institut du développement et des relations internationales durable

2050 ENERGY SCENARIOS

FOR FRANCE

Michel Colombier

IDDRI Paris

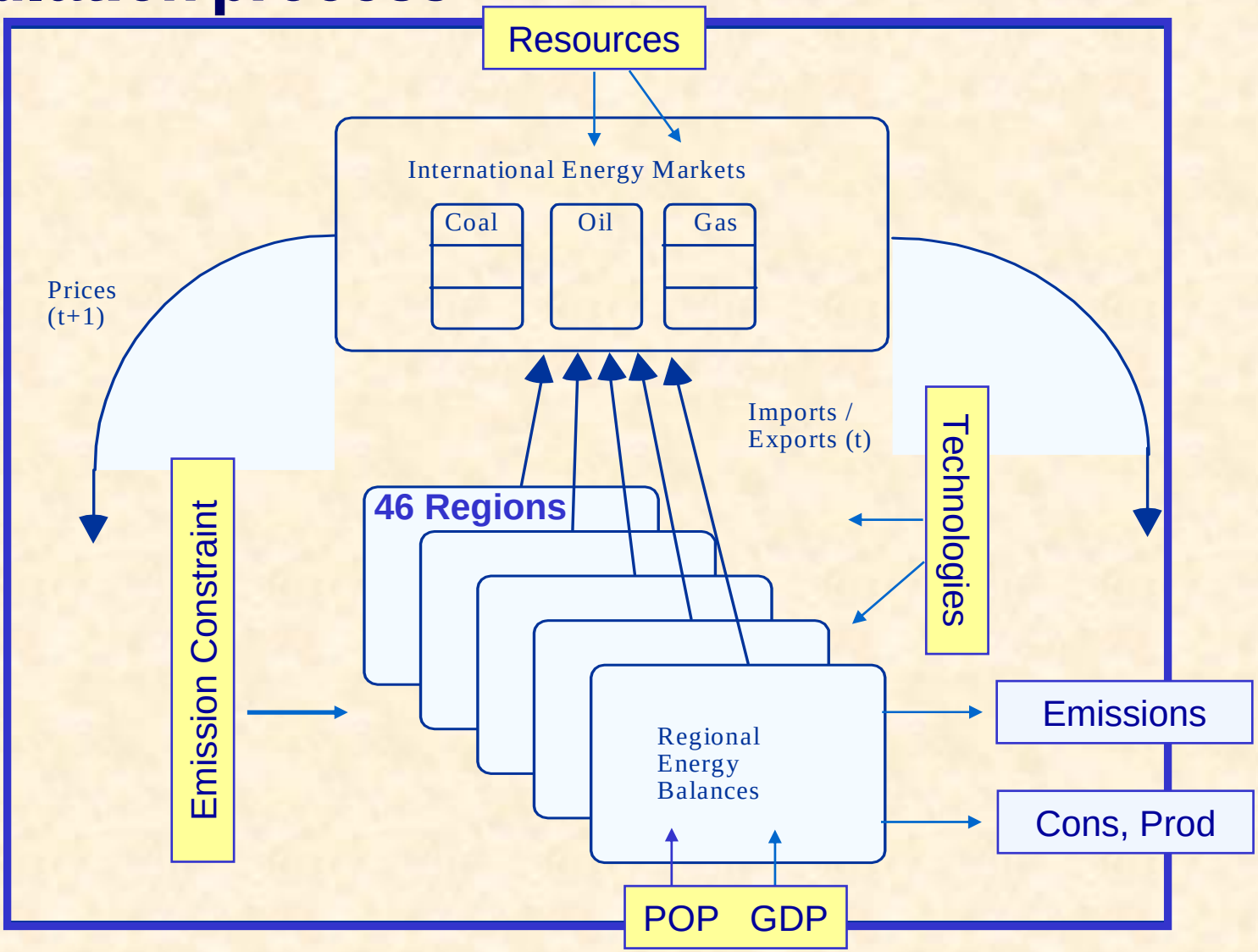
Outline of the presentation

- **Energy Technology Outlook, using the POLES model (P. Criqui, LEPII-EPE CNRS)**
- **« Factor four » MIES study, developped by P Radanne (former President of MIES)**
- **Lessons for policy makers**
  - Short and medium term policies
  - Research programmes
- **New developments on Industry (Iddri research programme with LEPII-EPE and CIRED)**

Energy Technology Outlook using the POLES model

- A dynamic partial equilibrium model
- EU research programmes (Joule, FP5)
- A Global, Energy Sector and GHG emitting Activities representation
- A recursive simulation framework exogenous/endogenous technologies

The POLES model year-by-year recursive simulation process



POLES : Energy demand modules

	Substituable Fuels	Electricity	Transport Fuels
Industry			
Steel industry	X	X	
Chemical industry	X	X	
Non Metallic Mineral	X	X	
Other industries	X	X	
Transport			
Road / passenger			X
Road / goods			X
Rail / passenger		X	
Rail / goods		X	
Air transport			X
Other			X
Tertiary	X	X	
Residential	X	X	
Agriculture	X	X	

