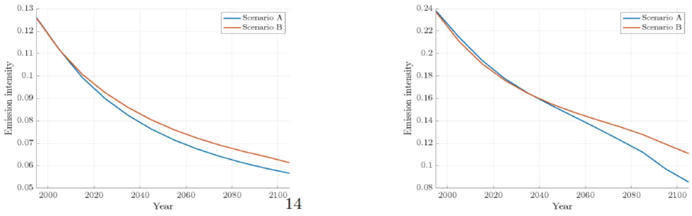
- Identify population centroids with grid data
- Compute distance to all reservoirs (Haversine formula) and identify minimum distance
- For each region compute GDP-weighted minimum distances
- Normalize GDP-weighted minimum distances so that our parameters go from least costly $\overline{D}(n) = 0$ to most expensive $\overline{D}(n) = 1$

Region	Initial CCUS stock	Distance
China	28.308	0.162
Eastern Europe (EE)	1.378	0.854
Europe	71.631	0.0
Lower Income (LI)	0.000	0.689
Lower-Middle Income (LMI)	2.700	1.0
Other High Income (OHI)	76.163	0.12
Middle Income (MI)	17.843	0.606
USA	64.205	0.007

4.9 Results – Emission Intensity

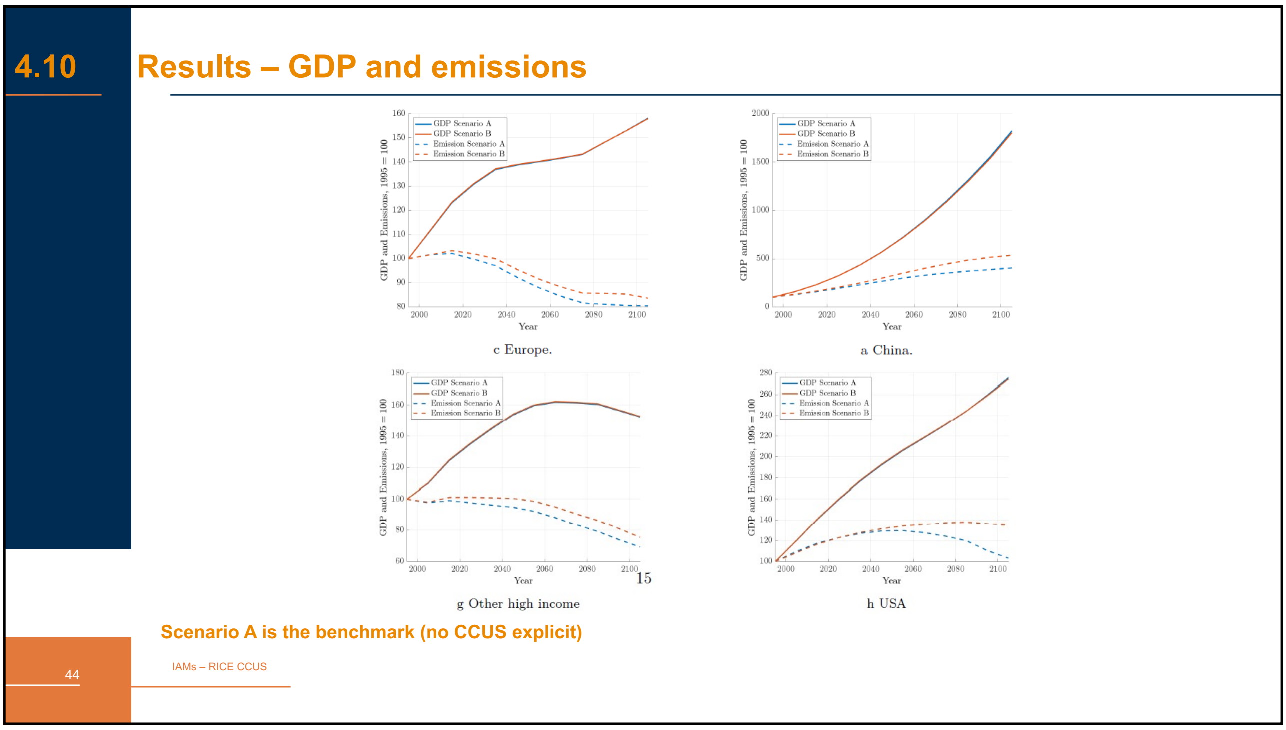


c Europe. a China.



g Other high income h USA

Scenario A is the benchmark (no CCUS explicit)



