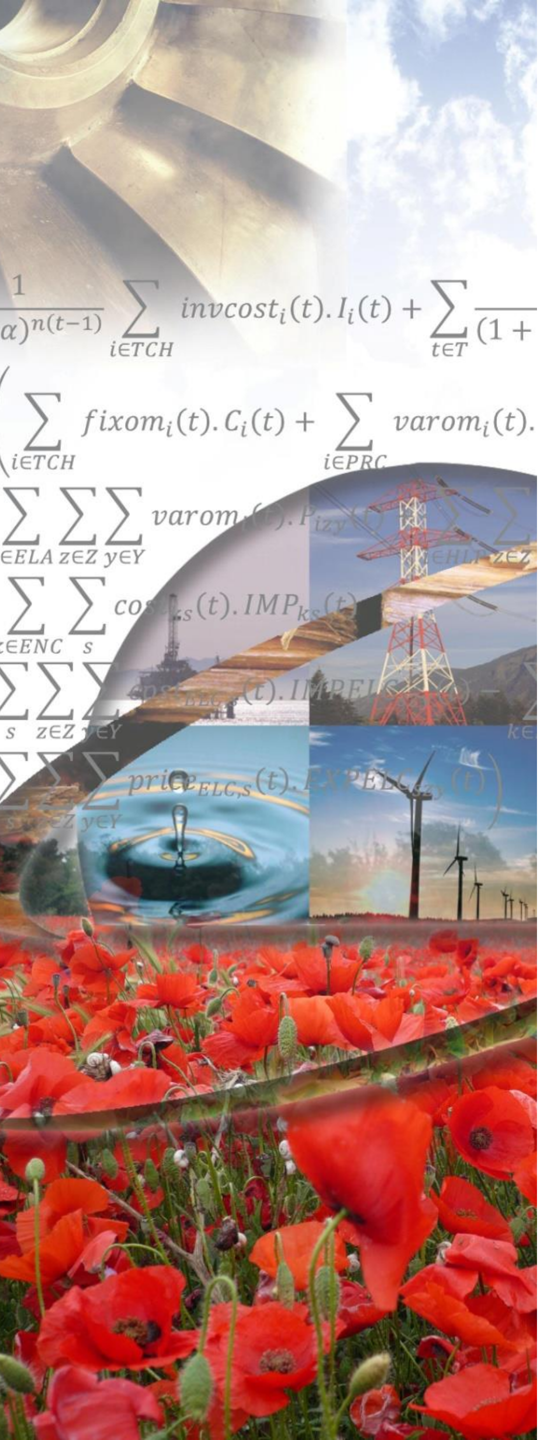

Centre for Applied Mathematics

ParisTech's Chair Modeling for sustainable development

Reconciling top-down and bottom-up energy/economy models: a case of TIAM-FR and IMACLIM-R

Edi ASSOUMOU[1], Frédéric GHERSI[2], Jean-Charles HOURCADE[2], Jun LI[2], Nadia MAÏZI[1] and Sandrine SELOSSE[1]

Chair Modeling for sustainable development

[1]: MINES ParisTech (CMA) and [2]: CIRED

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ETSAP-UCC Workshop

Methodologies linking energy systems models and economic models

Origin and context of the project

- 2008 : Chair Modeling for sustainable development
  - CMA : Bottom-up (BU) model: TIMES
    Technico-economic optimization model
  - CIRED : Top-down (TD) model: IMACLIM
    Computable general equilibrium (CGE) family
- Tackle the energy, environmental and economics constraints
  - Capitalise on their common, yet complementary experiences
- Provide consistent tools for the dialogue between engineers and economists
  - Develop a shared platform for modeling
  - Methodological reappraisal
  - Improve knowledge of the interaction between economic growth, energy and the environment

Reconciling TD and BU energy/economy models

- Improve knowledge of the interaction between economic growth, energy and the environment
- Assessment of the environmental and economic consequences of various energy demand and GHG policies
- Two roads with a persistent division line: BU and TD models

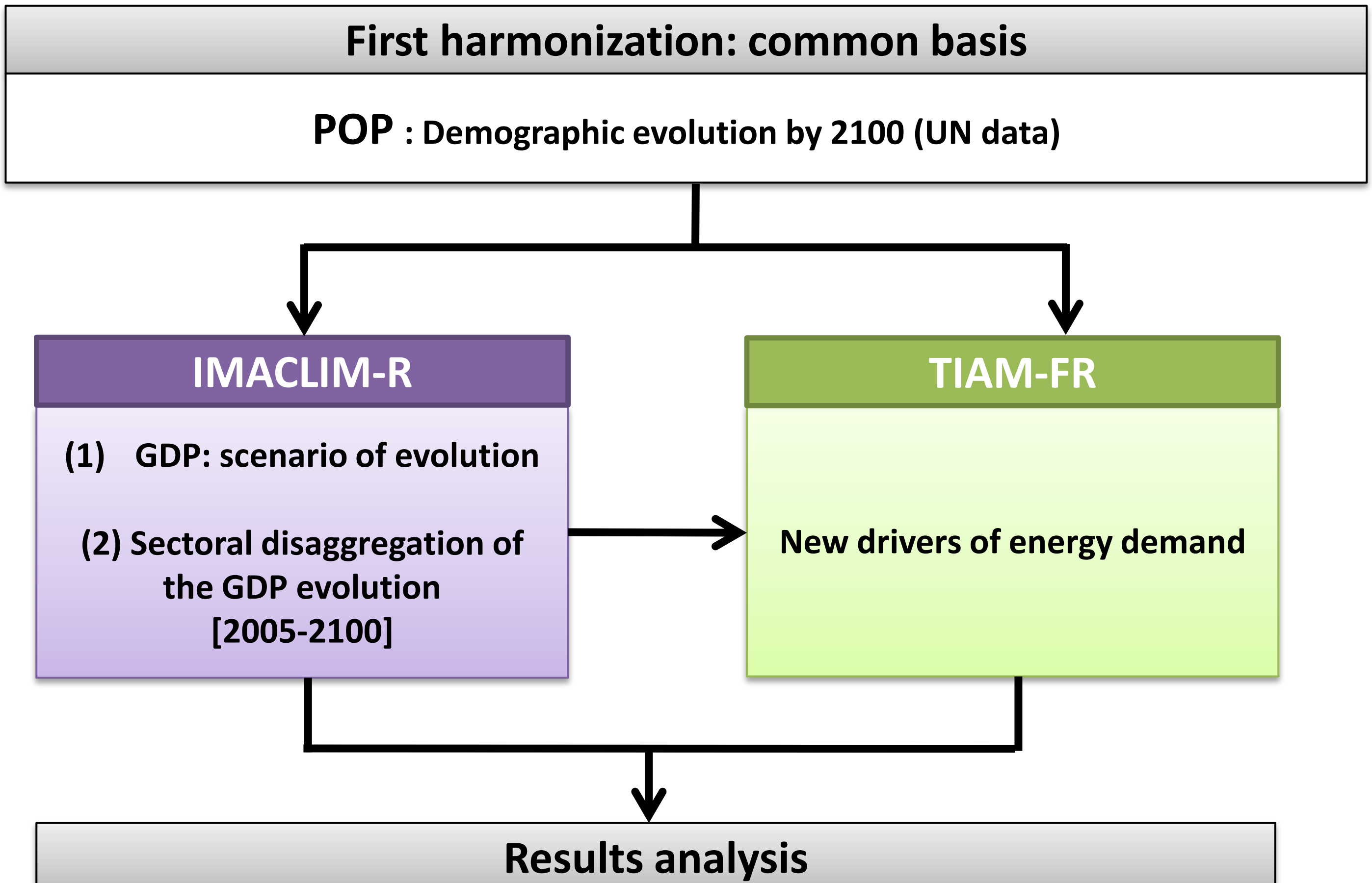
- Show out the conditions for a constructive dialogue
  - Systematic effort of clearing out the sources of misunderstanding at a very technical level for each model
    - Theoretical foundations
    - Structure
    - Specifications
    - Applicability to policy assessment

