Beyond the aggregated damage functions in integrated assessment models

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“Beyond the aggregated damage functions in IAMs” – why is this an important problem?

- **Climate policy had long been assessed in terms of mitigation efforts by “shadow price of carbon” (in systems-engineering IAM) or cost-benefit analysis by “social cost of carbon” (in climate-welfare economy IAM) [Weyant 2017].**
- **So-called “highly aggregated, simplified damage functions” in the climate-welfare economy IAM had been played key role for CBA, which are recently attacked seriously [e.g., Pindyck 2013] as lacking scientific basis and economic foundations.**
- **The systems-engineering models incorporate damage assessments either by the similar functions or by employing too complex modeling to be traceable (i.e. black-boxiness) [e.g., Fernando and Raul, 2018].**

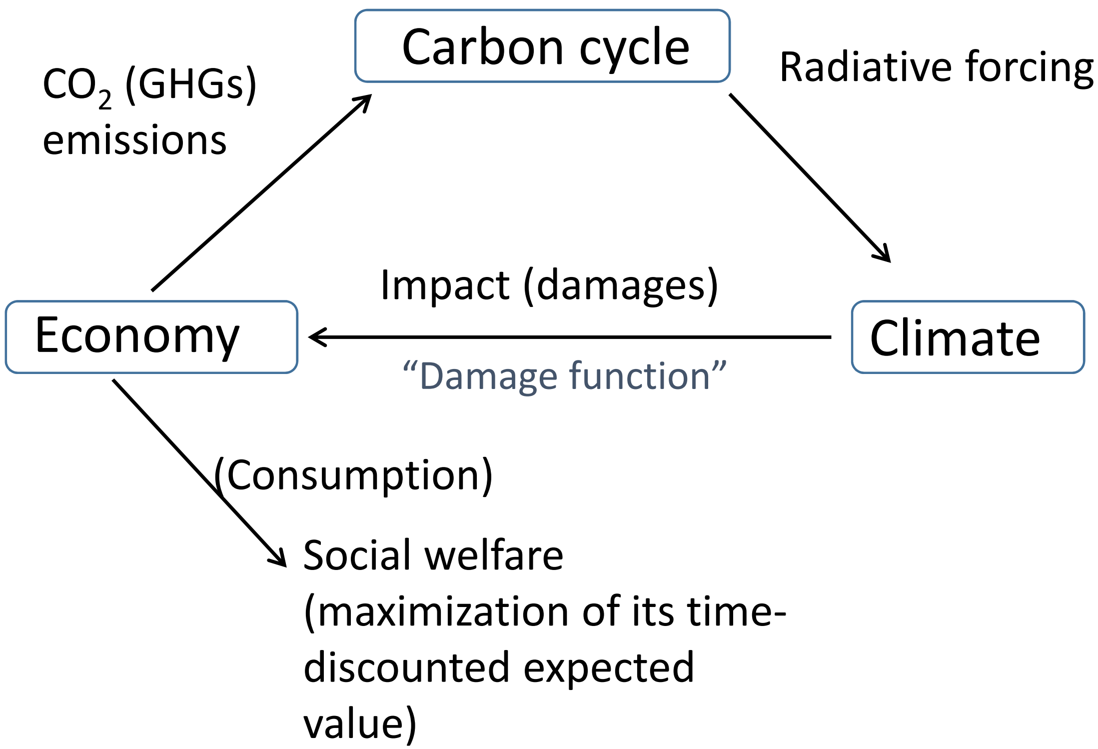
The model structure of "climate-economy welfare Integrated Assessment Models" (IAMs)

Representative economic agent (rationally) chooses the levels of:

- Consumption (savings)
- Emission control (which incurs costs)

* Formulation with "production functions" (GDP functions of capital, labor and technology)

When and how much emissions should be reduced?



