



Imaclim-R: an innovative hybrid model to foster the dialog on sustainable pathways, energy policies and climate stabilization

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Outline

- Motivations
- Technical Features of the Imacsim-R model
- From sector-based expertise to global assessment
- New insights from the model

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What we would like to represent?

Consistent long-run scenarios...

- Plausible and tangible technological change pathways
- Binding physical constraints (asymptotes, technologies embodied in existing capital stock)
- Binding economic constraints (investment levels and allocation, terms of trade, final demand patterns, budget constraint)
- Explicit growth engine (partial or total catch-up, specialization, etc.)

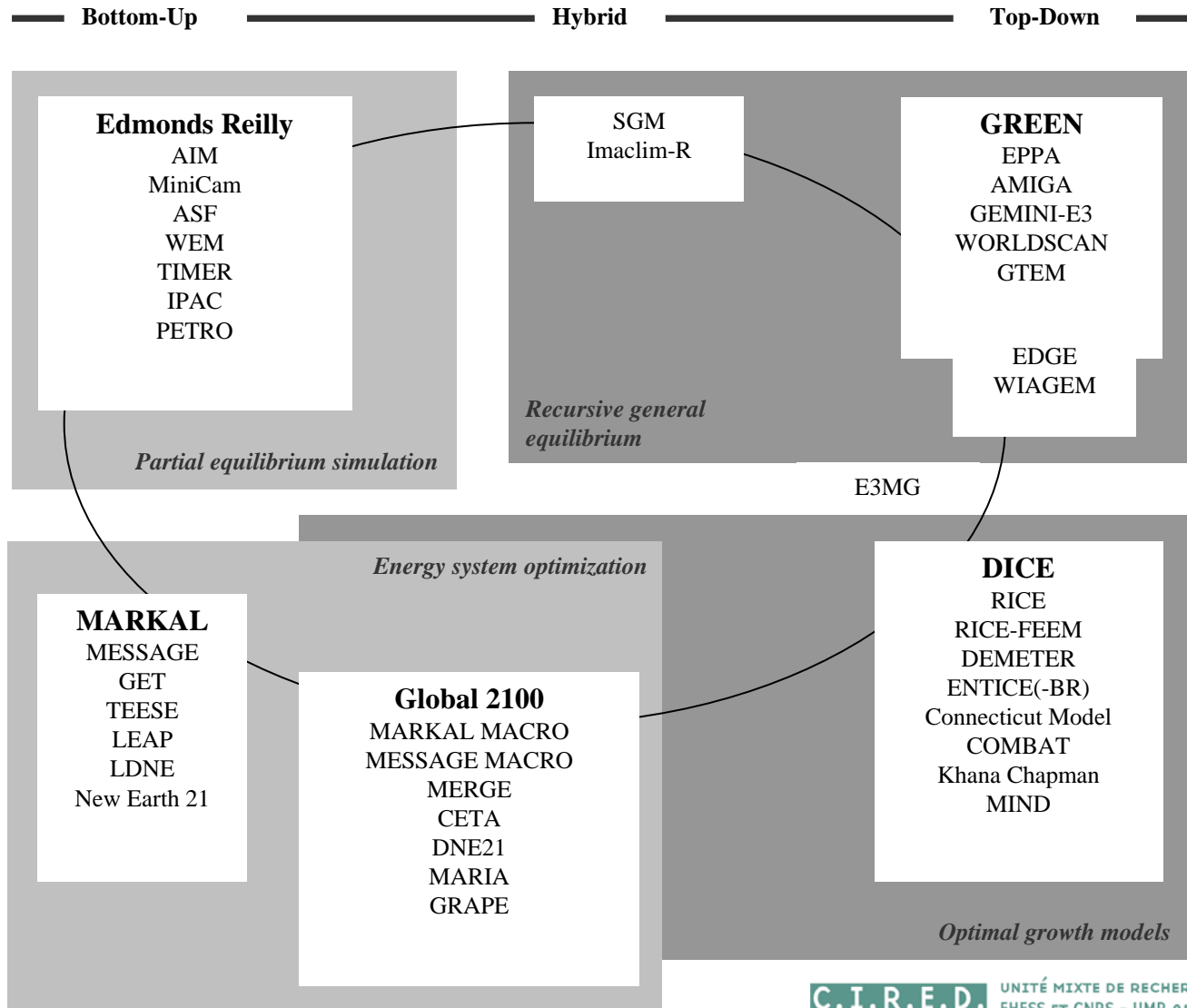
...to explore **system-wide issues**:

- Mimetic development styles against sustainability
- Food-Energy-Sequestration issue
- Competitiveness and carbon leakage
- Transferable quotas and terms of trade
- Etc.

Policy-oriented motivations

- The need to assess **which instruments** can enhance pre-identified technical potentials in a real globalized economy, at different time horizons.
- A quantitative way to feed the dialog between **experts and stakeholders** around tricky issues: What costs? Macro feedbacks? Rebound effects? Rhythm of GHG mitigation? Barriers to be removed? Design of institutions?

