Transition towards a 450 ppm CO_2 society – *Lessons from a Modeling Program with Imaclim-R*

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A 3-year interaction between modelers and industry

- **One question** posed by a consortium of 15 French industrial groups: Cement, Steel and Non ferrous, Energy, Transportation, Water Distribution

  - Can we transform the **F4 objective** mantra as a **mobilizing utopia** for industry instead of a pure constraint?

    - **technological breakthroughs** on the supply **and** demand side
    - **changes in final demand (structure and type of products)**
    - **incentive structure** with impacts on in industrial **competitiveness**

- **One modeling choice,** to support a dialogue between modelers, engineers and industry experts: an **hybrid approach** with

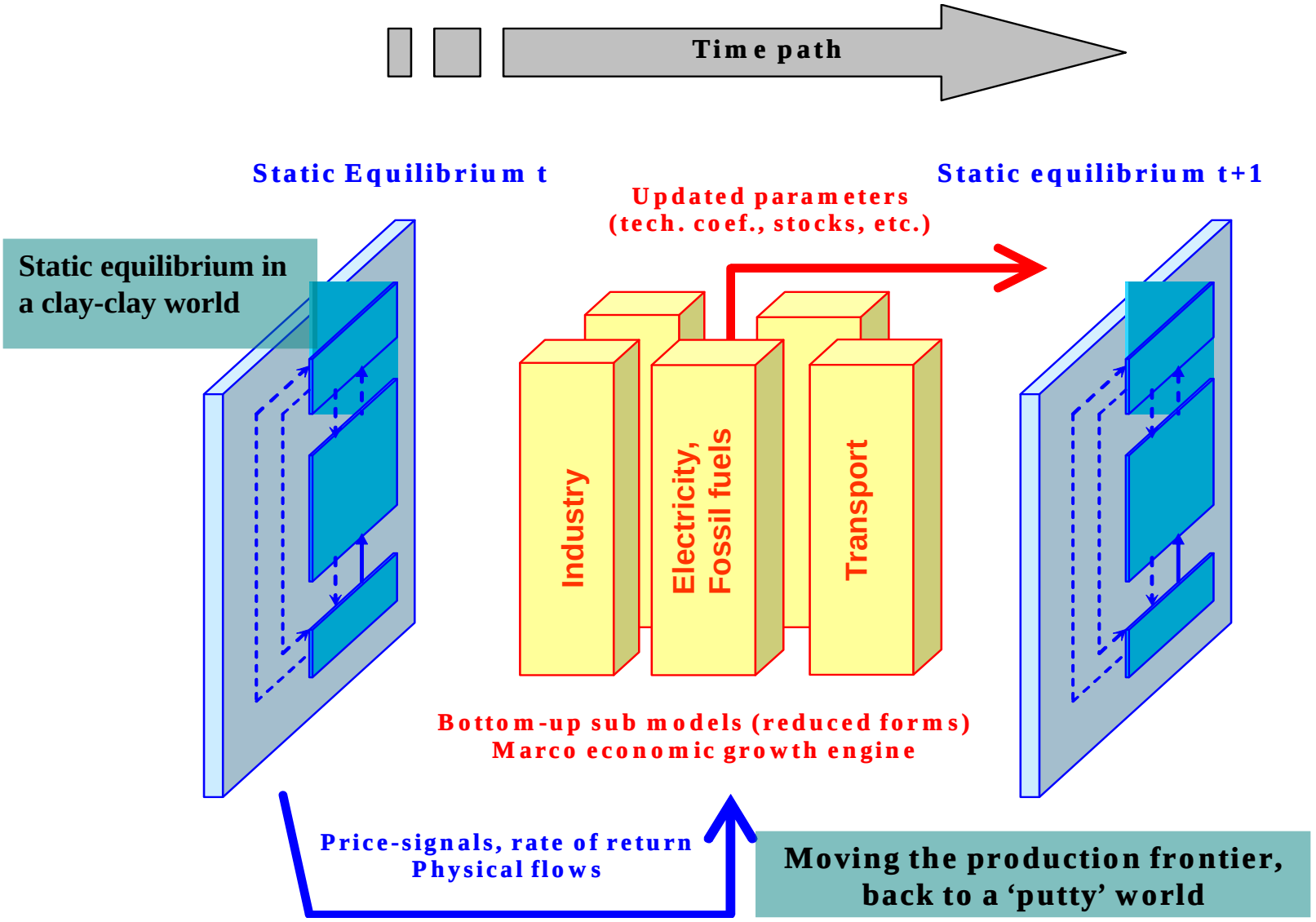
    - the **Imaclim-R** model (*CIRED*)
    - the **Poles** model (energy systems, *LEPII*)
    - Data support and engineering analysis from *Enerdata*

Methodological Challenges for (hybrid) modelers

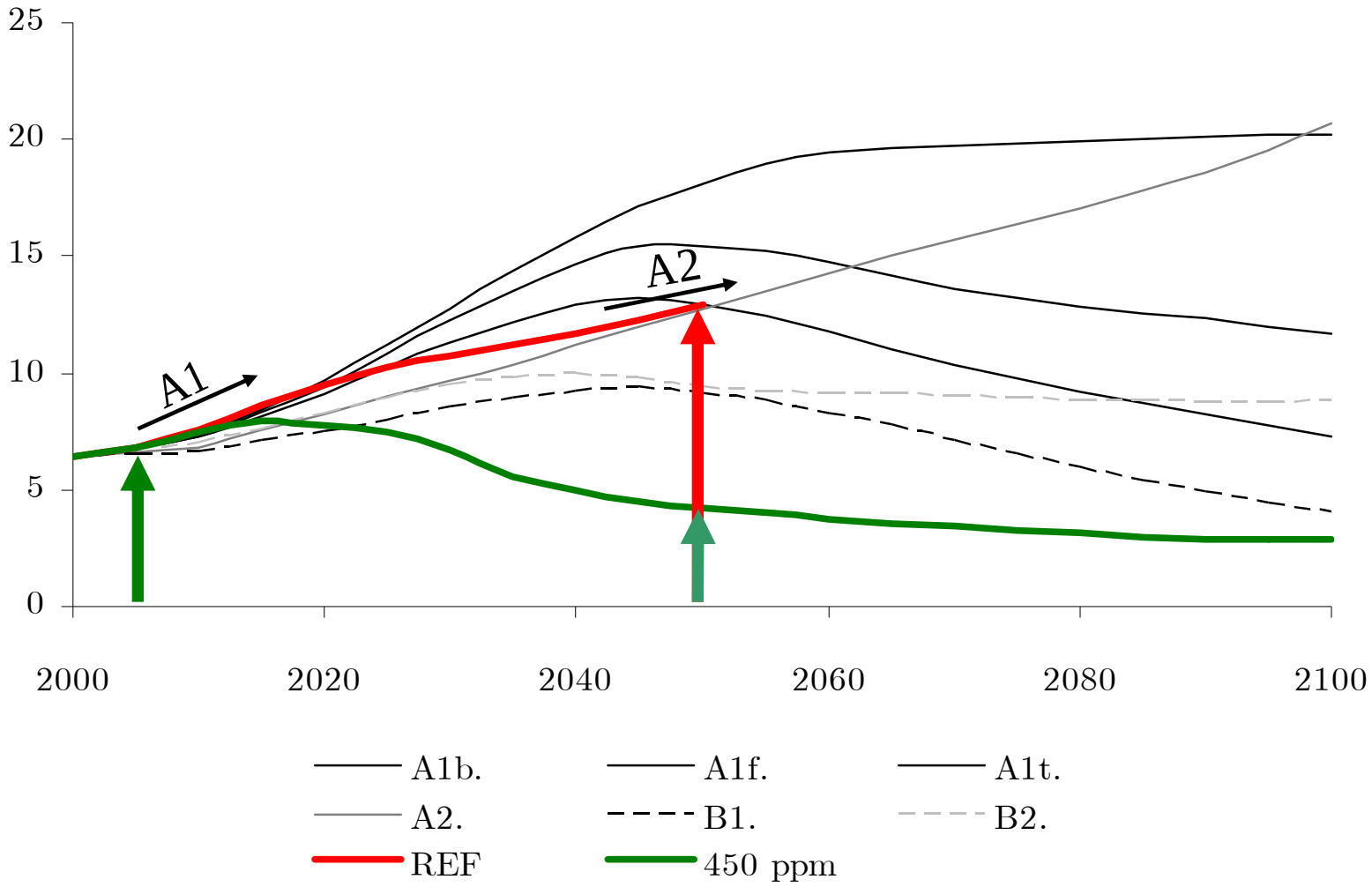
- Ensure that technical systems and economic growth are consistent and plausible
  - Physical and Economic Account of energy and materials (steel, cement, etc.)
  - ‘Open the box’ of production function to embark sector-based expertise
  - Describe infrastructures dynamics, inertia and technical lock-ins

- Monitor the transition:
  - Represent the interplay between inertia, imperfect foresight and ‘routine’ policy behaviors
  - Non optimal growth pathways
  - Adjustments mechanisms: capacity utilization, unemployment, capital flows, etc.

A recursive and modular architecture:
static equilibria + dynamic relations informed by the POLES model



A 450 ppm CO_2 stabilization target



Demographic dynamics : a growth slowdown linked to ageing

- Total population ➔ final demand dynamics
- Active population ➔ labor force dynamics
- Pyramid of ages ➔ saving rates

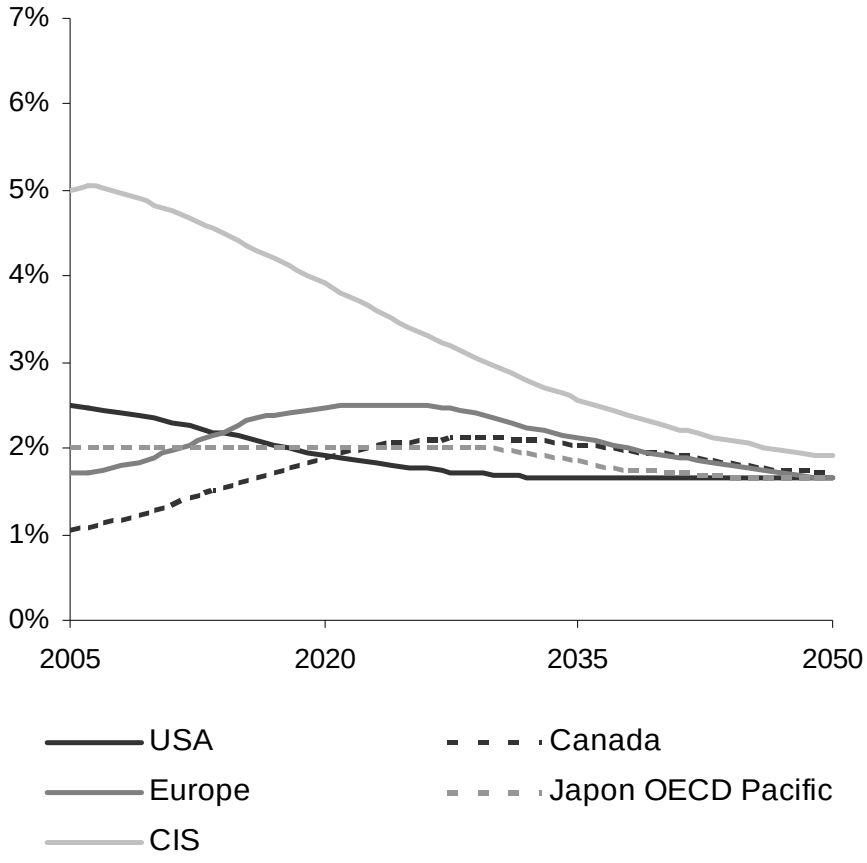
(e.g. the Chinese saving rates decreases from 44% in 2001 to 14 % in 2050)