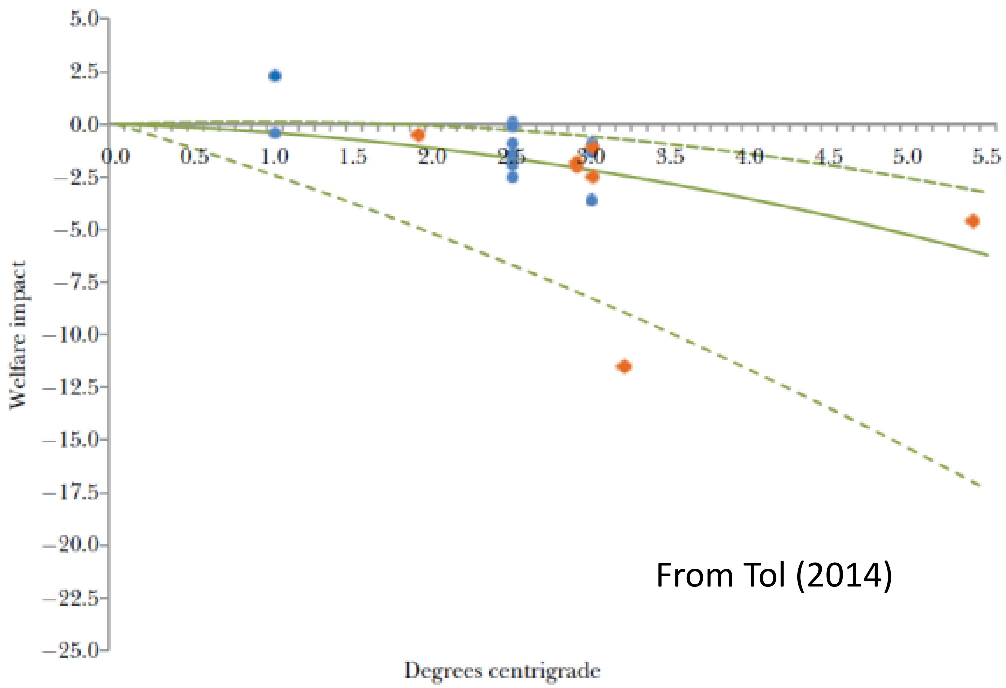
Courtesy; prof. Daiju Narita

Economic damage estimates of climate change (damage function)

Sum of sectoral impacts such as the following

- Agriculture and forestry
- Water resources
- Sea level rise
- Energy use
- Ecosystems
- Human health (tropical diseases, etc.),
- Extreme weathers (tropical cyclones, etc.)

Figure 2
Twenty-One Estimates of the Global Economic Impact of Climate Change



Notes: Figure 2 shows 21 estimates of the global economic impact of climate change, expressed as the welfare-equivalent income gain or loss, as a function of the increase in the annual global mean surface air temperature relative to preindustrial times. The figure includes two overlooked estimates from before the time of the original 2009 paper and five more recent ones. The dots and diamonds represent the estimates (from Table 1); dots were included in Tol (2009); diamonds are additional estimates. The central line is the least squares fit. The dashed lines are the boundaries of the 95 percent confidence interval.

Courtesy; prof. Daiju Narita

Our strategy – interlinking our LCIA model

Summary of the differences with state of the art

$$D(T) = 1/\left[1 + \pi_1(T) + \pi_2(T)^2\right]$$

- **Damage is expressed as percent of GDP loss**
- **modeler's choice of WTP and income elasticities**
- **Modeler's choice of highly aggregated algebraic form of functions and their parameter settings**

- **Damage is expressed as external environmental cost (EXT), deducted from gross output**
- **MWTP and income elasticities are delivered from conjoint analysis.**
- **Dose-Response functions are based on detailed sectorial models.**

$$EXT_{j,t} = \sum_{e} MWTP_{e,j,t} \cdot \sum_{i} DR_{e,i,j,t} \cdot Inv_{i,j,t}$$

