Integrated Assessment Modelling

Volker Krey

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NTNU course: Integrated Assessment Modelling (EP8900)

A few words about myself

- Diploma in physics (2002)
- PhD in mechanical engineering: energy systems modeling (2006)
- Research Scholar, Energy Program at IIASA (2007-2010)
- Broadened scope of work to integrated assessment modeling (incl. climate science, land use modeling, economics, …)
- Deputy Director – Energy Program at IIASA (2010-2020)
- Research Group Leader – Integrated Assessment & Climate Change Group at IIASA (since 2021)
- Adjunct Professor, Industrial Ecology Programme and Energy Transitions Initiative at NTNU (since 2018)
- Lead Author of IPCC WGIII SRREN (2009-2011), AR5 (2011-2014), AR6 (2019-2022)

Round of self-introduction

- What is your background?
- What do you hope to get out of this course?
- Do you have any previous modeling experience?
- Did you take an Operations Research course, in particular covering optimization?
- How much programming experience do you have?
- Do you have experience with version control systems and related tools (e.g., svn, git, GitHub)?
- Anything else?

Time: 15-20 minutes

An overview of this week

- Mix of lectures, hands-on session and group exercises.
- In general lectures in the mornings, hands-on sessions and group exercises in the afternoons.
- Depending on pre-existing knowledge in group and feedback some flexibility in adjusting material and session formats.

Plan for this week

	Monday	Tuesday	Wednesday	Thursday	Friday
	14/10/2024	15/10/2024	16/10/2024	17/10/2024	18/10/2024
09:00-09:45	Self-introduction of participants, Course introduction	Historical overview of IPCC scenarios, Representative Concentration Pathways	Policy analysis with IAMs: assessing current policies and NDCs	Coupling IAMs to disciplinary models for assessing broader SDG implications	MESSAGEix-GLOBIOM: Using a full-fledged IAM
09:45-10:30	A short history of IAMs, different modeling paradigms and system boundaries	Shared Socio-economic Pathways (SSPs)	An introduction to macro-economic modeling in IAMs	Integrating industrial ecology methods and IAMs	Example: MariTEAM-MESSAGEix linkage (Diogo Kramel)
10:30-10:45	Break	Break	Break	Break	Break
10:45-12:00	A short introduction to linear programming, good modeling practice and collaborative model development	An introduction to energy systems modeling in IAMs	Hands-on session: Simple macro-economic model	An introduction to climate modeling in IAMs	Integrating climate change impacts into process-based IAMs
12:00-13:30	Lunch	Lunch	Lunch	Lunch	Lunch
13:30-15:30	Hands-on session: Introduction to GAMS and developing an	Hands-on session: Expanding the energy systems model	Hands-on session: Linking the energy systems and macro-economic models	Hands-on session: Simple climate model	Hands-on: wrapping up Planning ahead: seminar and assignments

Credits

- This lecture is based on ongoing research and capacity building activities.
- It builds on material from a number people, in particular: Shinichiro Fujimori, Matthew Gidden, Arnulf Grübler, Daniel Huppmann, Paul Kishimoto, Gunnar Luderer, David McCollum, Nebojša Nakićenović, Shonali Pachauri, Simon Parkinson, Peter Rafaj, Keywan Riahi, Chris Smith, Heleen van Soest, Charlie Wilson

GitHub repository and OneDrive

- Create a GitHub user account: https://github.com/
- E-Mail account name to krey@iiasa.ac.at
- Go to ntnu_iam_2024 repository: https://github.com/iiasa/ntnu_iam_2024
- Create a *fork* of the repository under your username

Introduction to IAMs

What is integrated assessment modeling?