A few modelling paradigms since the 80's



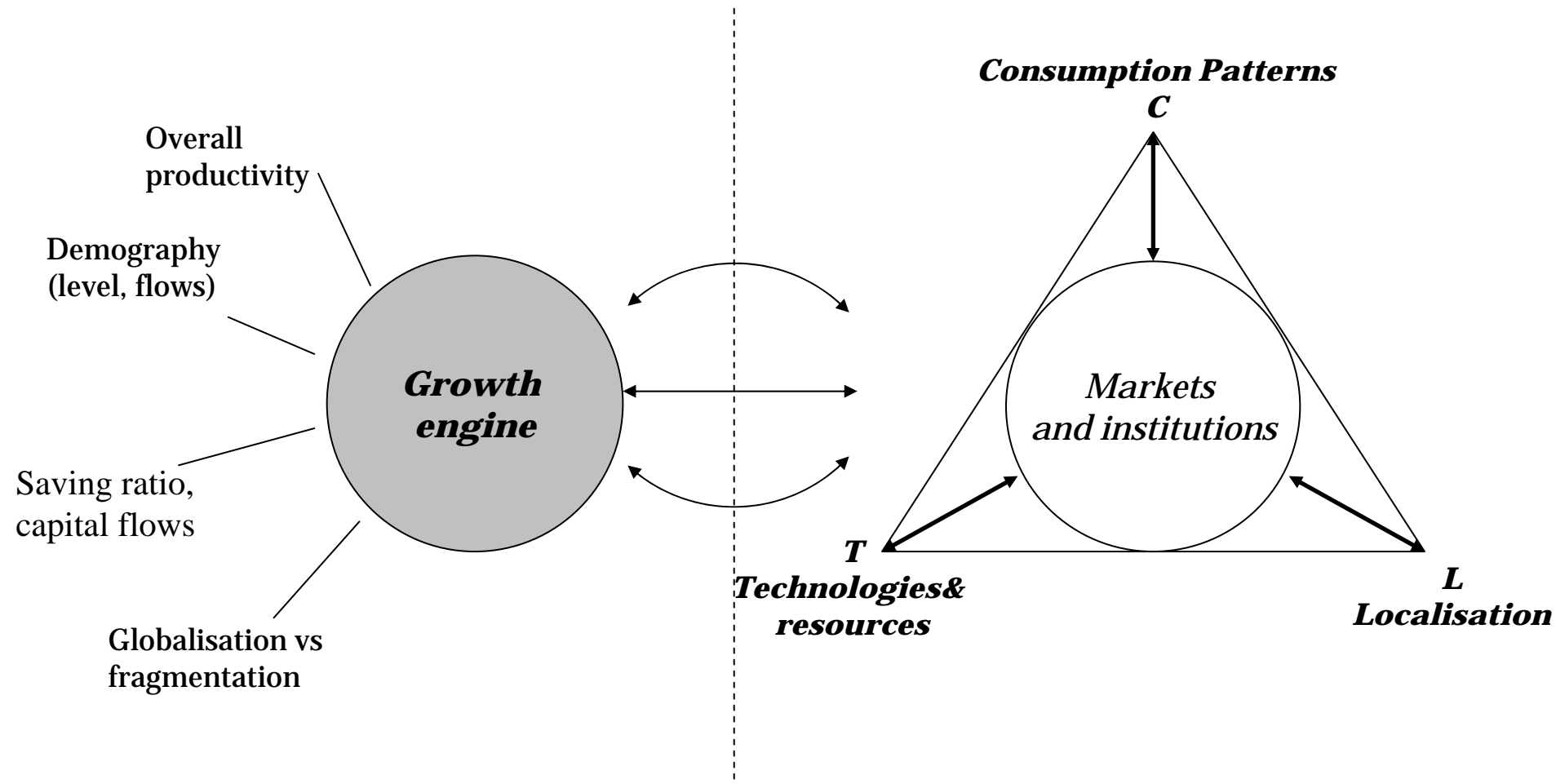
Simulation

Optimization

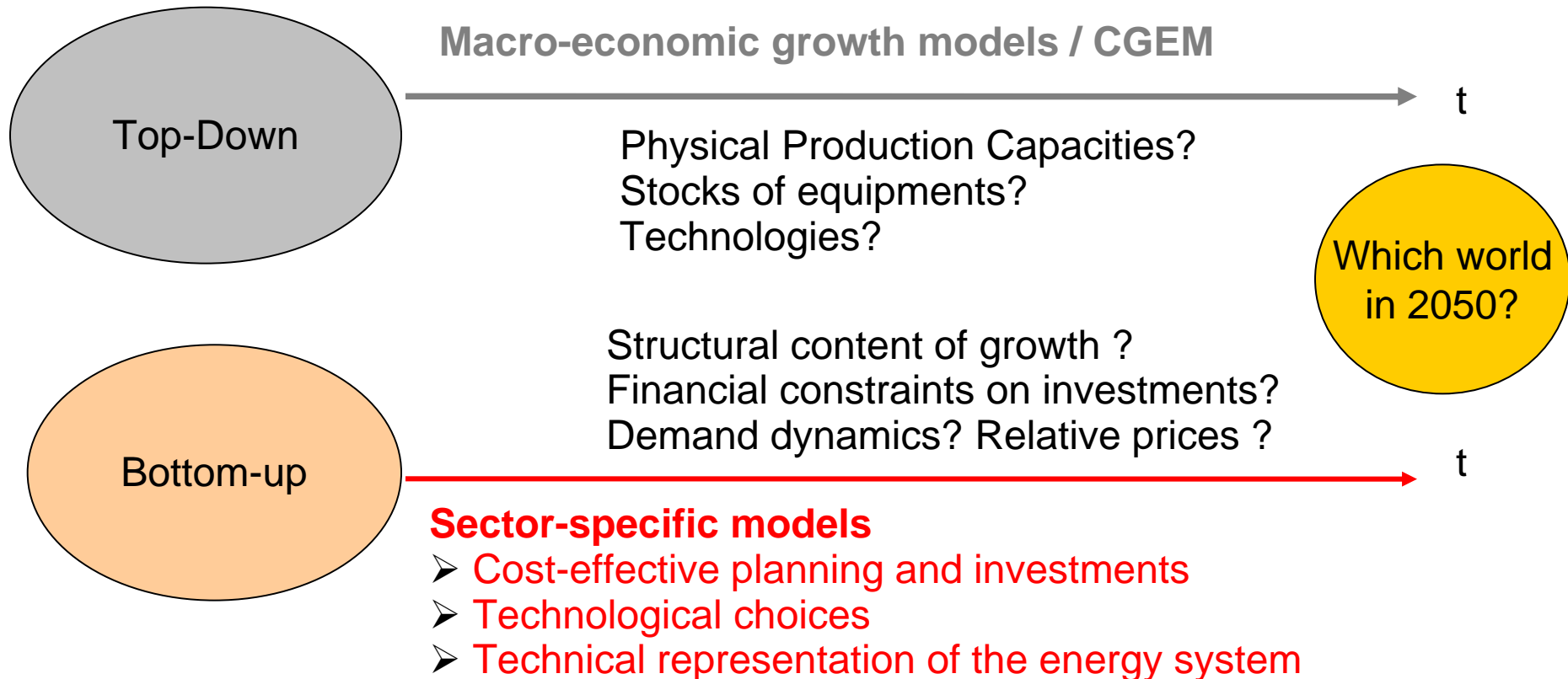
Current issues not (or rarely) addressed in the climate policy literature