Very Low Energy/Emission Technologies

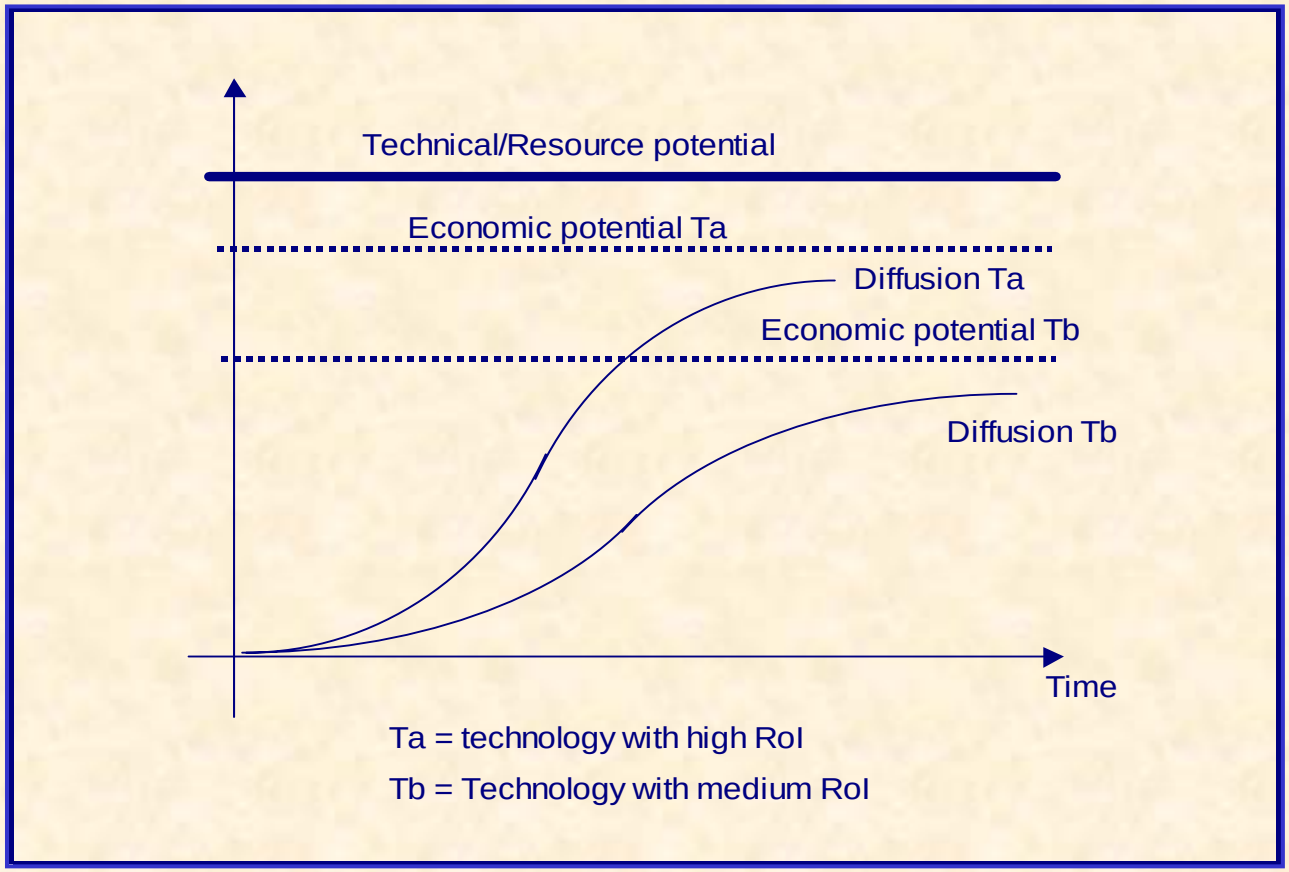
- **Low emission vehicles:**
  - Conventional ICE vehicle — ICE
  - Hybrid vehicle — HYB
  - Battery electric car — BEC
  - Direct H2-ICE vehicle — HCE
  - Methanol FCV — FCVM
  - Hydrogen Fuel-Cell Vehicle — FCVH
- **Low energy buildings:**
  - LEB in existing and new stock (50% of conventional)
  - VLEB in new stock (25% of conventional)

POLES : New and Renewable technologies

New and Renewable Technologies	
Waste Incineration CHP	BF2
Biomass Gasif. with Gas Turbines	BGT
Combined Heat and Power	CHP
Photovoltaics (windows)	DPV
Proton Exch. Membr. Fuel Cell (Fixed)	MFC
Solid Oxide Fuel Cell (Fixed Cogen.)	SFC
Rural Photovoltaics	RPV
Solar Thermal Powerplants	SPP
Small Hydro	SHY
Wind Turbines	WND
Biofuels for transport	BF3
Fuel Cell Vehicle (PEM)	FCV