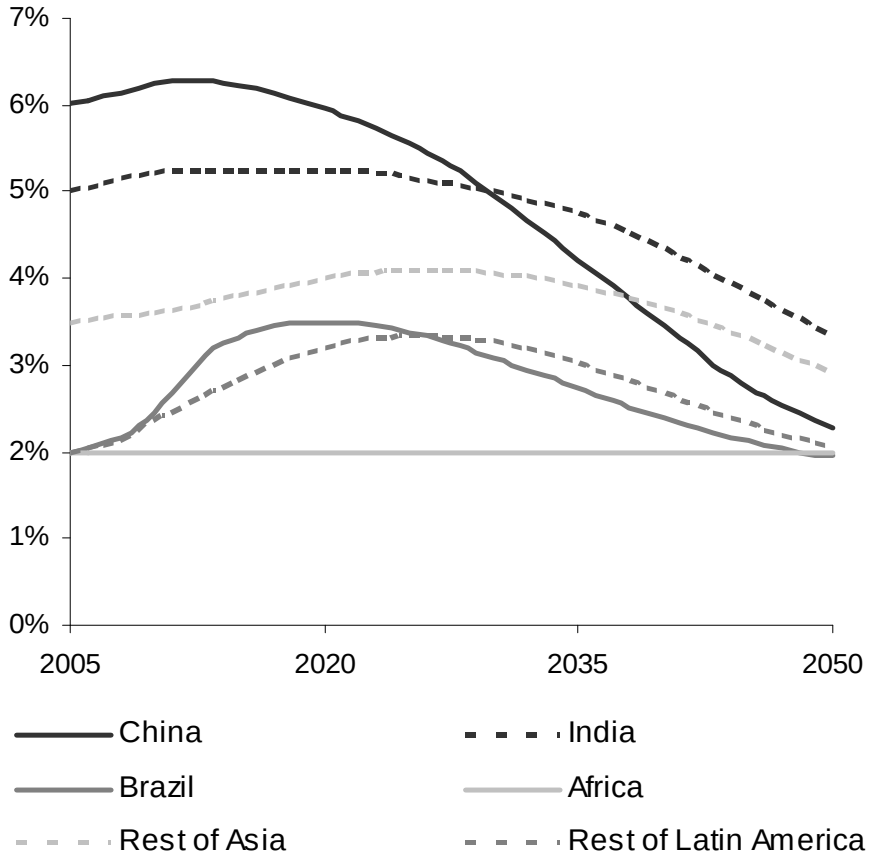
	Total Population	Active Population
North America	6.2 ‰	4.4 ‰
Europe	0.3 ‰	-2.9 ‰
Japan	-0.6 ‰	-5.6 ‰
CIS	-3.3 ‰	-4.9 ‰
South America	7.4 ‰	8.0 ‰
India	8.1 ‰	10.6 ‰
China	**1.2 ‰**	**-2.0 ‰**
Rest of Asia	10.0 ‰	11.8 ‰
Africa and Middle East	16.6 ‰	20.9 ‰

2005-2050 mean growth rate of Total and Active population

Growth engine: productivity catch-up

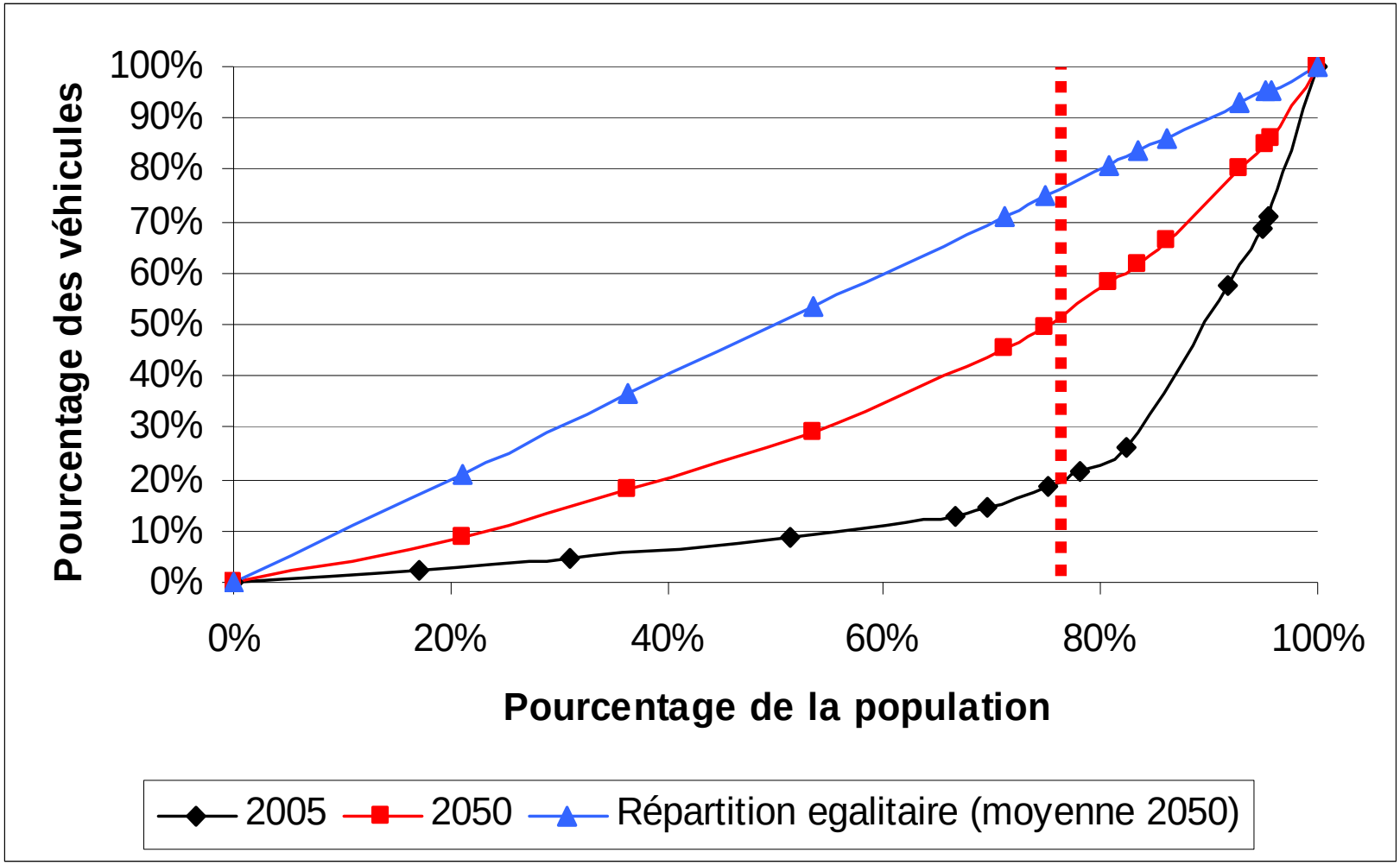
- ‘Club convergence’ of OECD countries to a 2% per year mean rate
- Differentiated catch-up phases for CIS and developing countries





Annual growth potential of labor productivity

The material content due to a ‘mimetic’ development pattern, the catch-up on vehicles



‘Lorentz Curve’ for personal vehicles around the world

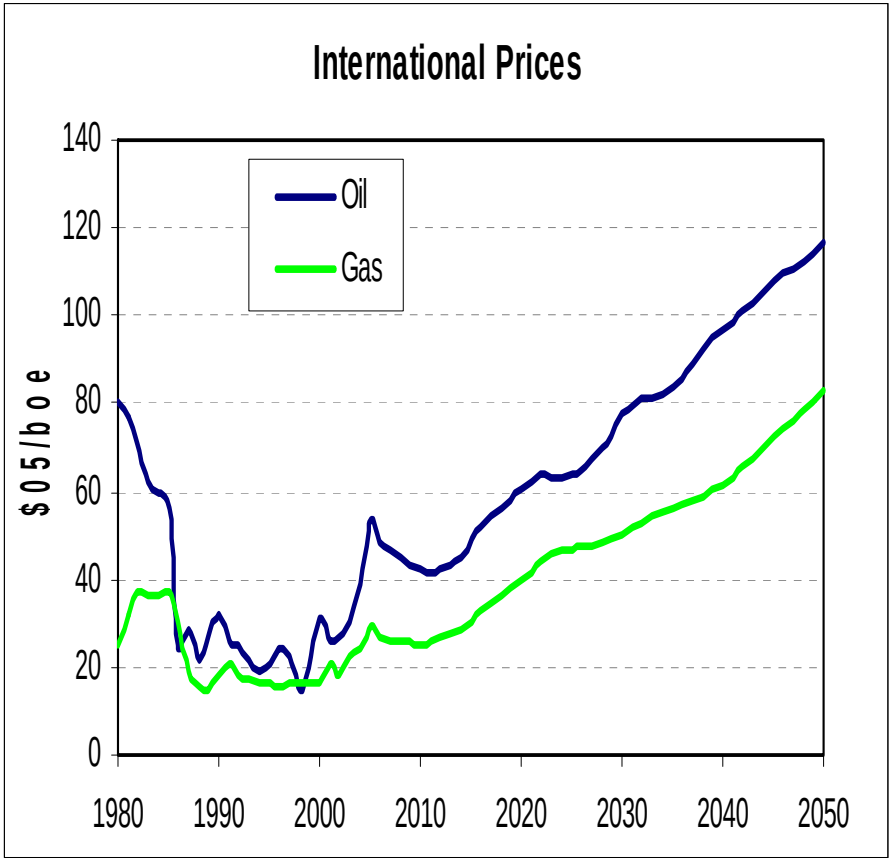
The material content due to a ‘mimetic’ development pattern: Housing

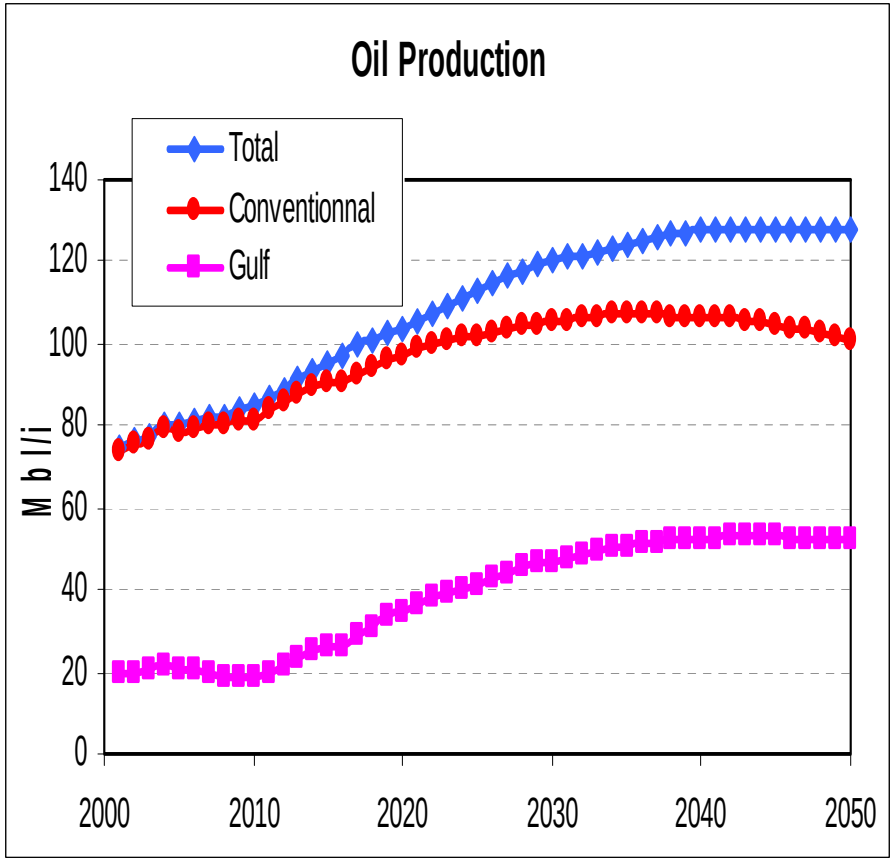
	2005	2030	2050
USA	60	62	67
Canada	48	62	79
Europe	33	36	39
Japan + OECD Pacific	29	32	34
CIS	27	36	41
China	20	23	28
India	8	12	19
Brazil	11	16	23
Middle East	20	27	39
Africa	11	15	22
Rest of Asia	18	23	31
Rest of Latin America	12	16	24

