Harmonizing the Bottom-up TIMES and the Top-down GEMINI-E3 Models: Characteristics of the Reference Case and Coupling Methodology

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Objectives

Rationale of the coupling

Briefly characterize the base case scenario

Describe the TIMES-GEMINI coupling methodology

Present preliminary results of the coupling

Rationale of coupling TD/BU models

To take advantage from both types of models

TD

- Explicit representation of the main aspects of the economy and their interactions
- Generally fail to precisely depict the evolution of substitution among technologies or the actual energy uses

BU

- Focus on detailed technology representation of the energy system ⇒ Provide detailed analysis of technology options
- In TIMES, demands for energy services are elastic to their own prices ⇒ capture the impact of rising energy prices on economic output
- But does not represent all the complex market interactions or macro-economic variables such as wages, consumption, and interest rates

Rationale of coupling TD/BU models

TOCSIN objective:

To provide a **detailed description of the available energy/technology options** that might significantly reduce GHG emissions in China and India and their **relative costs** in comparison with EU and other OECD members.

- TD model: economy global cost.
- BU model: detailed technology costs.

➡ Creating a hybrid model

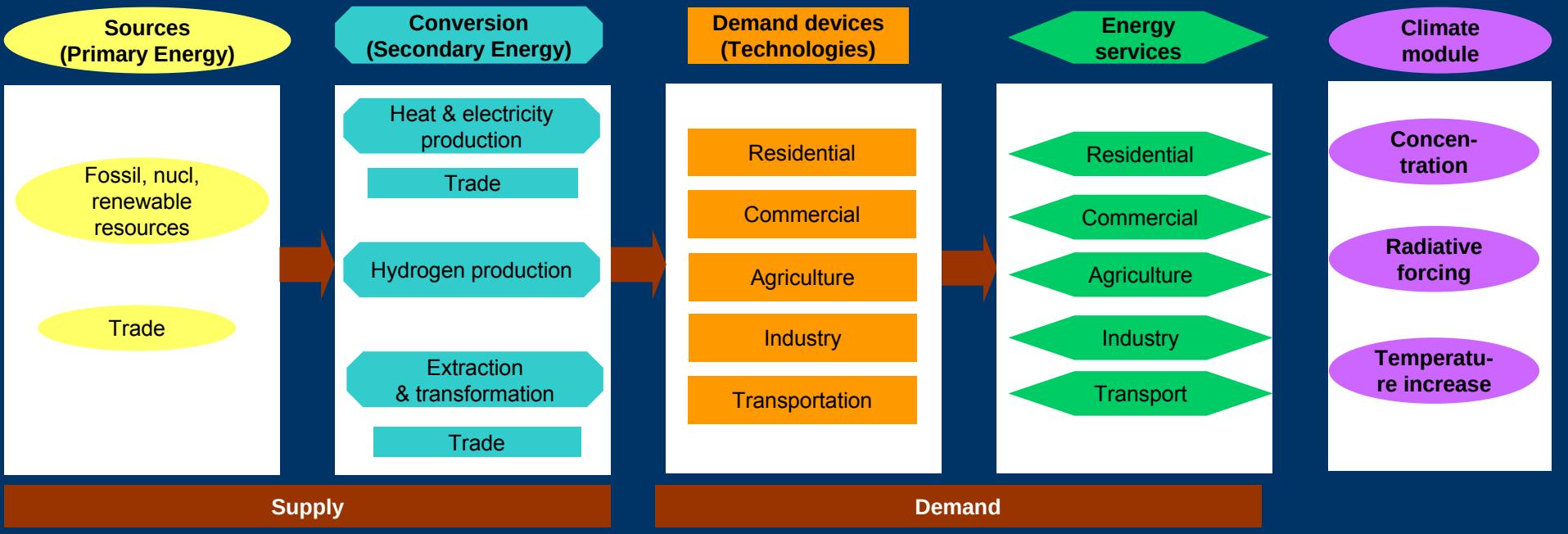
Coupling bottom-up and top-down models: existing experiences