"integrated assessment is an attempt to combine information, analysis and insights from the physical and social sciences to address the nature of climate change and to develop possible policy responses to it"

John P. Weyant
Climatic Change 95,
p. 317–323, 2009

Emergence of IAMs

- Formally modelled integrated assessment studies trace their inspiration, if not their precise methods, to the global models of the 1970s (Meadows et al. 1972, Mesarovic and Pestel 1974).
- Formal integrated assessment models emerged in the late 1970s from earlier economic and technical models of energy policy (e.g., Nordhaus 1979, Hafele et al. 1981, Nordhaus and Yohe 1983, Edmonds and Reilly 1985).
- The first integrated assessment model to extend fully from emissions to impacts did not address climate change but the more analytically tractable issue of acid rain (RAINS model developed at IIASA in the early 1980s, Alcamo, Shaw and Hordijk 1990).
- IPCC First Assessment Report (IPCC 1990) relied on Atmospheric Stabilization Framework (Lashof and Tirpak 1989) and IMAGE 1.0 (Rotmans 1990).
- Landmark of the maturation of IAMs of climate change was the first conference to assess activity in the field (Nakicenovic et al. 1994).

Source: IPCC SAR, WGIII, Chapter 10, Box 10.1

Two Kinds of Integrated Assessment Models

- Policy Optimization Models (aka cost-benefit models)
  - ⇒ Focused on finding optimal level of emissions
  - ⇒ Usually include impacts at the aggregate level