Per capita surface of housing

REF scenario: Tensions on fossil fuels and x2 emissions

- **World primary energy consumption : 26 Gtoe in 2050 despite a 45% decrease of energy intensity of GDP**
- **Coal 25%; Oil 25%; Gas 18%, Nuke 17% Renewables 15 %**





A 450 ppm scenario
‘at constant development pattern’

‘Political’ carbon price signals to reach 450 ppm

- One carbon price for all agents in each region but: **differentiatied responsibility’ and EU leadership**
- Linear time profile but credible and announced ex-ante

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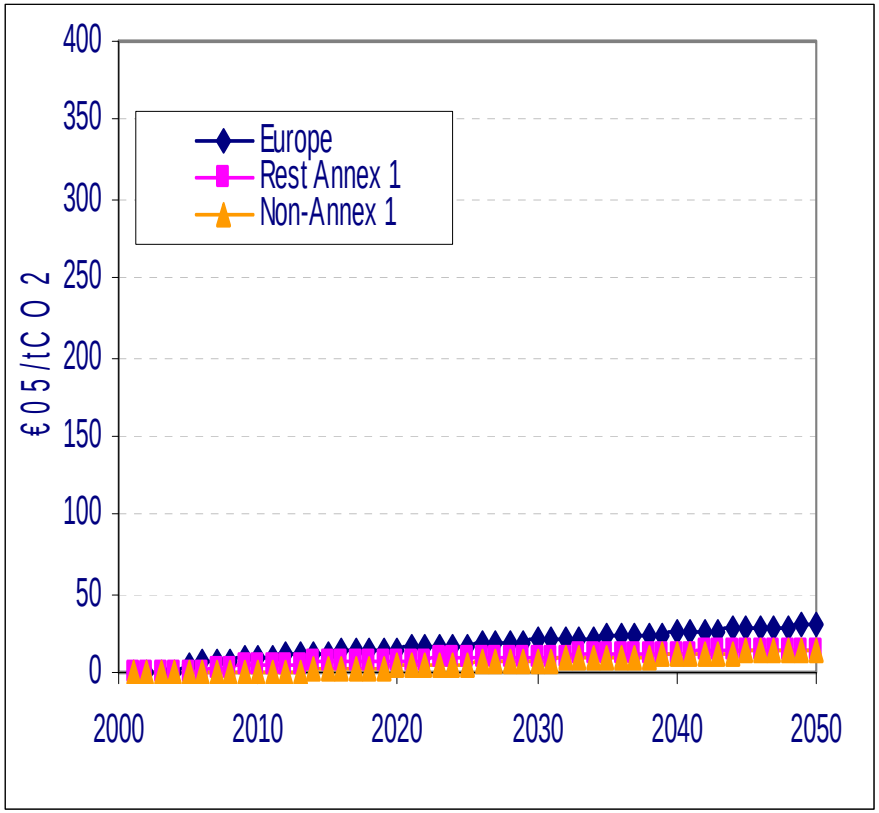
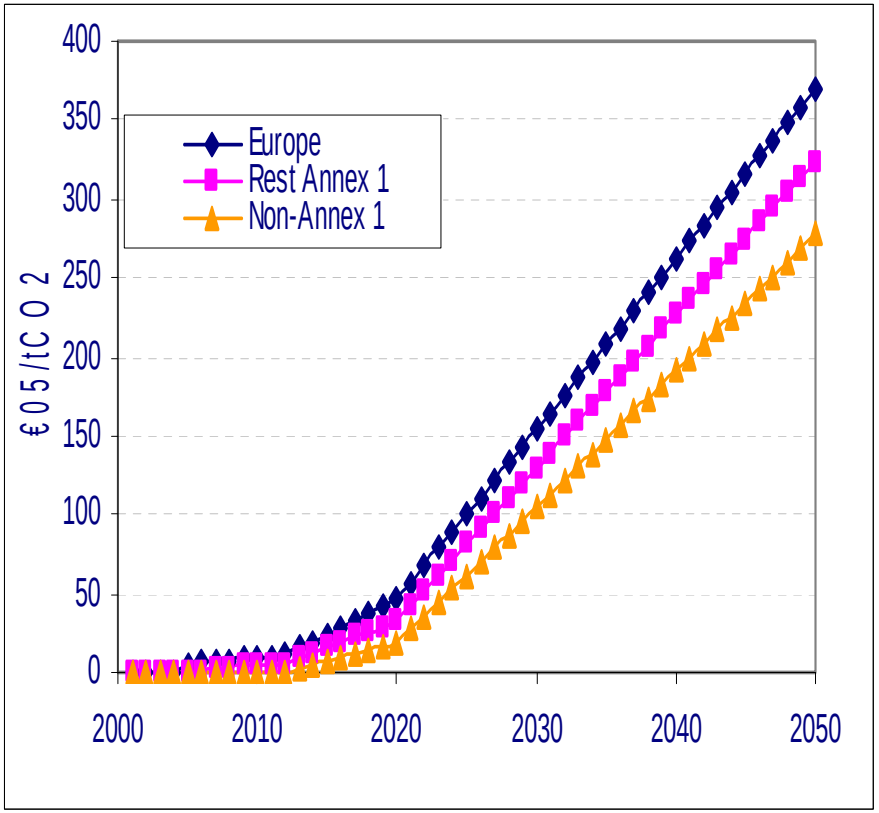


450 ppm



Complementary PAMs behind the carbon value

Price signals (only) trigger the decarbonisation of the energy supply and the decisions of energy consumers; but beyond the price induced changes in the technical space a set of PAMs are assumed on the demand side:

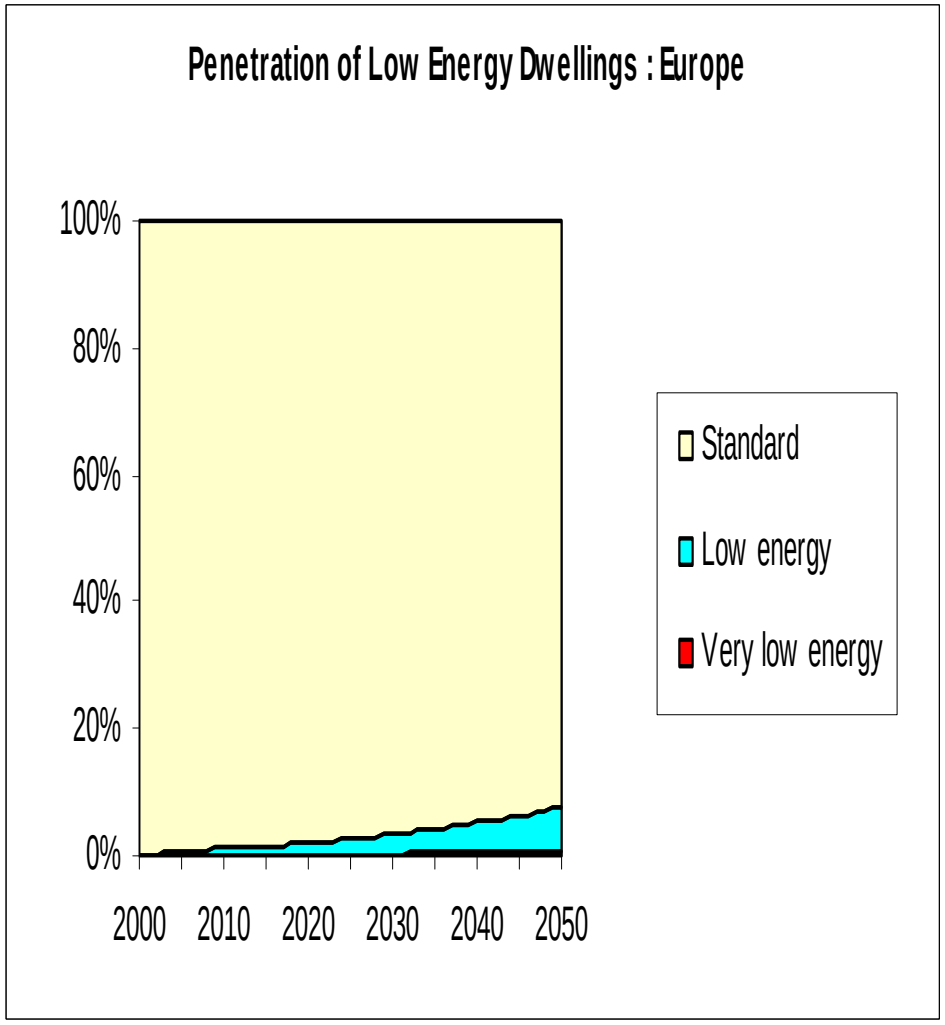
- **Accelerated turnover of existing builidings** and diffusion of aZEB (almost or zero energy buildings)
- Very strict **efficiency standards** for existing buildings
- R&D on High efficiency **vehicles**
- R&D on high efficiency and low carbon content **materials**

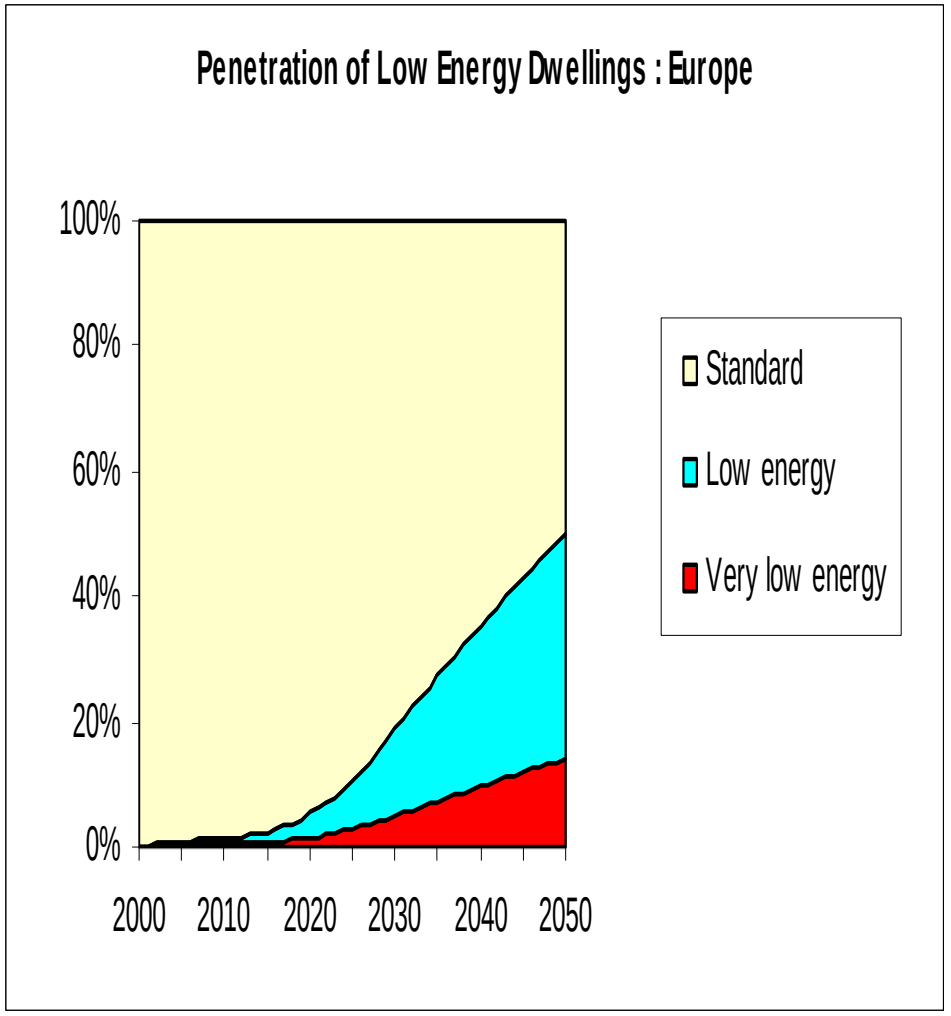
450 ppm CO_2: Factor 3 for Annex B

	Emissions reductions from 2005 (GtC)		Emissions reductions from REF (GtC)	
	2020	**2050**	**2020**	**2050**
USA	-15%	-72%	-28%	-82%
Canada	-1%	-54%	-18%	-65%
Europe	-13%	-64%	-23%	-71%
Japan + OECD Pacific	-11%	-62%	-21%	-63%
CIS	2%	-56%	-22%	-72%
Total Annex B	**-11%**	**-65%**	**-25%**	**-75%**
China	49%	-41%	-17%	-70%
India	78%	-29%	1%	-60%
Brazil	39%	-29%	-9%	-70%
Middle East	34%	10%	-11%	-64%
Arica	54%	44%	-16%	-71%
Rest of Asia	74%	36%	-10%	-62%
Rest of Latin America	52%	-5%	-8%	-68%
Total Non Annex B	**55%**	**-9%**	**-12%**	**-67%**