Main modeling specifications

Bottom-up model (TIAM-FR)
Energy sector
Rich description of technologies (current/future - supply/end-use)
Energy systems evolution: results from myriad of decisions on technology adoption
Optimization model : minimize discounted cost of the satisfaying energy service demands under a set of pre-determined constraints
Partial equilibrium : inable to consider feedbacks from non-energy markets, the price of the primary production factors and the overall general equilibrium effects (income, savings)
Ex: no impact of investments on the cost of capital (and on oil prices)

Top-down model (IMACLIM-R)
Interation between energy sector and the rest of economy
Aggregate description of systems
Model the supply and demand for goods & Services: National acounting data in monetary data: consumption, prices, incomes, factor costs
Computable General Equilibrium
Simulation of markets for primary factor of production, domestic and imported G&S that are brought into equilibrium by price adjustments
They reduce techniques to trade-offs between aggregated production inputs or consumption goods
Ex: capital costs are treated by default as the remainder of value-added once labor costs and natural resource rents subtracted

One preliminary numerical exercice: a soft linking



Aggregation of the regional distribution of IMACLIM-R to come closer to that of TIAM-FR

IMACLIM-R	
AFR	Africa
BRA	Brazil
CAN	Canada
CHI	China
EU	Europe
IND	India
MEA	Middle East
OECDpac	Japan, Australia, New-Zealand, South Korea
RoA	Rest of Asia
RoLA	Rest of Latin America
USA	United States of America

→

TIAM-FR	
AFR	Africa
AUS	Australia / New-Zealand
CAN	Canada
CHI	China
CSA	Central and South America
EEU	Eastern Europe
FSU	Former Soviet Union
IND	India
JPN	Japan
MEX	Mexico
MEA	Middle East
ODA	Other developing Asian countries
SKO	South Korea
USA	United States of America
WEU	Western Europe

Disaggregation of the heavy industry output of IMACLIM-R to be consistent with the industrial demand sector of TIAM-FR

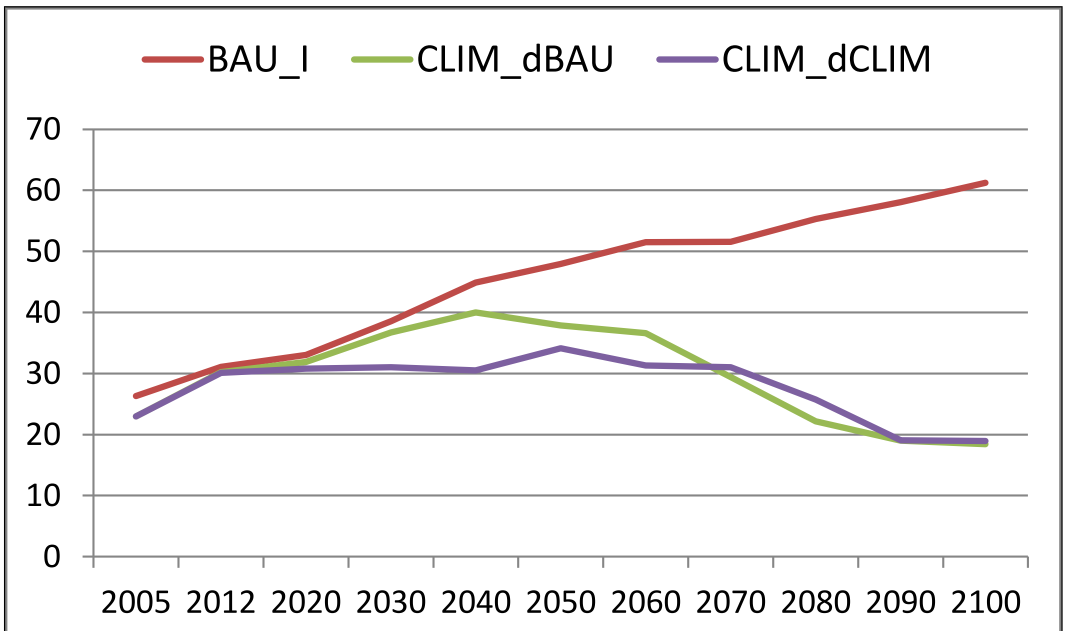
IMACLIM-R
Heavy industry output
Services output
Agricultural output

→

TIAM-FR
Chemicals **Iron & Steel and non-ferrous metal** **Non-metal minerals and paper** **Other energy intensive manufacturing**
Services output
Agricultural output

Scenarios investigation:
BAU and a climate policy (450 ppm)

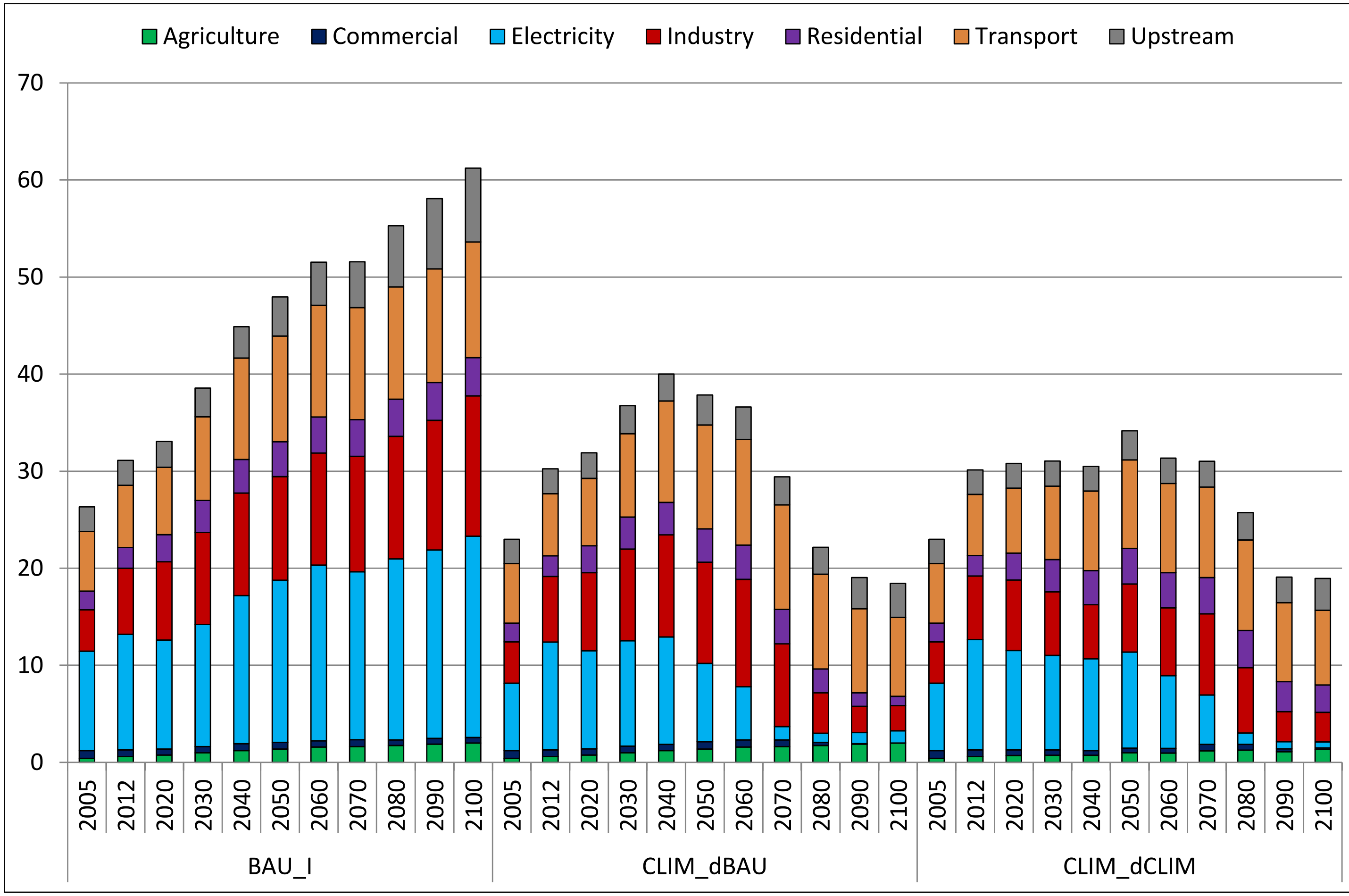
		Drivers – Growth indices from:	
		BAU scenario in IMACLIM-R	CLIM scenario in IMACLIM-R
Scenario in TIAM-FR	BAU	X	
	CLIM_dCLIM		X
	CLIM_dBAU	X	