- Policy Evaluation Models (aka process-based models)
  - ⇒ Focused on simulating effects of policies
  - ⇒ Usually much more detailed representation of processes and possibly impacts
  - ⇒ Can be run backwards – tolerable windows approach

Courtesy of John Weyant (Stanford)

How do IAMs represent …?

It depends … IAMs come in different flavors

- Cost-Benefit vs. Process-based IAMs

Process-based IAMs

- "Roots":
  Energy systems vs. Macro-economic models
- Solution concept:
  Optimization vs. Simulation
- Equilibrium concept: Partial vs. General
- Solution horizon: Intertemporal vs. Recursive-dynamic
- Model design: Monolithic vs. Modular

"Noble Prize" in Economics 2018

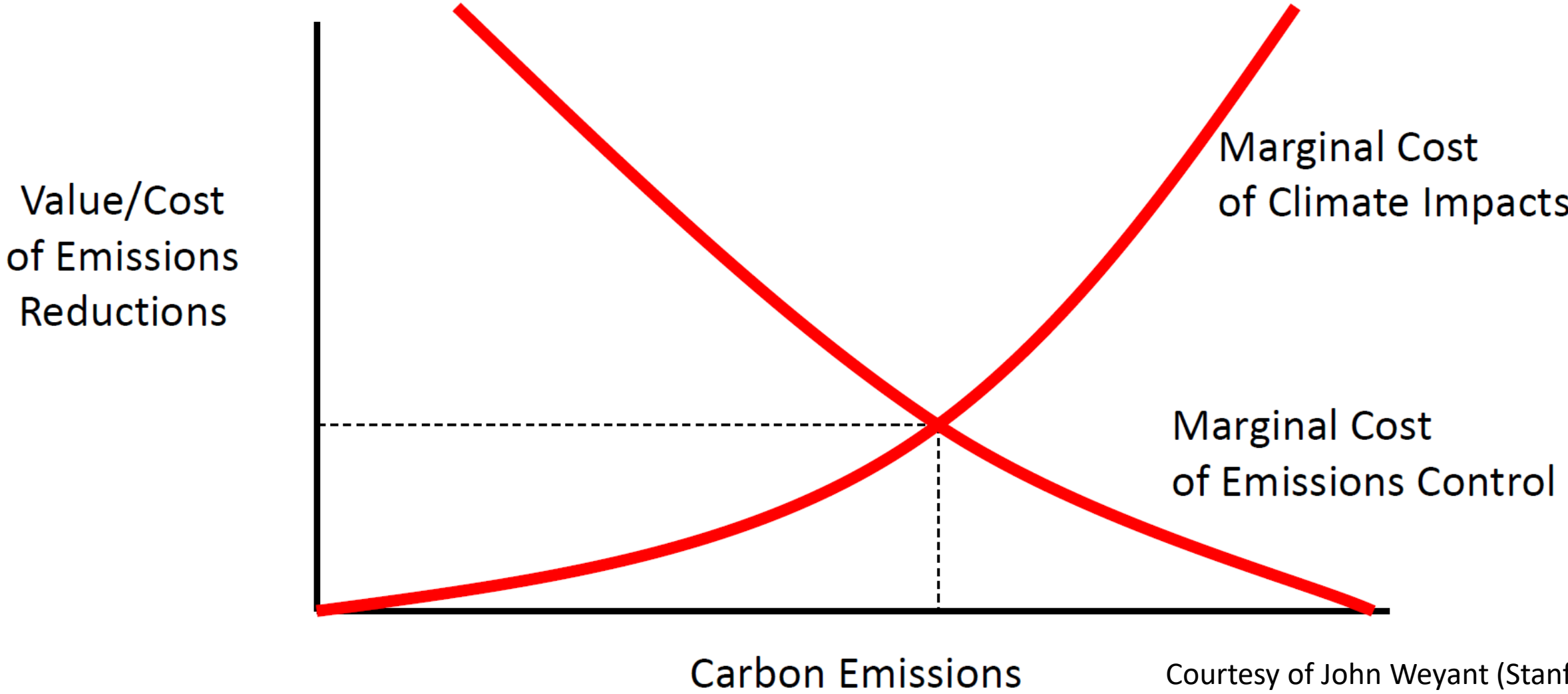
Climate change – Nordhaus' findings deal with interactions between society and nature. Nordhaus decided to work on this topic in the 1970s, as scientists had become increasingly worried about the combustion of fossil fuel resulting in a warmer climate. In the mid-1990s, he became the first person to create an *integrated assessment model*, i.e. a quantitative model that describes the global interplay between the economy and the climate. His model integrates theories and empirical results from physics, chemistry and economics. Nordhaus' model is now widely spread and is used to simulate how the economy and the climate co-evolve. It is used to examine the consequences of climate policy interventions, for example carbon taxes.