4.10 Results – GDP and emissions

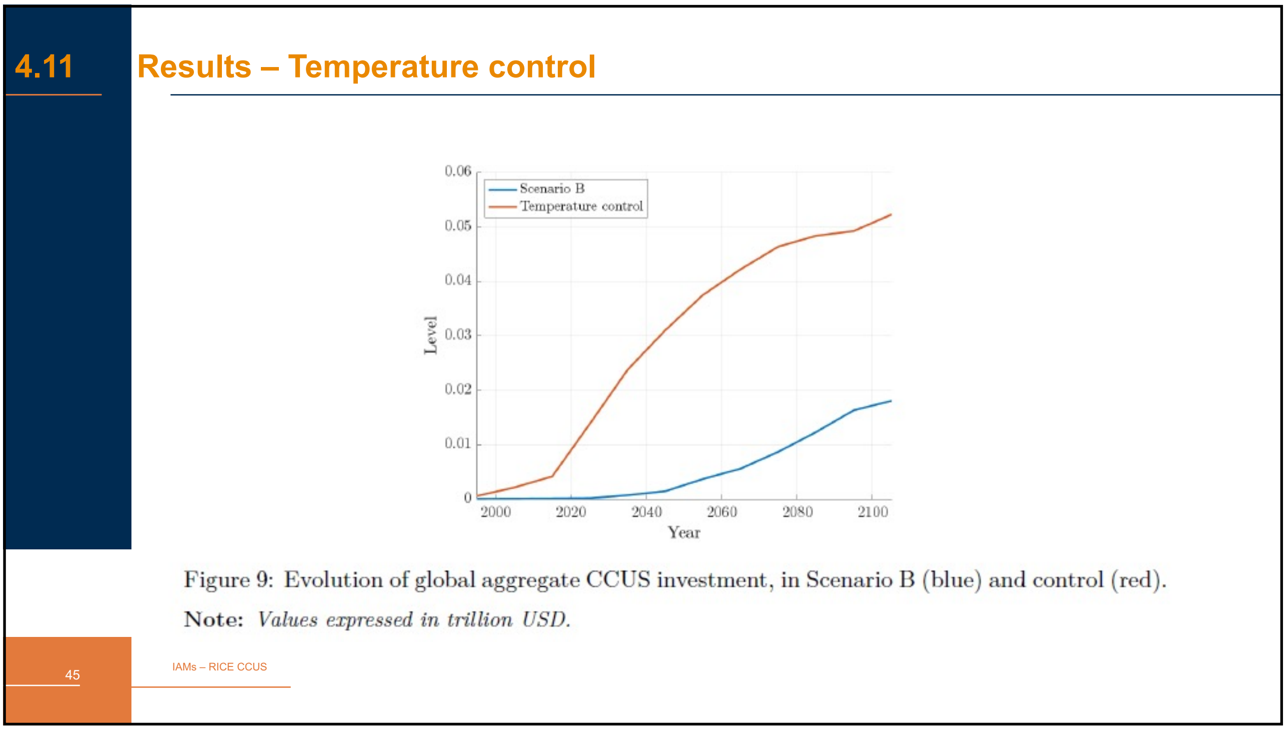
c Europe.

a China.

g Other high income

h USA

Scenario A is the benchmark (no CCUS explicit)

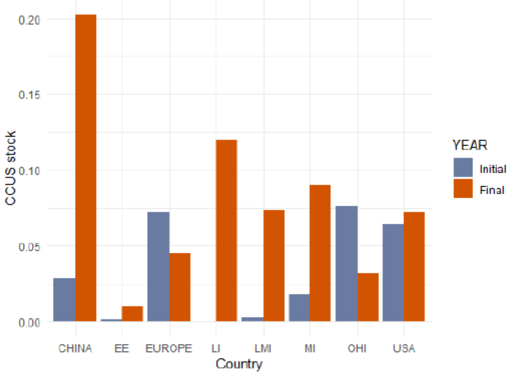


4.11 Results – Temperature control

Figure 9: Evolution of global aggregate CCUS investment, in Scenario B (blue) and control (red).

Note: *Values expressed in trillion USD.*

4.12 Results – CCUS Investments



Region	% Variation
China	−0.61
Eastern Europe (EE)	0.12
Europe	0.08
Lower Income (LI)	−0.53
Lower-Middle Income (LMI)	−0.03
Middle Income (MI)	0.12
Other High Income (OHI)	0.26
USA	0.10

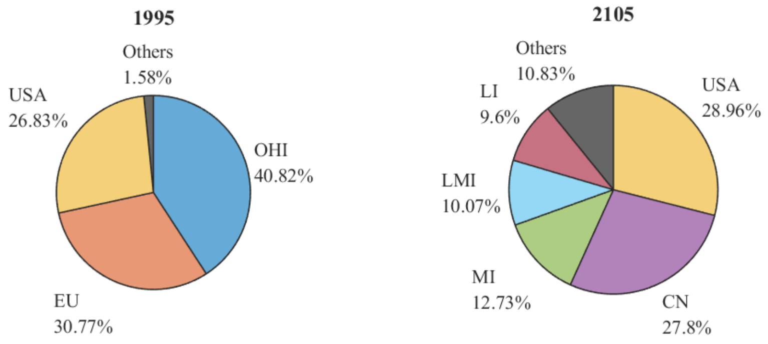
Table 3: Economic impacts by regions.

Figure 4: Level of CCUS investment at the beginning of the simulations and at end of the century.

Note: *Values expressed in trillion USD.*

4.13 Results – CCUS Investments

Initial and final CCUS investments



Thank you!