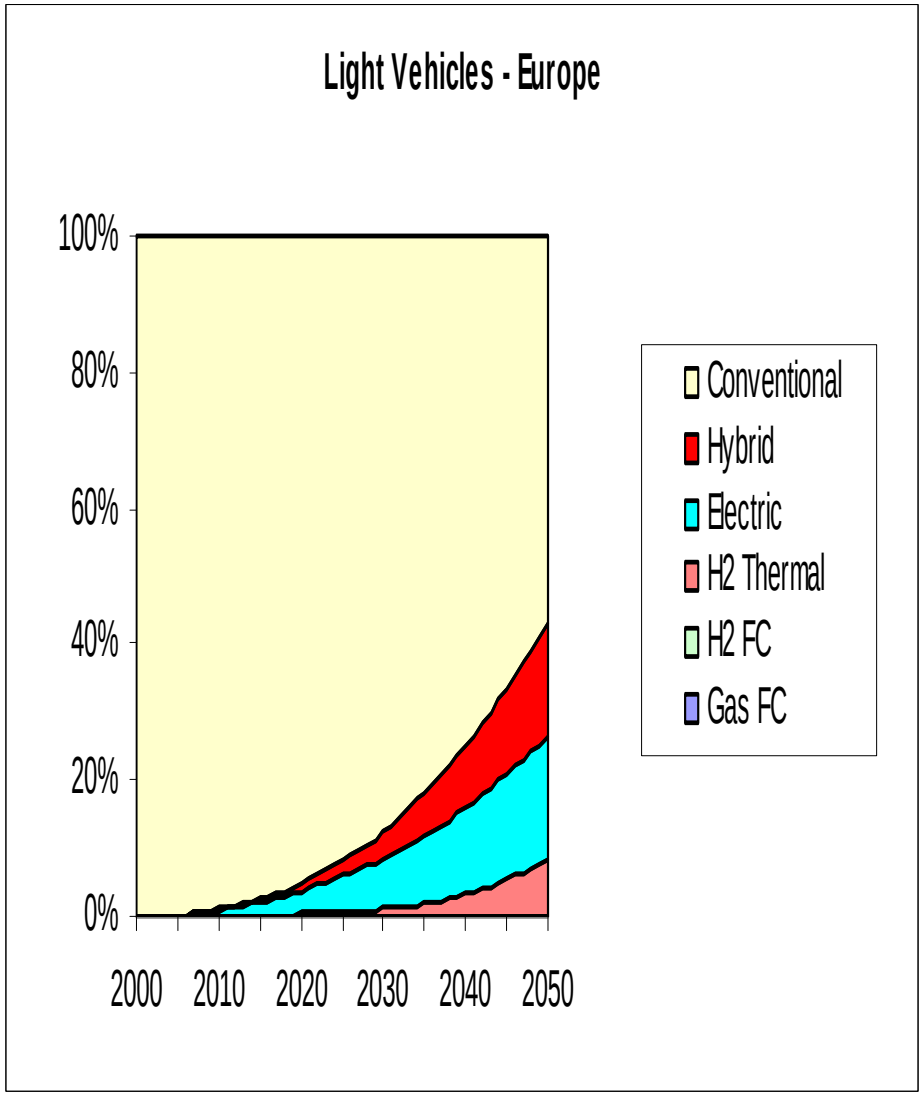
450 ppm – F3 scenario : what material and technical content?

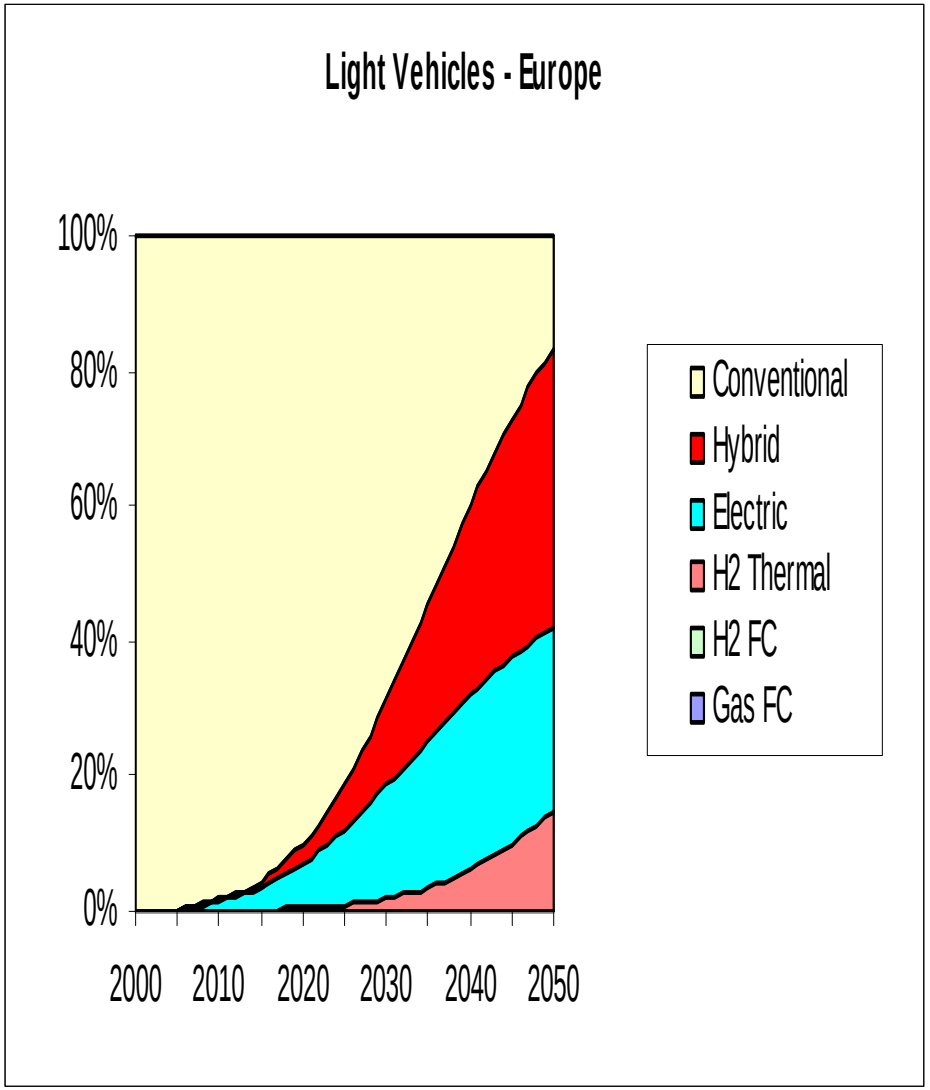
F4 scenario : towards almost Zero Energy Building in Europe (residential) with accelerated turnover





Low carbon intensive vehicles (Europe)





Total Steel demand in 2050 reduced by 8,6% only

- Lower steel content of vehicles and buildings is in part offset by accelerated turnover and renovation