World CO_2 emissions (Gt)

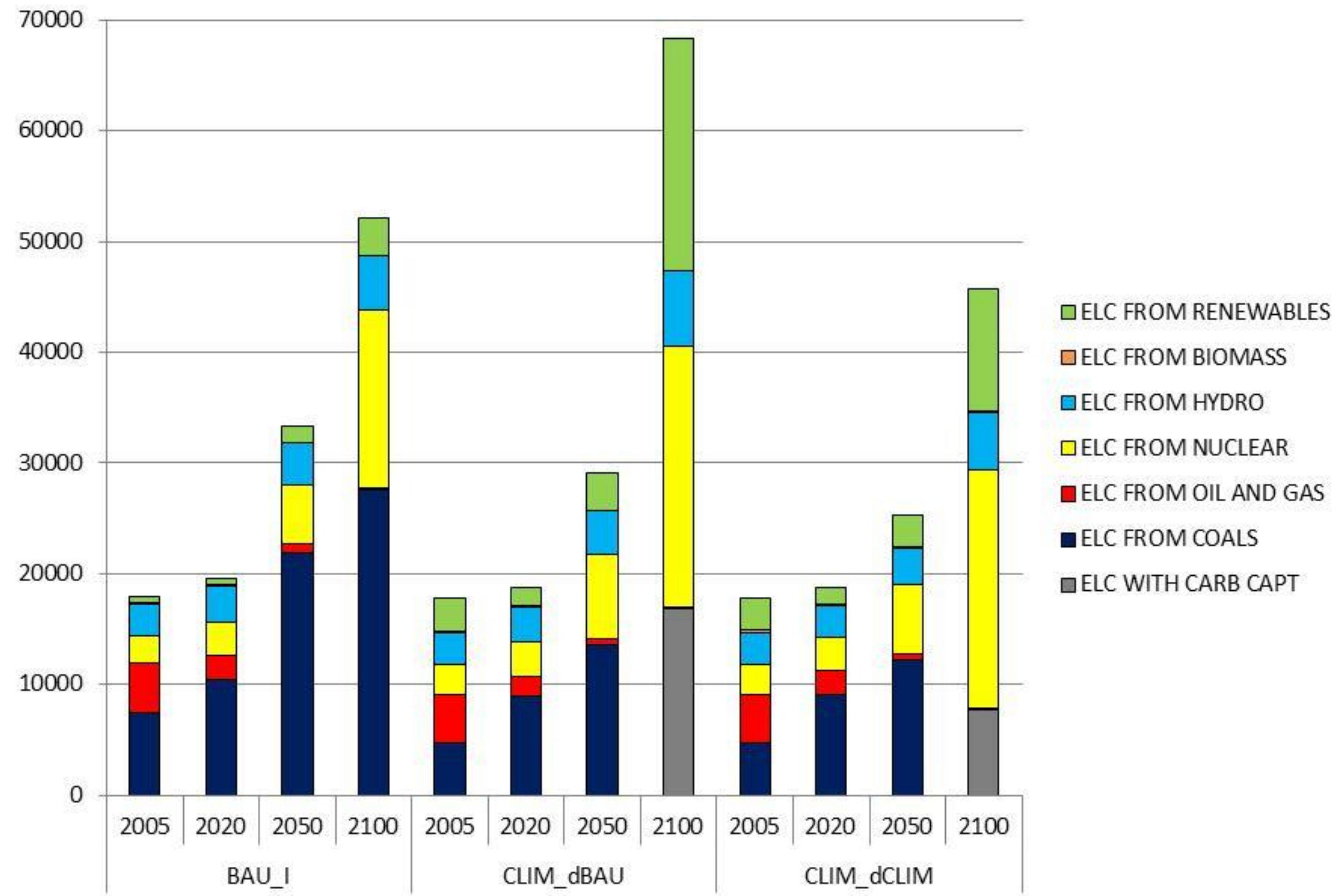
Two different trajectories consistent with the 450ppm target in 2100 for CO2 emissions

World emissions by sector (GT CO_2)



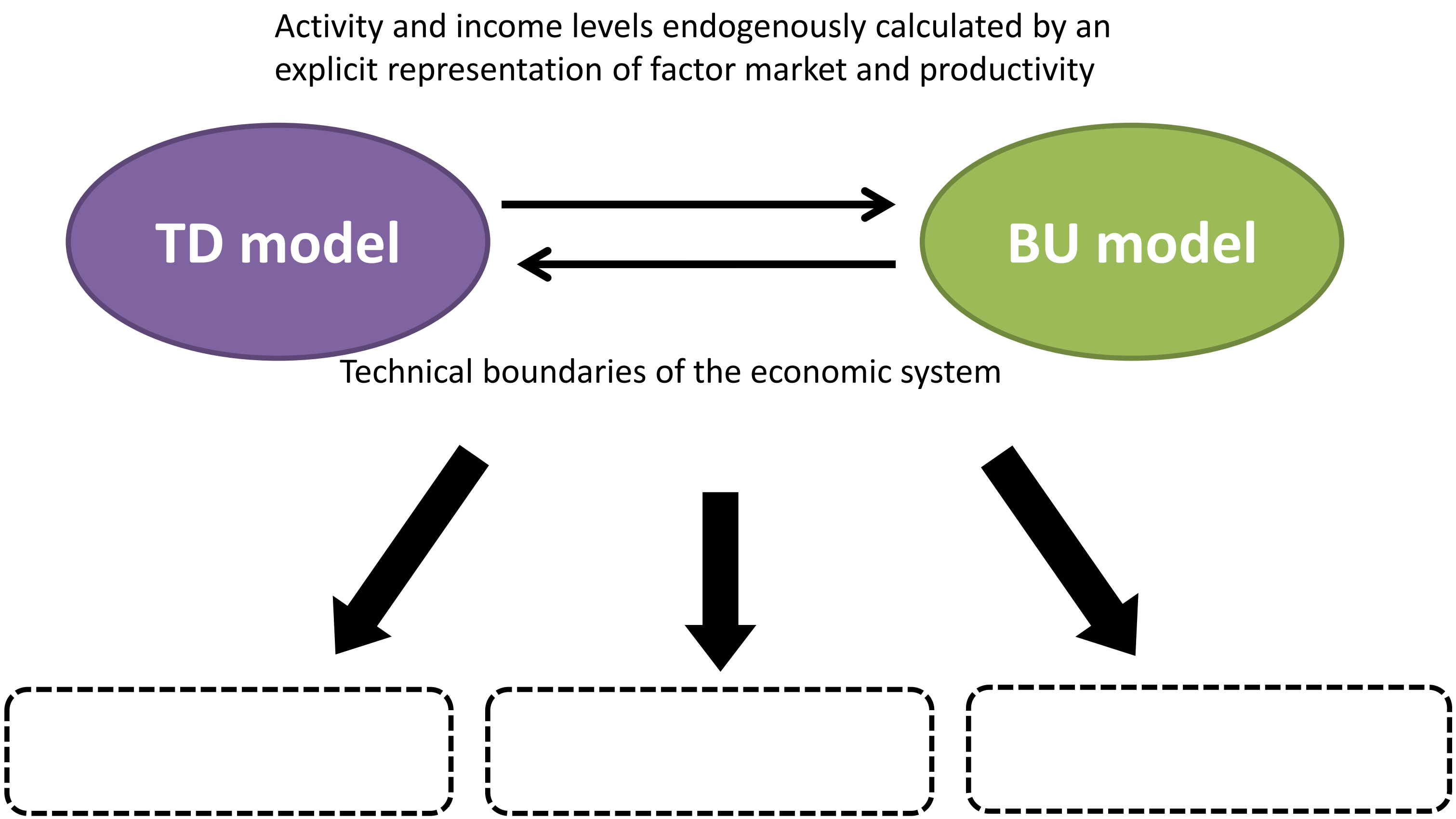
Distinct emissions paths for the same constraint according to the level of energy demand

World power generation (TWh)