William D. Nordhaus

Source: https://www.nobelprize.org/prizes/economic-sciences/2018/press-release/

Cost-Benefit IAMs

Approach: Balancing the Costs of Controlling Carbon Emissions



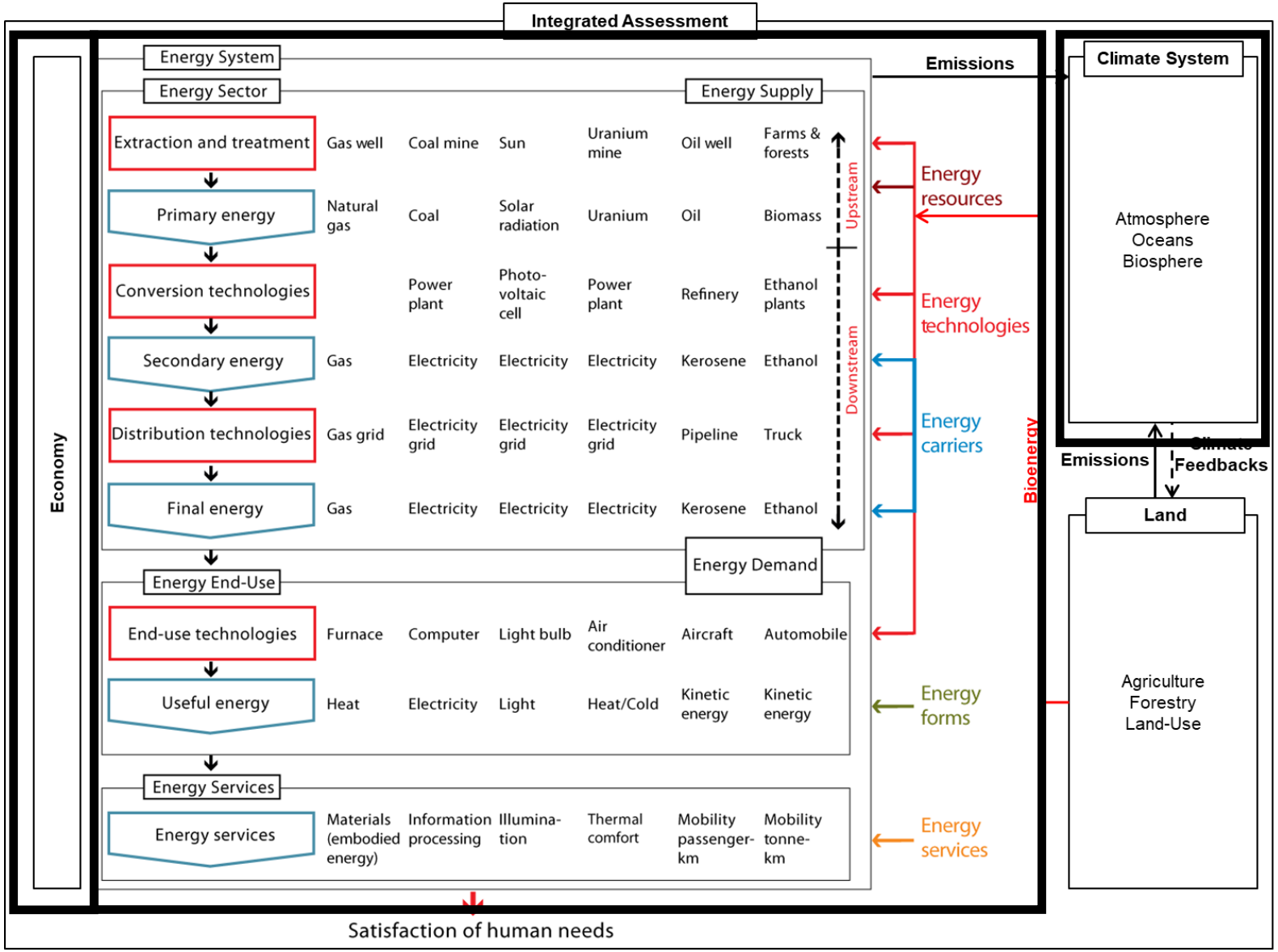
Courtesy of John Weyant (Stanford)

Generic Types of process-based IAMs

- Process engineering (aka activity analysis) models
  - ⇒ Individual technologies represented
  - ⇒ Need to add in market and economy wide effects
- Energy market (aka partial equilibrium) models
  - ⇒ Bring in energy market feedbacks
  - ⇒ Weaker on technology & economy
- "General equilibrium" models
  - ⇒ Bring in economic growth & economy-wide feedbacks
  - ⇒ Optimal growth (e.g., REMIND) and/or CGE (e.g., EPPA) variants
  - ⇒ Typically weaker on energy markets and technology
- Most models are hybrids of above types