Our strategy – interlinking our LCIA model

$$D(T) = 1/\left[1 + \pi_1(T) + \pi_2(T)^2\right] \qquad Y = D(T)\cdot F(K, L)$$

$$Y = F(K, H, EL, NE, M, LR) - TC - EXT$$

$$EXT_{j,t} = \sum_e MWTP_{e,j,t} \cdot \sum_i DR_{e,i,j,t} \cdot Inv_{i,j,t}$$

Environmental external cost | **marginal willingness to pay** | **Dose-Response relations** | **Inventory release**

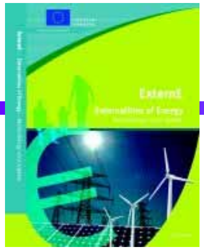
e： end points (human health, resources, biodiversity, photosynthetic NPP)
i：global warming, ozone layer depletion, acid rain, local air pollution, mining and disposal of mineral resources, land use and its change

- **face to face, internet**
- **G20+10 Asian**
- **over 7,400ss, 100 (min) to 600 (max)**

Y: GDP
N: population number
σ: income elasticity

$$MWTP_{e,j,t} = MWTP_{e,j_0,t_0} \cdot \left(\frac{Y_{j,t} / N_{j,t}}{Y_{j_0,t_0} / N_{j_0,t_0}} \right)^{\sigma_e}$$ **Unit value transfer**

$$MWTP_{e,j,t} = \sum_k a_{k,e} x_{k,j,t} + dummy_e$$ **Value function transfer**



Our strategy – interlinking an LCIA model

Extern-E study (2005) - interdisciplinary works from sources to monetary value of impacts

SOURCE
(specification of site and technology)

→ emissions
(e.g., kg/yr of particulates)

DISPERSION
(e.g., atmospheric dispersion model)

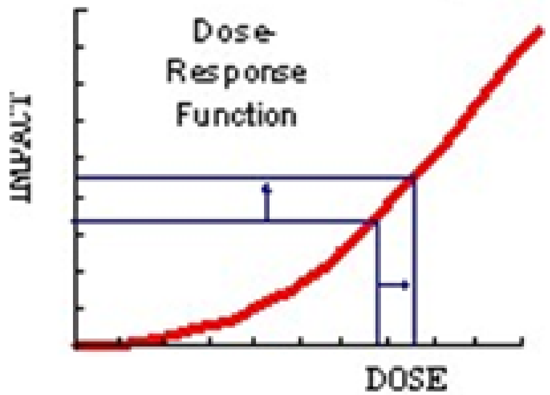
→ Increase in concentration at receptor sites (e.g., micro gram/m3 of particulates in all affected regions)

DOSE-RESPONSE FUNCTION
(or cause-effect chain)

→ impact
(e.g., cases of asthma due to ambient concentration of particulates)