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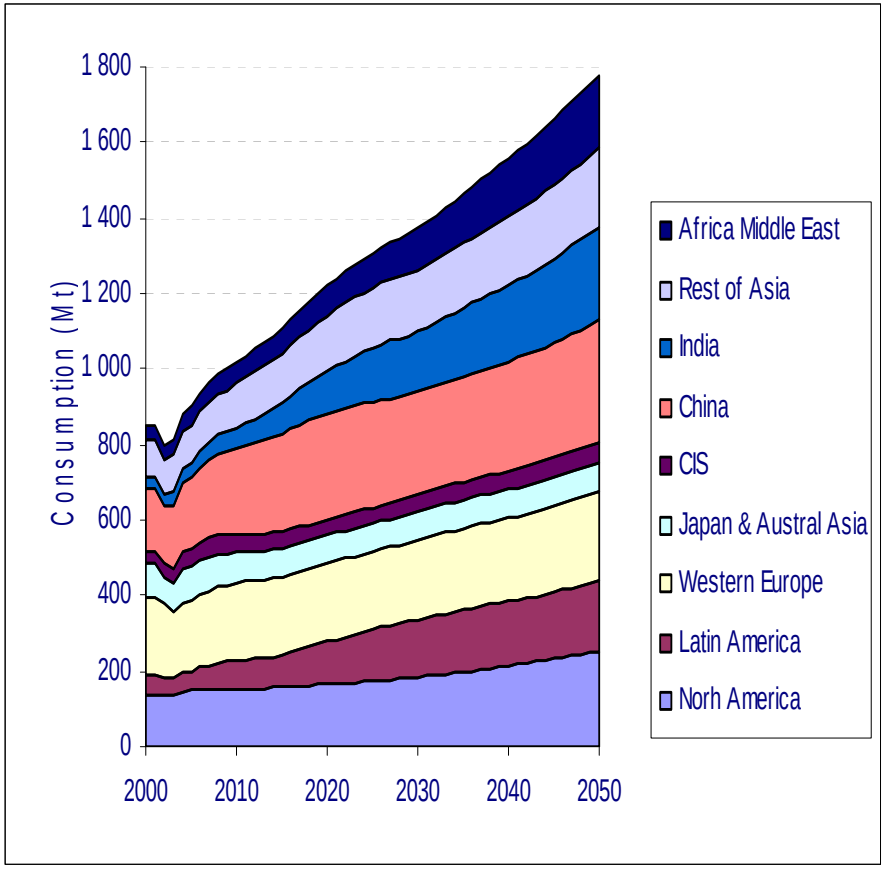
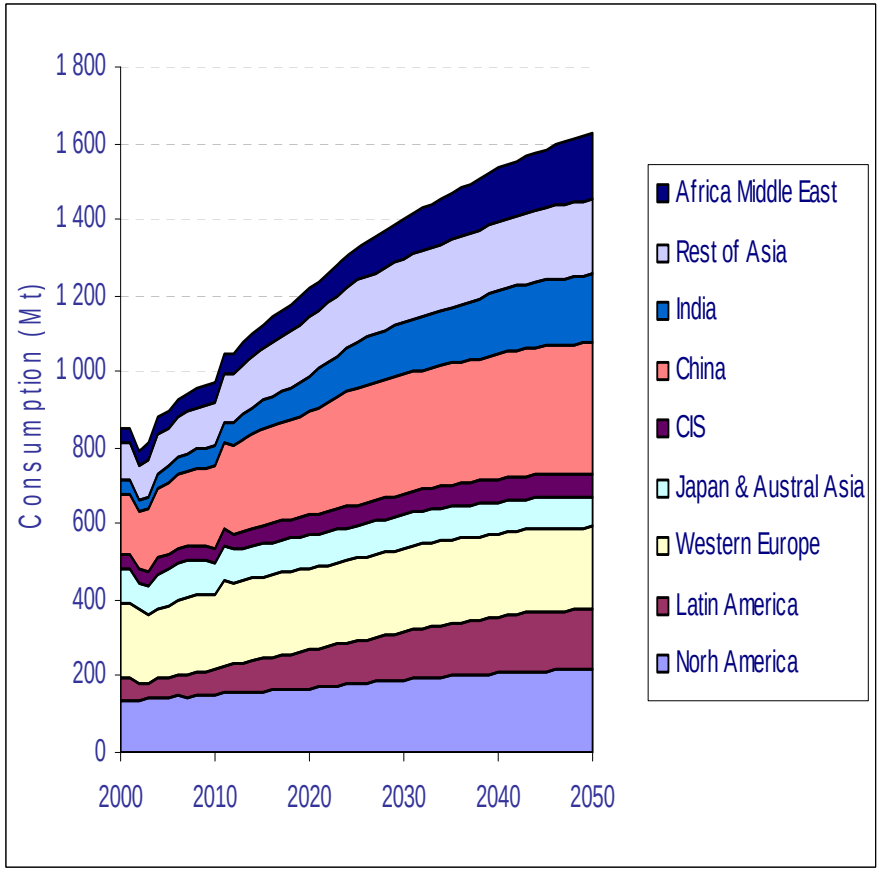
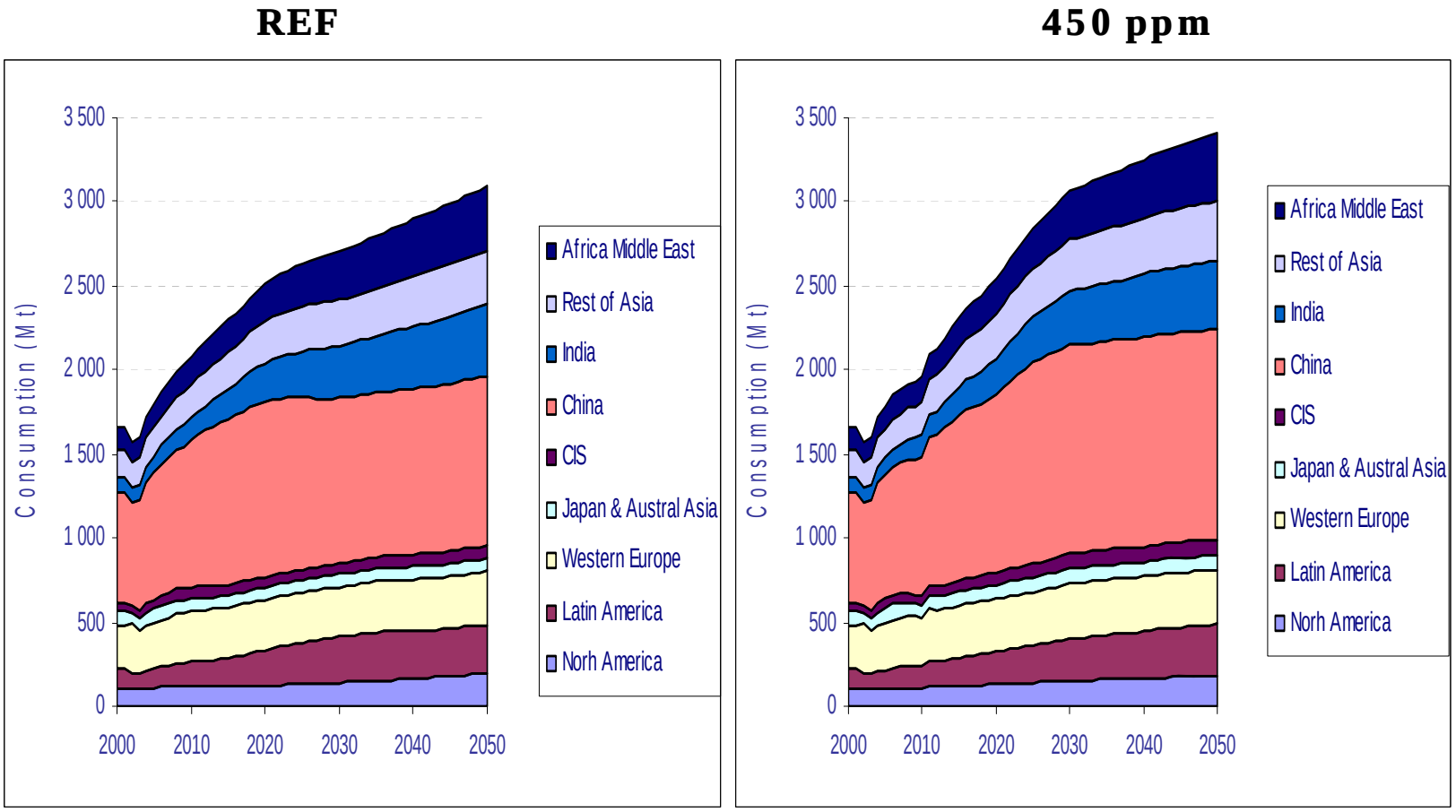


450 ppm



Total cement demand in 2050 increases by 10%

- Lower steel content of vehicles and buildings is in part offset by accelerated turnover and renovation dominates the content effect



Total aluminium demand decreases by 7%

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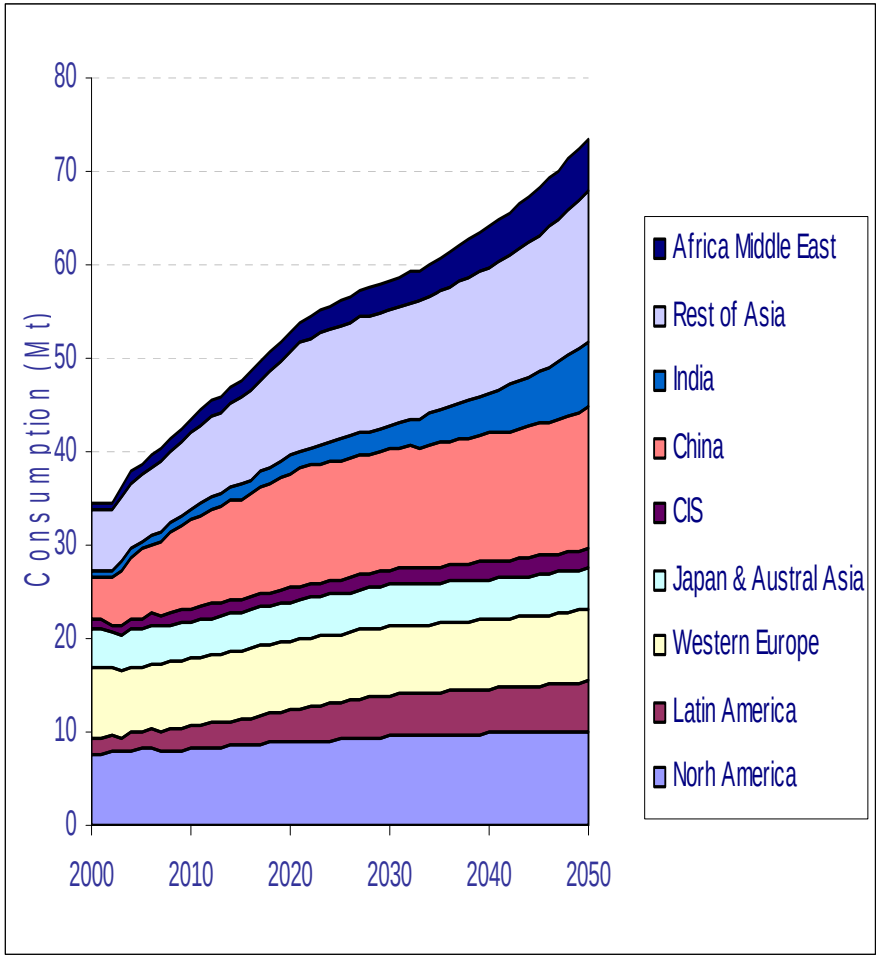
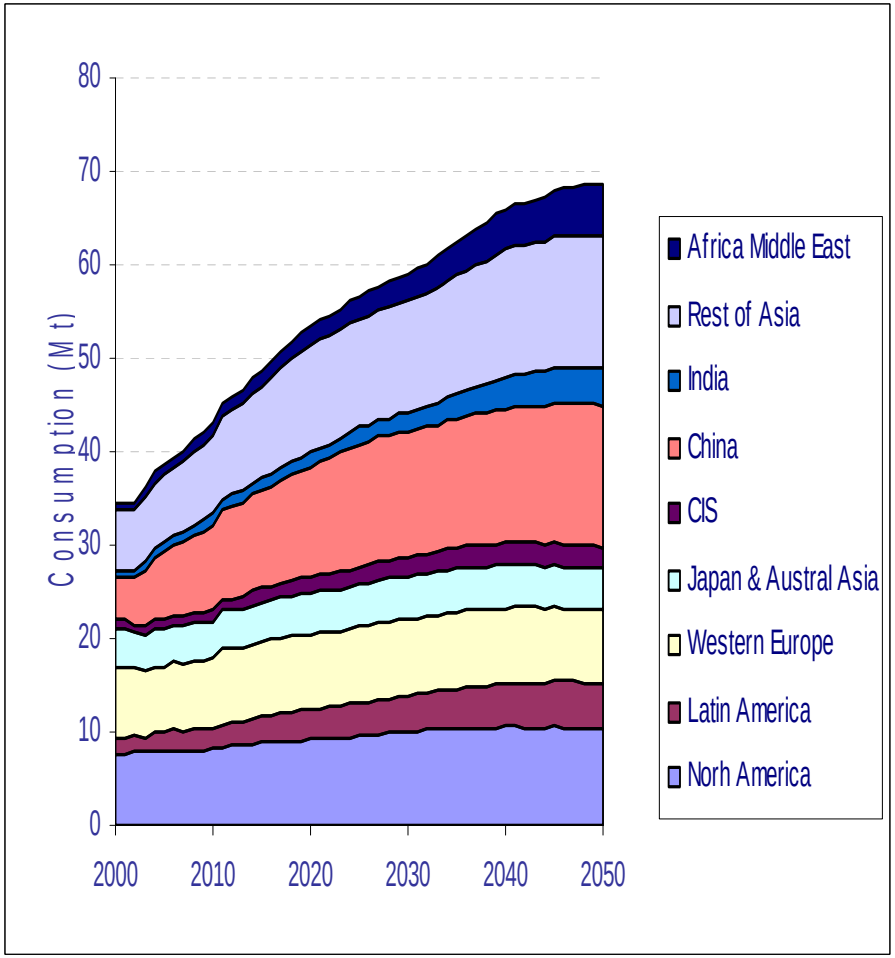


