Linking TIAM-ECN and E3ME:
Analysis of the energy system and economy in Latin America

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Outline

1. Rationale
2. Brief model description (E3ME and TIAM-ECN)
3. Steps to link the two models

Rationale

- Energy system costs are not representative of whole economy impacts
  - Distribution and timing of impacts matters
- Downstream: energy system costs are absorbed differently by different consumers
  - E.g. demand response
  - Trade flows
- Upstream: energy system 'suppliers' (capital, fuel, etc.) have differing economic characteristics with implications for macroeconomic impacts
- Technology diffusion/transfer
  - Innovation can be cross sectoral (e.g. batteries)

E3 interactions within E3ME
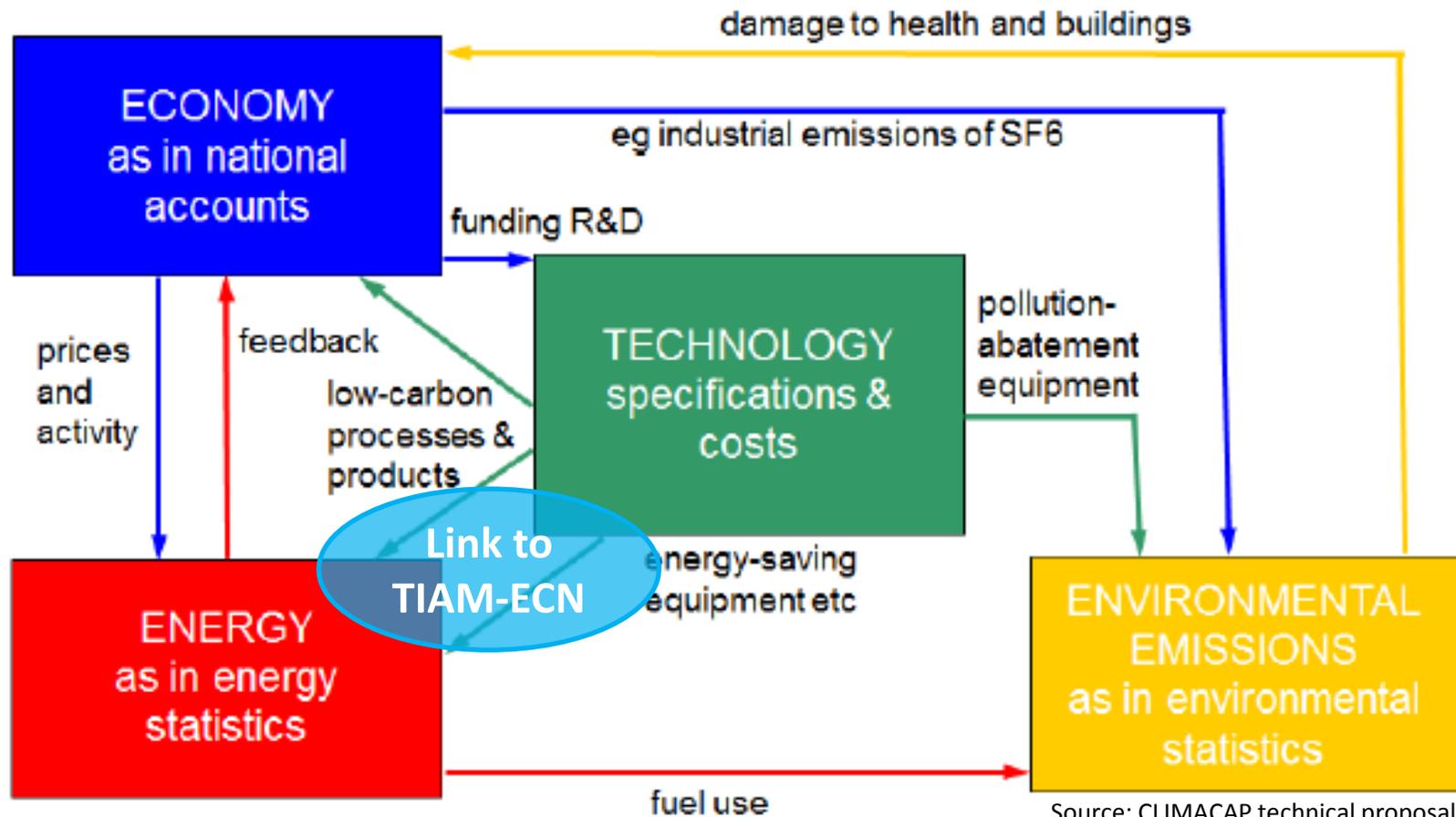
Source: CLIMACAP technical proposal