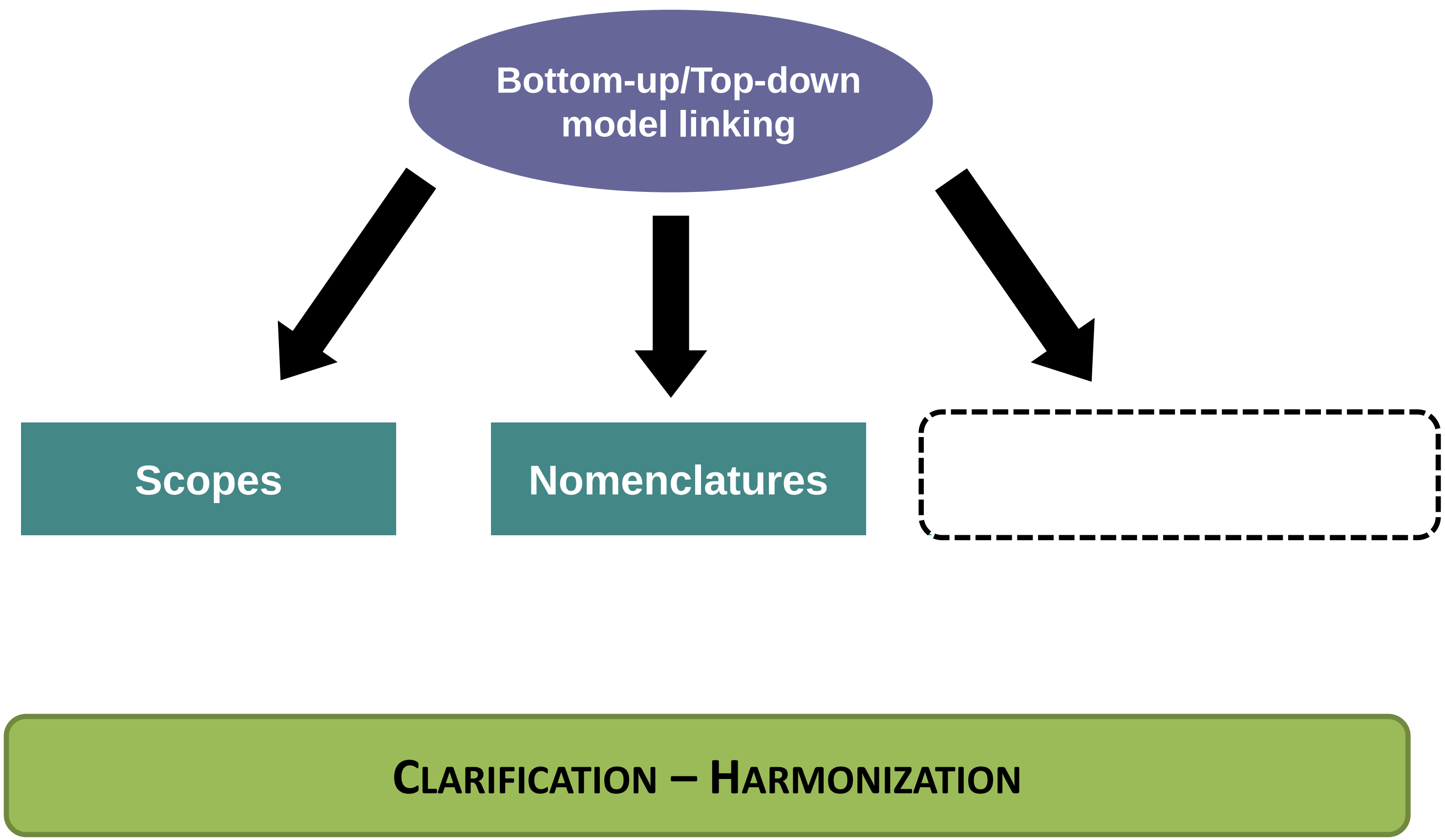


Interesting effect of the lower level of end-use demand due to drivers taking into account the policy effect