1. ***Calibrating TD model with BU model***
   - Electricity sector: Pizer et al. (2003)
   - Transport sector: Schäfer and Jacoby (2005, 2006)
2. ***Integrating BU specifications in a TD model***
   - MARKAL-MACRO: Manne and Wene (1992)
   - MERGE: Manne et al. (1995)
   - Electricity sector: Wing (2006)
3. ***Coupling TD & BU models***
   - US models: Hoffman (1977)
   - Housing sector: Drouet et al. (2005)
   - Decomposition: Böhringer and Rutherford (2006)

TIAM-GEMINI coupling: ETSAP-TIAM

TIMES-Integrated-Assessment Model

- Technology rich, integrated energy/emissions model
- Dynamic inter-temporal partial equilibrium, 2005-2100
- Based on maximum total surplus (LP) with own price elastic service demands
- 15 regions linked by ~10 commodity trades
- Driven by end-use demands (eg. tons aluminium, km driven by cars, etc.)



TIAM-GEMINI coupling: GEMINI-E3

GEMINI-E3 version 5

- Computable General Equilibrium Model
- Total price flexibility, detailed representation of indirect taxation
- Welfare cost of policies and components
- 2005 Base year SAM calibrated with GTAP-6 data and with IEA, OECD and IMF information
- 28 regions linked by an international trade market

Sectors		Primary Factors
Energy	**Non-Energy**	Labour
Coal	Agriculture	Capital
Crude Oil	Forestry	Energy
Natural Gas	Mineral Product	Fixed factors
Refined Petroleum	Chemical Rubber Plastic	Others inputs
Electricity	Metal and Metal Products	
	Paper Products Publishing	
	Transport n.e.c.	
	Sea Transport	
	Air Transport	
	Consuming Goods	
	Equipment Goods	
	Services	
	Dwellings	

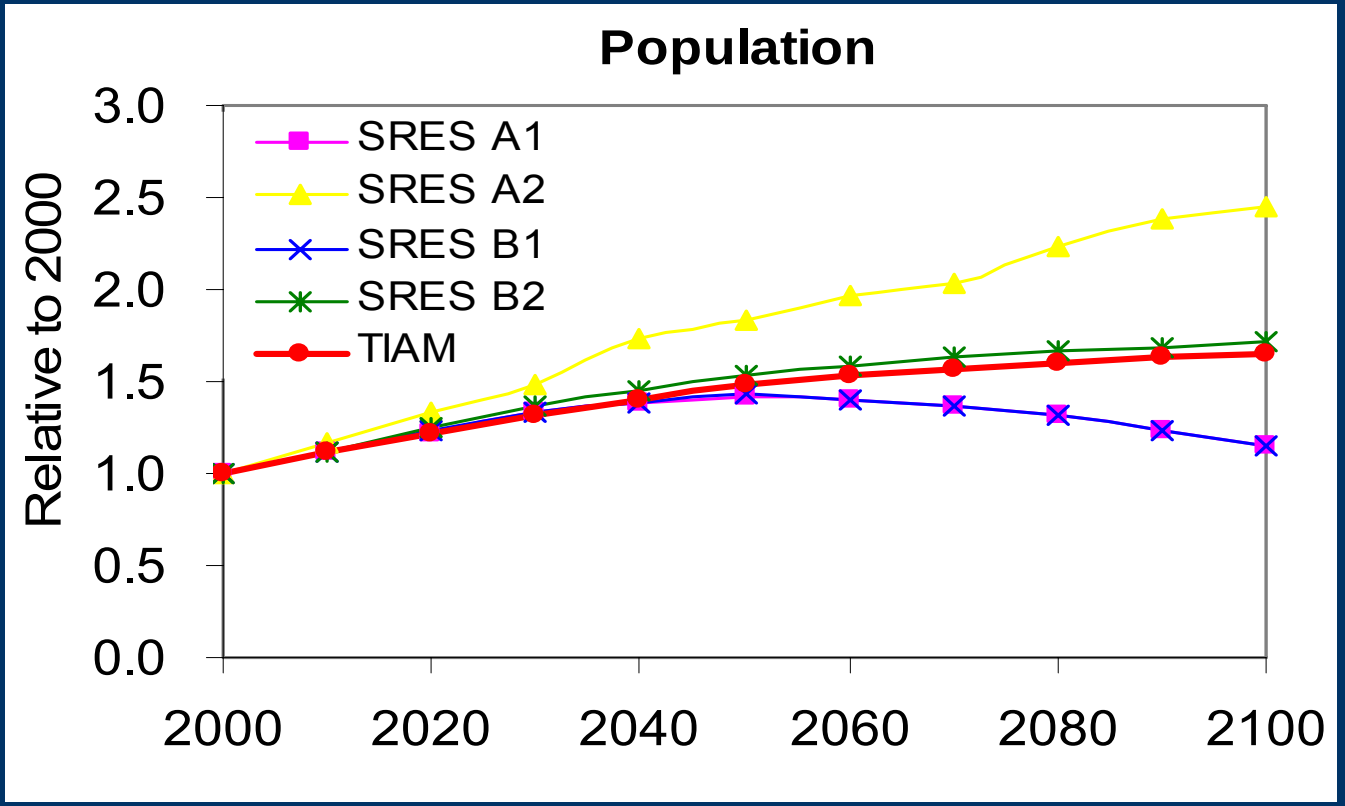
Characteristics of the base case scenario