E3ME – global version

Detailed Coverage

- 33 European regions + 15 world regions
- 69/43 economic sectors and 43/28 consumption categories
- 22 fuel users of 12 fuels

Comprehensive

- whole energy, environment (including material) and economy system
- two ways feedbacks between each module
- many policy instruments

Highly Empirical

- 1970-2010 database
- 33 stochastic equations
- no prior assumptions*
- econometrics specification allows for short-medium and long term analysis

Consistent

- based on system of national accounting
- input-output tables
- bilateral trade*

Forward Looking

- annual projections to 2050
- behavioural equations with effects from previous outcomes
- ex-ante scenario analysis (ex-post is also feasible)

Modular

- E3: Energy, Environment (inc. material) and Economy modules
- power generation sub-module
- research can be decentralised

E3ME vs. CGE models

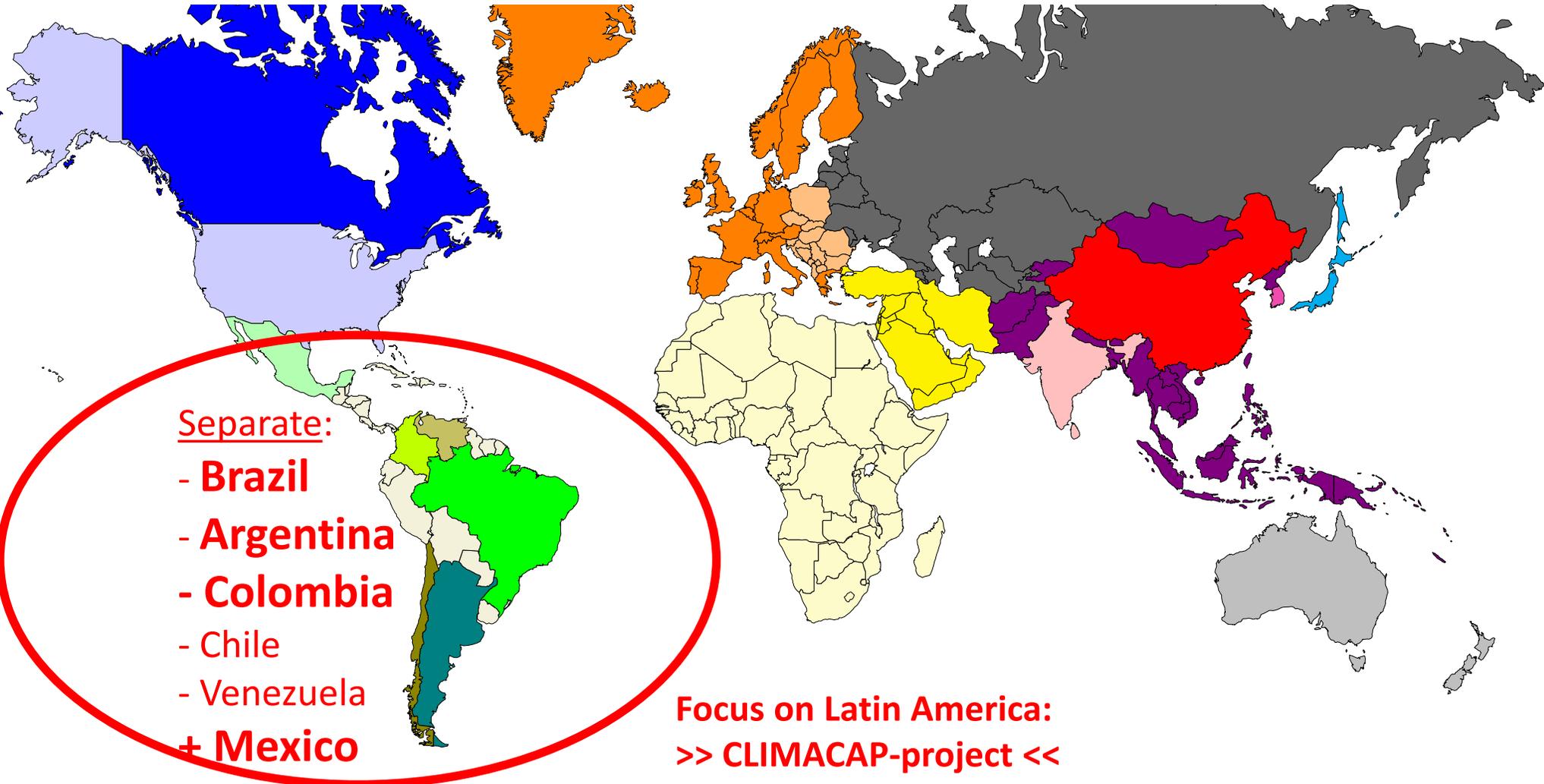| Features	Econometrics	CGE
Demand and Supply	• demand driven, D&S imbalances • non-optimal behaviour/outcomes • partial adjustment • adjustment to extent of empirical experiences	• D&S match and market clear • optimisation • full adjustment via prices • happening in all markets hence 'general' equilibrium
- prices and wages	• product prices reflect historical relationship and not set so that D&S match • restrictions on parameters • spare production capacity allowed • producers price depending on various explanatory factors including level competition	• product prices are set so that D&S matched • price adjustment given by a set of elasticities • all production capacity used • producers charging price that will optimise profit
- saving and investment	• allows for unproductive (non-optimal) capital available which may be used for new investment • no need to reduce investment or increase savings elsewhere when introduce new investment	• constraint on investment based on availability of savings • crowding out effects