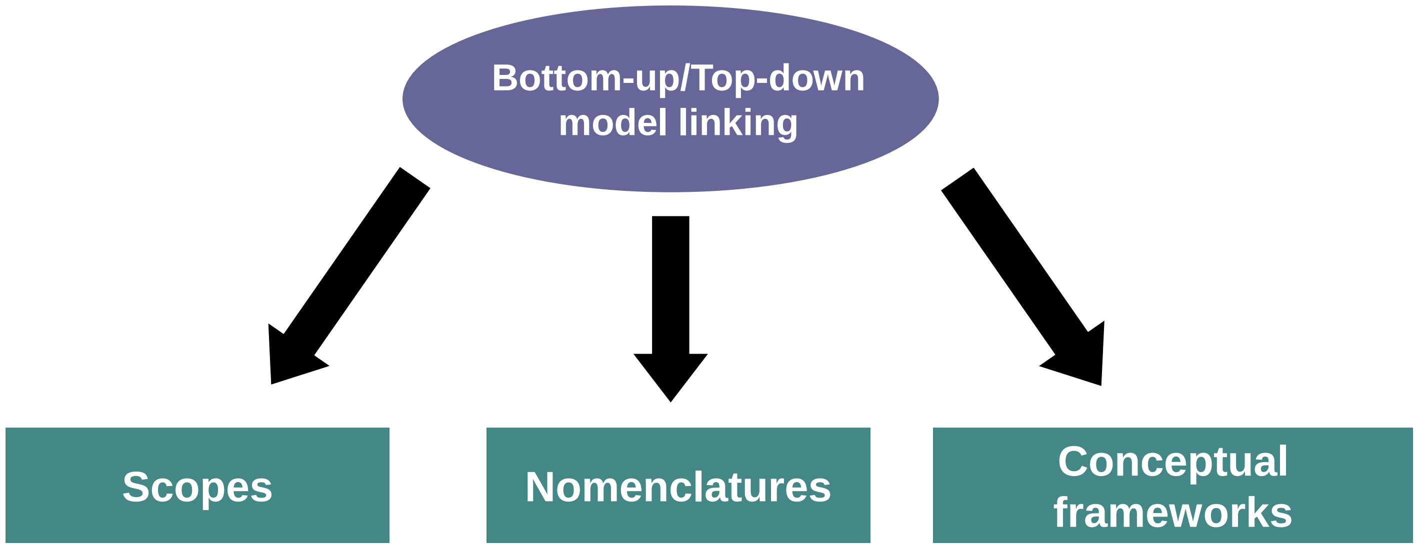
The model linking challenge



The model linking challenge



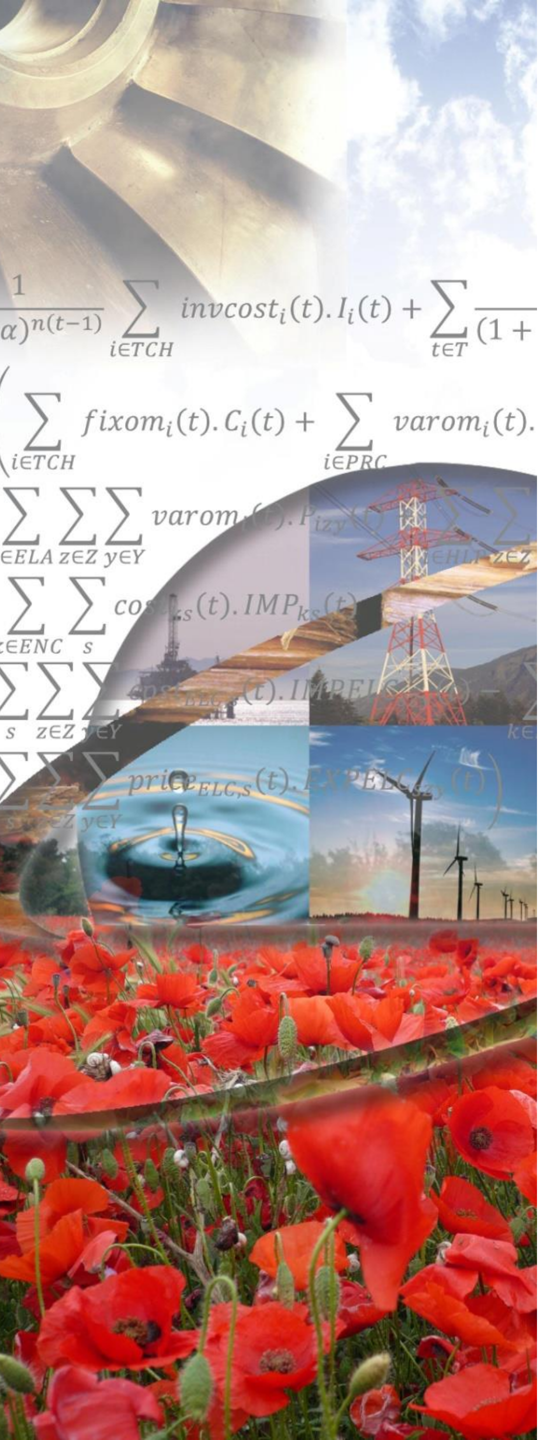
The model linking challenge



CLARIFICATION – HARMONIZATION - CONCILIATION

Conceptual framework: the challenge of the conciliation

- The major obstacle to harmonizing the two frameworks
  - With divergences in predictions as an indicator of the degree of harmonization
- Optimization vs recursive approach of time dynamics
  - TIAM-FR: results describe cost-minimizing investment and consumption pathways under perfect foresight
  - IMACLIM-R: results under imperfect anticipations
  - Gap but potential bridge with constraints representing sub-optimal features (ex: crude oil context with exogenous constraints expressing strategic international markets and increasing trading cost representing rents)
- Heavy program of rerunning every 5 years time periods to be recalibrated in function of IMACLIM-R feedbacks



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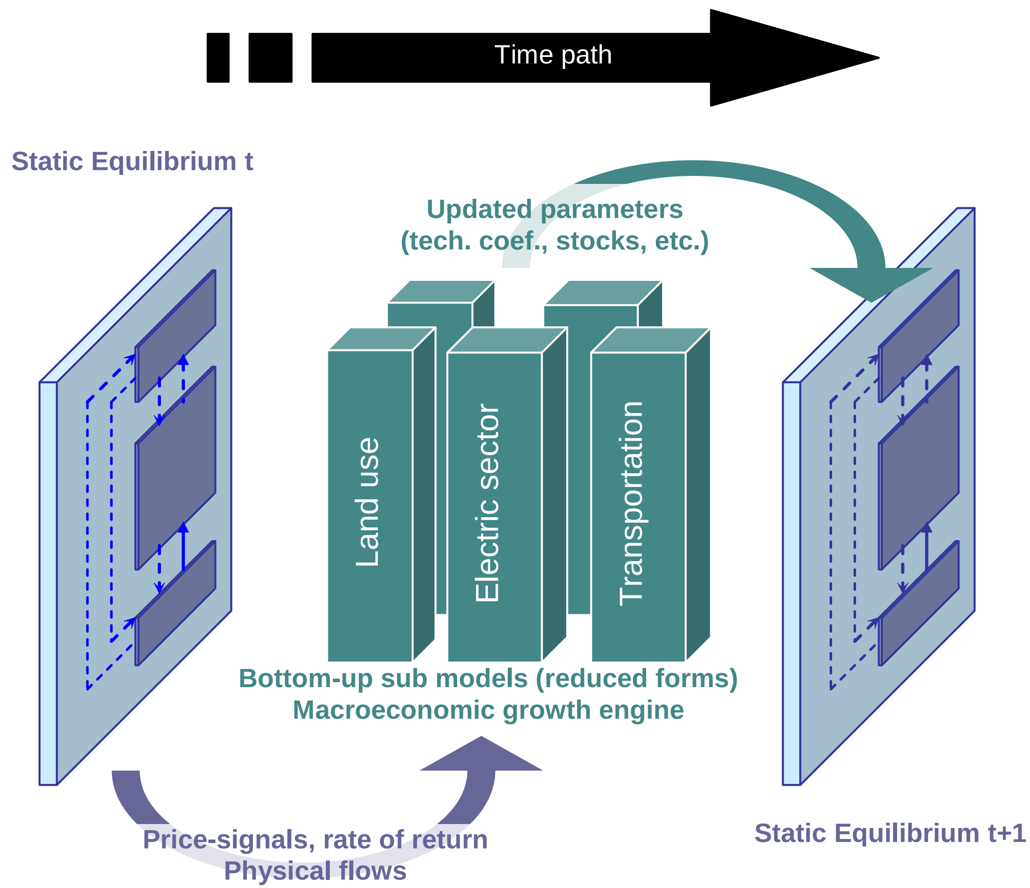
Thank you for your attention!

Harmonization of inputs/outputs

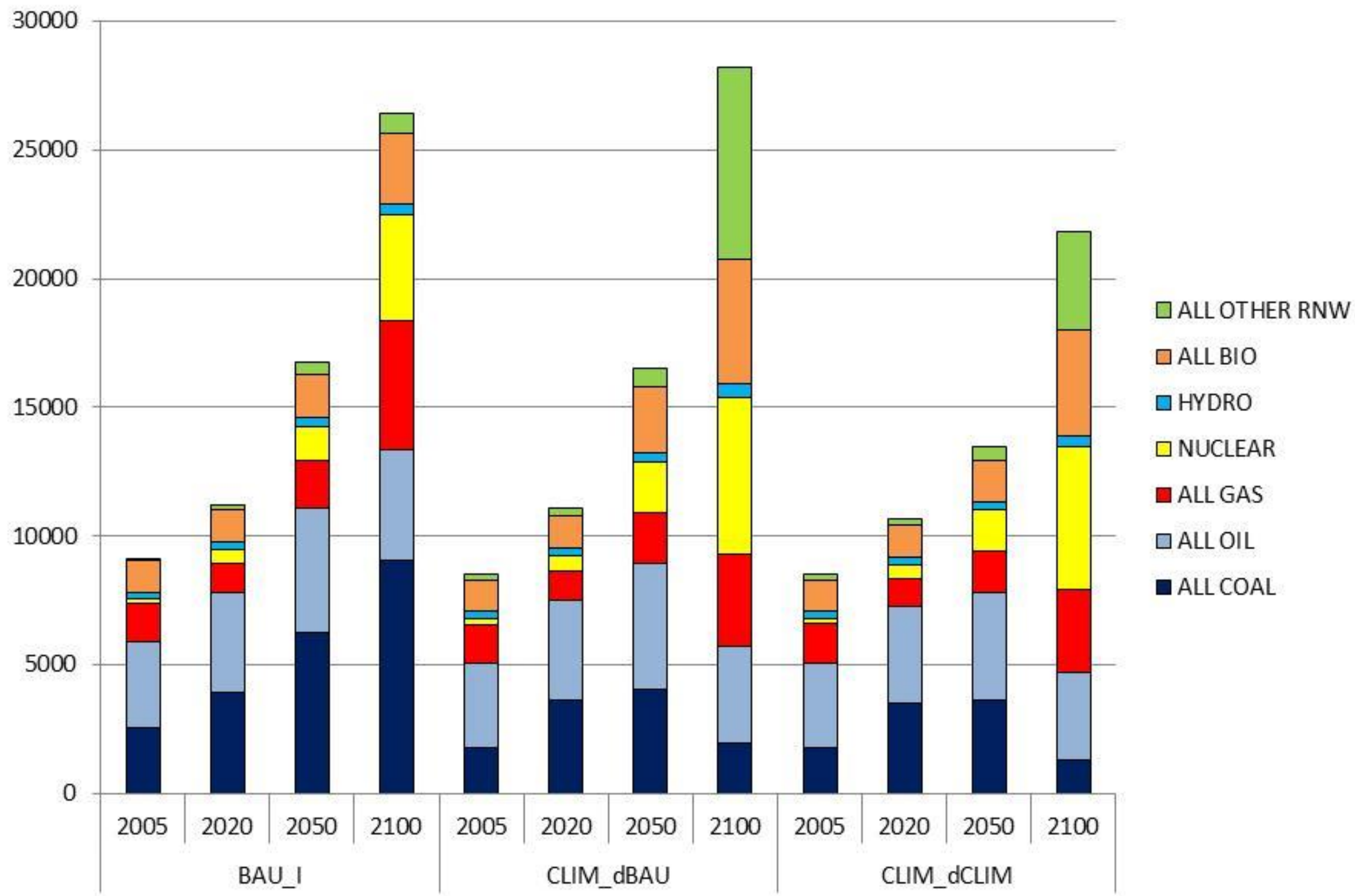
Main inputs	
• Evolution of population • GDP growth • Sectors outputs • Lifecycle costs of energy supply and end-use technologies • Extraction costs of primary resources • Reserves or potential of primary resources	**TIAM-FR**
• Evolution of Population • Evolution of Active population • Labour productivity • Savings rate • Substitution elasticity of household consumption • Substitution elasticity of international trade • Extent of primary resources	**IMACLIM-R**