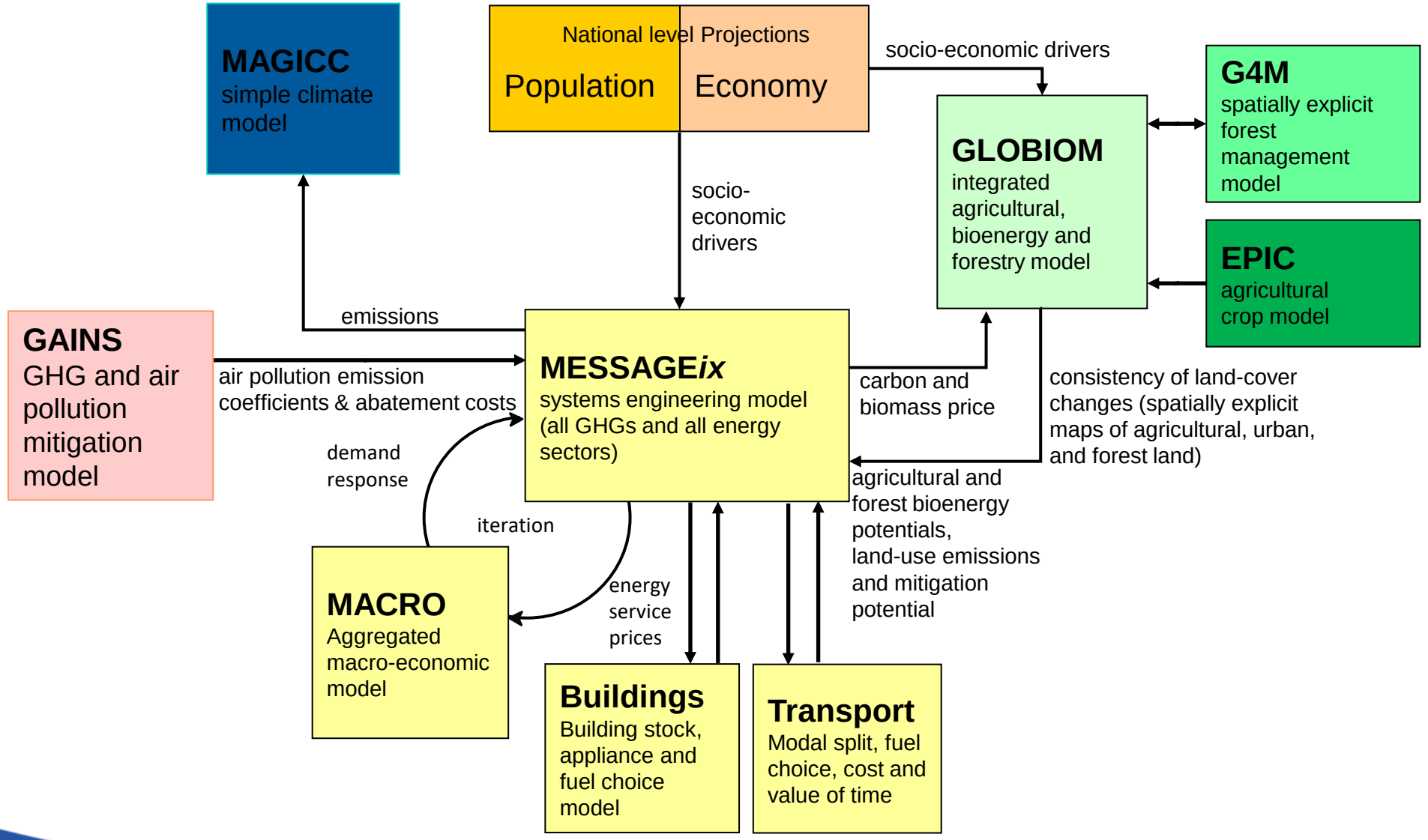
Courtesy of John Weyant (Stanford)

Integrated Assessment Modeling



Source: Krey 2014, adapted from Grubler et al. 2012

Example: IIASA Integrated Assessment Framework



Examples of IAM research questions

- How much do current policies and the NDCs achieve on the way to limit temperature change to 1.5 and 2°C?
- What are investment needs to limit temperature rise to 1.5 and 2°C?
- What are implications of climate policy to achieve the 1.5 and 2°C targets for SDGs?
- How much can behavioral change contribute towards mitigation (e.g., diets, transport)?

Strengths and Limitations

Strengths

- Globally and sectorally comprehensive analysis
- Interlinkages between sectors, regions (incl. trade in some commodities), human and natural systems

Limitations

- Technology focus – integration of behavioral aspects emergent
- Supply side bias – demand side typically less well represented
- Representation of national/sectoral barriers
- Limited spatial and temporal resolution
- Sectoral detail, e.g., IAMs are not power system models

"The purpose of computing is insights, not numbers."

Richard W. Hamming

Numerical Methods for Scientists and Engineers

McGraw-Hill, 1962

"Essentially, all models are wrong, but some are useful."

George E. P. Box
Empirical Model Building
and Response Surfaces
John Wiley & Sons, 1987

Thank you very much for your attention!

Volker Krey
Integrated Assessment & Climate Change (IACC) Group
Energy, Climate & Environment (ECE) Program
International Institute for Applied Systems Analysis (IIASA)
Laxenburg, Austria
krey@iiasa.ac.at
www.iiasa.ac.at