- Poor representation of the growth engine: large bifurcations cannot be treated *at the margin* of baseline trajectories
- Broad spread of long run scenarios (e.g. SRES): a misunderstanding about uncertainty?
- Weak representation of medium-run dynamics: a lack of insights about the magnitude of transition costs
- Few attempts to use models of a non-perfect world with imperfect foresight and disequilibria : the idea that existing ‘barriers’ can be easily removed is not backed by quantitative assessment

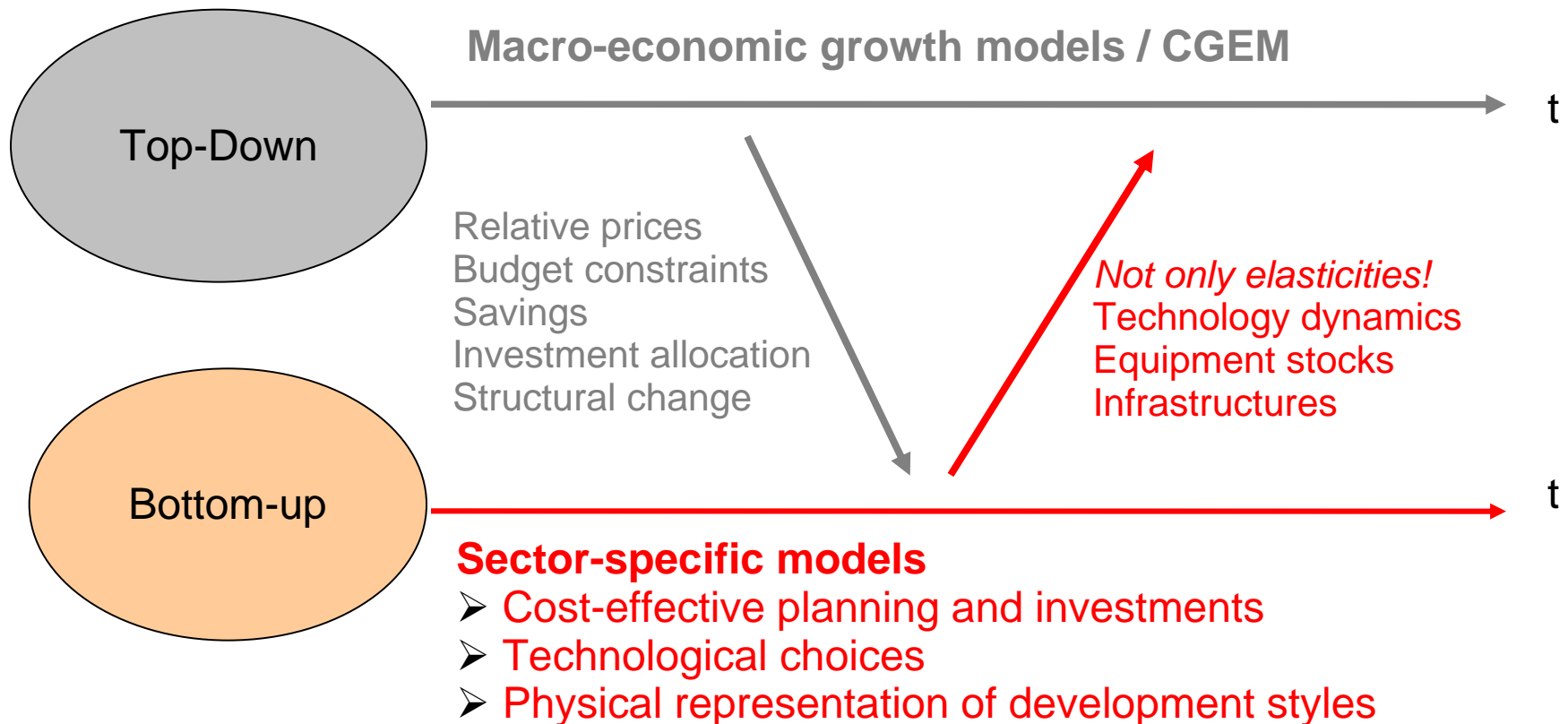
The 'C-T-L' challenge of hybrid modelling



Well-known difficulties: Linking pre-existing models always intricate...