	Main outputs
TIAM-FR	• A set of investments in all technologies • The operating levels of all technologies • The imports and exports of each type of tradeable energy forms • The extraction levels of each primary energy form • The flows of each commodity into and out of each technology • The emissions of CO_2, CH_4 and N_2O by each technology, sector, and total • The change in concentration of the GHG • The radiative forcing induced by the atmospheric concentration of GHG in the atmosphere • The change in global temperature induced by the change in radiative forcing
IMACLIM-R	• GDP • Output (12 productions) • Intermediate and final demands (12 goods) Inc. final energy demand • Producer and consumer prices • CO_2 emissions • Investment in energy producing capacity • GHG emissions

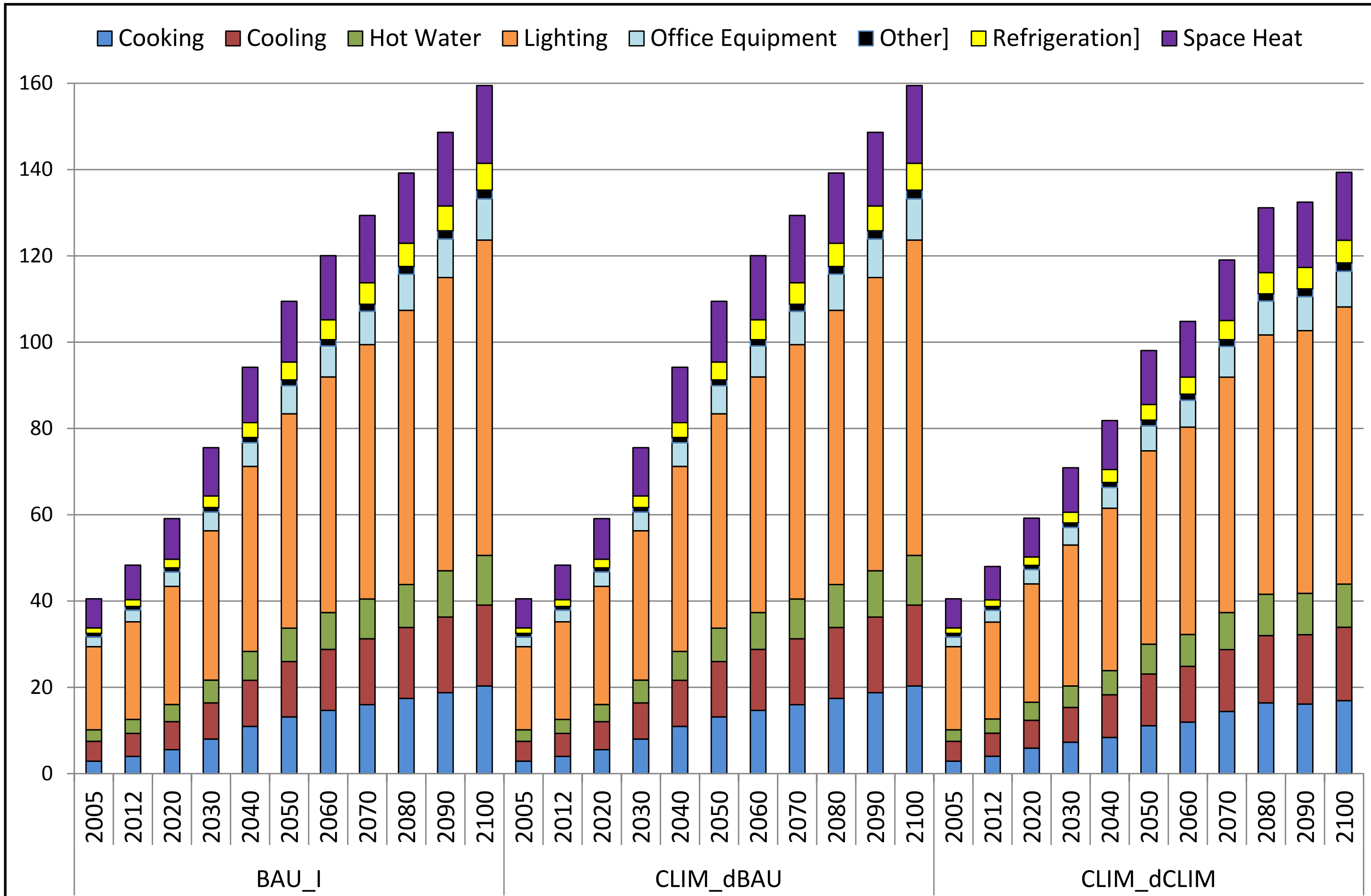
Static equilibrium and dynamic nexus coupling in IMACLIM-R



World primary energy supply (mtoe)