E3ME vs. CGE models

Features	Econometrics	CGE
Parameterisation	• parameters estimated from time series historical data • Econometric estimation method seeks to isolate the effects of one model variable on another	• key parameters values taken from economic literatures and previous studies • other parameters calibrated for consistencies
Labour market	• wages do not automatically adjust – wage stickiness • allow for involuntary unemployment	• wages adjusted automatically so that labour supply and demand match • not possible to have involuntary unemployment • however some CGE models allow for unemployment due to labour market frictions
Long and short-term impacts	• Econometrics specifications allow for short and long-term analysis	• equilibrium unlikely to take place in the short run therefore more suitable for long-term analysis

TIAM-ECN
model characterisation

- Origin: ETSAP-TIAM (**T**IMES **I**ntegrated **A**ssessment **M**odel)
- Global, technology rich, long-term energy system model
- Economic optimisation: determination of cost optimal configuration of the system to fulfil energy services demand
- 20 world regions with trade of energy, emission certificates and captured CO_2
- Time horizon from 2005 to 2100 (mainly 10-year intervalls, and 6 time slices per year)
- All energy supply and demand sectors (from resource extraction to the final end use of energy)
- Comprehensive energy technology portfolio, e.g. hydrogen and synfuel production, CCS in power, industry and upstream sector, renewables for heat and power, heat pump technologies,
- Emissions: CO_2, CH_4, N_2O

Regional coverage in TIAM-ECN

ECN

ce cambridge econometrics

Separate:
- **Brazil**

- **Argentina**

- **Colombia**

- Chile

- Venezuela

+ **Mexico**

**Focus on Latin America:
>> CLIMACAP-project <<**

Step-wise model linkage

1. **Complementary analysis**
   – Baseline & climate policy (CP)

2. **Performing integrated analysis**
   – two-way soft link with different scenarios
   – new demand scenarios
   – developing new sets of parameters (demand elasticities)
   – Climate policy with recycling of carbon tax revenues

Complementary analysis

- Initial data harmonisation
  - Energy prices, initial demand, population
- Using TIAM-ECN model outputs as input to E3ME
  - Energy supply structure (capacities or <u>investments</u>)
  - Final energy consumption per sector / subsector
  - Energy trade (emissions certificate trade)
  - **Challenge: procedure to transform aggregated data on industry into disaggregated input for E3ME**
- Response/results from E3ME about macro-economic impacts
  - GDP effects
    - Trade, consumption, investment
  - Employment / unemployment
  - Income, wages and prices
  - Sector output

Scenarios

Group	Scenario name	Description
Base	Core Baseline (CBS)	No policy promoting climate change mitigation
	Policy Baseline (PBS)	Copenhagen/Cancun pledges
GHG reduction & price paths	Low CO_2 price path	10 $/tCO$_2$e in 2020 and + 4% p.a. afterwards
	High CO_2 price path	50 $/tCO$_2$e in 2020 and + 4% p.a. afterwards
	Weak GHG target	-5% in 2020 comp. to 2010, -20% in 2050
	Ambitious GHG target	-10% in 2020 comp. to 2010, -40% in 2050
Radiative forcing	4.5 W/m^2	to be reached by 2100; targets refers to all anthropogenic forcing not including direct forcing from land use albedo changes, mineral dust, and nitrate aerosols (A3NA)
	3.7 W/m^2	
	2.6 W/m^2	

Integrated analysis

- **E3ME delivers insights into demand response**
  - Different demand scenarios
  - Update of demand elasticity factors for TIAM-ECN (long-term option)
  - Iterations necessary(?)