POLES : New energy technology diffusion

- **Market potential and speed of diffusion increase with cost-competitiveness**

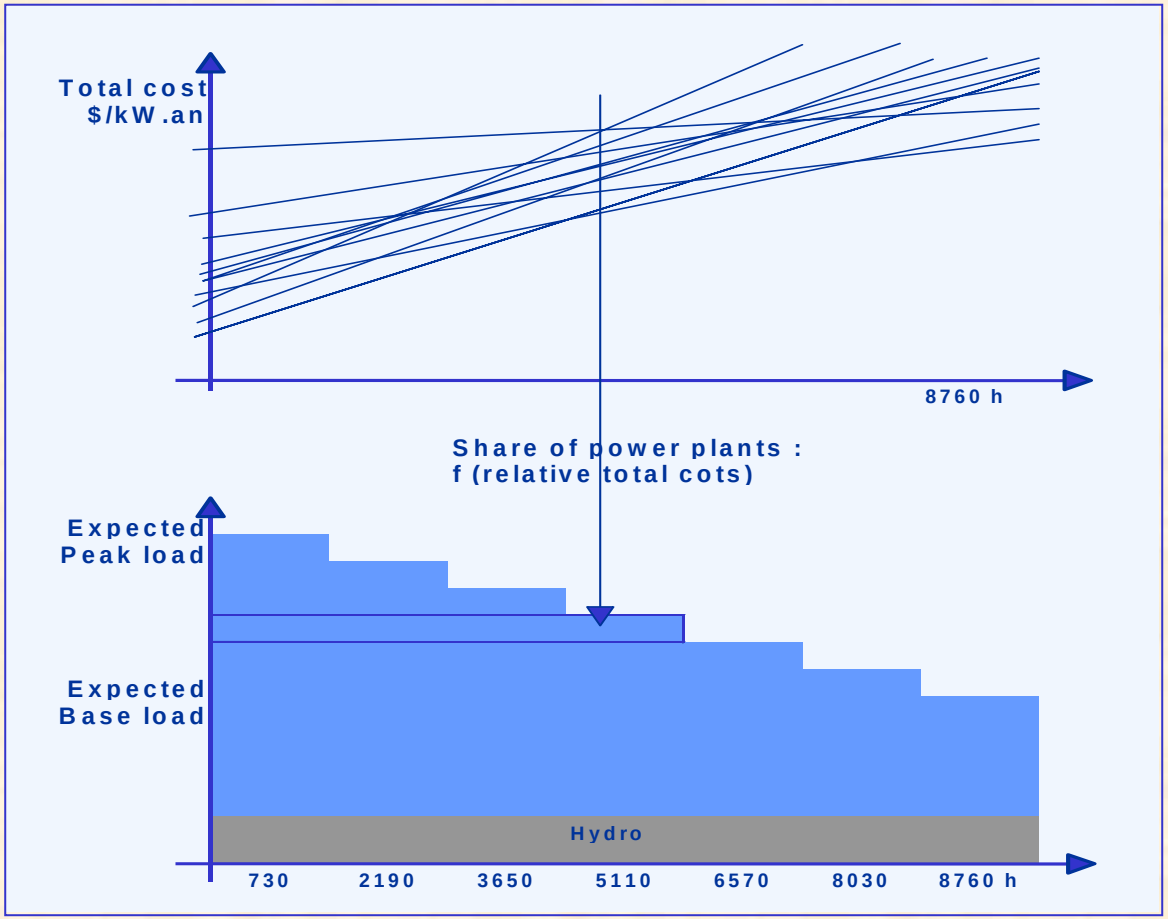


POLES : Large scale power technologies

	Large Scale Power Generation	
	Advanced Thermodynamic Cycle	ATC
	Super Critical Pulverised Coal	PFC
	Integrated Coal Gasif. Comb. Cycle	ICG
	Coal Conventional Thermal	CCT
	Lignite Conventional Thermal	LCT
	Large Hydro	HYD
	Nuclear LWR	NUC
	New Nuclear Design	NND
	Gas Conventional Thermal	GCT
	Gas Turbines Combined Cycle	GGT
	Oil Conventional Thermal	OCT
	Oil Fired Gas Turbines	OGT

POLES : Power generation capacity planning

- Investment costs from CTS E3DB database
- Fuel costs endogenous to the model



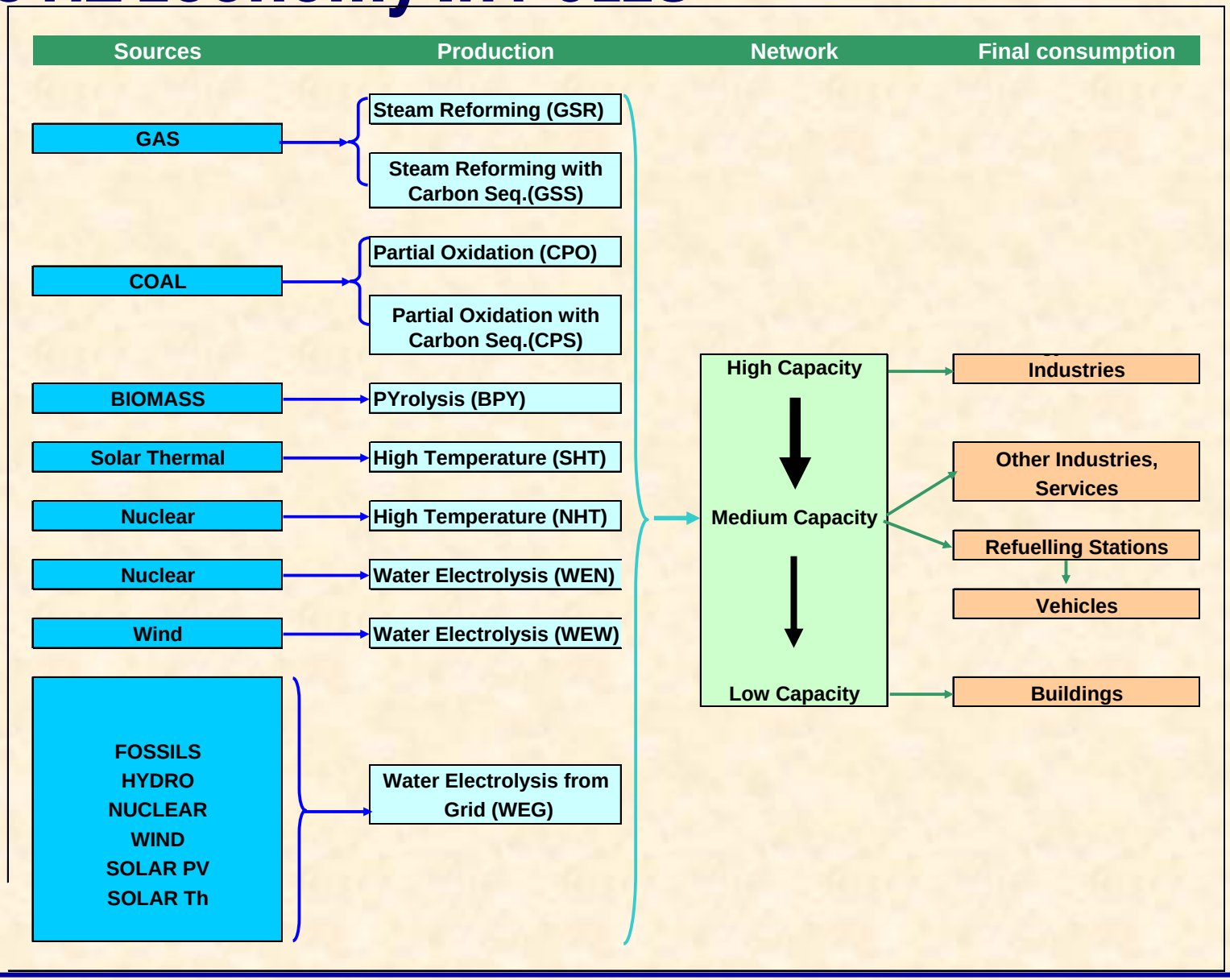
POLES : Endogenous technological progress