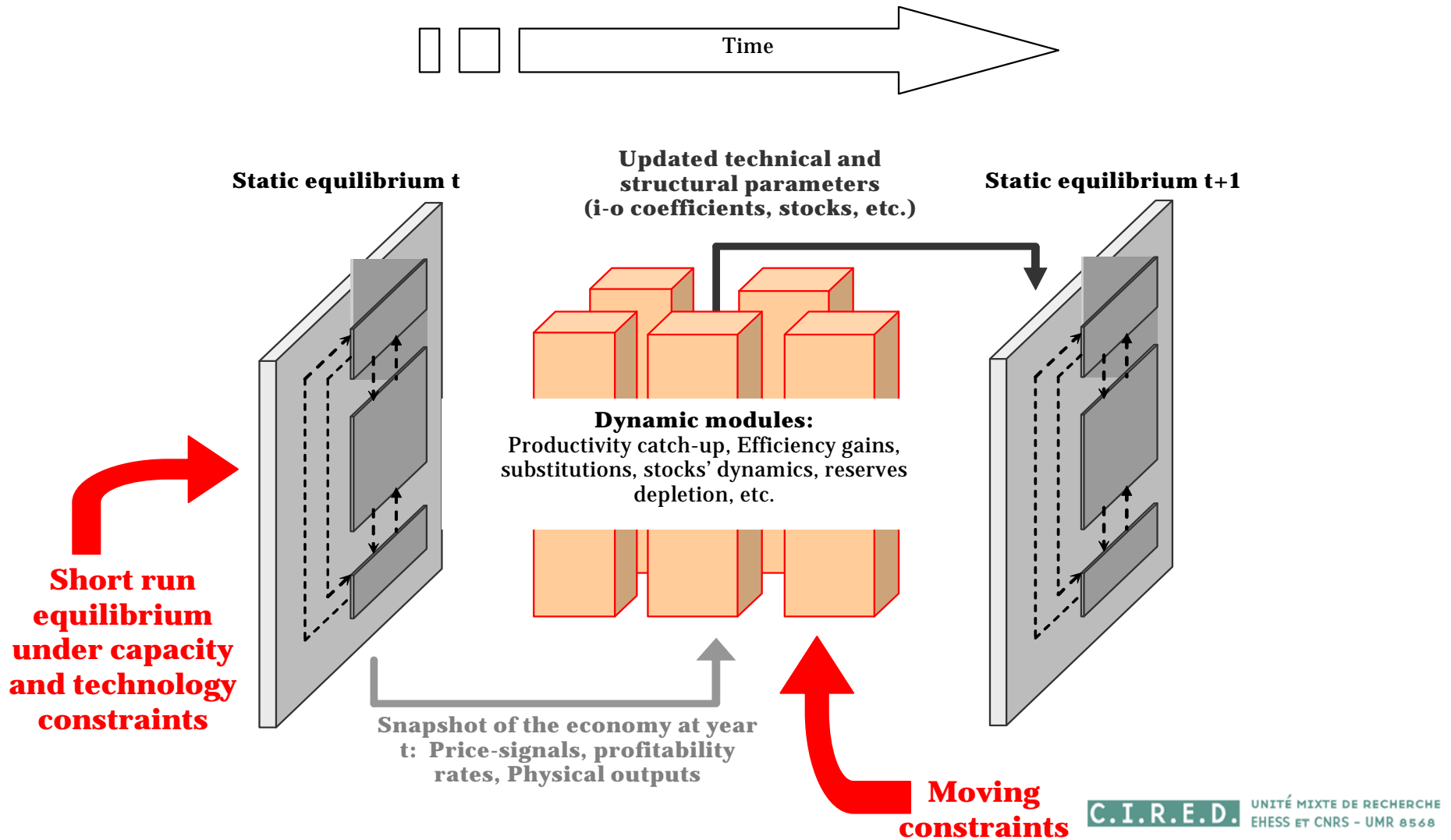
Well-known difficulties: Linking pre-existing models always intricate... and often unsatisfying



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A recursive dynamic approach to disentangle short run constraints/adjustments and long run dynamics



General features of the Imaclim-R model

1. A recursive dynamic framework :

- Succession of **static equilibriums** under short-term constraints
 - Consistent Macroeconomic snapshot (inc GE effects)
 - Technology and capacity constraints
- **Moving constraints** informed by reduced forms from BU models
 - Stock dynamics, technological asymptotes, technological choices

2. A comprehensive **price & physical quantities** account :

- energy (Mtoe), transportation (PKT) & material accounting
- Hybrid matrices, physical production capacities, physical i/o coefficients

General features of the Imaclim-R model

- Utility maximization under income constraint does not explain well patterns of energy and transportation demand
 - Energy consumption does not provide satisfaction by itself but through the **services** (light, heating, devices) it delivers.
 - Transport consumption shows specific patterns: **Zahavi's law** (constant time-budget), rebound effect, congestion.
 - Energy consumption and transportation are driven and constrained by the **ownership of durables**, cars and square meters of housing (themselves driven by their prices)
- Explicit the technical potentials behind 'all-in-one' production functions
 - Distinguish short-term **rigidities** and long-term **flexibilities** (Marshall, Johansen, 1930): with rigid i-o coefficients on the short-run
 - Allows to incorporate all the information available from all sources on the **dynamics** of the i-o coefficients.
 - Back to the real 'envelope' of **technical possibilities** over the long-term: no mathematical constraints such as constant elasticity.

Static equilibrium under short-run constraints: demand

Utility maximization:

$$U_k(\vec{C}_k, \vec{S}_k) = \prod_{\substack{\text{goods } i \\ \text{services } j}} (C_{k,i} - bn_{k,i})^{\xi_{k,i}} (S_{k,j} - bn_{k,j})^{\xi_{k,j}}$$

$$S_{k,mobility} = \left(\left(\frac{pkm_{k,air}}{b_{k,air}} \right)^{\eta_k} + \left(\frac{pkm_{k,public}}{b_{k,public}} \right)^{\eta_k} + \left(\frac{pkm_{k,cars}}{b_{k,cars}} \right)^{\eta_k} + \left(\frac{pkm_{k,nonmotorized}}{b_{k,nonmotorized}} \right)^{\eta_k} \right)^{-\eta_k}$$

Under two constraints:

$$ptc_k \cdot Income_k = \sum_i pArmC_{k,i} \cdot C_{k,i} + \sum_{\text{Energies } Ei} pArmC_{k,Ei} \cdot (S_k^{cars} \cdot \alpha_{k,Ei}^{cars} + S_k^{m^2} \cdot \alpha_{k,Ei}^{m^2})$$

$$Tdisp_k = \sum_{\text{means of transport } T_j} \int_0^{pkm_{k,T_j}} \tau_j(u) du$$

Capacity=function (infrastructures, equipments)