- **Recycling of carbon tax revenues**
  - Carbon prices are used representatively in energy system models
  - If assumed revenue is recycled into economy, how does this offset the impact?
  - Demand response?
  - Technology-specific subsidy: NCAP_ISUB
  - Consumer-specific: COM_SUBPRD

Conclusions

- Linkage to assess economic impacts of climate change mitigation policy in Latin America, incl. employment / unemployment effects

- Pathway for economic deployment in near-term from E3ME

- 2 step approach for model linkage

- Challenges:
  - Approach to transform data of different levels of sectoral aggregation

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Thank you!

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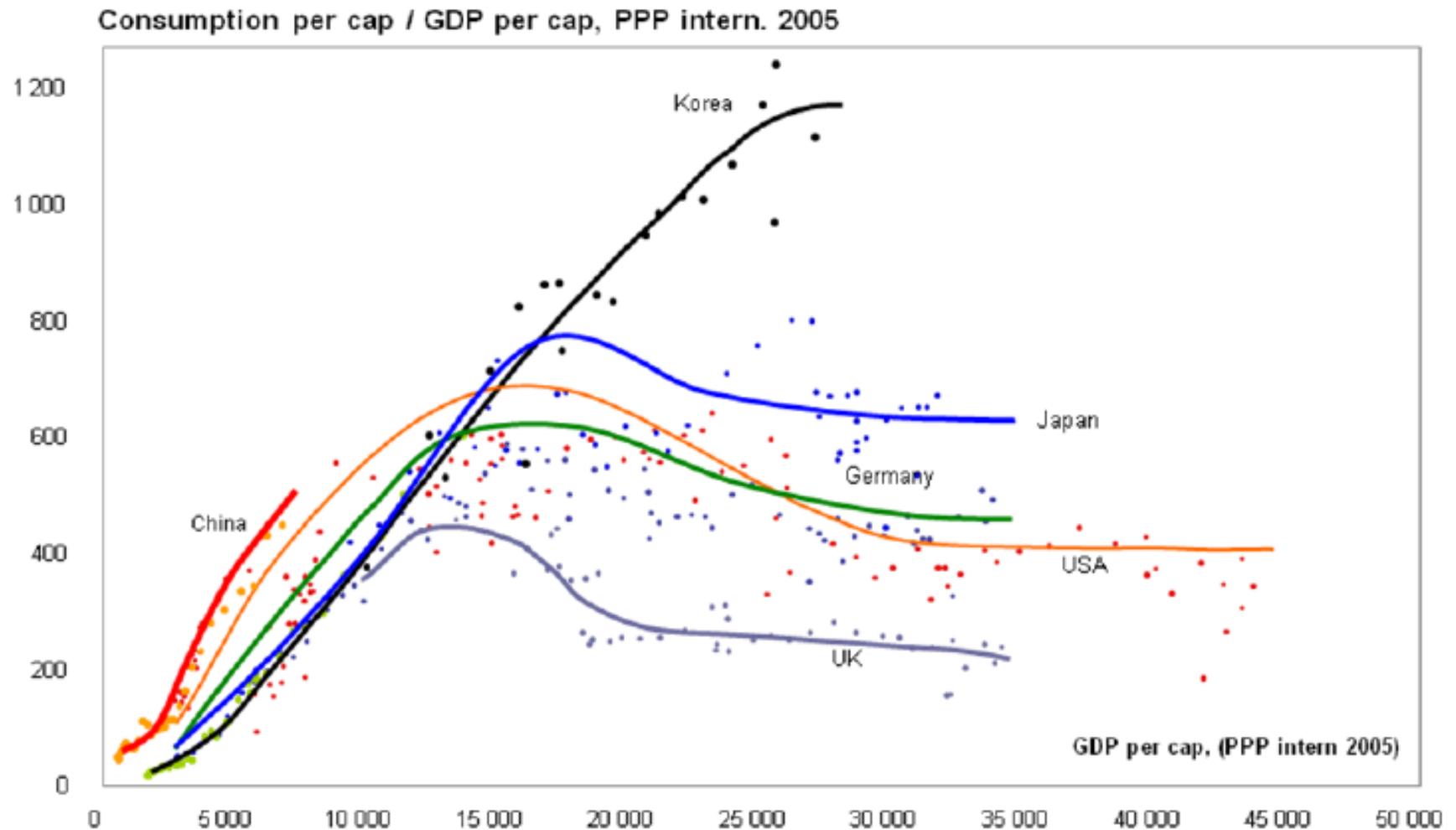
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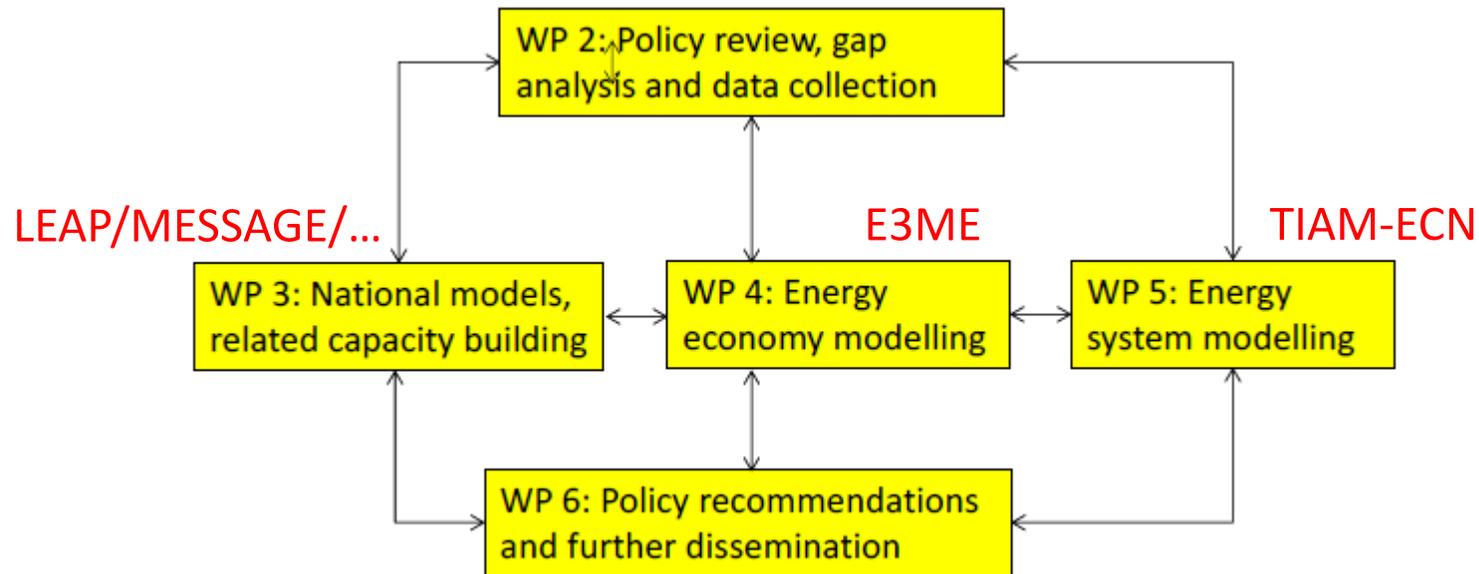Reuben House, Covent Garden, Cambridge, CB1 2HT, UK