- In POLES Reference case, a « Two Factor Learning Curve », simulates cost decrease with cumulative installed capacities and cumulative R&D spending (public and private)

$$COST = A * CUMCAP^{-b} * CUMRD^{-c}$$

with: CUMRD = Government Energy R&D
+ Business Energy R&D

The H2 Economy in POLES



2 + 10 Hydrogen technologies

2 End-use technologies

- Hydrogen Fuel-Cells for stationary uses (+Gas FC) — HFC, GFC
- Hydrogen Fuel-Cell Vehicles (+Methanol FCV), — FCVH, FCVM

10 H2 Production technologies

- Hydrogen from Gas Steam Reforming — GSR
- Gas Steam Reforming with CO2 Sequestration — GSS
- Coal Partial Oxidation — CPO
- Coal Partial Oxidation with CO2 Sequestration — CPS
- Biomass Pyrolysis — BPY
- Solar High-temp. Thermochemical cycles — SHT
- Wind Energy Water electrolysis — WEW
- Nuclear High-temp. Thermochemical cycles — NHT
- Water Electrolysis, dedicated Nuclear power plant — WEN
- Water Electrolysis, baseload electricity from Grid — WEG

5 Carbon Capture & Sequestration options

Electricity technologies

- PFC + CCS => PSS Pulverized fuel Supercritical with CCS
- ICG + CCS => CGS Integrated Coal Gasification with CCS
- GGC + CCS => GGS Gas powered Gas turbine in combined cycle with CCS