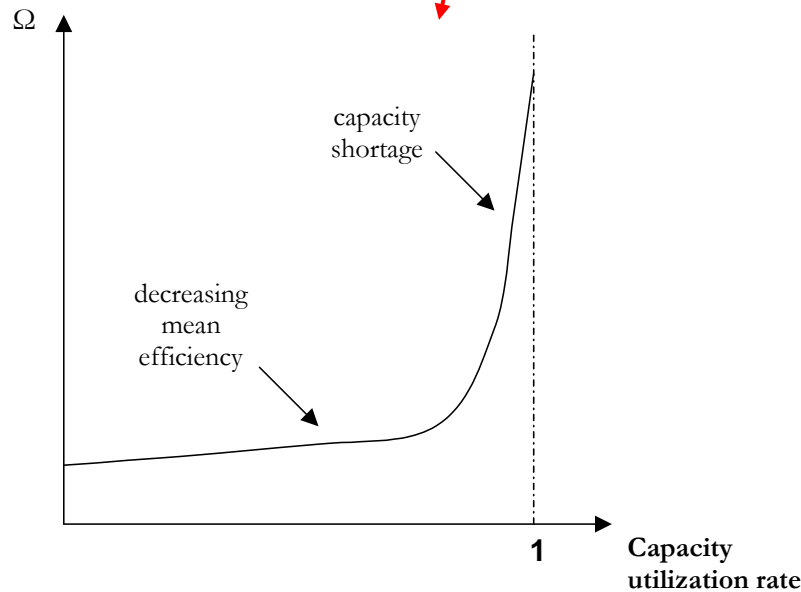
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Static equilibrium under short-run constraints: supply

- Short-term lock-in on technology and capacity (putty-clay capital), represented by a **rigid cost function** plus a **flexible rate of capacity utilization**

$$P_{k,i} = \sum_j pArmIC_{j,i,k} \cdot IC_{j,i,k} + \left(\Omega_{k,i} \cdot w_{k,i} \right) \cdot l_{k,i} \cdot (1 + tax_{k,i}^w) + \pi_{k,i} \cdot P_{k,i}$$



Additional features

- One-year time steps
- Walrasian equilibrium of all goods and services (Armington-type international trade)
- Capital flows fixed or endogenized
- Unemployment (wage curve)
- 12 regions (inc. USA, Europe, China, India, Brazil, OPEC, CIS)
- 12 sectors (5 energy supply and conversion, 3 transportation, building, energy-intensive industry, agriculture, composite)

Dynamic modules: the growth engine

- A **potential growth** the drivers of which are:
 - Demography
 - Saving rates (linked to the evolution of the pyramid of ages)
 - Catching up assumptions about labor productivity in each sector

- Gaps between **potential** and **real growth**:
 - Interaction with the energy sector
 - Price shocks
 - Maladaptation of installed equipment
 - Technology choices
 - Interaction with international markets
 - Representation of many sources of frictions on:
 - Capital flows
 - Investments derived from imperfectly expected increases of future demand and profitability
 - Rigidity of the terms of trade
 - Endogenous transitional disequilibrium with phases of over and under production capacities with related price cycles

Dynamic modules: sectoral modules

- An explicit **technology portfolio** for critical elements of the energy system
 - Power generation (Advanced coal, CCS, nuclear, various renewable...)
 - Light Duty Vehicles (Efficient ICE, Hybrid, plug-in Hybrid...)
 - Alternative liquid fuels (Biofuels, Coal to liquid...)
- An effort to represent **physical constraints** bearing on energy supply and demand
 - Temporal availability of oil resources
 - Load curve for power generation
 - Technical asymptotes for energy efficiency gains
- Including **Structural Change** within the ITC vs. ATC debate
 - R&D and learning-by-doing mechanisms applies to the sets of techniques
 - Endogenous Structural Change results from interactions between demand, supply, and ITC mechanisms

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Methods to integrate sector based expertise, links with B-U models and data

- **Exogenous prescription**
 - One input-output coefficient follows a prescribed temporal trend
 - Test of assumptions, macroeconomic consistency of scenarios
- **Reduced forms**
 - A function is calibrated to reproduce, at an aggregated level, the reaction of a technical coefficient to a signal
 - Calibration of the function with runs of a B-U model on the signal's interval of variation
- **Compact models**
 - Optimization of the technological choices in one isolated sector under current and expected economic conditions
 - Simplified reproduction of a complex B-U modeling structure
 - Interaction with B-U models to calibrate reactions and evolutions of the technologies portfolio
- **An existing Bottom-up Model:** WEM-ECO (IEA), POLES, Markal France...

Ongoing development and quest for BU data/discussion

➤ **Current state of dynamic modules:**

- Comprehensive Bottom-up submodels: electricity, fossil fuels, steel, cement, residential, cars
- Reduced forms: transportation technologies and infrastructures, services, agriculture
- Exogenous prescription: transportation input in sectors, material content of investment, material content of infrastructures