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Decoupling of demand and drivers

Consumption per cap / GDP per cap, PPP intern. 2005

Source : WorldSteel, Worldbank, Laplace Conseil analysis

● Back-up

Model interaction in CLIMACAP project

Possible model parameters to be exchanged/harmonised

- End use demand & elasticities (E3MG $\rightarrow$ TIAM-ECN)
- Electricity capacity (E3MG $\leftarrow\rightarrow$ TIAM-ECN)
- Emissions CO_2 (E3MG $\leftarrow\rightarrow$ TIAM-ECN)
- Emissions CH_4, N_2O (TIAM-ECN $\rightarrow$ E3MG)
- Final energy consumption total (E3MG $\leftarrow\rightarrow$ TIAM-ECN)
- Final energy consumption sector level (TIAM-ECN $\rightarrow$ E3MG)
- Alternative Fuel production (TIAM-ECN $\rightarrow$ E3MG)
- Investment needs (TIAM-ECN $\rightarrow$ E3MG)
- Fuel and carbon certificate prices (E3MG $\leftarrow\rightarrow$ TIAM-ECN)
- Primary energy and resource use (E3MG $\leftarrow\rightarrow$ TIAM-ECN)
- Energy and carbon certificate trade (E3MG $\leftarrow\rightarrow$ TIAM-ECN)
- Energy and climate policy impact on GDP and employment (?) (E3MG $\rightarrow$ TIAM-ECN)