POPULATION:

World UN median scenario : 6.1 billions in 2000, 9.1 in 2050, 10 in 2100

China: stabilized to 1.5 billions from 2050

India: 1.6 billions in 2050, 1.7 in 2100

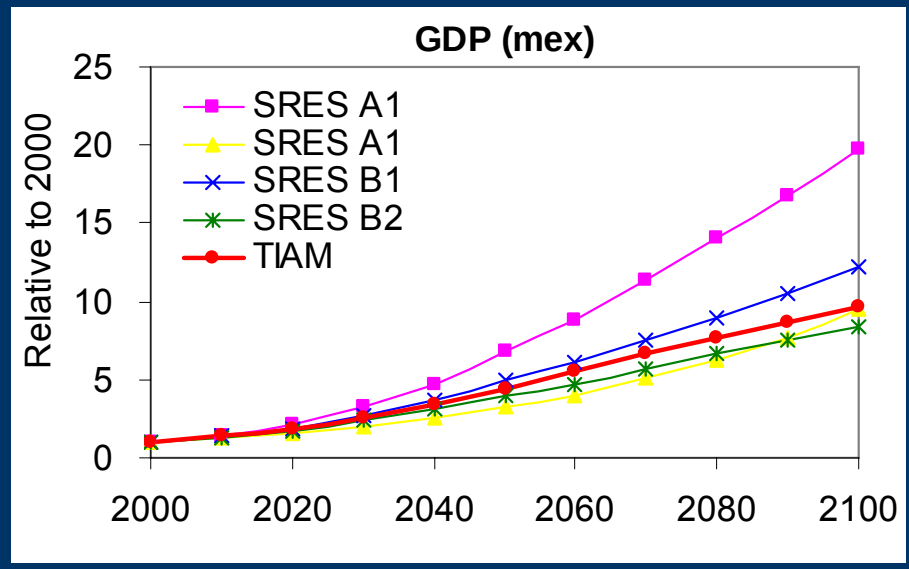


Characteristics of the base case scenario

GDP

World GDP increases by a factor 10 between 2000 and 2100 (1.8% annual)

Between SRES B1 and B2 (intermediate to high levels of economic development)