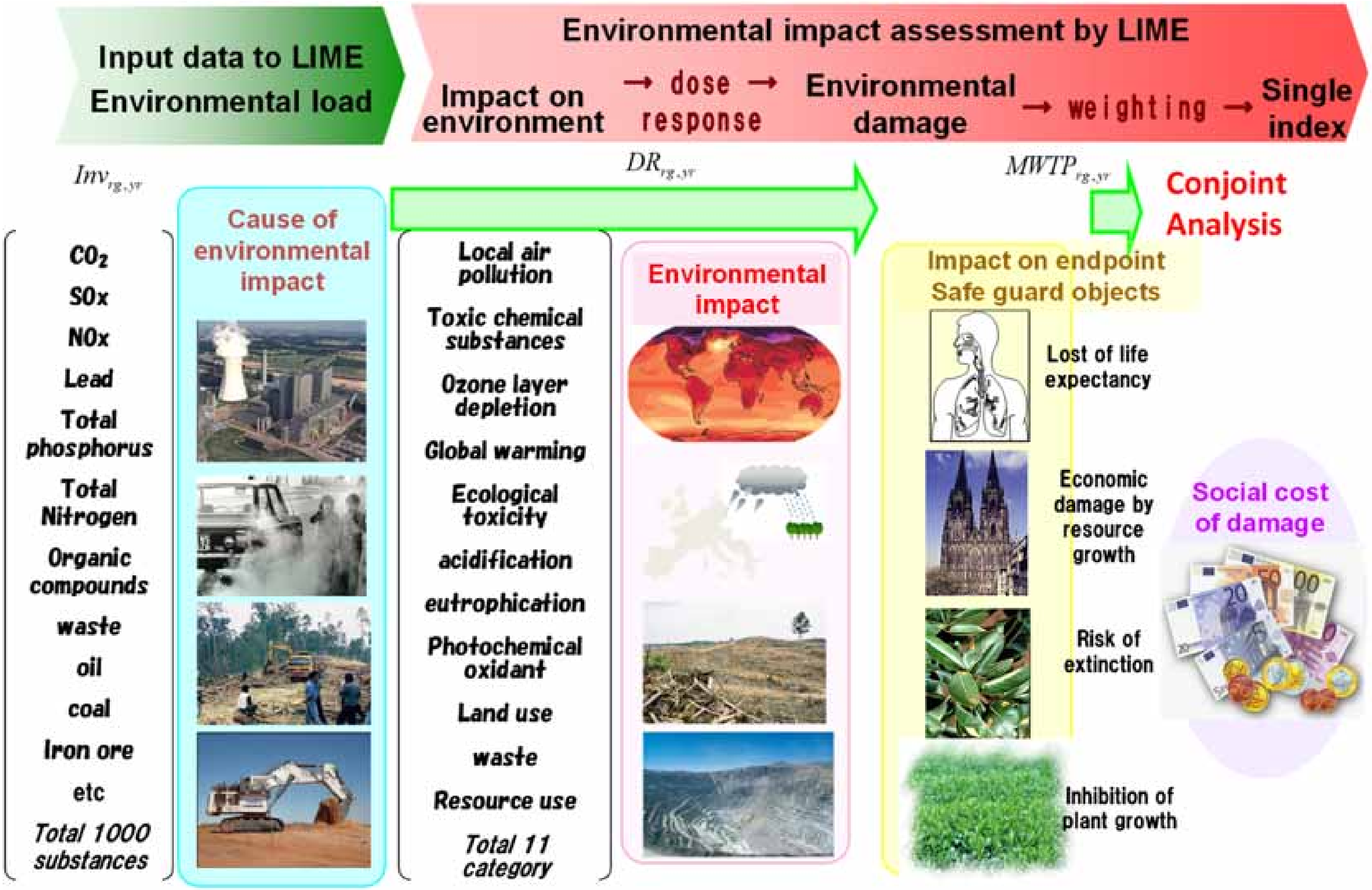
MONETARY VALUATION

→ cost
(e.g., cost of asthma)