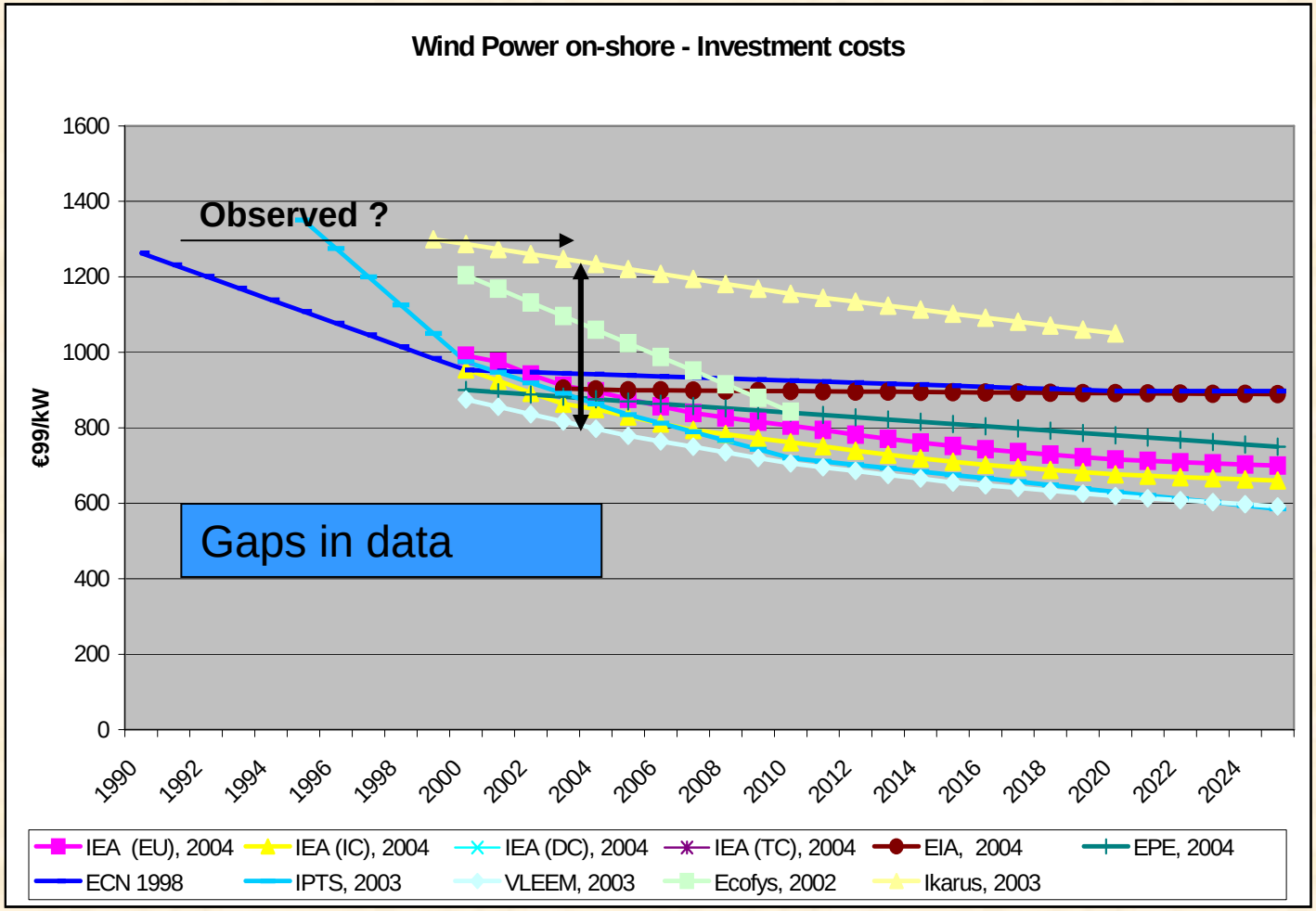
Hydrogen technologies

- GSR+CCS => GSS Gas Steam reforming with CCS
- CPO+CCS => CPS Coal Partial oxidation with CCS

Techs-DB: a database for key energy technologies

- Techs-DB is developed in the framework of the CNRS Energy Programme and of different DG-Research projects, on a collaborative basis
- It aims at improving the quality and consistency of technology hypotheses in modelling and policy analysis exercises
- Detailed cost/performance data are gathered and harmonised for a set of about 50 generic technologies, corresponding to the POLES model portfolios

Techs-DB:
understanding and harmonising technology data



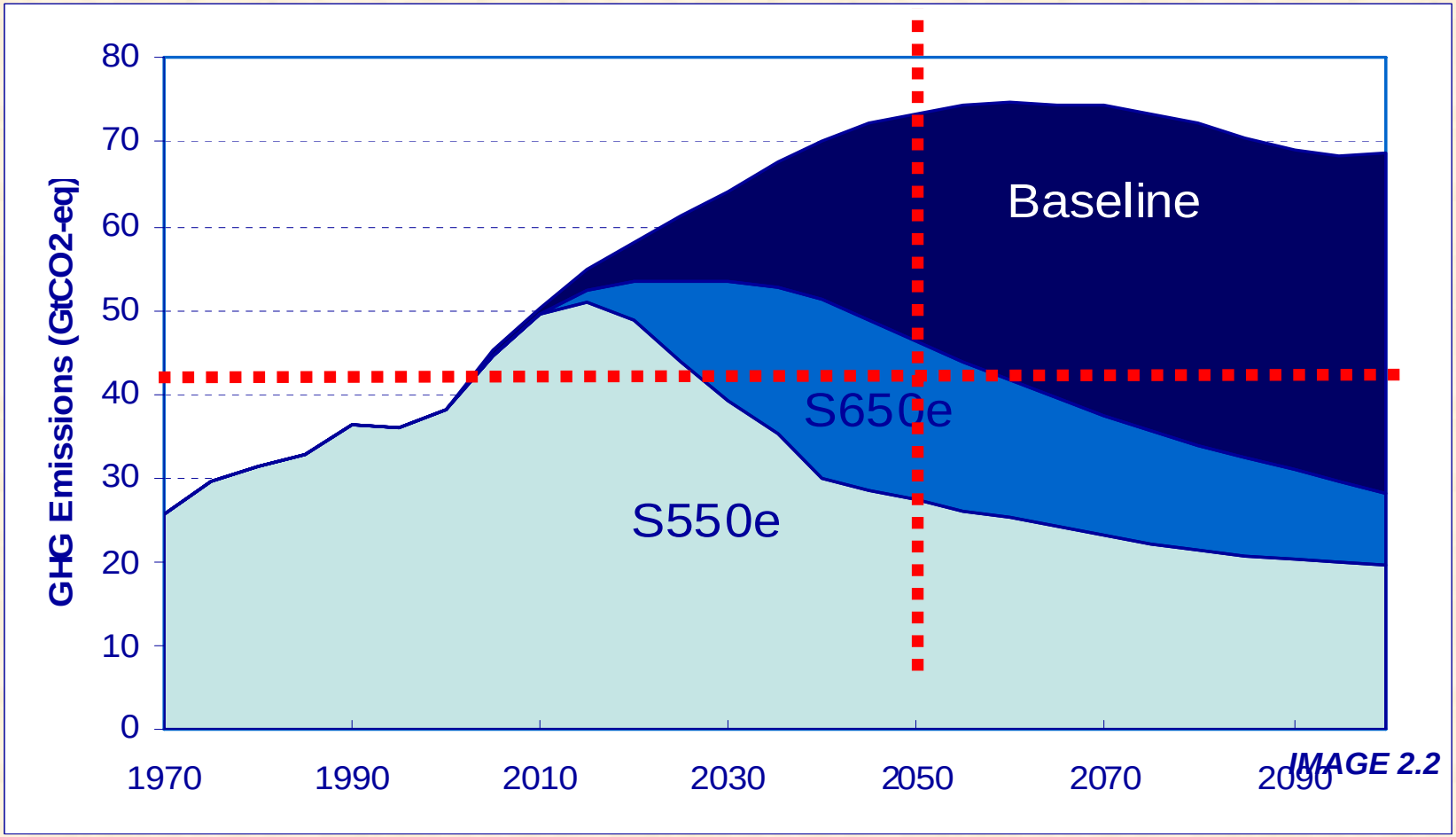
Techs-DB: the fundamentals of H2 production