450 ppm



Demand of laminated glass increases by 63%

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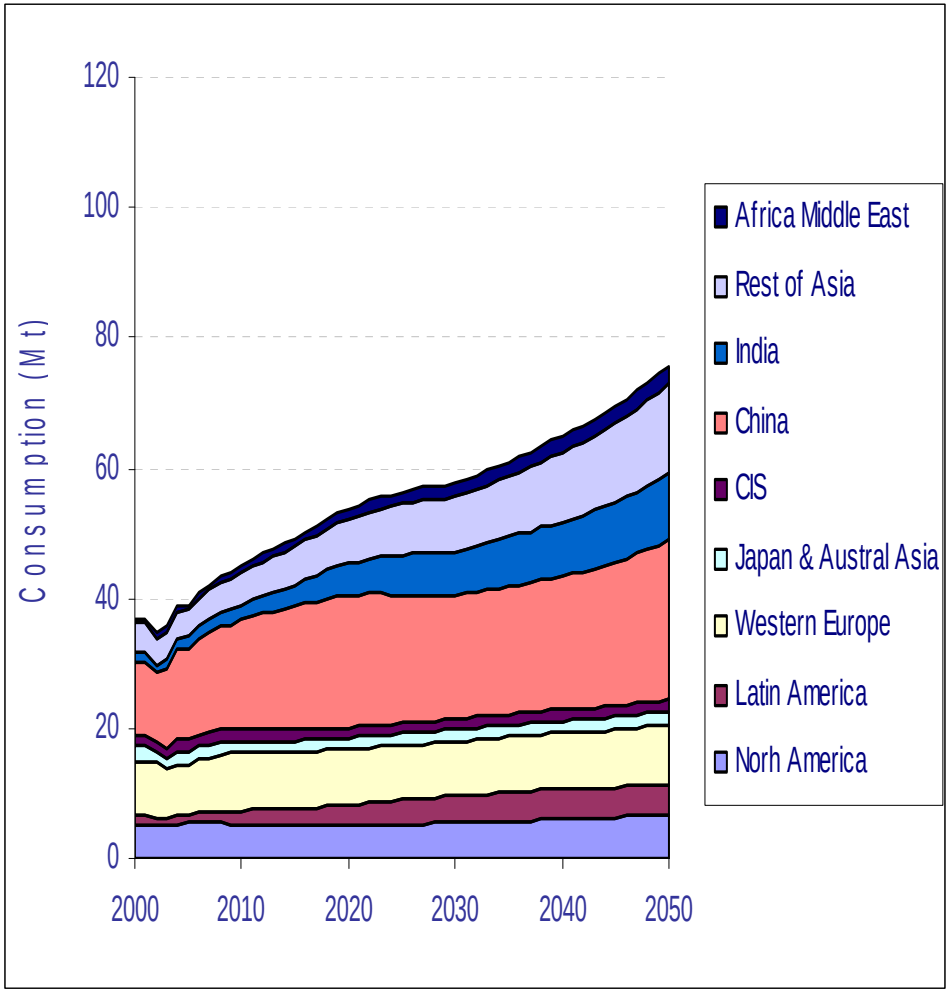
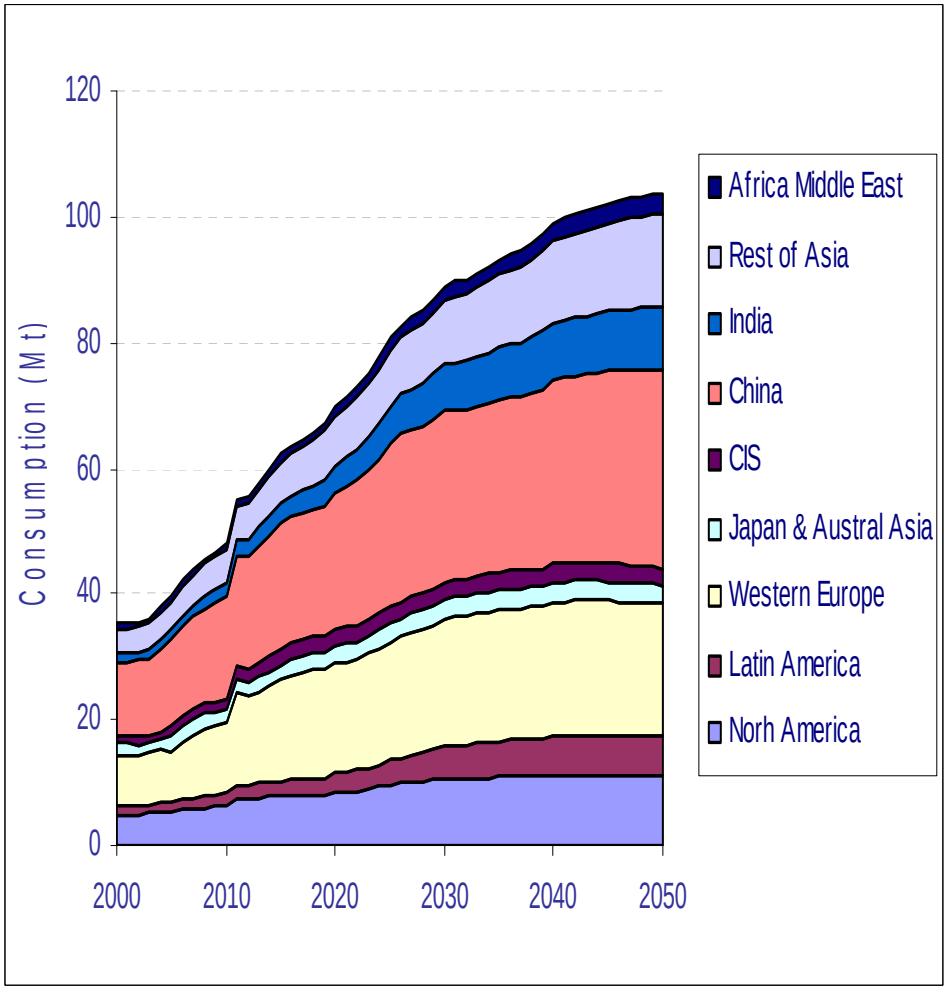


450 ppm



450 ppm – F3 scenario :
what implications for energy intensive industry?

450-F3 scenario: what place for materials' industry in the OECD ?

- Sustained domestic demand

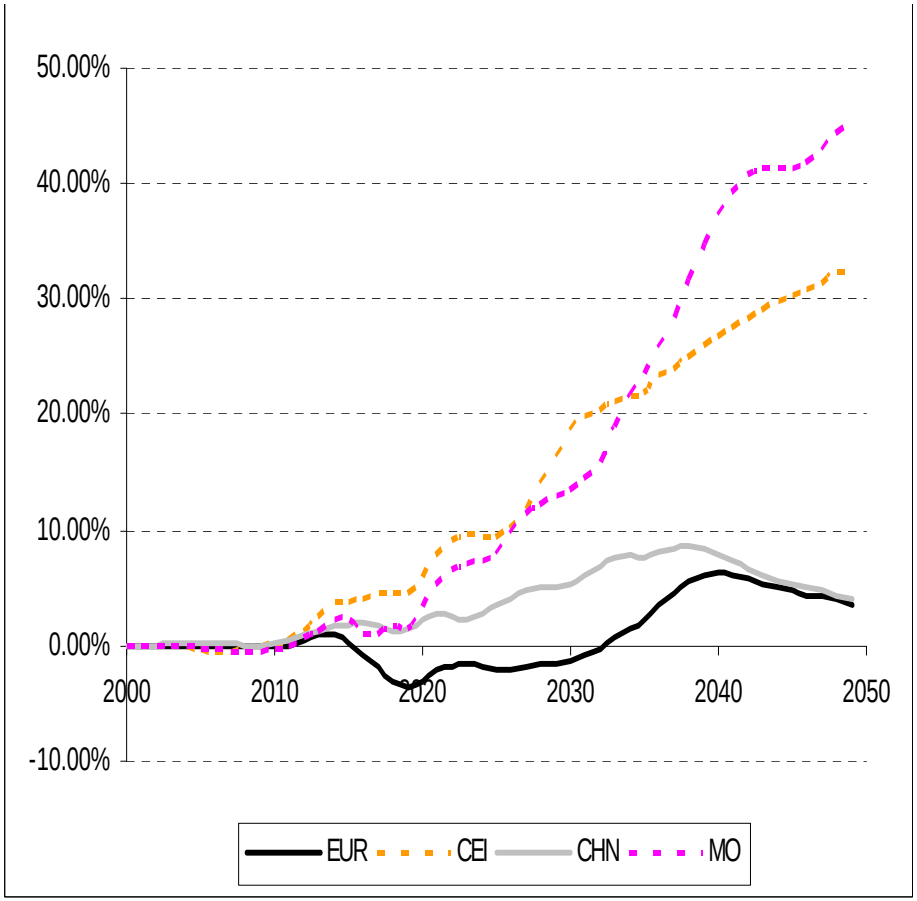
- What localization of production in a context of heterogeneous carbon constraints and rising domestic energy costs?

- Localization may result from competitiveness variations due to:
  - Energy costs (carbon price included)
  - Variation of terms of trade
  - Increase in (international) transportation costs
  - Border taxes?

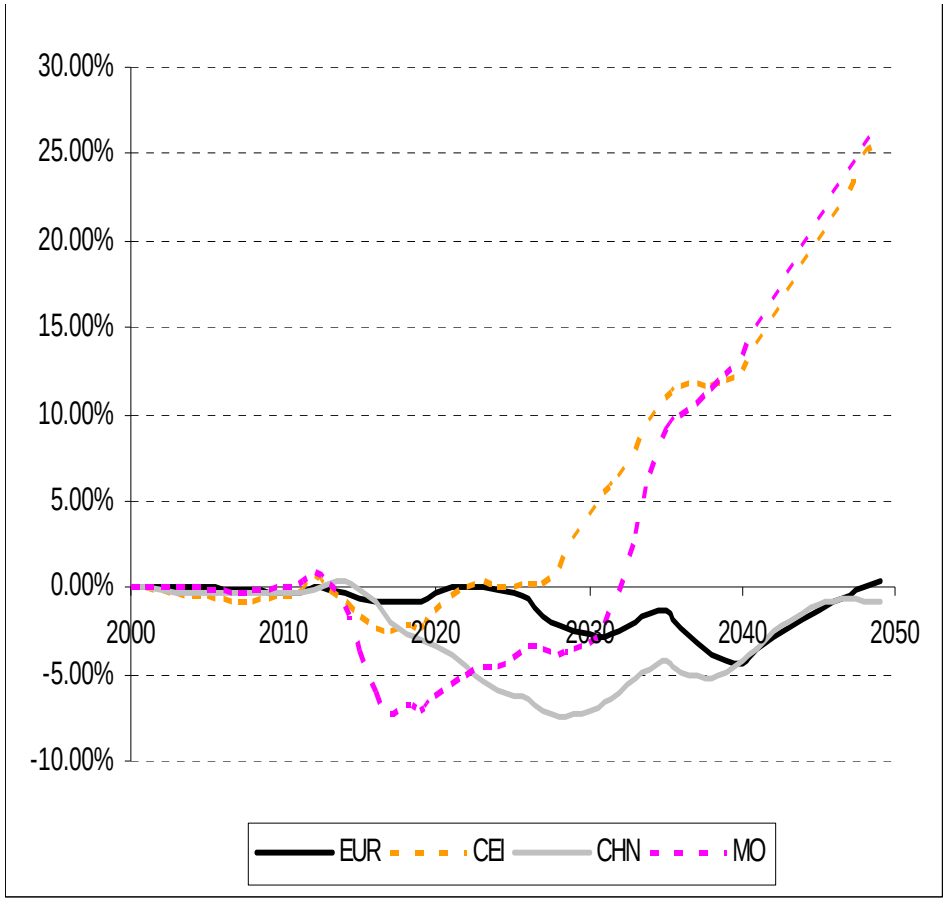
- Localization ma also result from the attractiveness for capital flows (profit margin, risk aversion and intangible costs)