Integrated assessment:
The energy system approach

Source: Blesl and Remme 2008
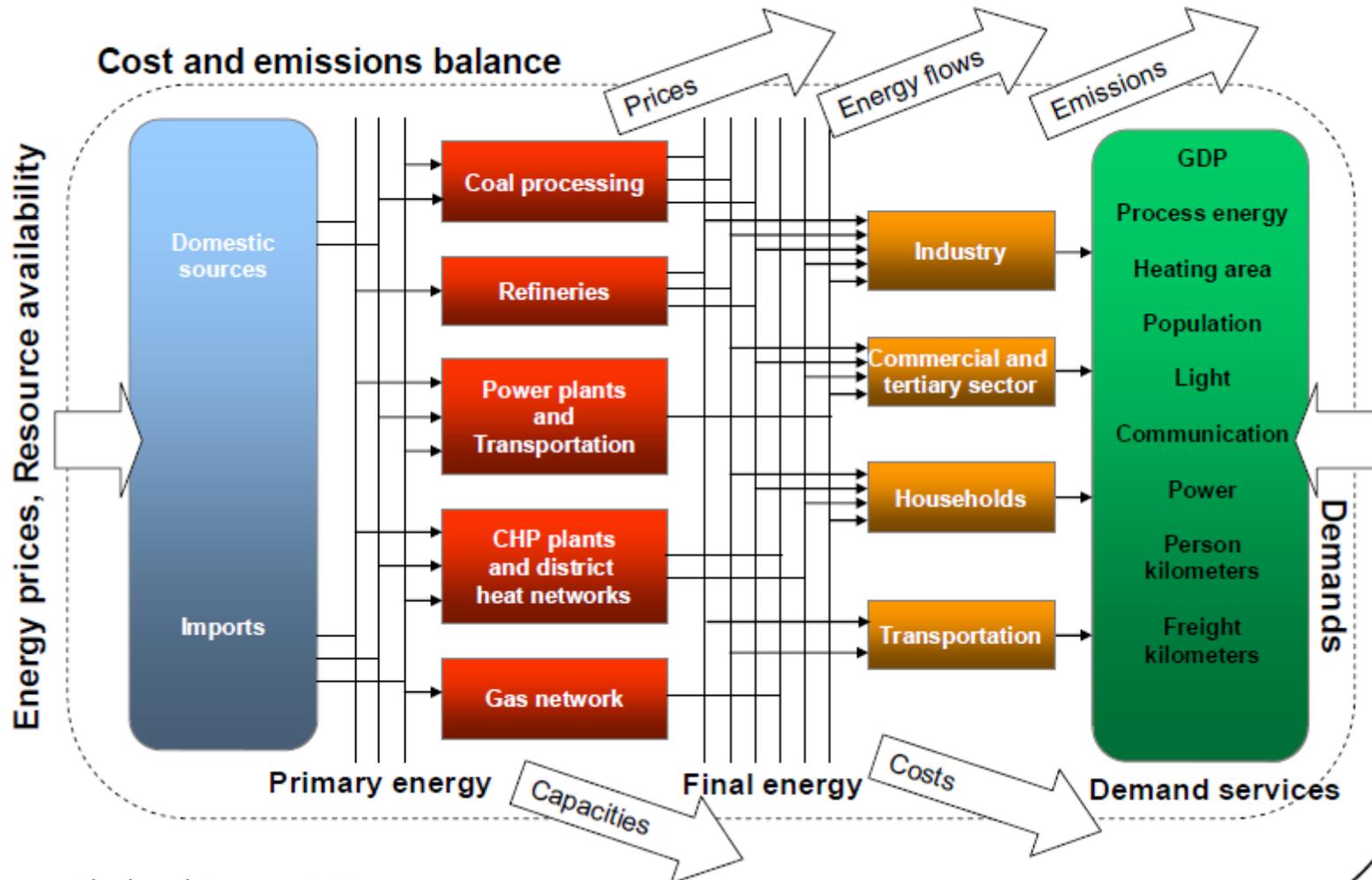
TIAM-ECN: objective function

- Linear costs optimisation model

- Costs included:
  - Investment
  - Operation and maintenance
  - Fuel costs
  - Other system costs

- Social planner view: optimises over whole time horizon, all regions and all technology pathways

- Technology-specific discount rates

TIAM-ECN: demands and drivers

- All in all some 45 demand categories in transport, agricultural, commercial, residential and industrial sectors (useful demand)
- These demands are defined for each time period as

$$\text{Demand} = K * \text{Driver}^X$$

  - K is the demand in 2000,
  - X is the region specific response to a change in the indexed driver
- Demand specific drivers are:
  - Population
  - GDP
  - GDP/household
  - Sectorial GDP
  - GDP/capita
  - Number of households
- Demand elasticities

TIAM-ECN: energy resources

- The cumulative available fossil resources are given in different types of reserves, based on:
  - Availability (located, enhanced recovery, new discovery)
  - Resource type
    - Coal: brown coal, hard coal
    - Oil: conventional, Heavy oil, oil sands, shale oil, EOR
    - Gas: conventional, shale gas, aquifer gas
  - Cost-supply steps
- For renewables potential estimates are made based on literature
  - Cost-supply steps
- Annual resources extraction constraints
- Nuclear fairly constrained

