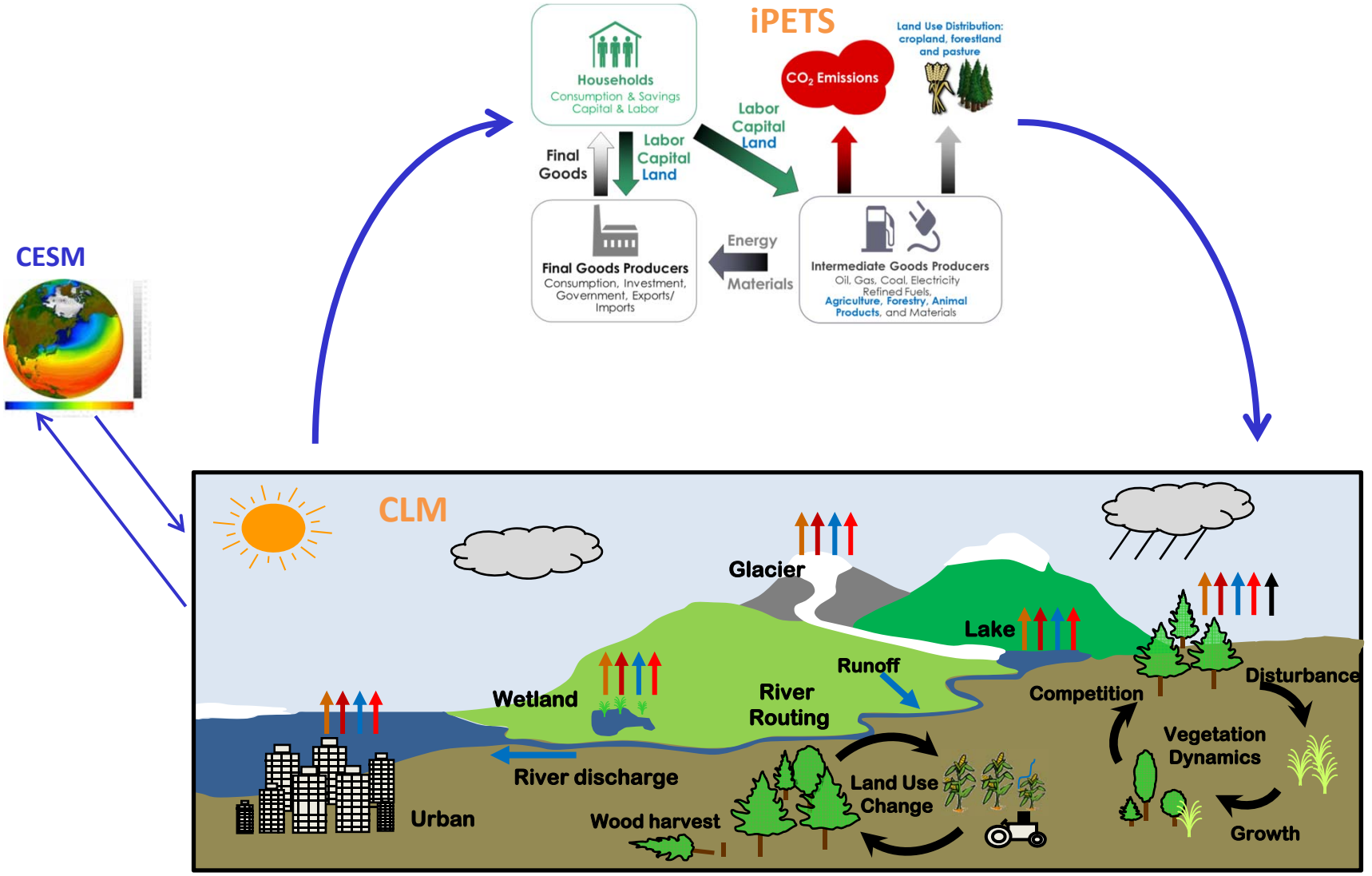
Linking CLM and iPETS to estimate climate impacts on building energy use

Bas van Ruijven, Keith Oleson

NCAR – CGD – IAM

CLM as Physical Impacts Model: Part of the integrated assessment framework!