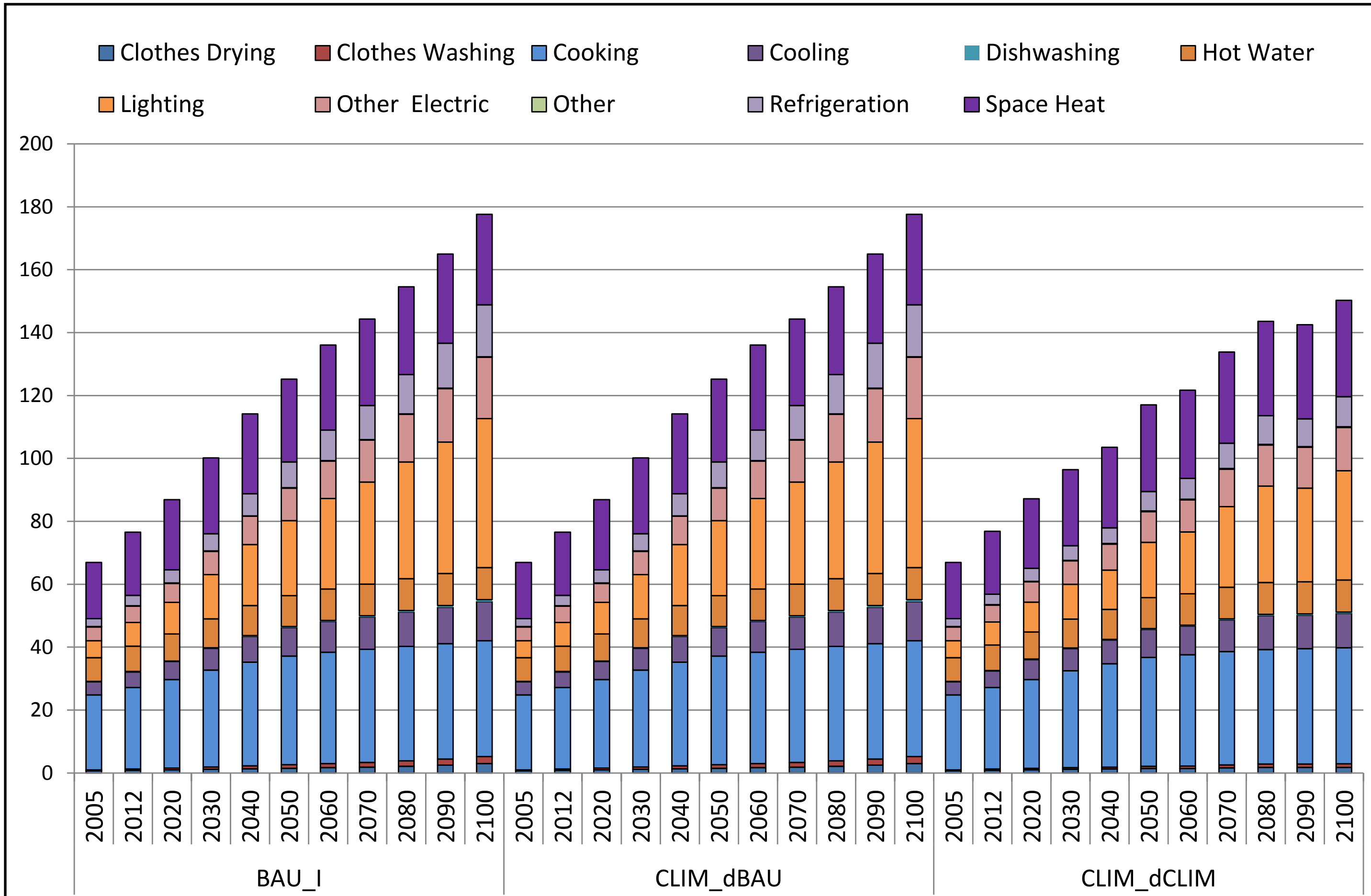


Energy services demands



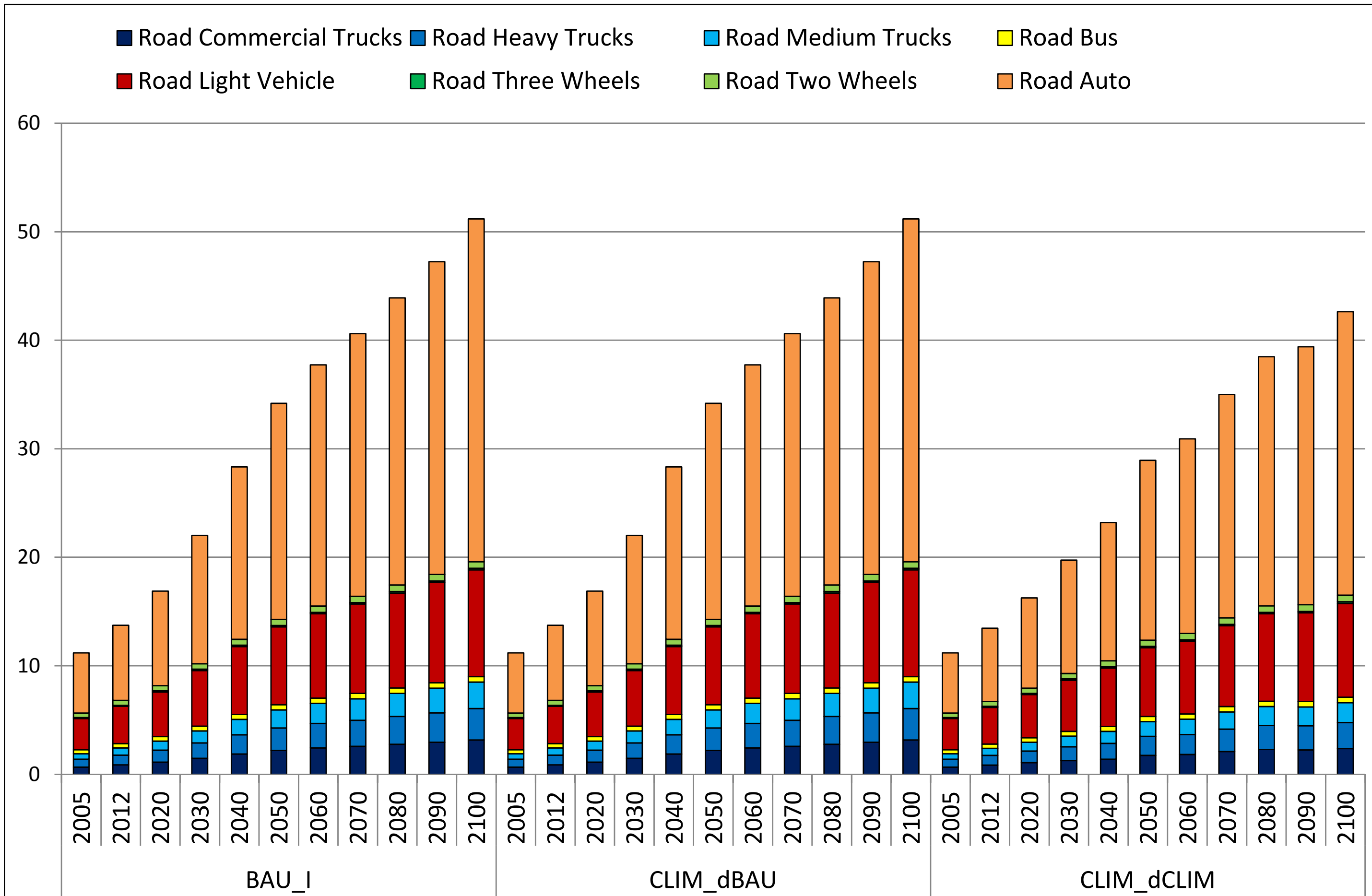
Demands for energy services in commercial sector (EJ)

Energy services demands



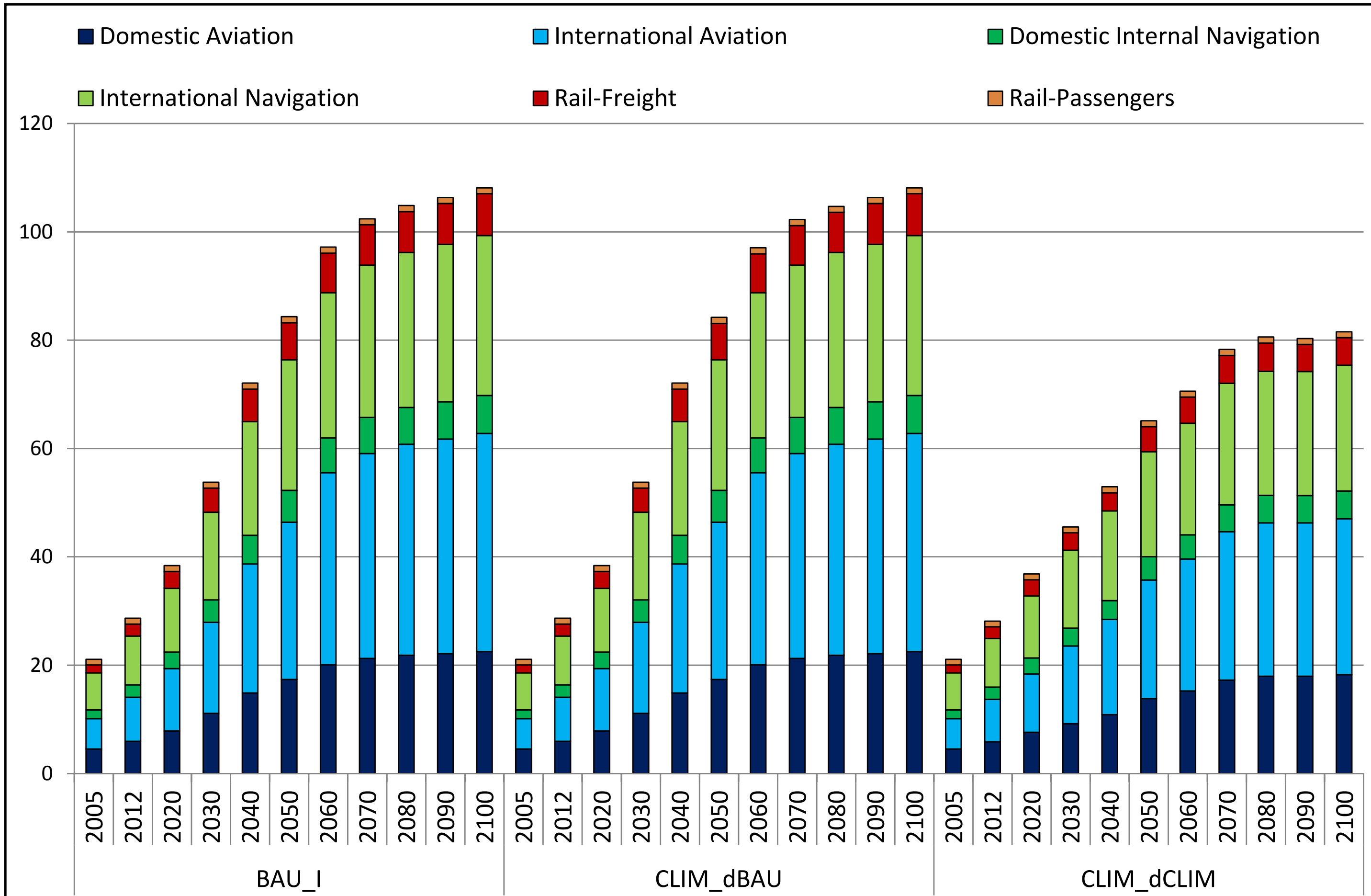
Demands for energy services in residential sector (EJ)