Competitiveness variations: when macroeconomy matters

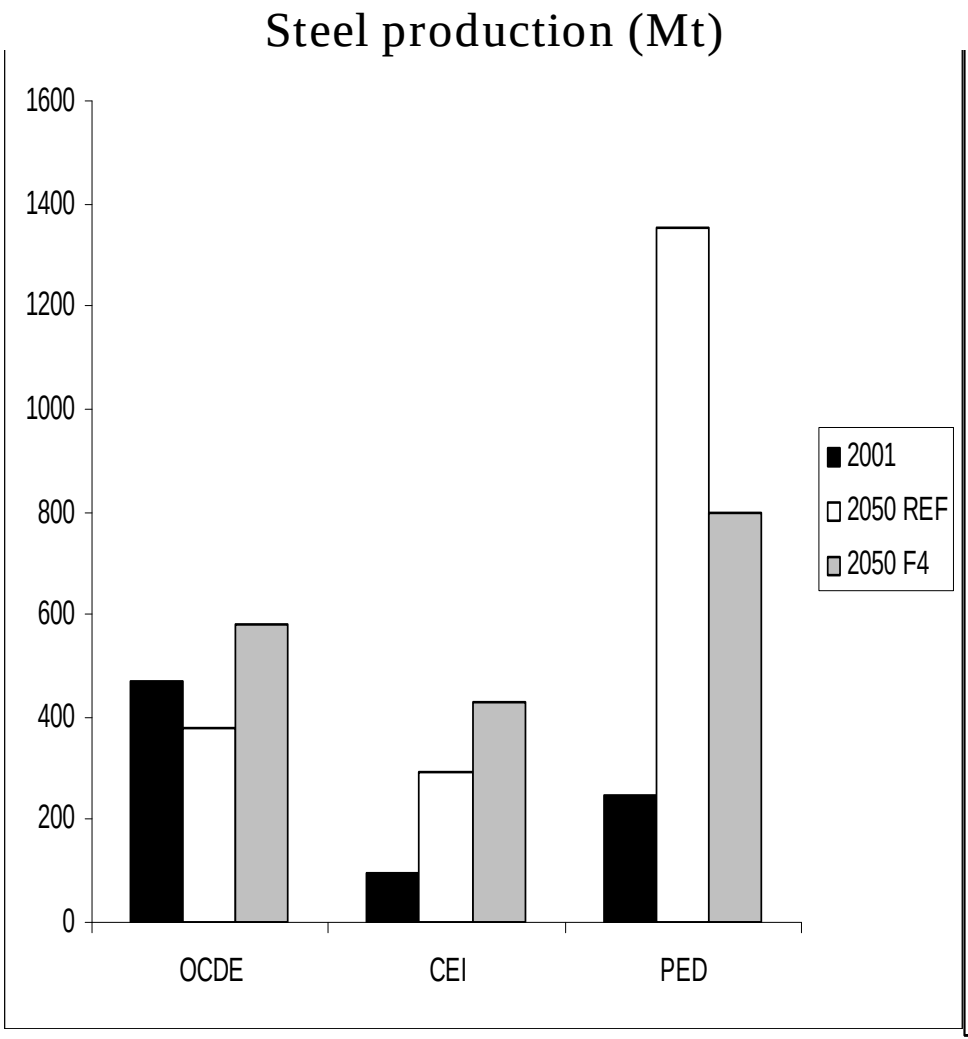
REF vs. 450ppm composite price levels

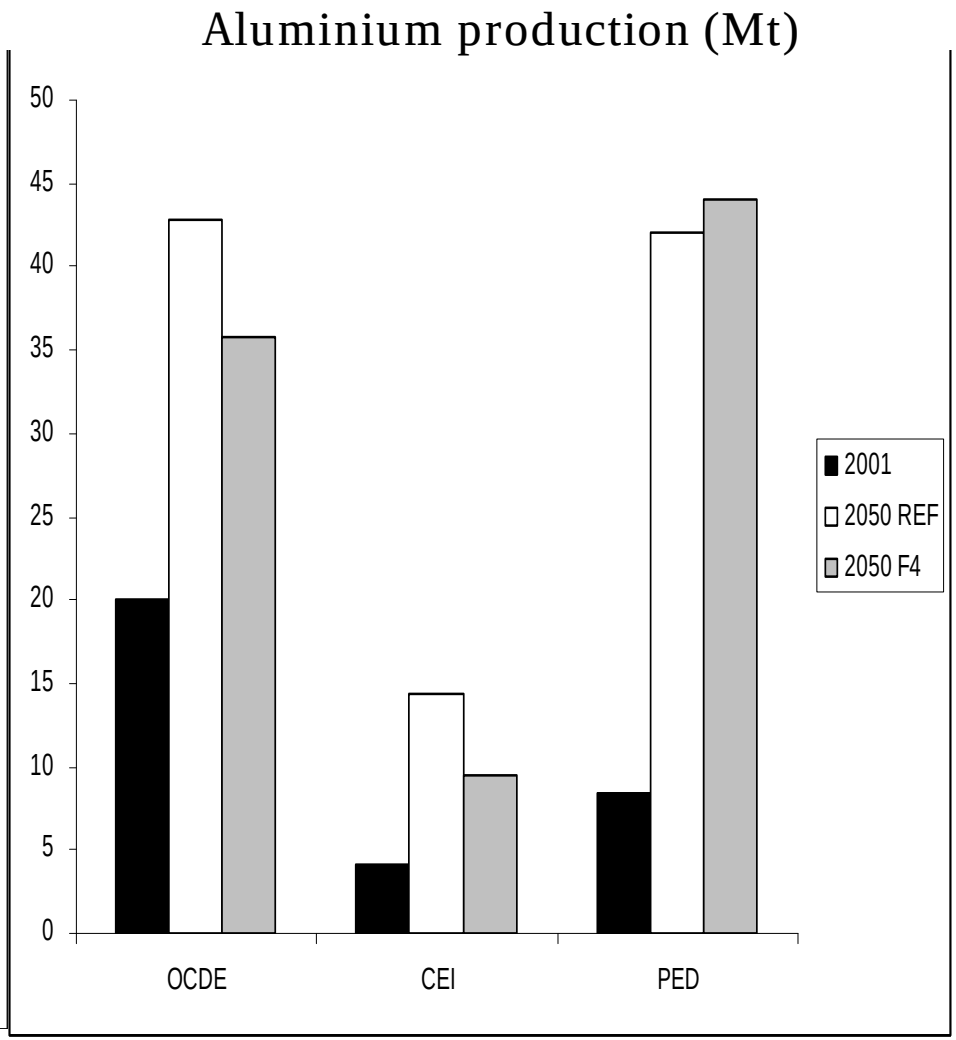


REF vs. 450ppm energy-intensive industry price levels



A global and tight constraint slows down the relocation of energy intensive industry?





Key underlying questions behind such a result

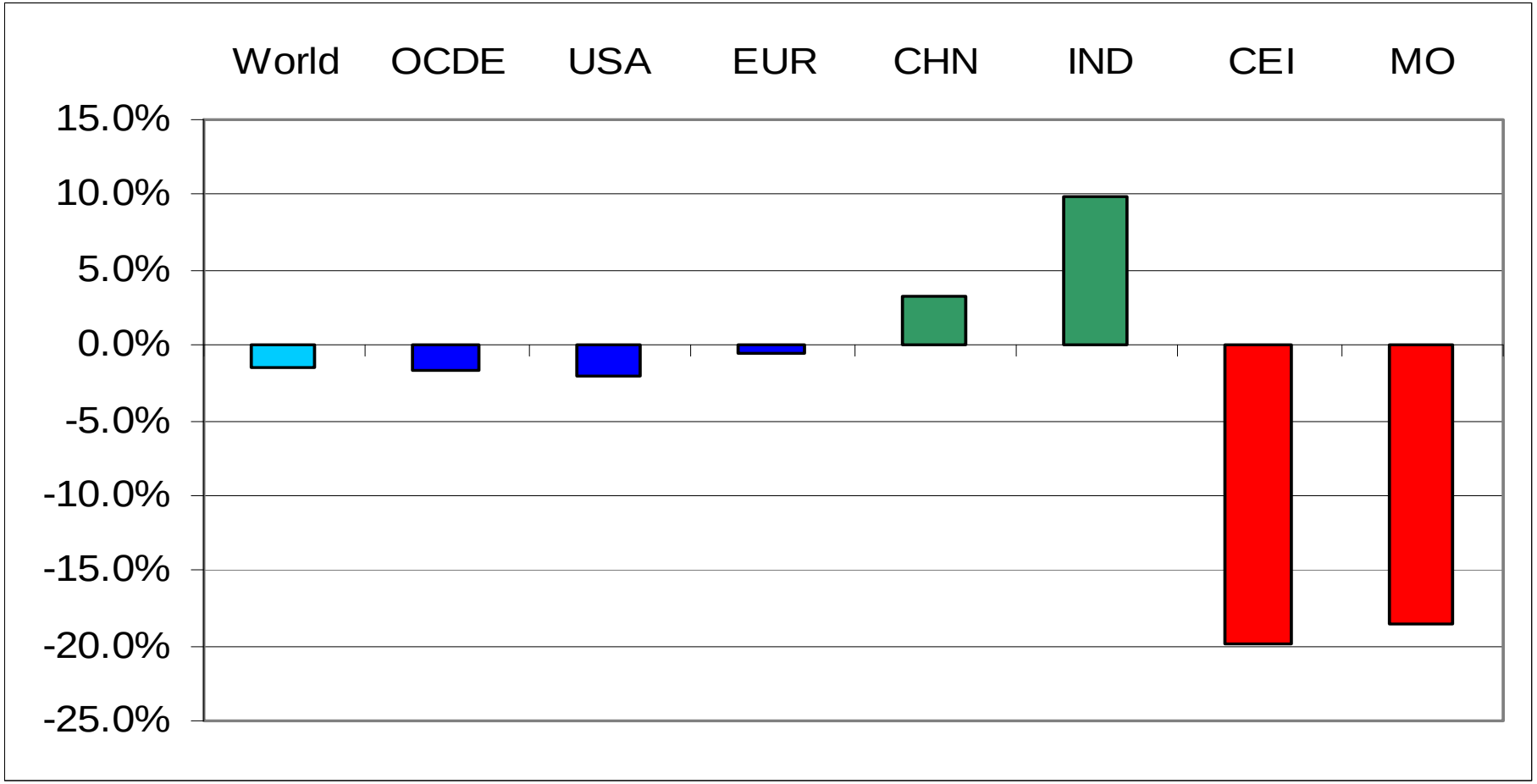
- Uncertainty about future « pass-through » behaviors
- What future market dynamics (product differentiation, towards higher value added products?)
- The level of recycling does not only depend on industrial decision-makers
- What about the reversal of current trends in the « transport content» of productions (overall costs are very sensitive to this parameter)
- Regional Investment Dynamics?
  - Security
  - Market proximity
  - Solidarity of technical segments
  - « Intangible costs »

The economics of a 450 ppm – F3 scenario: from good news to bad news?