		GSR		CPO		BPY		SSE		HWE	
		2000	2050	2000	2050	2000	2050	2000	2050	2000	2050
Investmt Cost	€/(M3d)	45	27	113	68	118	71	600	350	124	74
Technical lifetime	Years	35	35	35	35	35	35	35	35	25	25
Annual fixed cost											
Capital Cost	€/(M3d)	3,8	2,3	9,7	5,8	10,1	6,1	51,5	30,0	11,6	7,0
FOM (10%)	€/(M3d)	0,38	0,23	0,97	0,58	1,01	0,61	5,15	3,00	1,16	0,70
Fixed cost	€/(M3d)	4,21	2,54	10,62	6,37	11,15	6,69	56,63	33,03	12,75	7,65
Fixed cost	€/koed	393	237	992	595	1041	625	5288	3085	1191	715
Availab. Factor	%	75%	75%	75%	75%	75%	75%	20%	20%	33%	33%
Fixed cost	€/toe	60	36	151	91	158	95	3019	1761	412	247
Variable Costs											
Fuel price (end)	€/toe	103	292	80	147	200	220	0	0	648	660
Fuel efficiency	%	75%	80%	50%	65%	65%	65%	*15%*	*15%*	75%	75%
VOM	€/toe	6	6	35	35	35	35	35	35	21	21
Variable cost	€/toe	143	371	195	262	343	373	35	35	885	901
Production cost	€/toe	203	407	345	352	501	469	3054	1796	1297	1148

A « factor 4 » scenario using the Poles model

- Developped for the ministry of industry
- Consistent with EU goals (2°C increase)
- A « factor 4 » for AI countries, but a « factor 3 » for France (taking into account the current level)

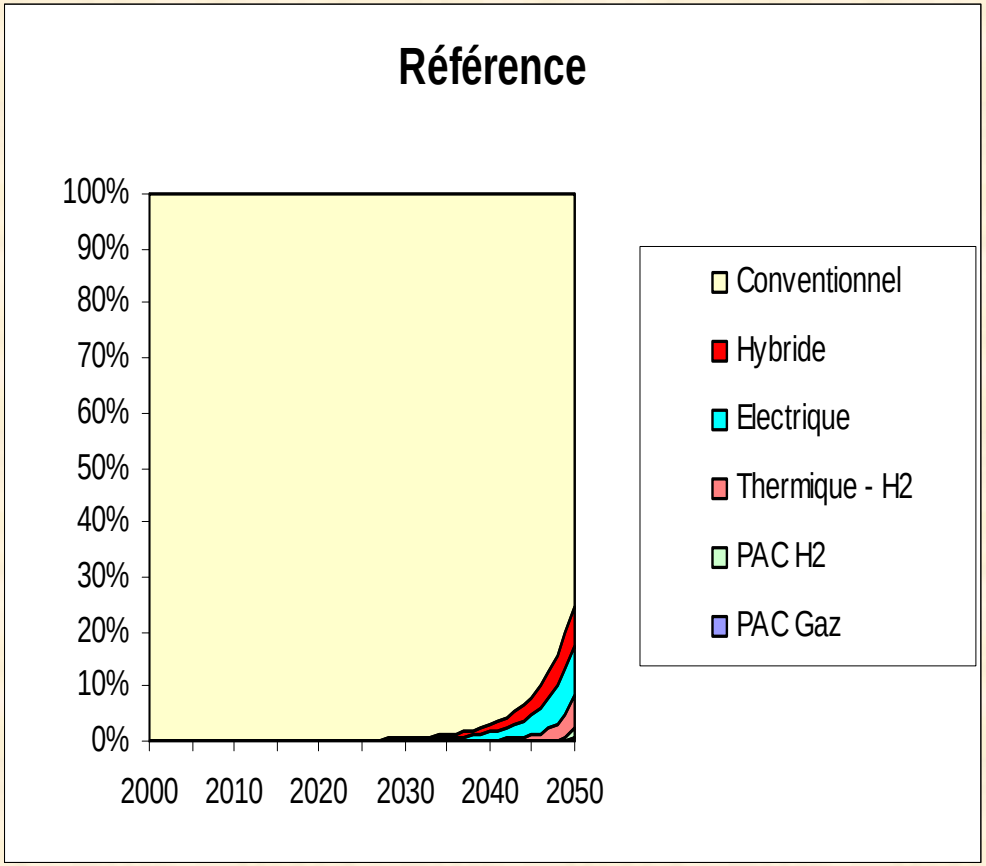
The global Context : S550e and S650e profiles