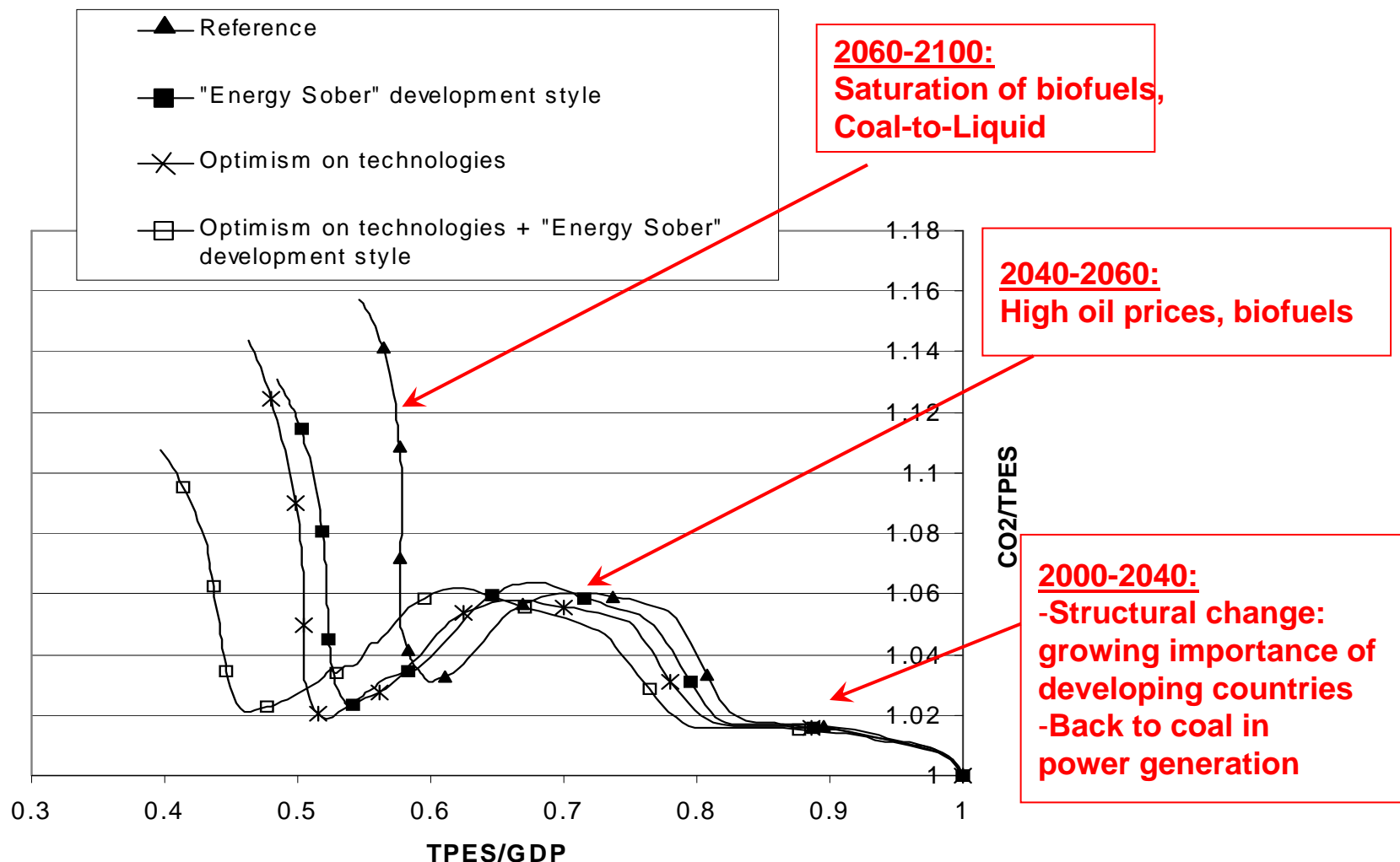
➤ **Advantages of this approach:**

- Transparency and discussion along the scenario-generating process
- Keeps open all the dynamics but still to be represented:
 - Specific modules devoted to the input-output structure in each sector
 - Critical 'silent' input-output coefficients (e.g. transportation in sectors)
 - Harder work but force us to explicit all the dynamics!

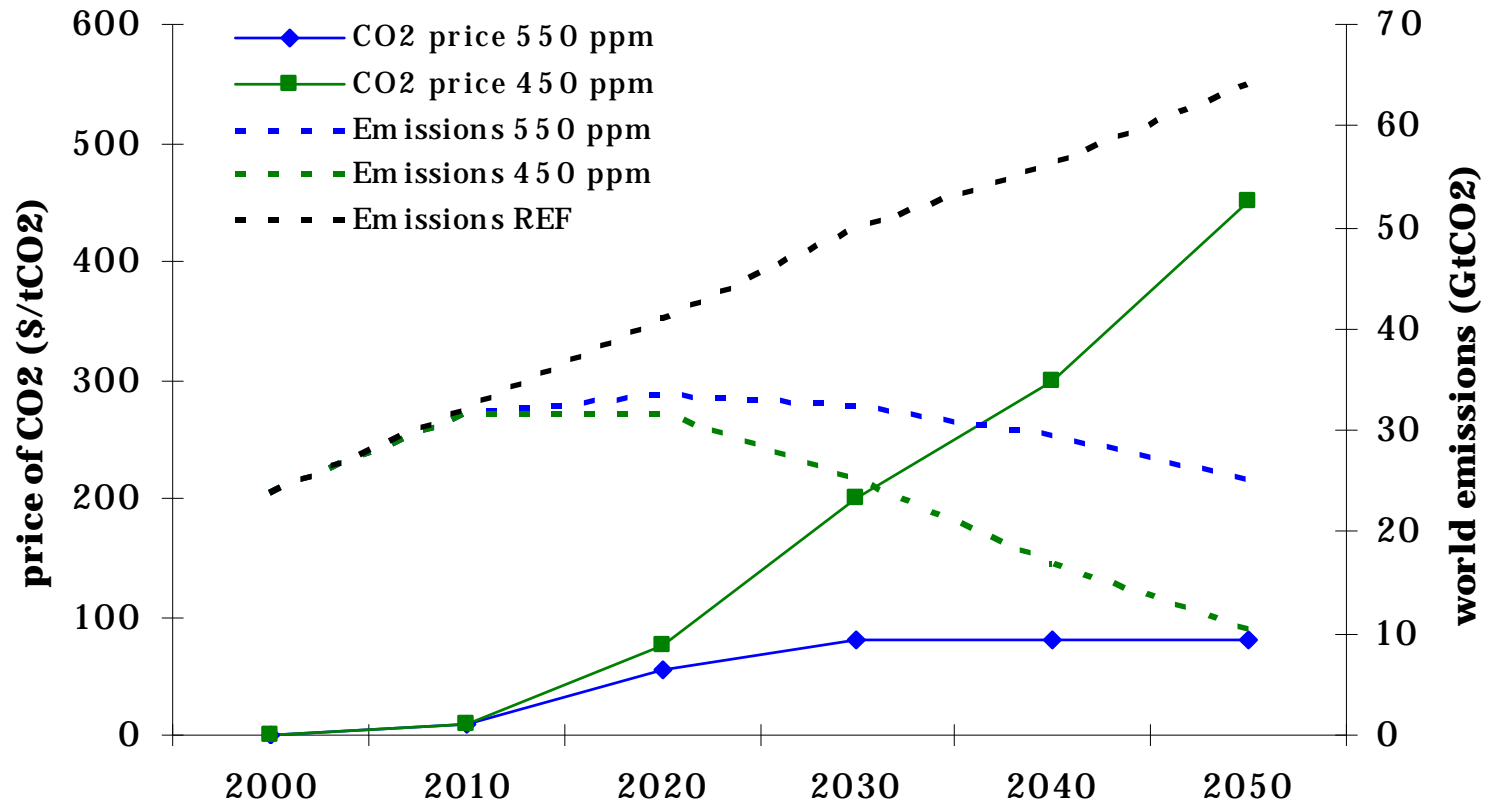
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No-policy scenario: the mechanisms underlying the risks of increasing emissions