Endogenous trade in TIAM-ECN

- Trade can be defined for any commodity desired, including environmental ones
- On global level or bilaterally for chosen regions
- Uni- or bi-directional trade between regions
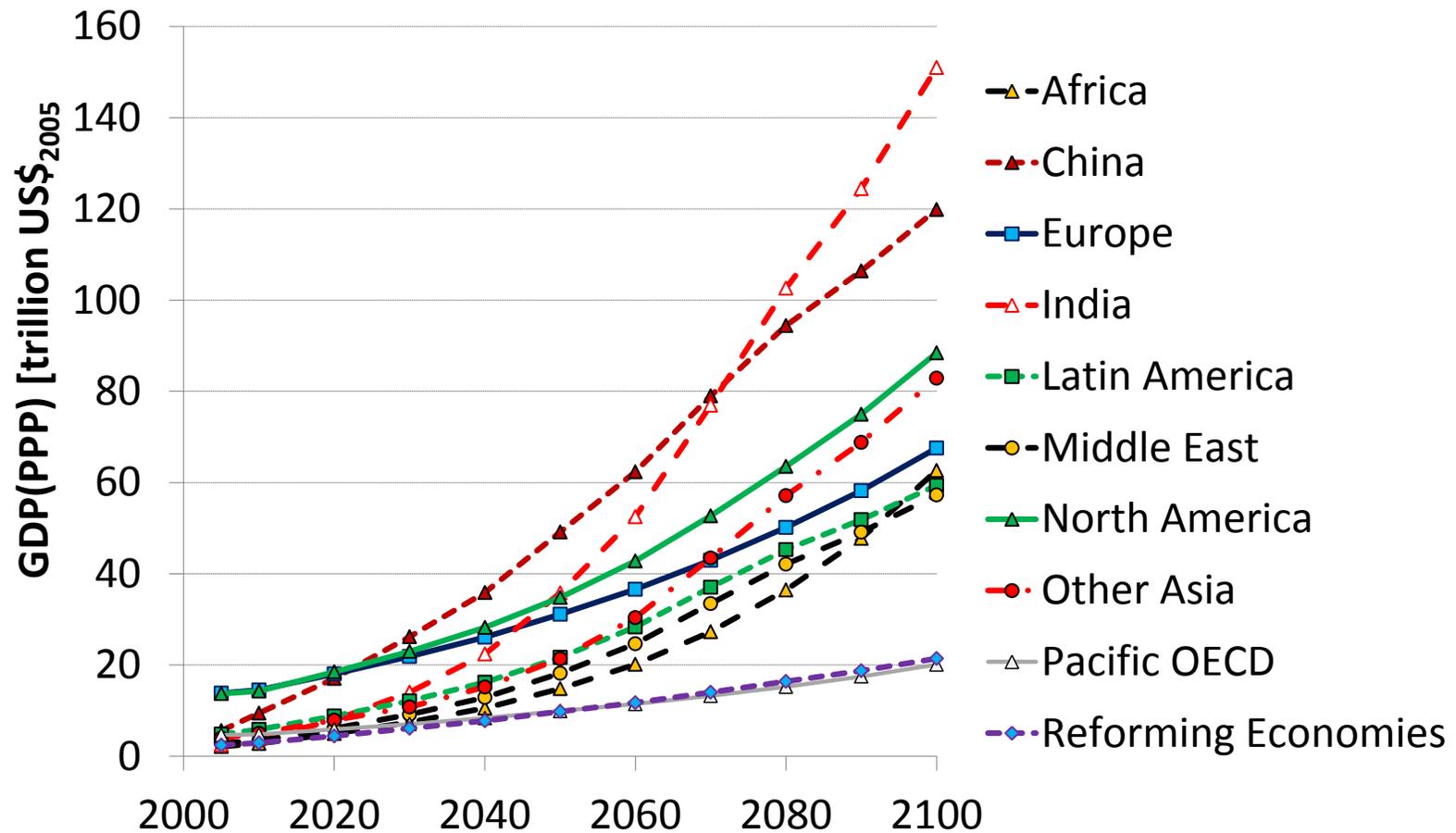- Trade costs and constraints imposed

- Traded commodities in the model:
  - Hard coal
  - Crude oil and oil products
  - Natural gas (pipeline and LNG)
  - Biomass (solid and liquid)
  - Electricity
  - Certificates for GHG emissions
  - Captured CO_2 for storage abroad