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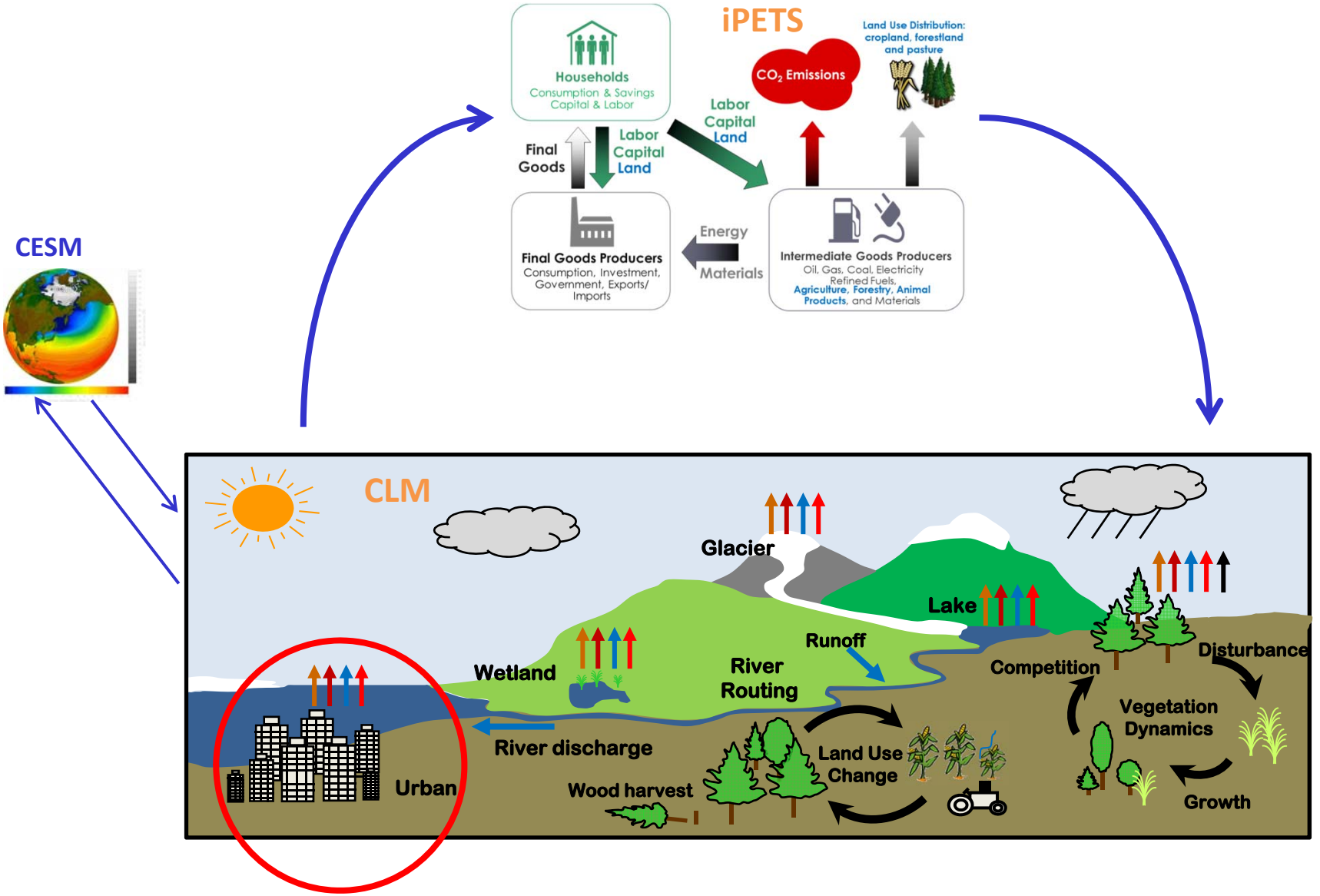
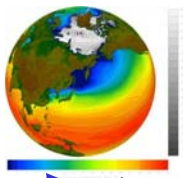
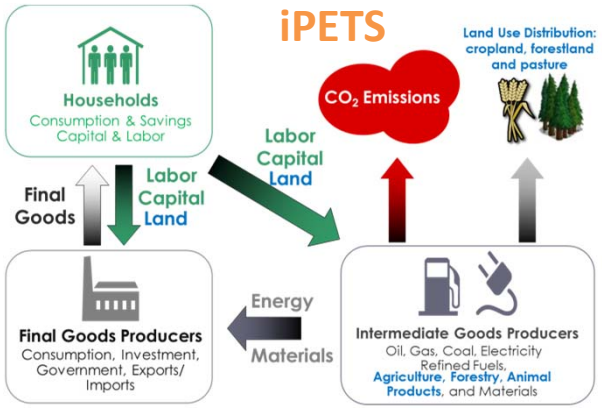


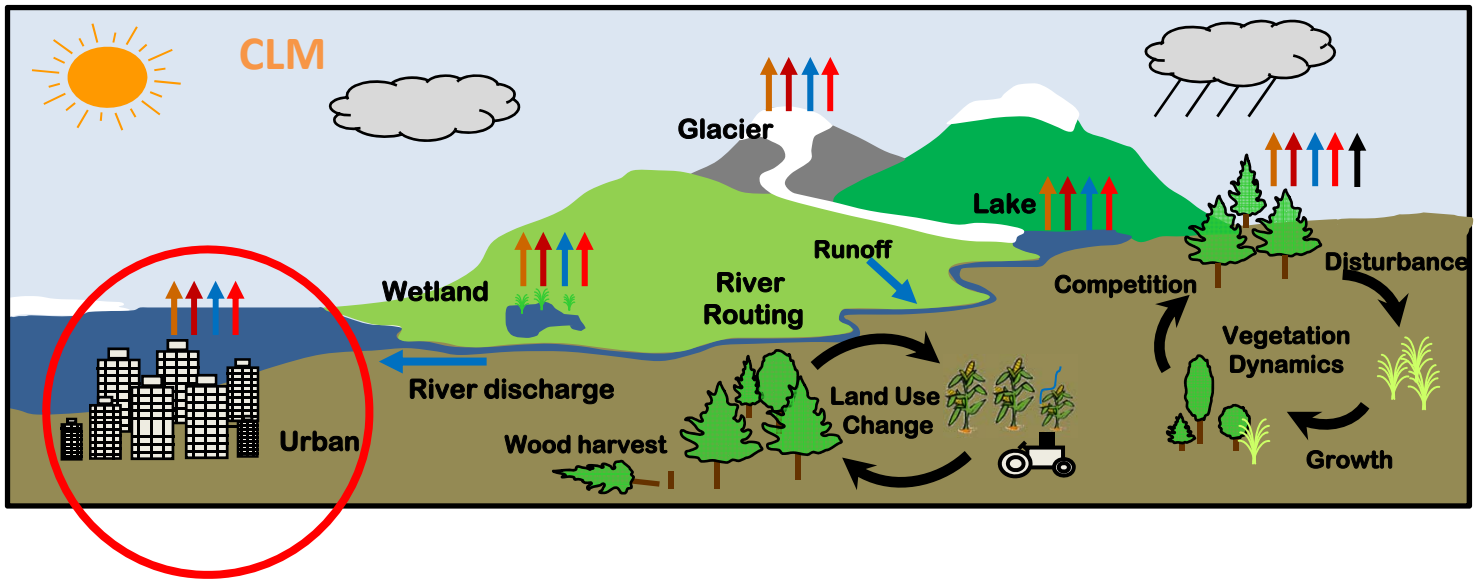
CLM as Physical Impacts Model: Part of the integrated assessment framework!

Crop/forest yield
Building energy use
Urban heat waves
LU emissions
Water availability
Renewables potentials