China: GDP per capita approx 16 000$ in 2050 and 47 000$ in 2100

India: GDP per capita approx 7 000$ in 2050 and 19 000$ in 2100

Sources: Project's partners, US-DOE, IEA

GDP annual growth	2005	2010	2020	2030	2050	2070	2100
Africa	5.0%	4.5%	4.0%	3.7%	3.4%	3.0%	2.4%
Australia - New Zeland	2.6%	2.3%	2.2%	2.0%	1.4%	1.3%	1.4%
Canada	2.6%	2.3%	2.0%	1.3%	1.1%	1.2%	1.4%
China	**11.8%**	**9.0%**	**6.0%**	**6.0%**	**4.0%**	**2.9%**	**2.2%**
Central and South Amer	4.1%	3.6%	3.3%	3.4%	3.3%	2.8%	2.3%
Eastern Europe	2.4%	2.1%	2.0%	2.0%	1.8%	1.4%	1.4%
Former Soviet Union	6.3%	4.7%	3.3%	3.0%	2.5%	1.9%	1.5%
India	**6.7%**	**8.0%**	**8.0%**	**7.3%**	**3.9%**	**2.8%**	**2.1%**
Japan	2.0%	1.7%	1.2%	1.0%	1.2%	1.3%	1.4%
Middle East	5.4%	4.8%	3.8%	3.6%	3.0%	2.7%	2.4%
Mexico	3.7%	3.3%	3.9%	4.0%	3.4%	2.8%	2.2%
Other Developing Asia	4.9%	4.1%	3.6%	3.3%	2.7%	2.4%	2.2%
South Korea	3.0%	2.7%	2.2%	1.8%	1.7%	1.6%	1.5%
USA	3.3%	3.0%	2.9%	2.6%	1.6%	1.4%	1.4%
Western Europe	2.3%	2.0%	2.0%	2.0%	1.6%	1.4%	1.4%

Characteristics of the base case scenario

Other characteristics

Oil price between the Reference and High scenarios of the US-DOE and of the IEA: 65 $/bbl in 2030, 87 $/bbl in 2050 (oil market controlled by OPEC)

Gas price close to the Reference IEA scenario: around 7 $/GJ in 2030, 9 $/GJ in 2050

Decoupling of the demands to the drivers due to exogenous energy efficiency improvements, dematerialization of the economy, saturation effects when the economy reached a certain level of development

Initial year (2005) calibrated to the statistics of the International Energy Agency, adjusted by the CHI and IND partners

TIAM-GEMINI coupling: proposed methodology

Changes in the models

GEMINI-E3:

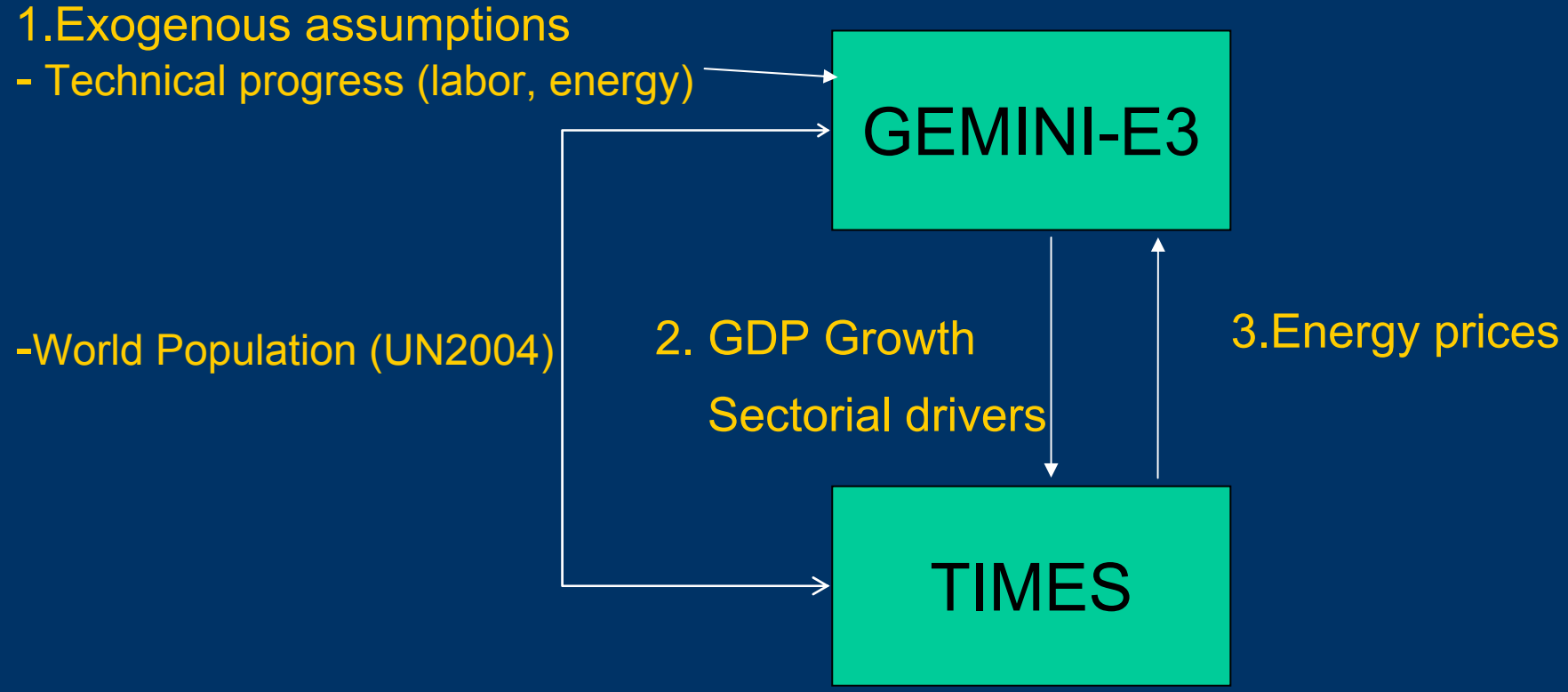
- Integration of fuel mixes:
  - The CES functions become Leontieff functions
  - Energy consumption (tep) are converted in monetary equivalent
- Technical progress as input
- Re-calibration of the CES functions
- Household sector represented as a CES function

ETSAP-TIAM:

- Re-calibration of end-use demands
- Extraction and aggreggation of data

TIAM-GEMINI coupling: proposed methodology

Phase 1: Harmonizing common baselines

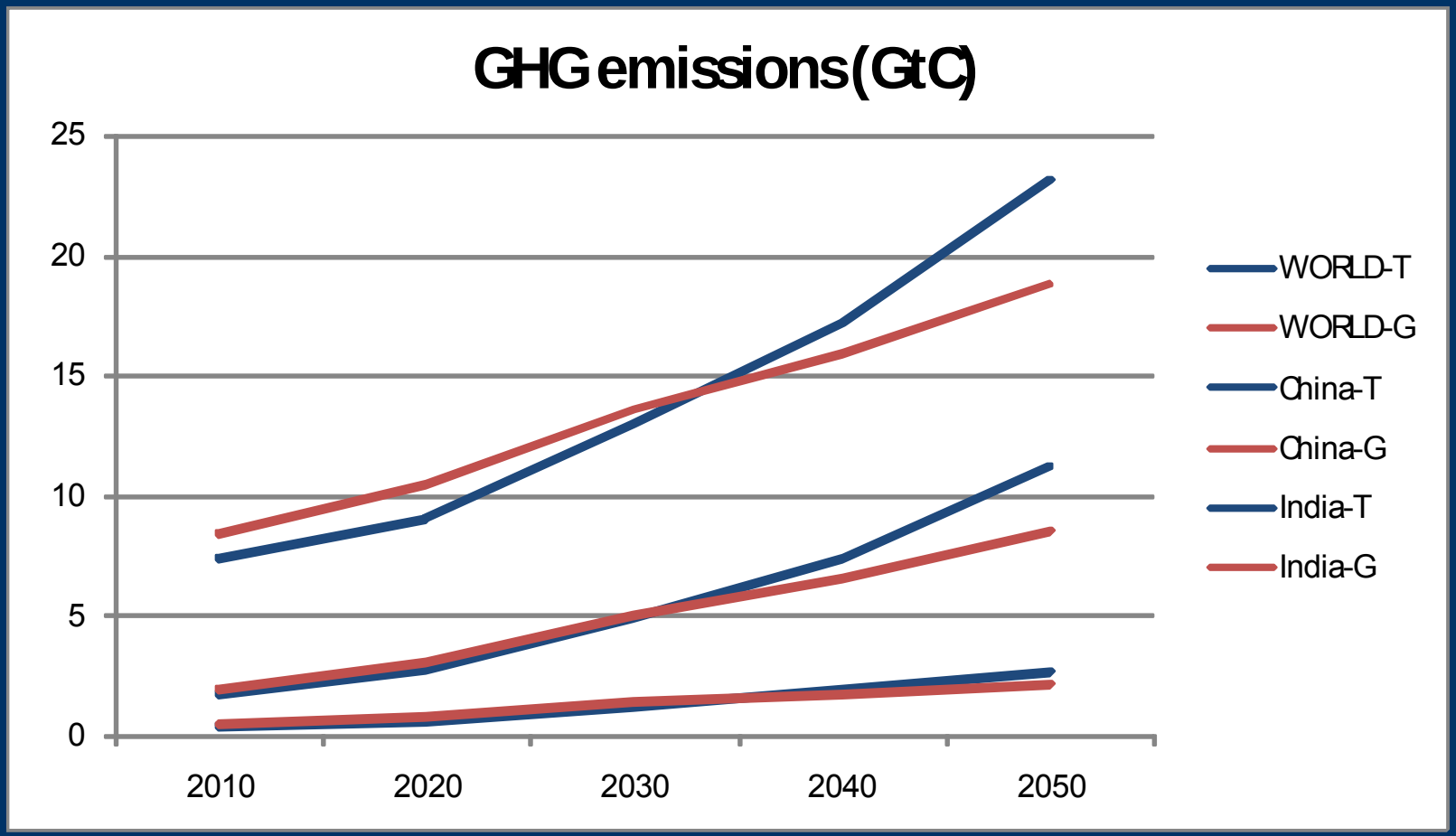


and iterate until convergence

TIAM-GEMINI coupling: proposed methodology

Phase 2: data comparison

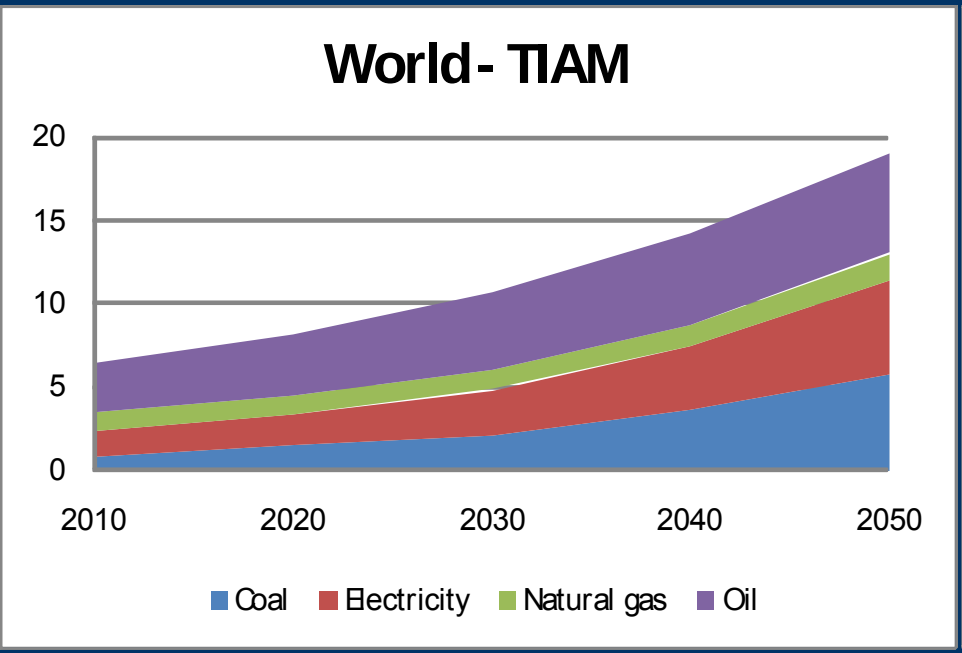
- GHGs emissions

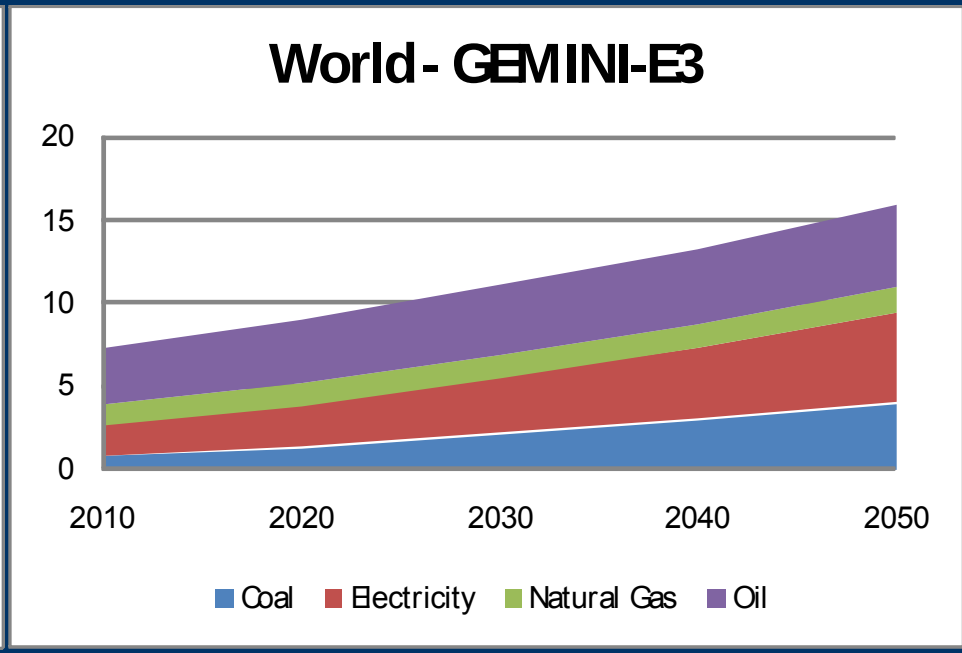


TIAM-GEMINI coupling: proposed methodology

Phase 2: data comparison