Population development
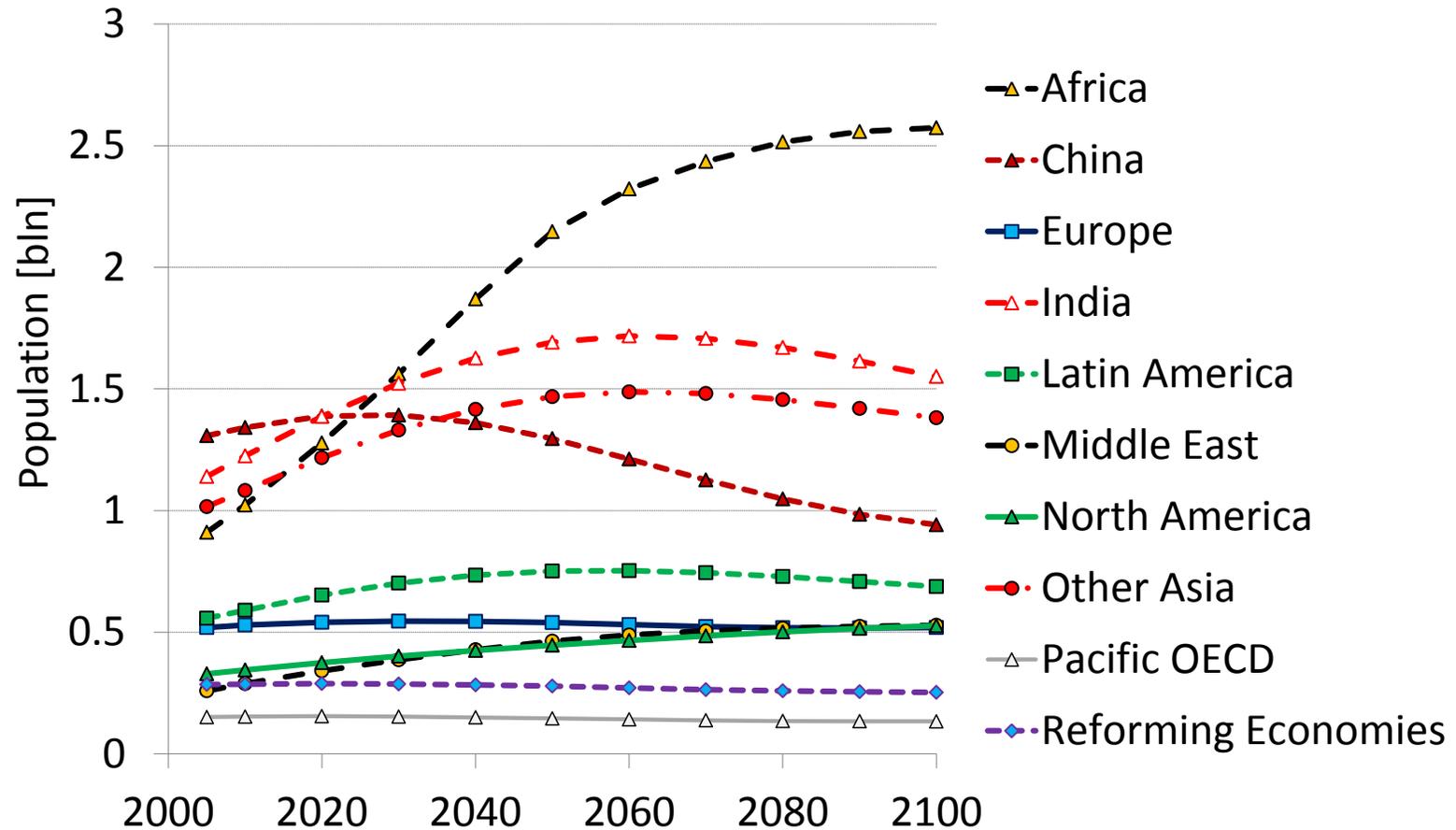
Source: UN 2011, own calculations

Development of GDP (PPP)

Source: IEA 2012, own calculations

TIAM-ECN technology Portfolio: electricity generation (excerpt)

Fuel	Technology	Particularity
Fossil fuels	Ultra-supercritical power plants IGCC, NGCC Fuel Cells	also incl. CCS
Nuclear	Generation 3+ and 4	
Biomass	Solid biomass direct combustion Solid biomass gasification Biogas engine	also incl. CCS
Geothermal	Binary / Flash / Hot Dry Rock	CHP and electricity only
Hydro	Large / small	
Wind	Onshore Offshore	incl. infrastructure investments
Solar	Photovoltaic CSP (with and w/o storage)	incl. infrastructure investments

Road transport technologies included in TIAM-ECN

Passenger cars	Trucks	Busses	Small vehicles
Diesel car	Diesel truck	Diesel bus	Diesel small vehicle
Gasoline car	Gasoline truck	Gasoline bus	Gasoline small vehicle
Ethanol car	Ethanol truck	Ethanol bus	
LPG car	LPG truck	LPG bus	
NGA car	NGA truck	NGA bus	
Electric car		Electric bus	
Plug-in hybrid car			
Hydrogen car			