CESM







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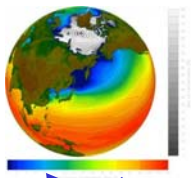
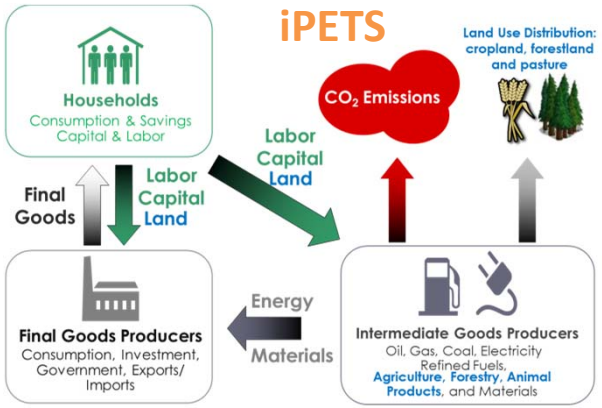
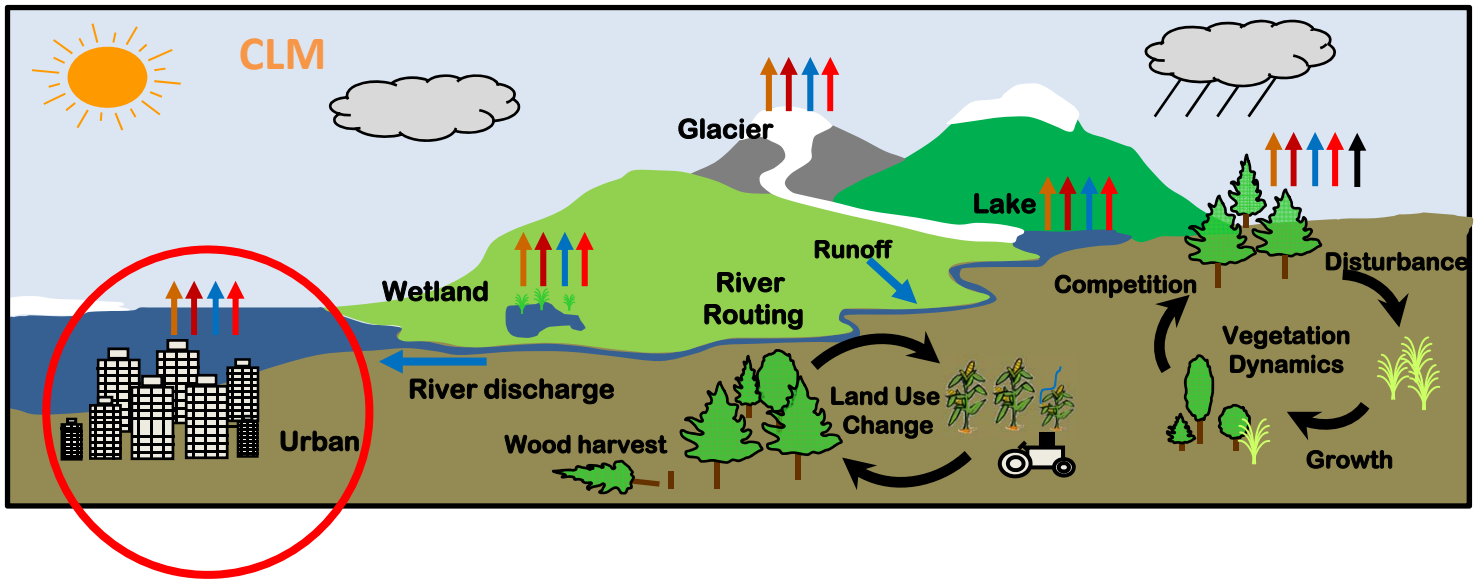




Agricultural land use
Land management
Wood harvest
Urbanization



This study

- Objective:
  - analyze the impacts of climate change on household energy use

- Scenarios:
  - CLM: CESM RCP 8.5 temperature/humidity/radiation
  - iPETS: SSP5 socioeconomic scenario,
    - low population growth
    - high economic development
    - high per capita energy use and emissions

Horses for courses

Change in…	CESM CLMU		Economic IAM (iPETS)
… temperature	✓		
… demand for cooling/heating service	✓		
… energy use for cooling/heating	✓		
… energy use for buildings/HHs			✓
… energy system			✓
… CO_2 emissions			✓
… energy expenditures			✓
… household expenditures			✓
… macro-economy (GDP)			✓

Horses for courses

Change in…	CESM CLMU	Physical IAM (IMAGE)	Economic IAM (iPETS)
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… energy system		✓	✓
… CO_2 emissions		✓	✓
… energy expenditures		✓	✓
… household expenditures			✓
… macro-economy (GDP)			✓