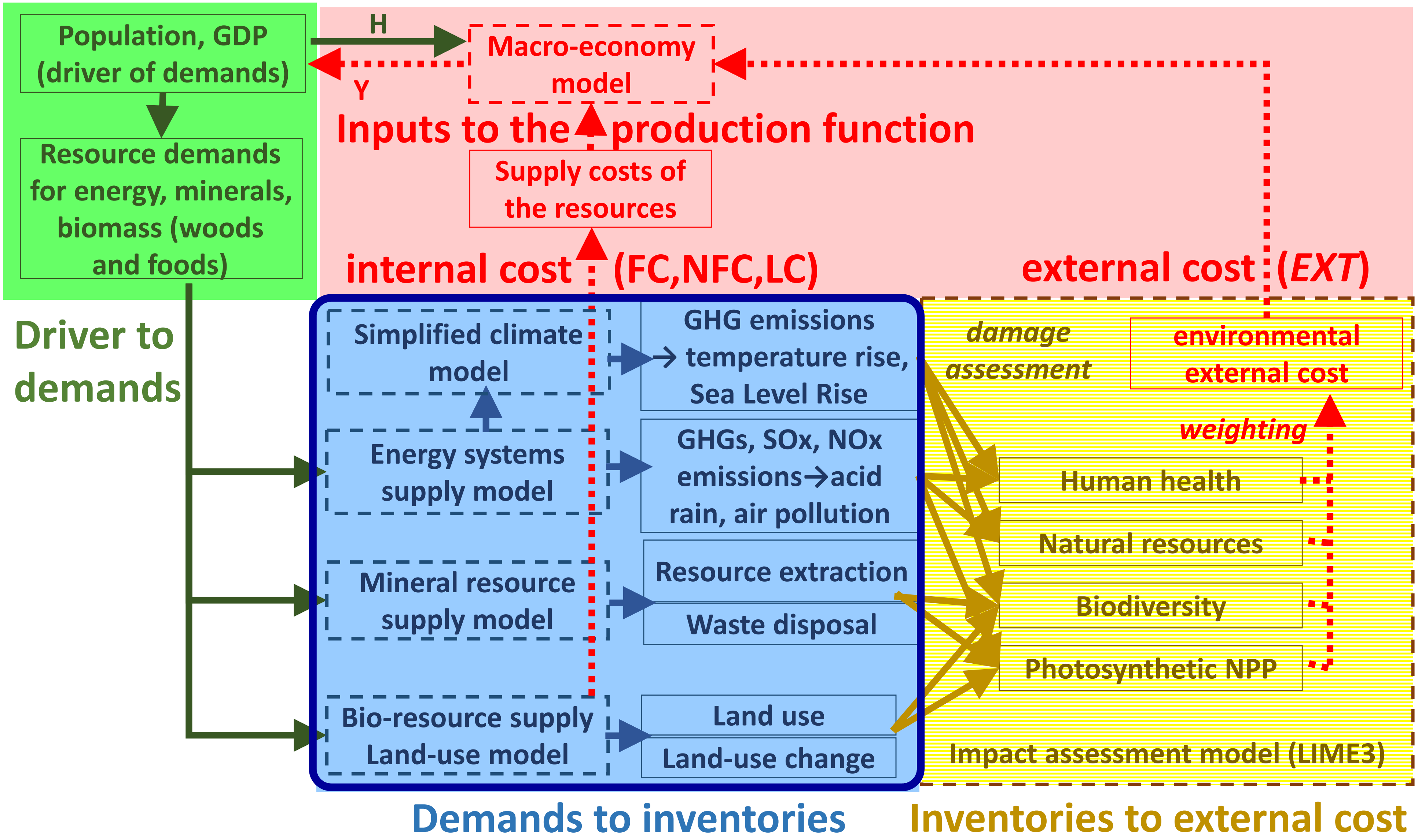


Our strategy – interlinking our LCIA model (LIME3)