Winners and loosers

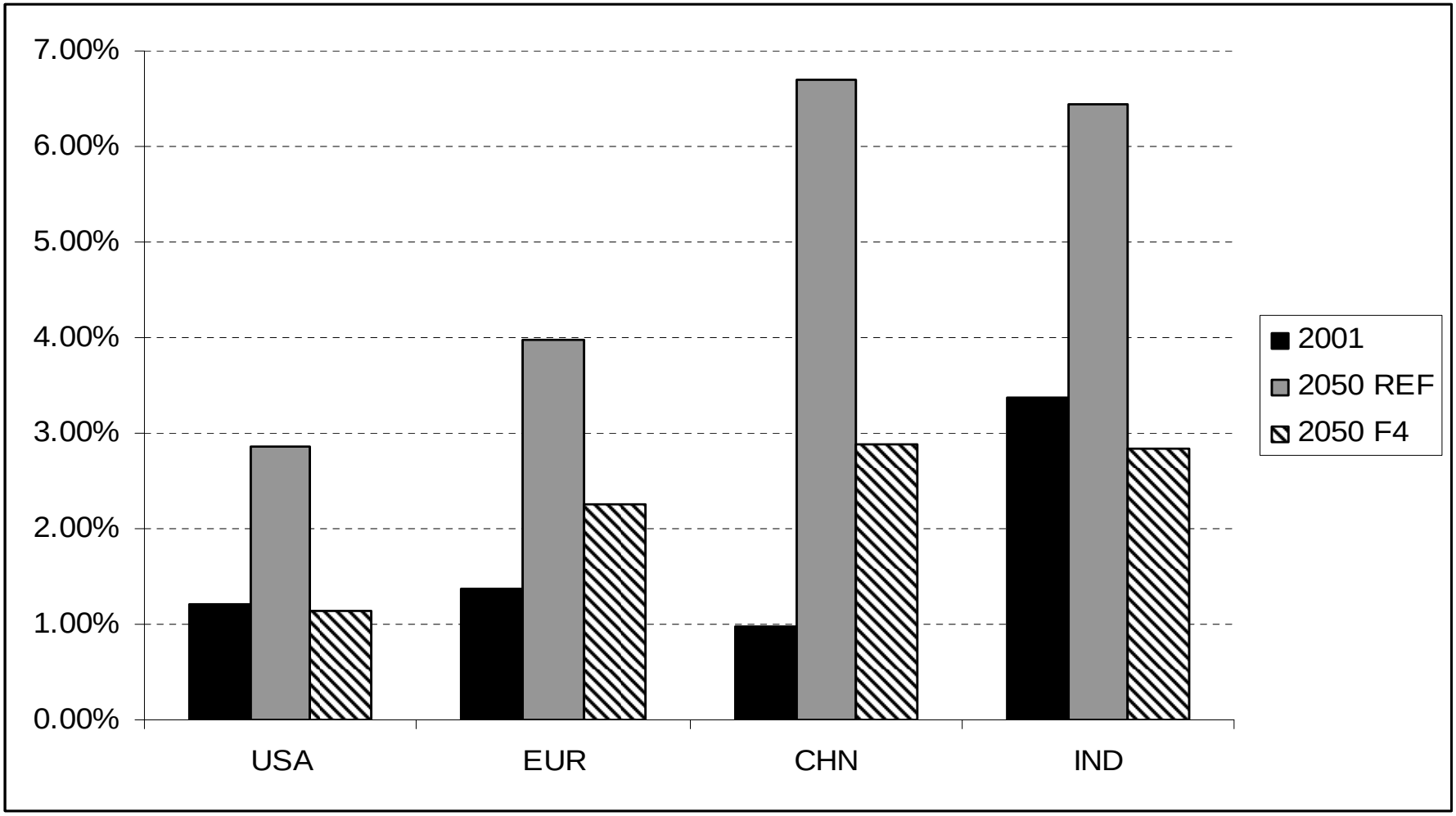
Growth delay or gain :

EU: -0.25 yrs / *US:* -0.85 yrs / *China & India:* +2.5 yrs / *CEI & ME*: -4 yrs



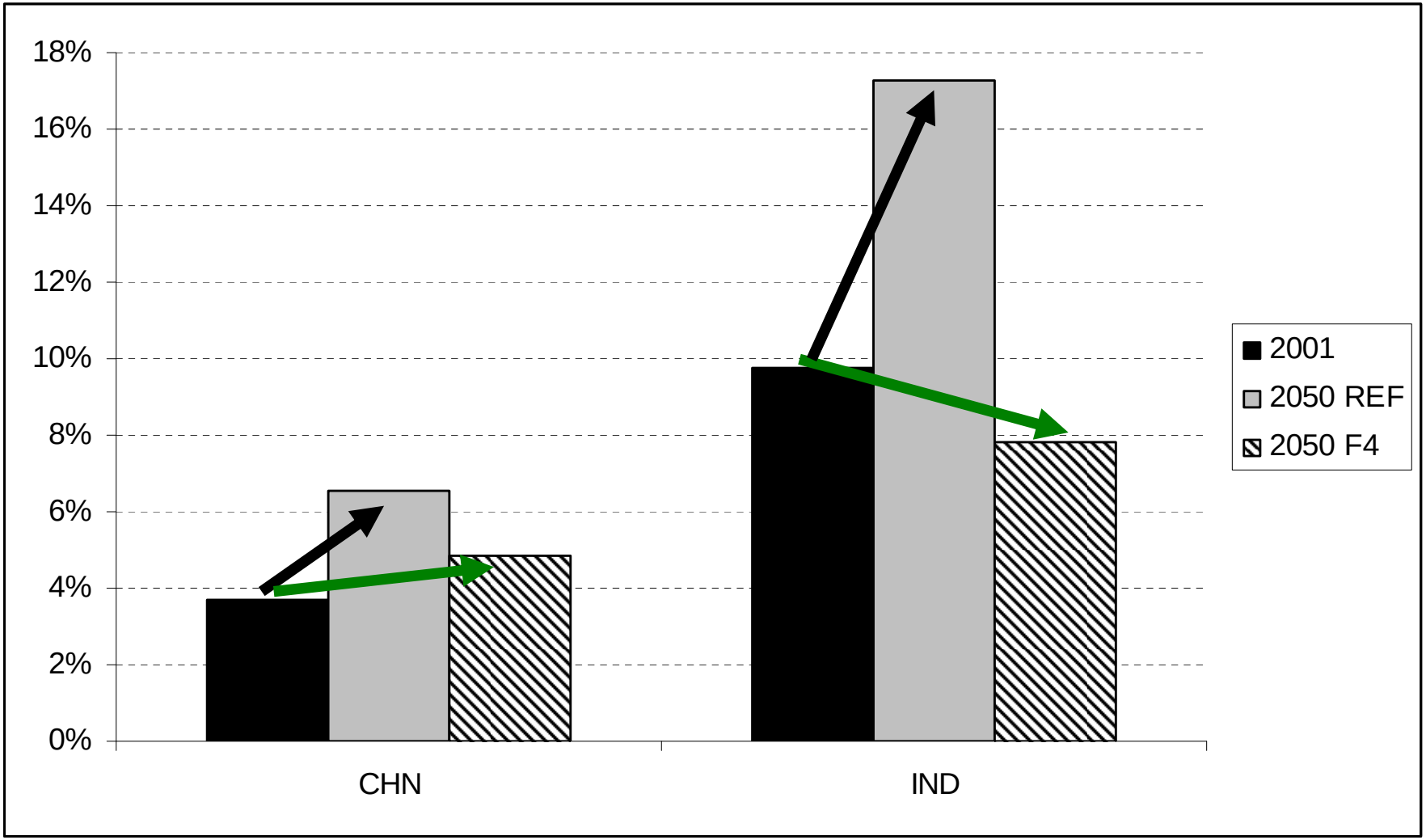
PIB variations in 2050 between REF et 450 ppm - F3 scenarios

A side dividend of climate policy in developed and developing countries: far lower energy imports



Ratio of energy trade over GDP – REF and 450-F3 scenarios

Why India and China do so well in a 450 ppm scenario in 2050?



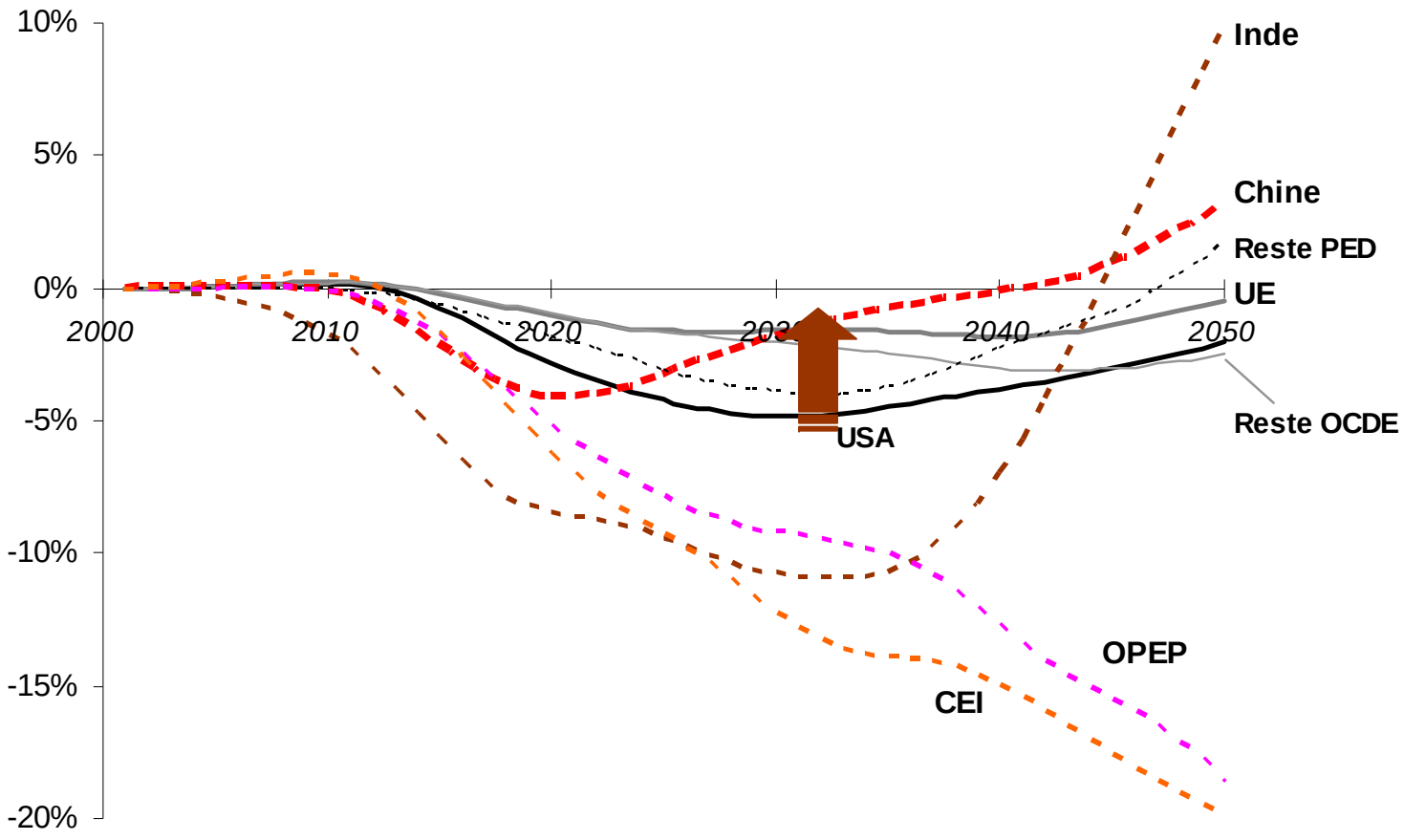
Share of energy in household budget

When the ‘nice’ picture in 2050 may be misleading …

- **This encouraging story in 2050 depends upon**
  - **Steadily growth price signals and PAMS**
  - **A ‘reasonable’ but strong technological optimism**
  - **Totally flexible terms of trade**
  - **Smooth absorption of external payments disequilibrium**
  - **Political capacity to respond to OPEC and CEI strategic reactions**

- **And the pathway towards this F4 is full of asperities**

Nothing like smooth pathways!



GDP variations: ratio of the 450 ppm scenario over the REF scenario

Why the US suffer more at a first period

Household energy expenses 450 ppm-F3 vs. REF		
	2020	2050
USA	+62.64%	-11.88%
EUR	+23.18%	-25.71%

Price of Industrial goods 450 ppm-F3 vs. REF		
	2020	2050
USA	+4.76%	-3.68%
EUR	+5.57%	-4.07%

‘A few’ institutional implications?

- A paradox: the carbon price hurts DCs when it is low, not when it is high at the end of the period
- Back to the original interpretation of a ‘Kyoto-type’ system
  - A unique international carbon price
  - Differentiated signals across sectors ta take into account second-best ‘real world’ constraints
  - Other complimentary PAMs such as fiscal reform, infrastructure and urban planning
- A need for early action in DCs:
  - ✓ Activate a ‘Marshal plan’ to subsidy low-carbon infrastructure choices
  - ✓ Deal with the distributional effects of the climate policy
  - ✓ Issue linkage (e.g. monetary policies)