Horses for courses

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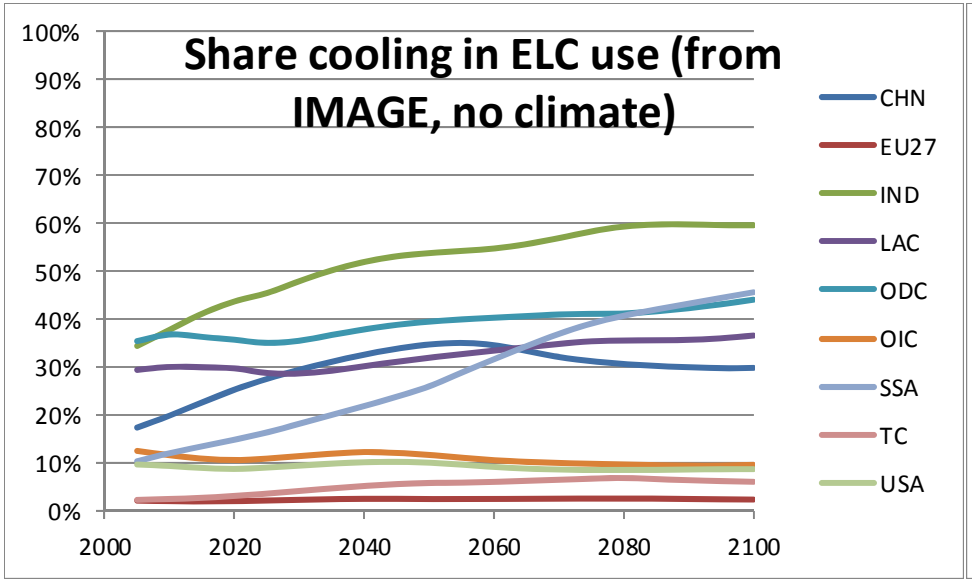
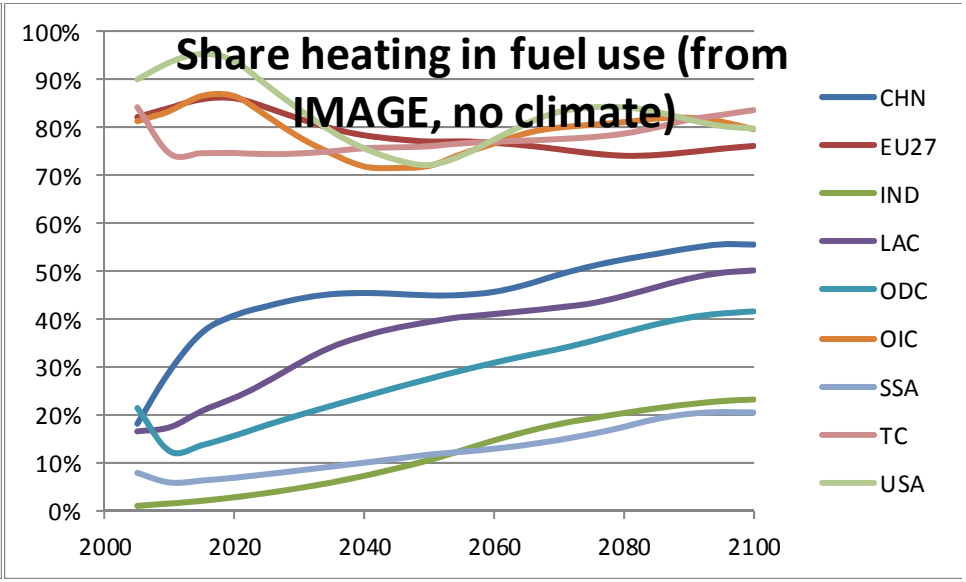
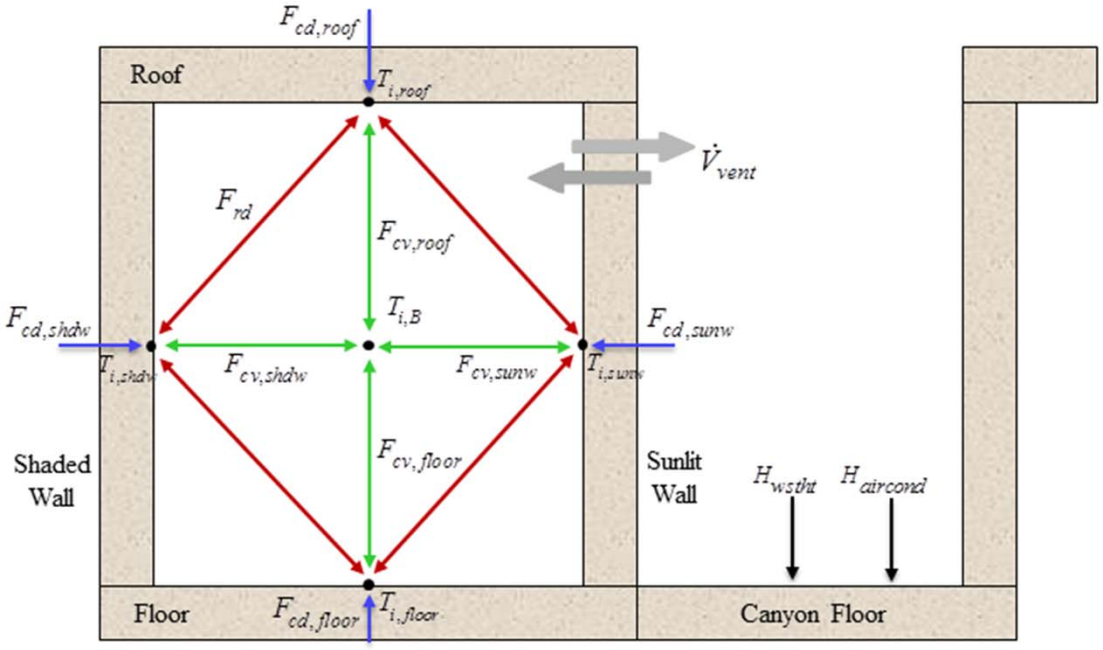
… CO_2 emissions		✓	✓
… energy expenditures		✓	✓
… household expenditures			✓
… macro-economy (GDP)			✓

Share of heating/cooling in HH energy use





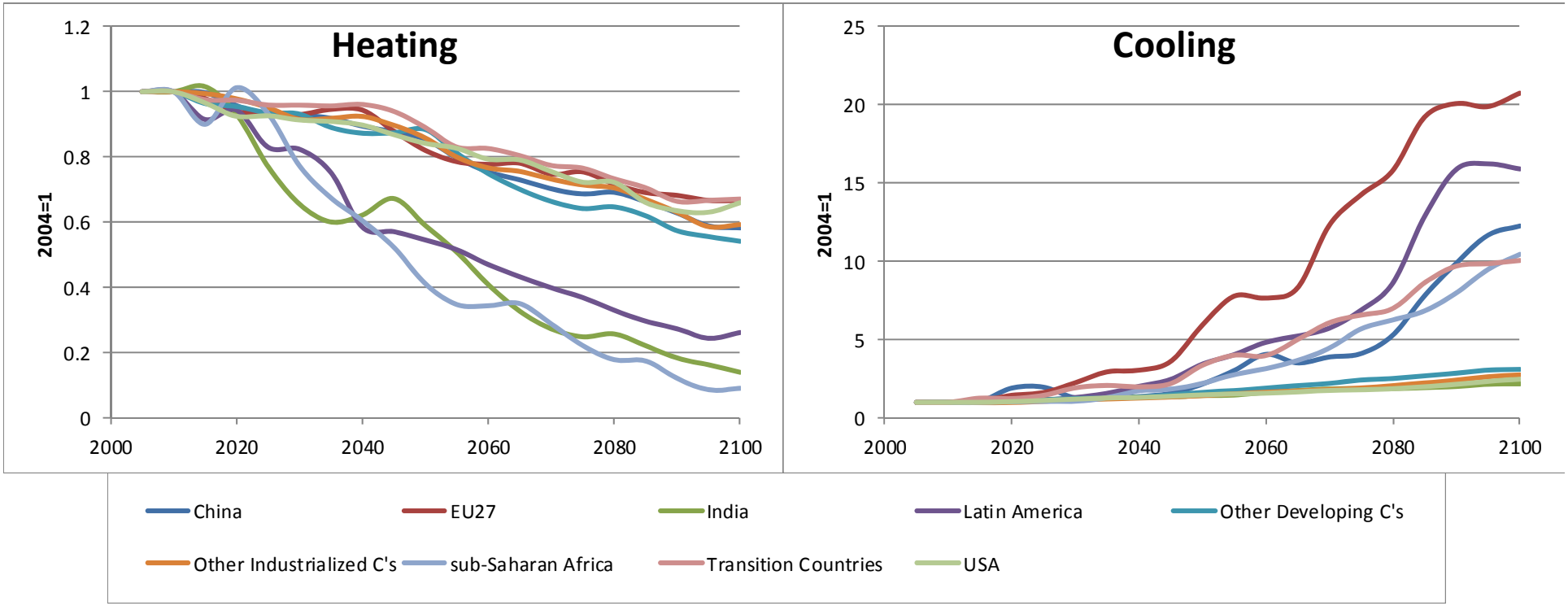
CLM Building Energy Model



- The model determines energy demand through
  - Building thermal properties (heat transfer through roofs/walls/floors)
  - Wasteheat factors (efficiency of heating/cooling systems and the conversion of primary to end use energy)
  - Building thermostat settings