The Japanese model; sources, dose-response, 4 endpoints, and conjoint analysis



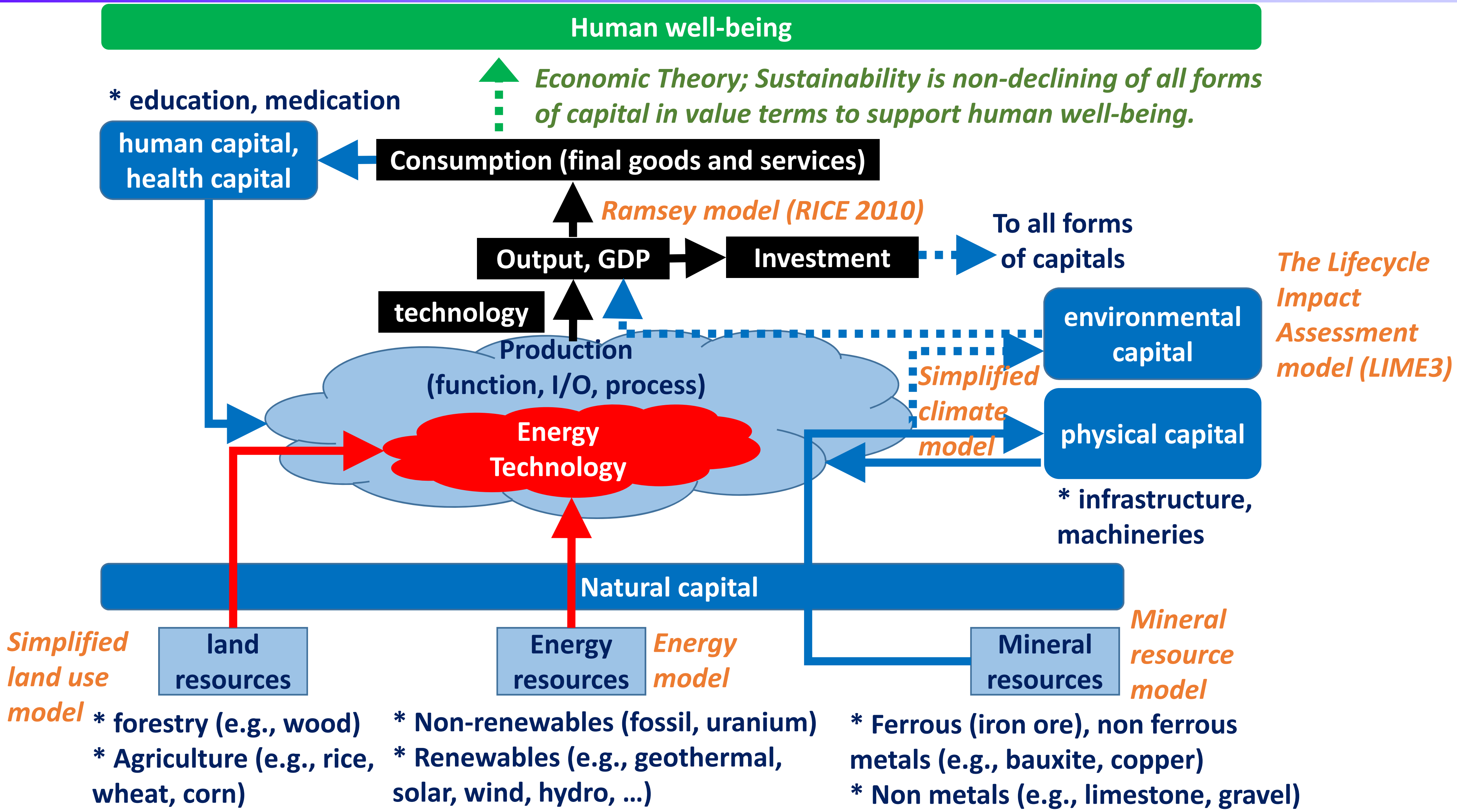
Integrating systems-engineering into climate-welfare econ



Linking the three resource models (inventories generated) to the impact assessment model (LIME3)