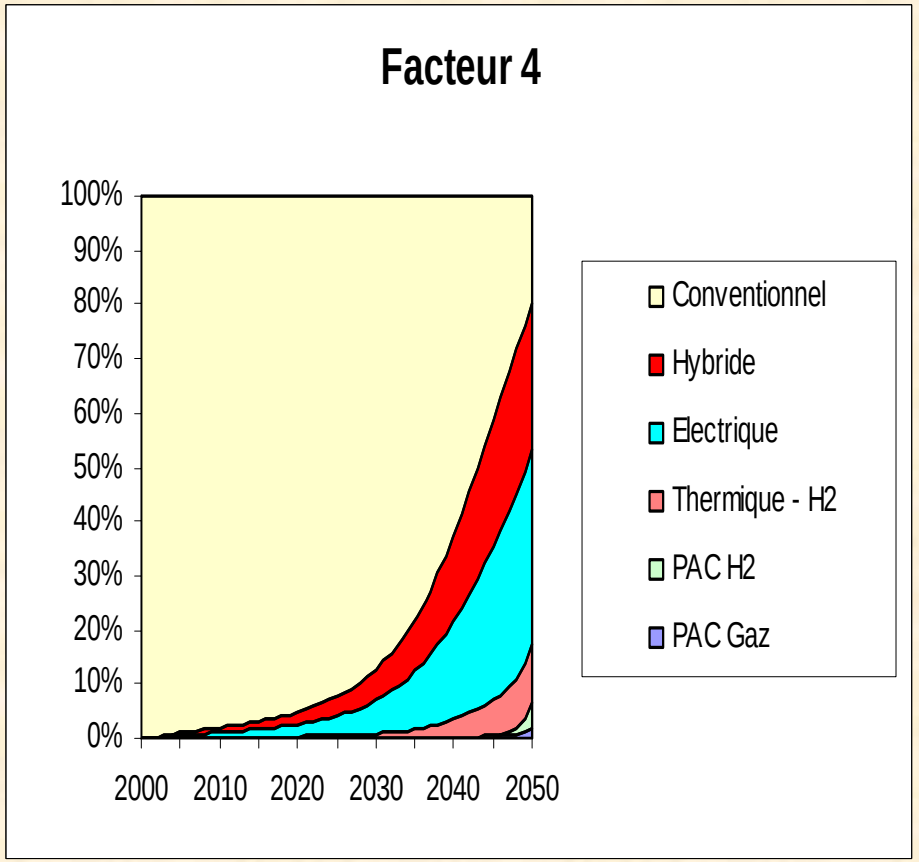


2050 regional profiles

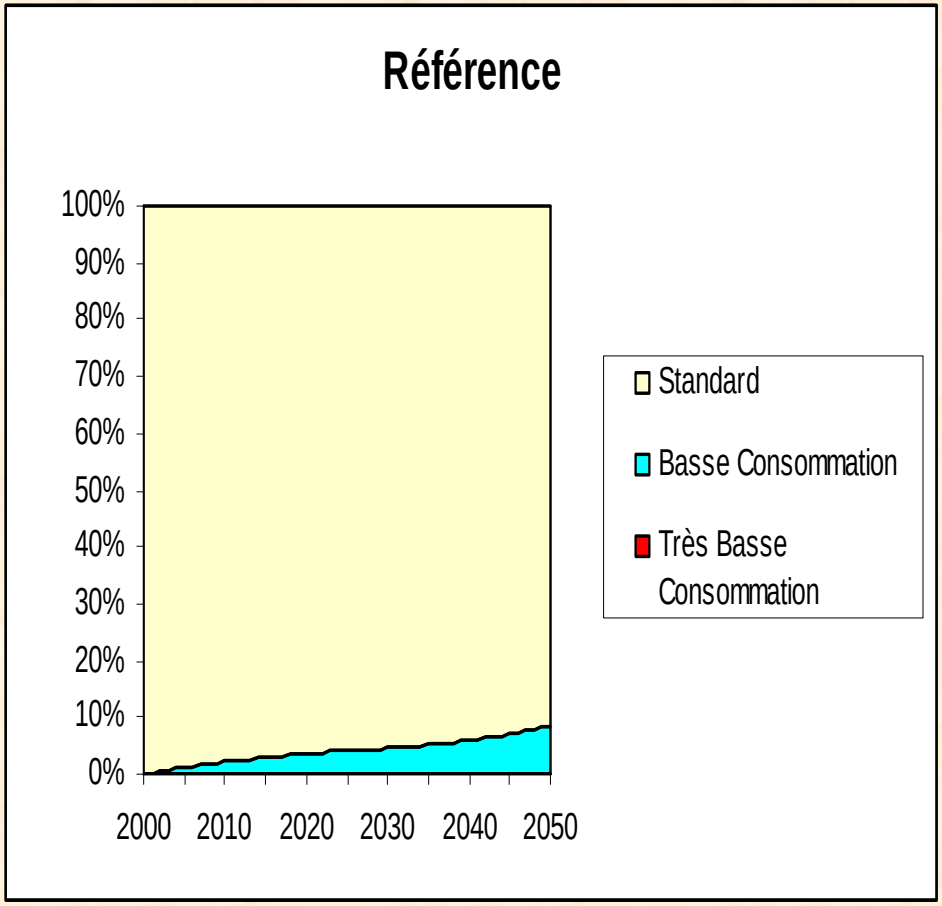
Emission profile	Temp. increase (median IPCC 2001 CSF)	2050 endowmts. compared to 1990 emiss.	
		Annex I	Non Annex I
S650e	+ 2.5°C from pre-ind. + 1.9 °C from today	/ Factor 2	x 2 (LAM, MET, SEEA) x 5 (AFR, SOA = baseline)
S550e	+1.6 °C from pre-ind. + 1.0 °C from today	/ Factor 4	x 1 (LAM, MET, SEEA) x 3 (AFR, SOA)