K.W. Oleson, G.B. Bonan, J. Feddema and T. Jackson, An examination of urban heat island characteristics in a global climate model, *Int. J. Climatol.* 31: 1848–1865 (2011)

Change in heating/cooling energy use in CLM, RCP8.5



iPETS Model

Population-Economy-Technology Model

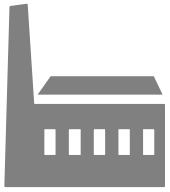
O'Neill BC, Dalton M, Fuchs R, Jiang L, Pachauri S, Zigova K. Global demographic trends and future carbon emissions. Proceedings of the National Academy of Sciences 2010;107; 17521-17526.

iPETS Model

Population-Economy-Technology Model

Households

Consumption & Savings
Capital & Labor



Final Goods Producers

Consumption, Investment, Government, Exports/ Imports

Intermediate Goods Producers

Oil, Gas, Coal, Electricity
Refined Fuels, Agriculture, Materials

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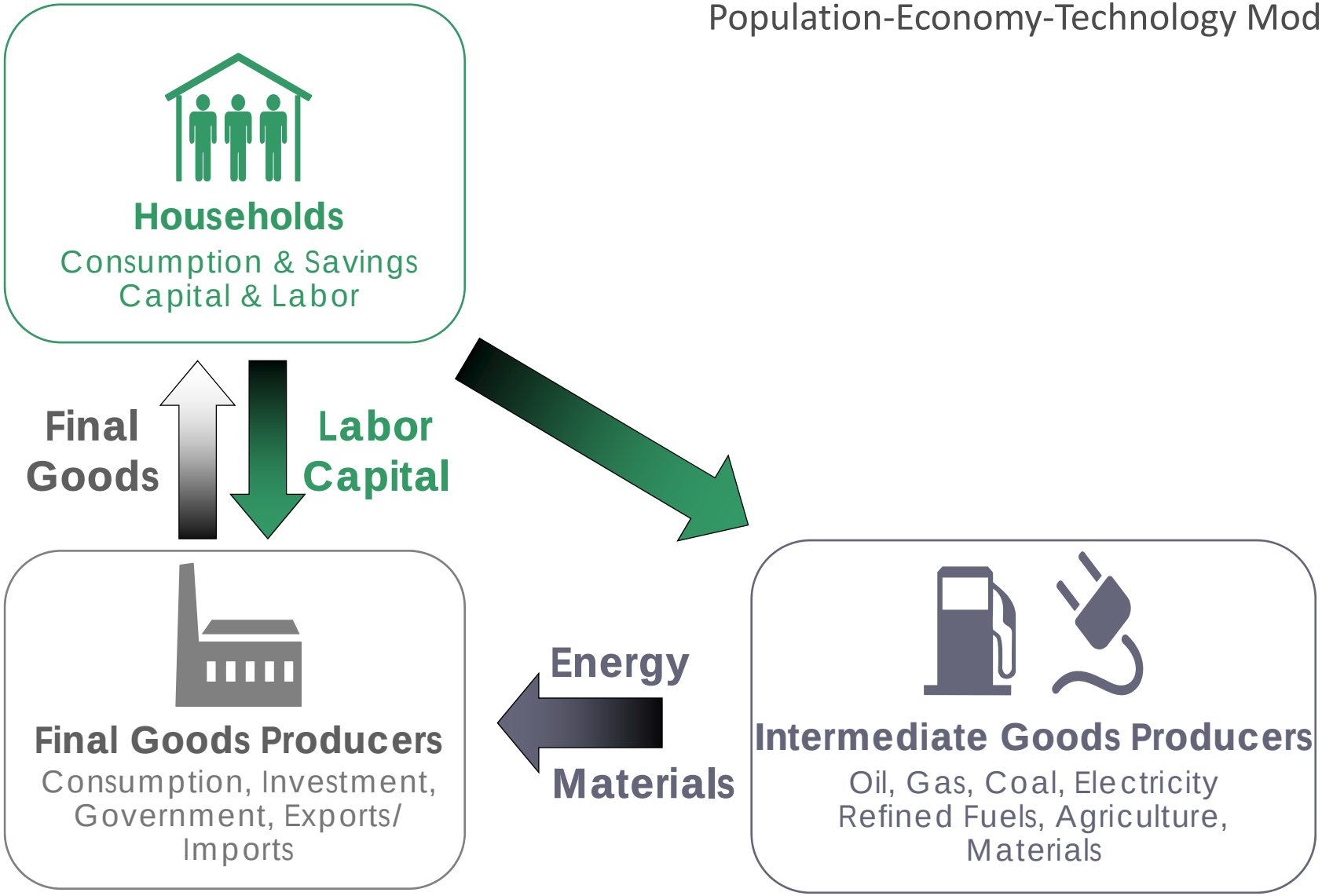