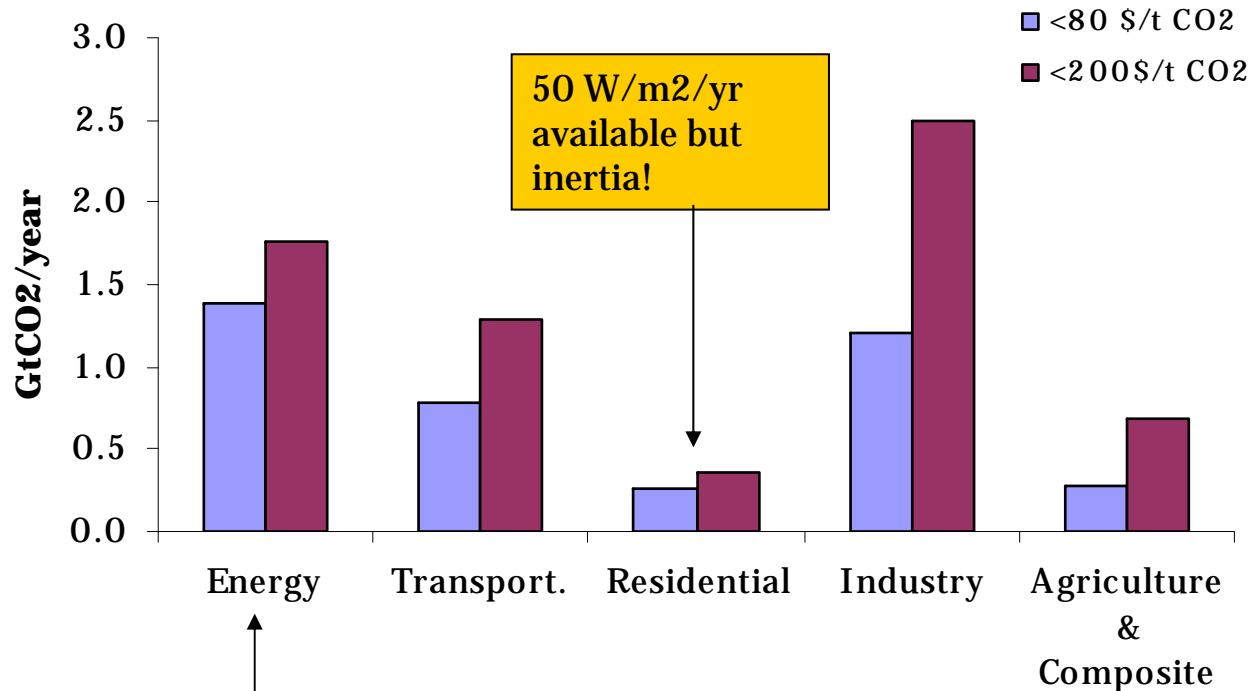


Policy scenarios



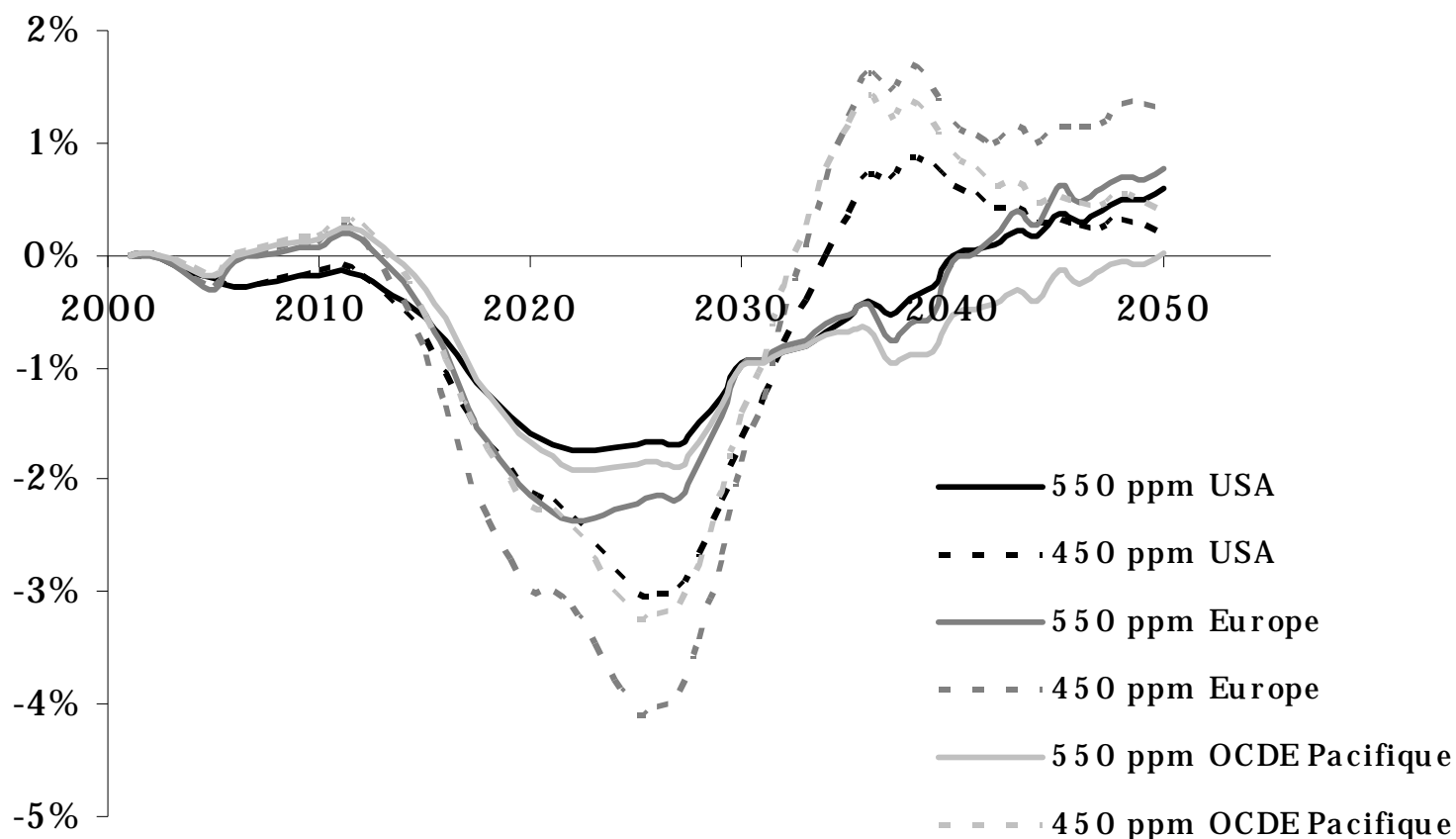
Policy scenarios: Effective reductions may differ from *ex ante* technical potentials