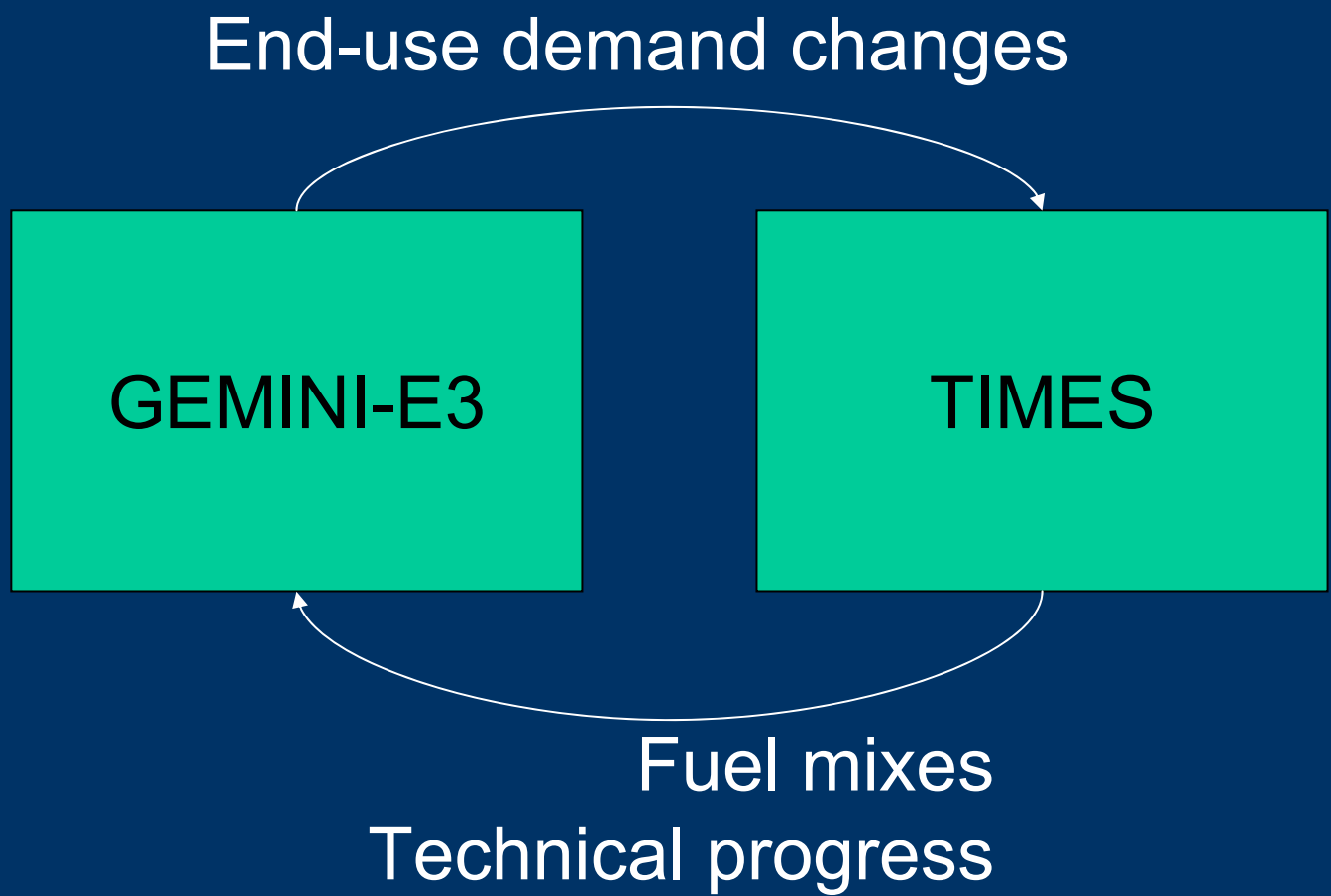
- Energy final demands (Gtep)





TIAM-GEMINI coupling: proposed methodology

Phase 3: coupling the models and assessing policies



TIAM-GEMINI coupling: proposed methodology

Algorithm

D: End-use demands (over regions, sectors, periods)

F: Fuel mixes (over regions, sectors, commodities, periods)

Θ: Technical progress (over regions, sectors, periods)

1. $k=0$
2. Set D_0
3. $\Theta_k, F_k \leftarrow T(D_k)$
4. $D_{k+1} \leftarrow G(F_k, \Theta_k)$
5. If $norm(D_k, D_{k+1})<\varepsilon$ then stop else $k = k + 1$ and go to 3.

TIAM-GEMINI coupling: expected results

Evaluate the technology portfolio, the macro-economic impacts, and the financial transfers, in reaching specific climate target within specific cooperation contexts

Partial example - only TIAM modeling:
Constant 100$/tCO2eq (“low” tax: long-term conc. is around 600 ppm !)
China and India represent around 70% of the reductions in 2050