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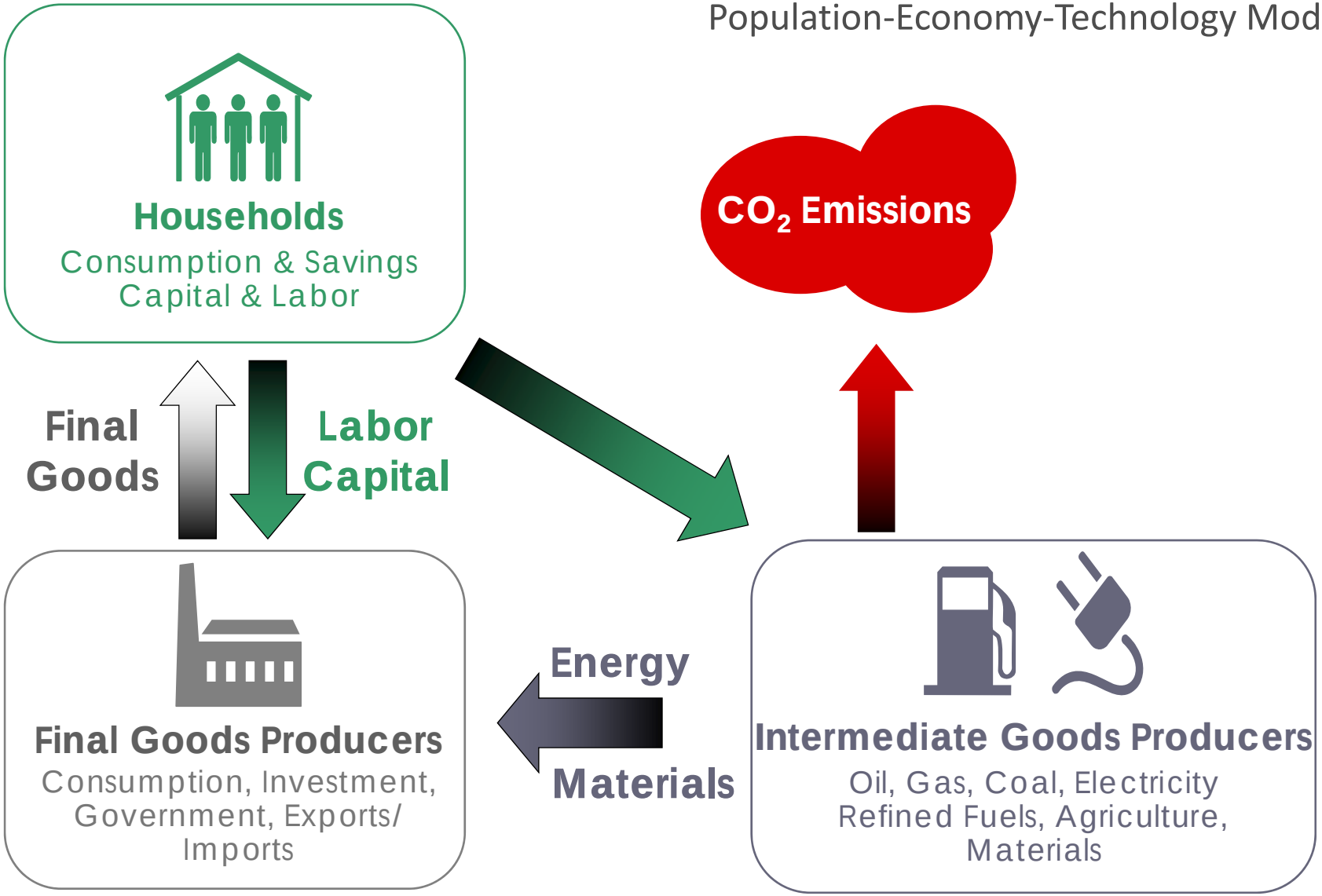

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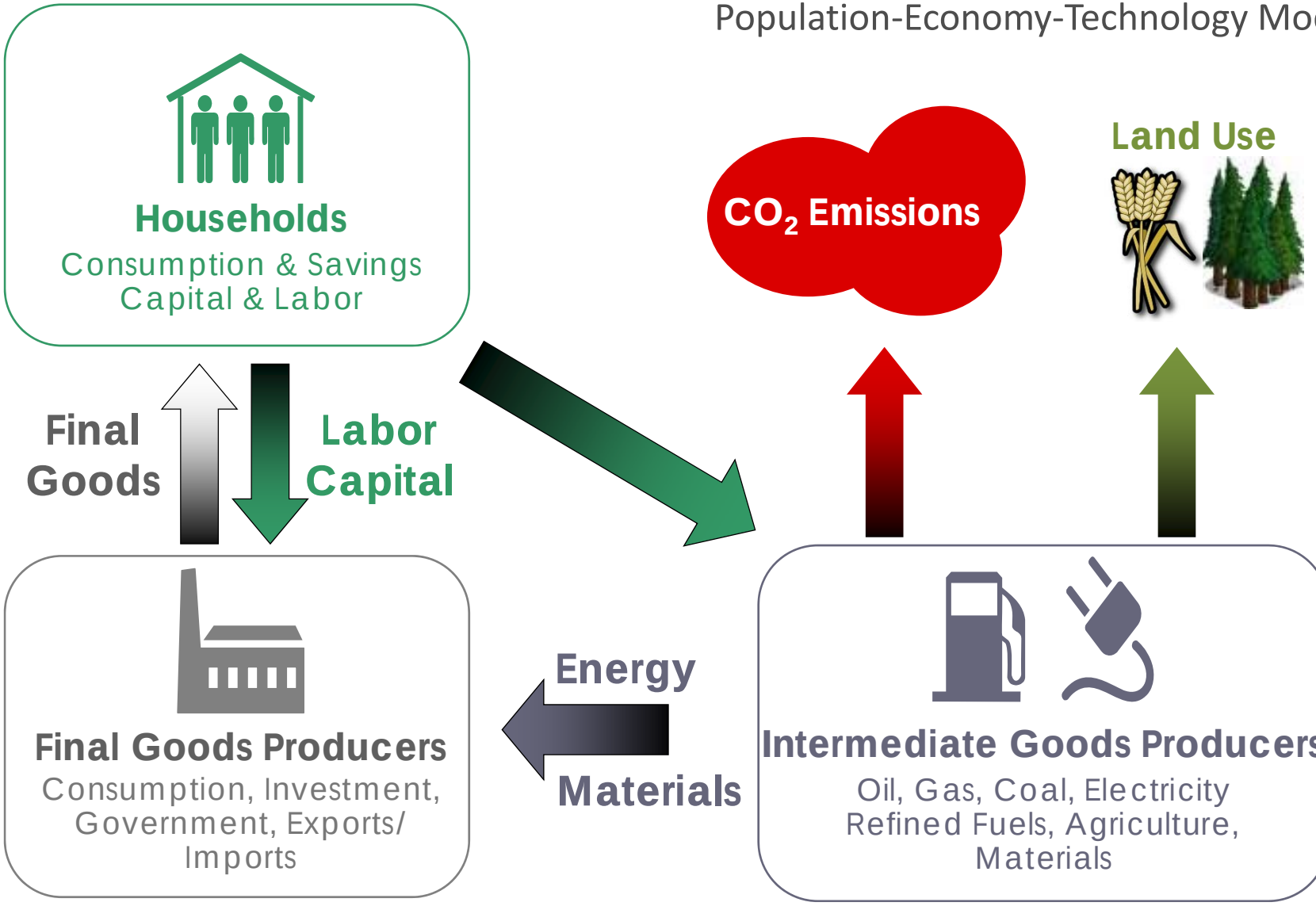