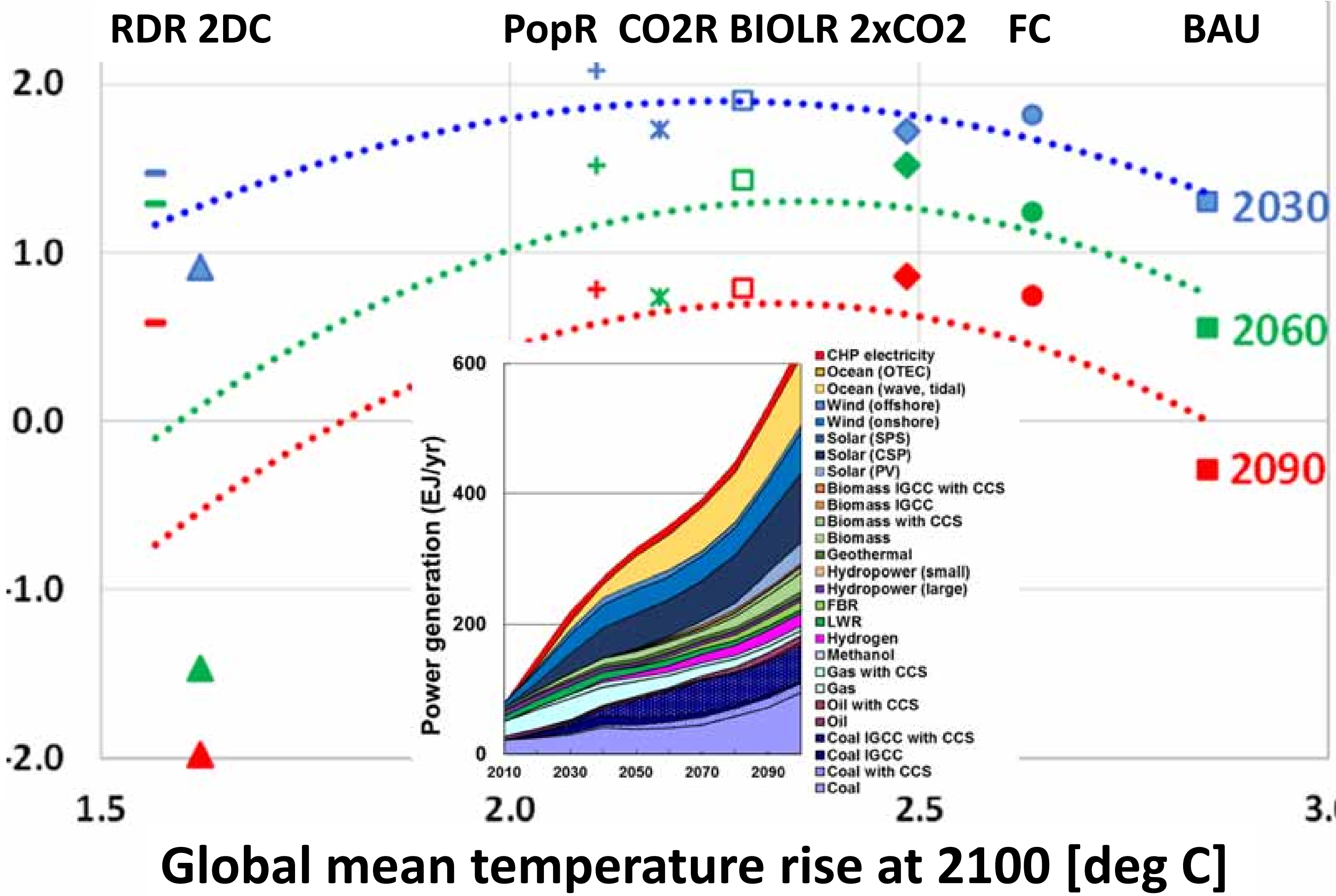
input data from other models to the impact assessment model	Model name	Contents of the impact assessment model		
		Impact category	endpoints	
global mean temperature rise (endogenous)	Simplified climate model	Global warming	Human health	Heart disease, diarrhea, malnutrition, flood, malaria
			Natural resources	Crop yield (rice, corn, wheat)
				Sea level rise (flooded surface)
				Energy consumption (cooling and warming)
			biodiversity	
Ozone Depletion Substances (14 kinds) (exogenous)	Simplified climate model	Ozone layer depletion	Human health, natural resources, net *photosynthetic* primary productivity (NPP)	
SO_X, NOx (endogenous)	Energy model	Acid rain	natural resources	
		Local air pollution	Human health, natural resources, NPP	
Land use (endogenous)	Simplified land use model	Land use	NPP	
Land-use change (endogenous)	Simplified land use model	Land use change	NPP, biodiversity	
Copper, lead, zinc, bauxite, iron ore, limestone, coal (endogenous)	Mineral resource model	Resource extraction	NPP, biodiversity	
Mineral resource waste, scrap of concrete (endogenous)	Mineral resource model	waste	NPP, biodiversity	