Mean CO₂ reductions 2010-2030 (world)



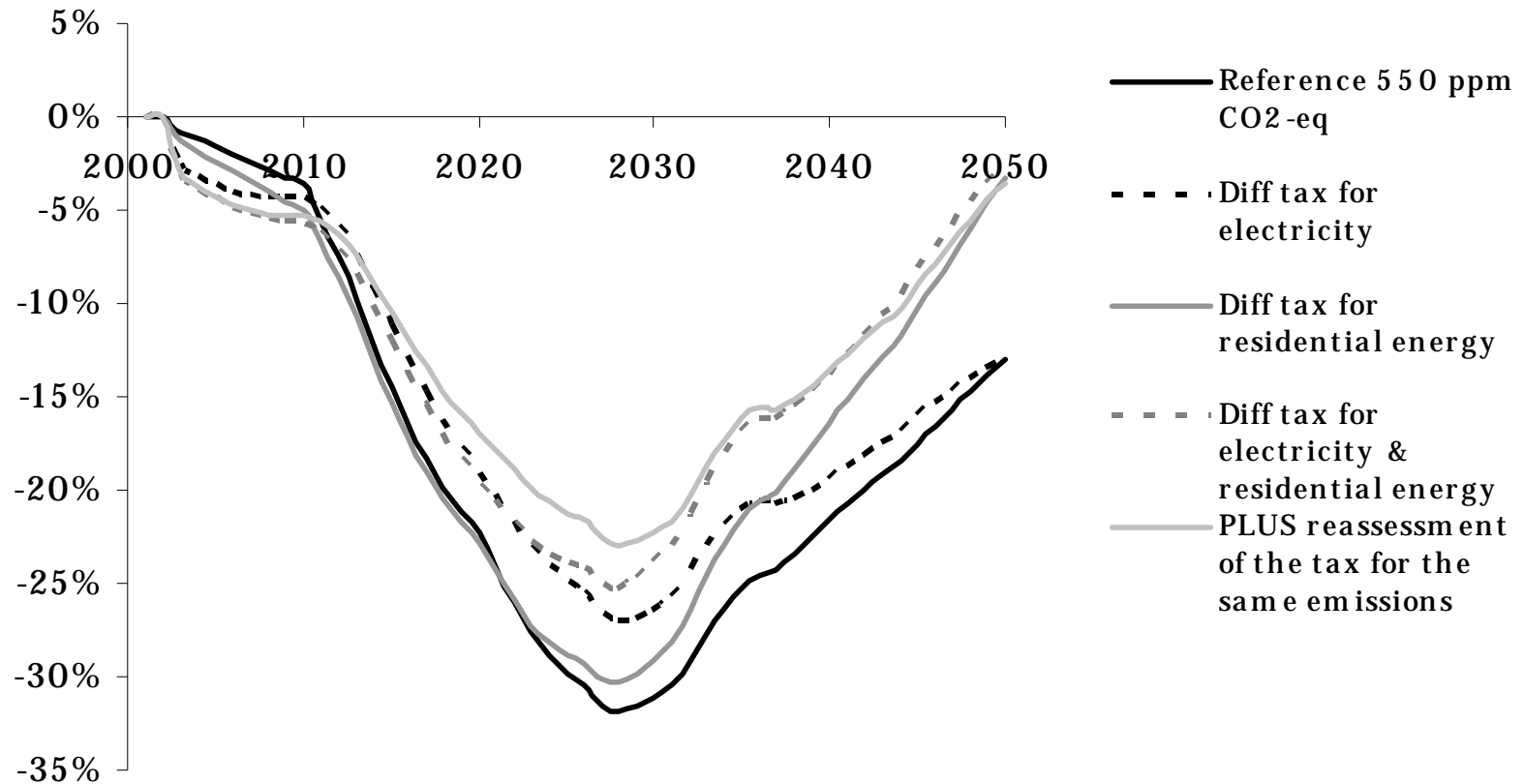
Low carbon technologies under 100 \$/tCO₂ but inertia

Policy scenarios: possible transition costs could explain the fears of decision-makers



Transitional GDP losses for stabilization, (Imaclim-R, 2008)

Policy scenarios: possibly high transition costs must be avoided with fine-tuned measures



Transitional GDP losses for 550 ppm CO2-eq, Imaclim-R, 2008)

Thank you!

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