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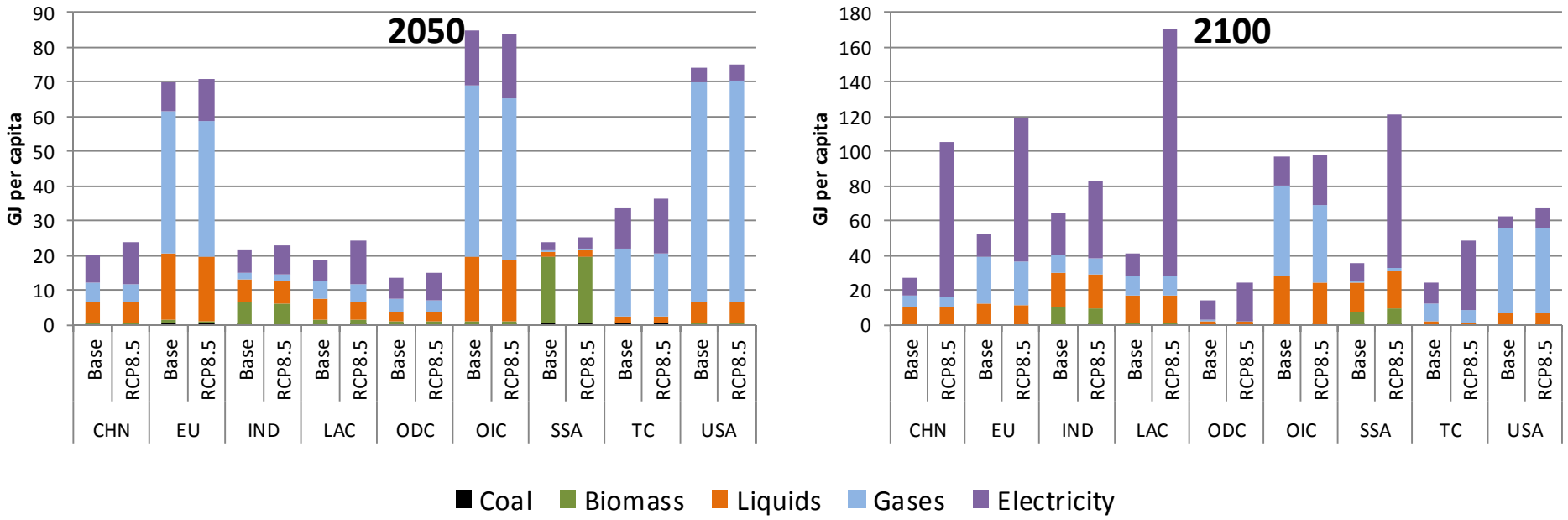
Heating/Cooling impacts in iPETS

- No explicit modeling of heating/cooling
  - Six goods for consumption
  - Electricity, CoalBio, Other energy, Food, Transport, Other

- Utility ← consumption ← preference, price, income
- Simulate decisions under changing circumstances

- More cooling -> increase in electricity preference
- Less heating -> decrease in “other energy” preference
- Results influenced by preference change and prices

Change in household final energy use in iPETS



Wrapping up

Findings

- Climate impacts on cooling energy use are large in CLM for several regions.
  - This can be due to thermostat settings, time resolution, buildings/walls
- Temperature change under RCP8.5 leads to considerable changes in household energy use.

Next steps

- Explore the large cooling impacts by doing an in-depth comparison between CLMU and IMAGE (physical IAM)
- Provide socioeconomic changes from IAM framework to CLM (such as change in urban area, income, AC-ownership)

Model differences

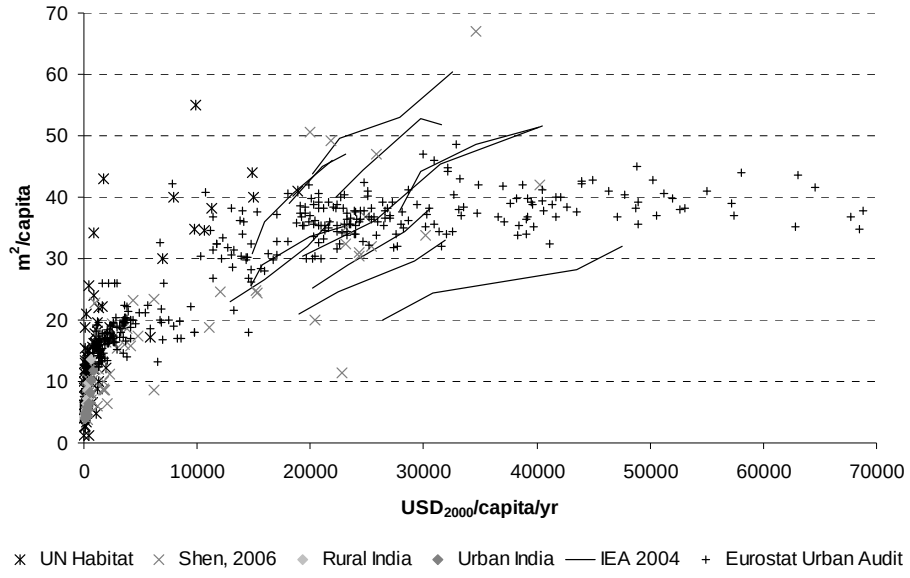
	CESM CLMU	Physical IAM (IMAGE)	Economic IAM (iPETS)
Main model unit	Watt	EJ/yr	$
Time resolution	30 min	annual	annual
Climate information	Temperature	Degreedays	-
Set point	Min: 13-20 ^{o}C Max: 28-38 ^{o}C	18 ^{o}C	-
Scope	Urban building energy	Energy, emissions	Economy, energy, emissions
Socioeconomic changes	-	Population, GDP, technology	Population, GDP, technology
Nr. world regions	33	26	9
Sub-categories	TBD/HD/MD	Urban/rural, income	-