Interlinking all forms of capitals and transformations in our IAM



Temperature target is evaluated in terms of an “aggregated” SD indicator

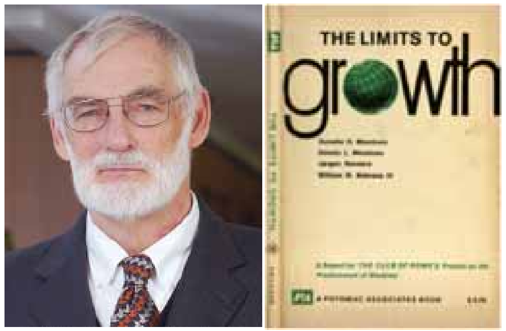
An “aggregated” indicator for “sustainable development (SD)” – Genuine Savings (GS) with adjustment of growth rate in technology and population (GSnt) [%/yr]



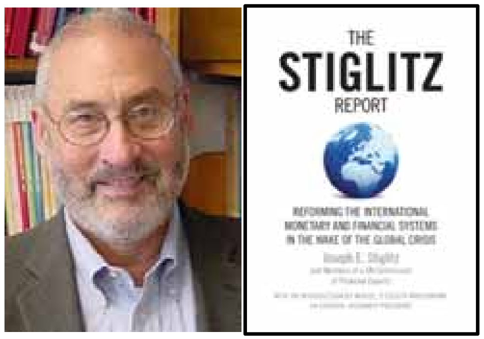
Tokimatsu et al., “Using Genuine Savings for climate policy evaluation with an integrated assessment model”, *Environmental and Resource Economics,* 72(1)281-307 https://link.springer.com/article/10.1007%2Fs10640-018-0292-2

Contributions of our IAM approach

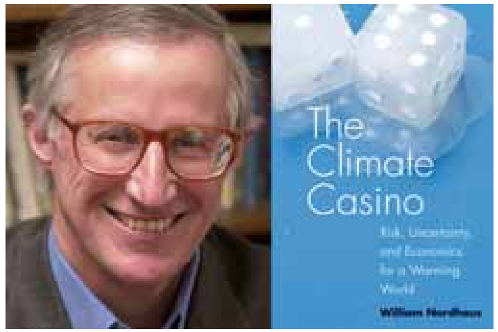
1. **Modeling and using sustainability indicator backed by Econ theory (vs systems dynamics)**
2. **Model development; inclusive integration of env. and res. econ. and ener. tech. (vs extrapolation)**
3. **Sustainability-based climate policy assessment (vs cost-benefit of climate change mitigation)**



1. Meadows (2009 Japan prize winner)



2. Stiglitz (2001 Novel Econ prize winner)



3. Nordhaus (2018 Novel Econ prize winner)

“Beyond the aggregated damage functions in IAMs” – why are we better?

1. **It is founded on more scientific basis and less depending on expert judges.**
   - *Dose-Response Function, large MWTP survey, conjoint analysis*

2. **Wider coverage and inclusiveness of natural resources and their environmental consequences in consistent manners.**
   - *10 energy and mineral resources and 8 environmental impact categories*

3. **Simple and compact – compared with “huge” scale IAMs**
   - *(pros) LCIA models provides (aggregated) “factors”* for LCA practitioners
   - *(cons) sacrificing higher resolution of time and space (limitations)*

4. **Modeling inclusive nature of natural resources and environment enables us to compute various indicators related to sustainable development (SD).**
   - *econon (e.g.; GS, Carrying Capacity, HANPP) and non-econ(e.g.; eco-efficiency)*