Energy services demands



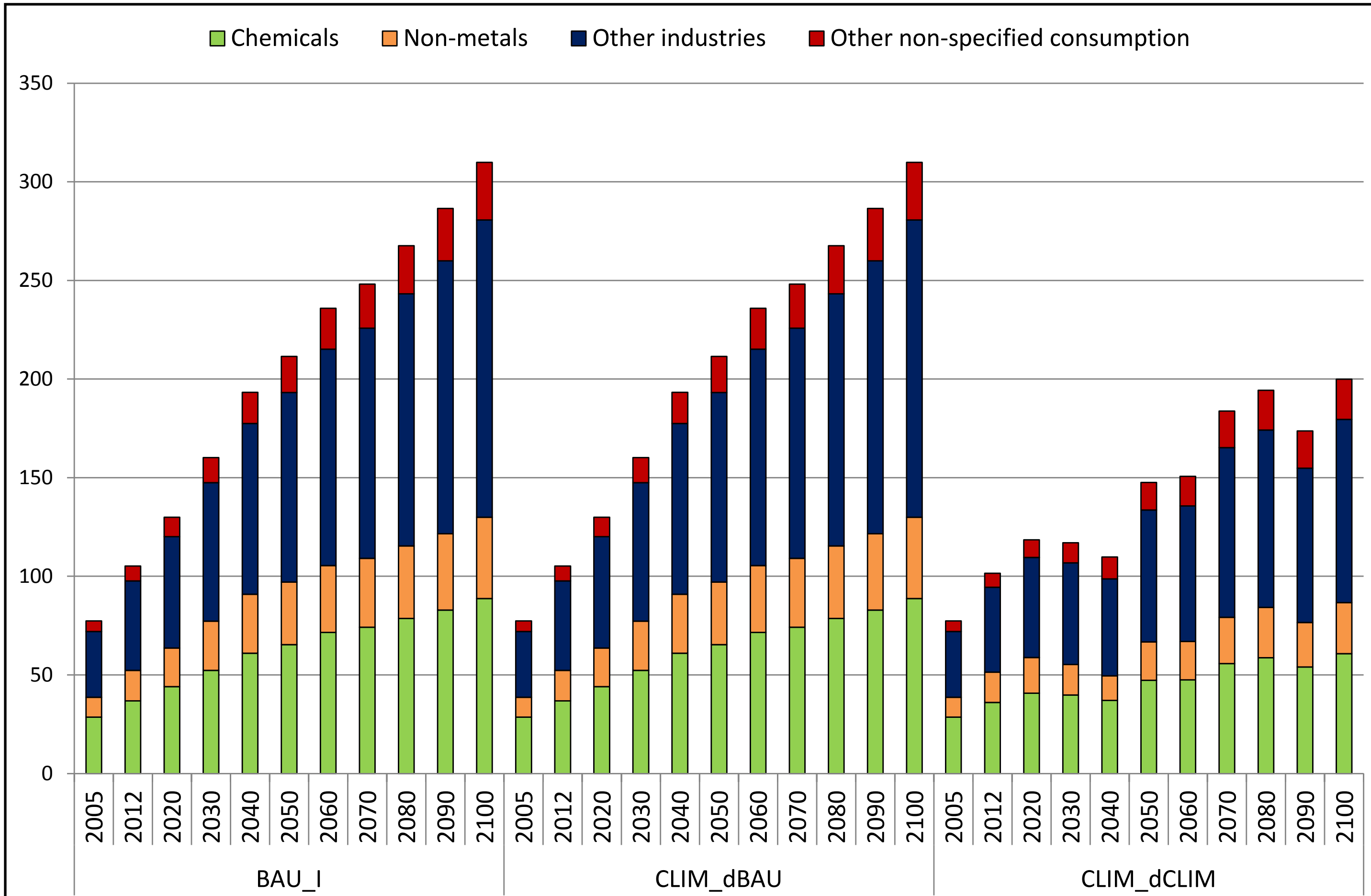
Demands for energy services in transport sector (road transportation) (Bv/km)

Energy services demands



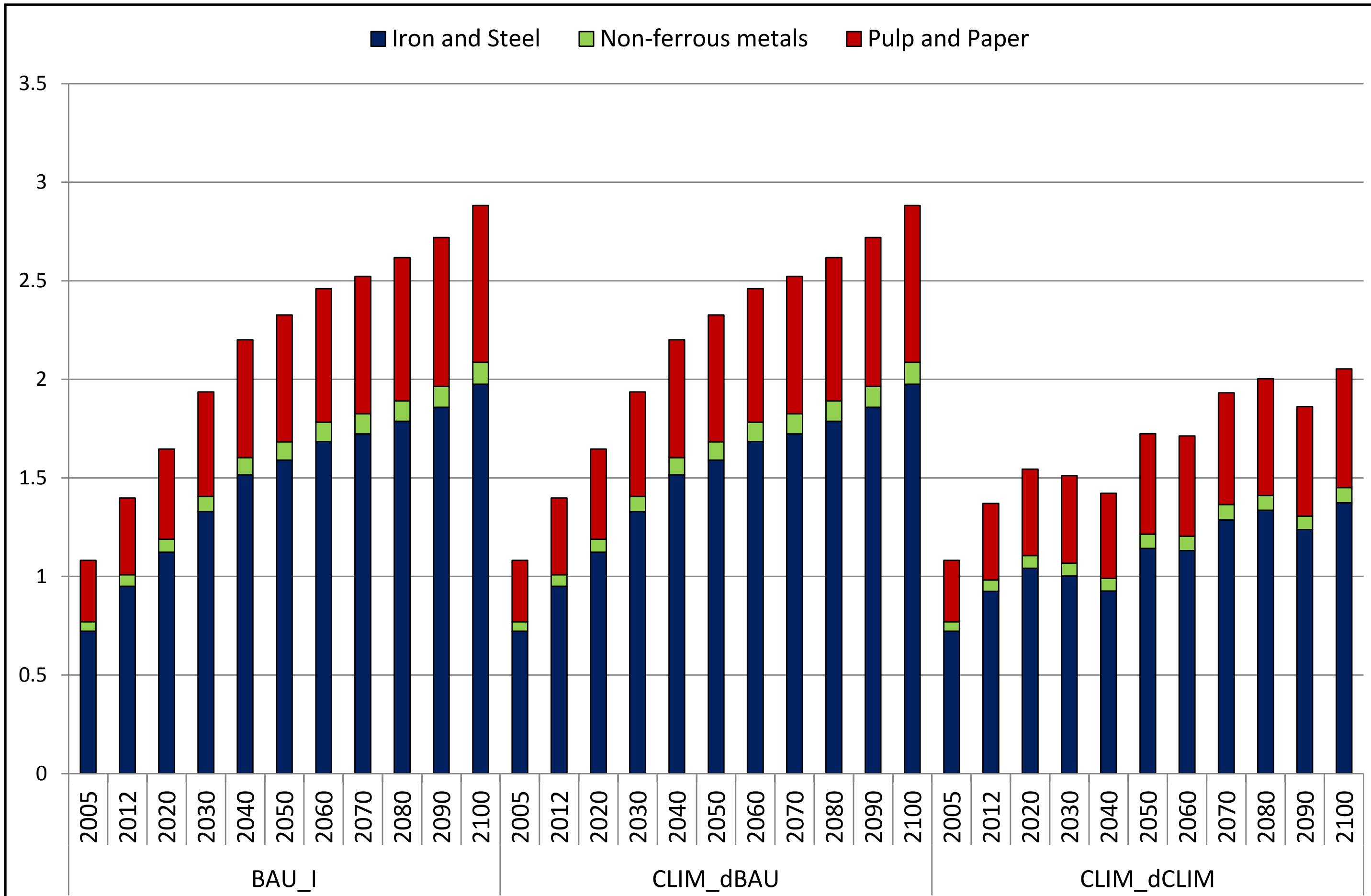
Demands for energy services in transport sector (excl. road transportation) (EJ)

Energy services demands



Demands for energy services in industry sector (EJ)

Energy services demands



Demands for energy services in industry sector (Mt)