IMAGE - heating

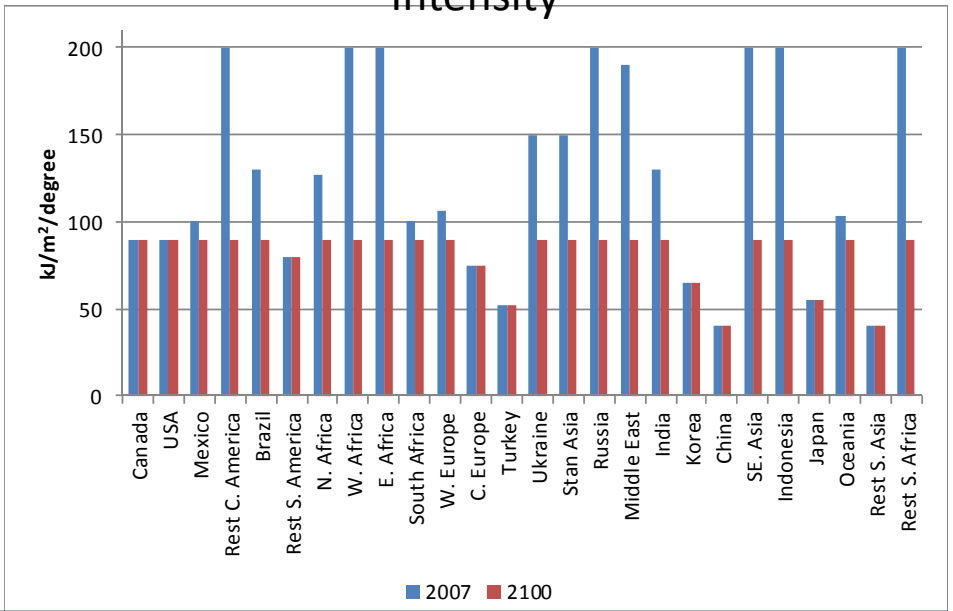
$$Heating = Floorspace \cdot HDD \cdot Intensity$$

m^2 ^oC $kJ/m^2/^oC$

Floor space



Intensity



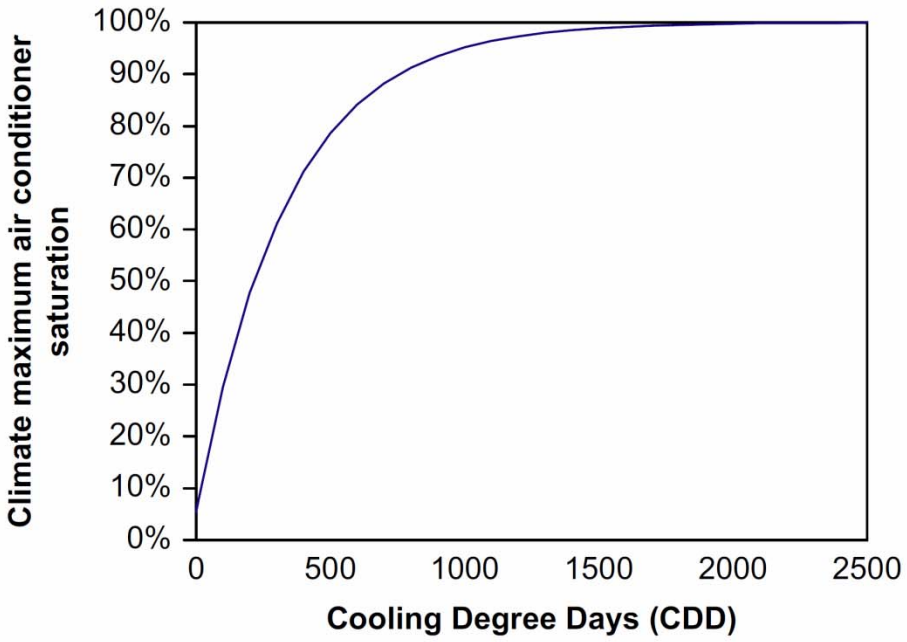
van Ruijven BJ, van Vuuren DP, de Vries HJM, Isaac M, van der Sluijs JP, Lucas PL, Balachandra P. Model projections for household energy use in India. Energy Policy 2011;39; 7747-7761.

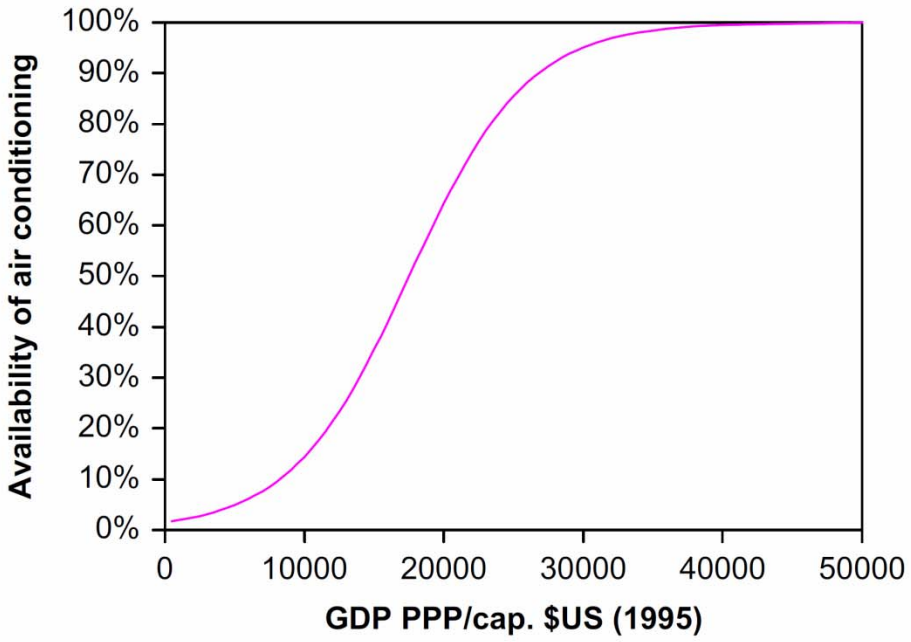
IMAGE - cooling

$$Cooling = HHs \cdot penetration \cdot \frac{UEC}{efficiency}$$

$$penetration = ClimateMaxSaturation \times availability$$

$$UEC = CDD \times f(income)$$





Isaac M, van Vuuren D, P. Modeling global residential sector energy demand for heating and air conditioning in the context of climate change. Energy Policy 2009;37; 507-521.

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