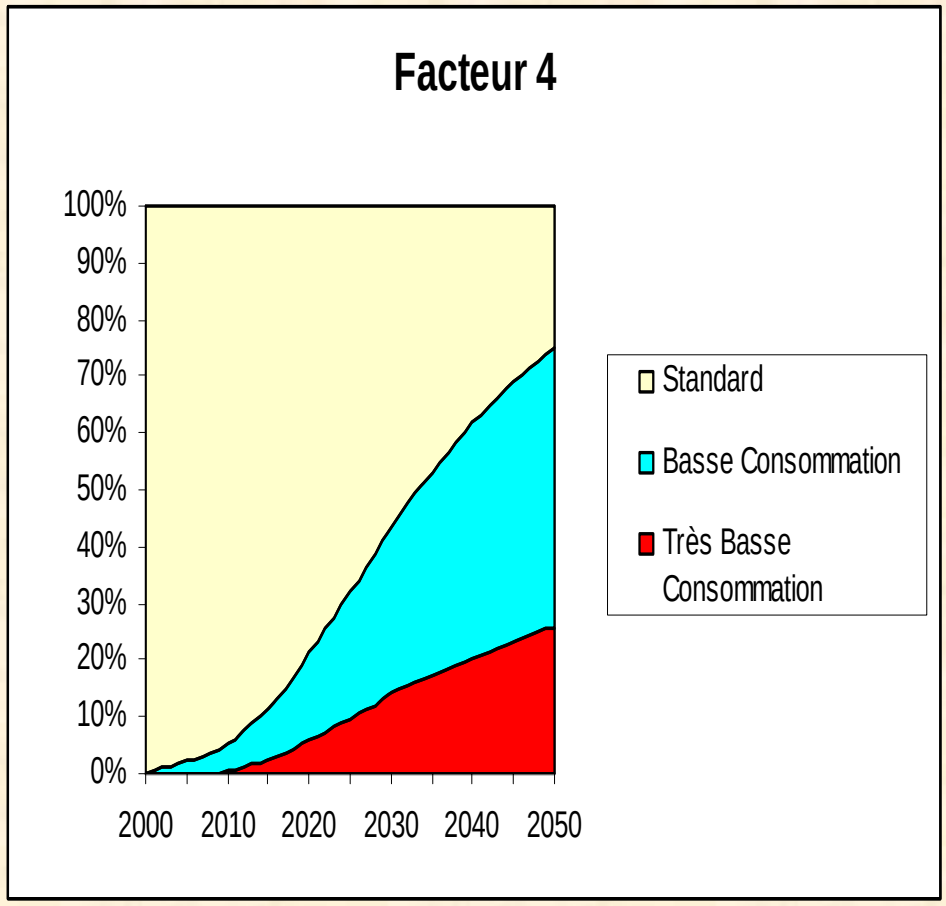
Share of VLE Vehicles



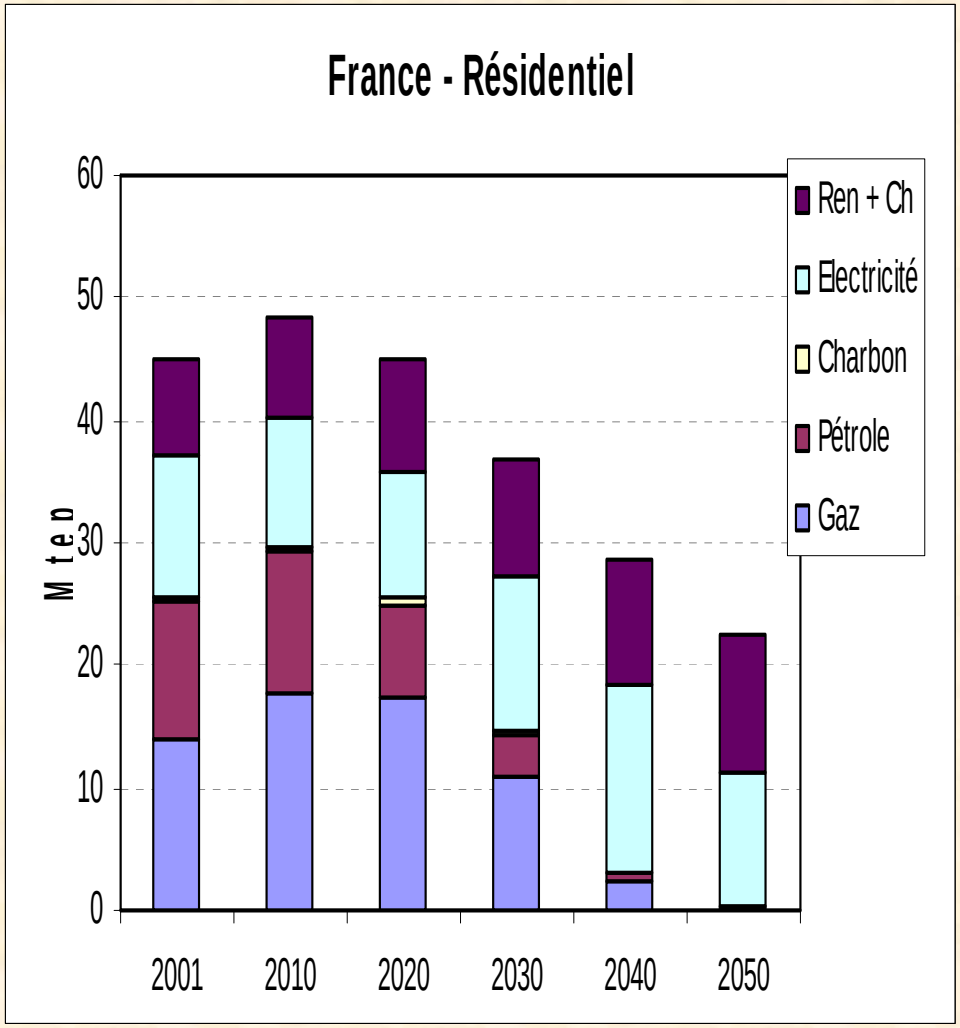


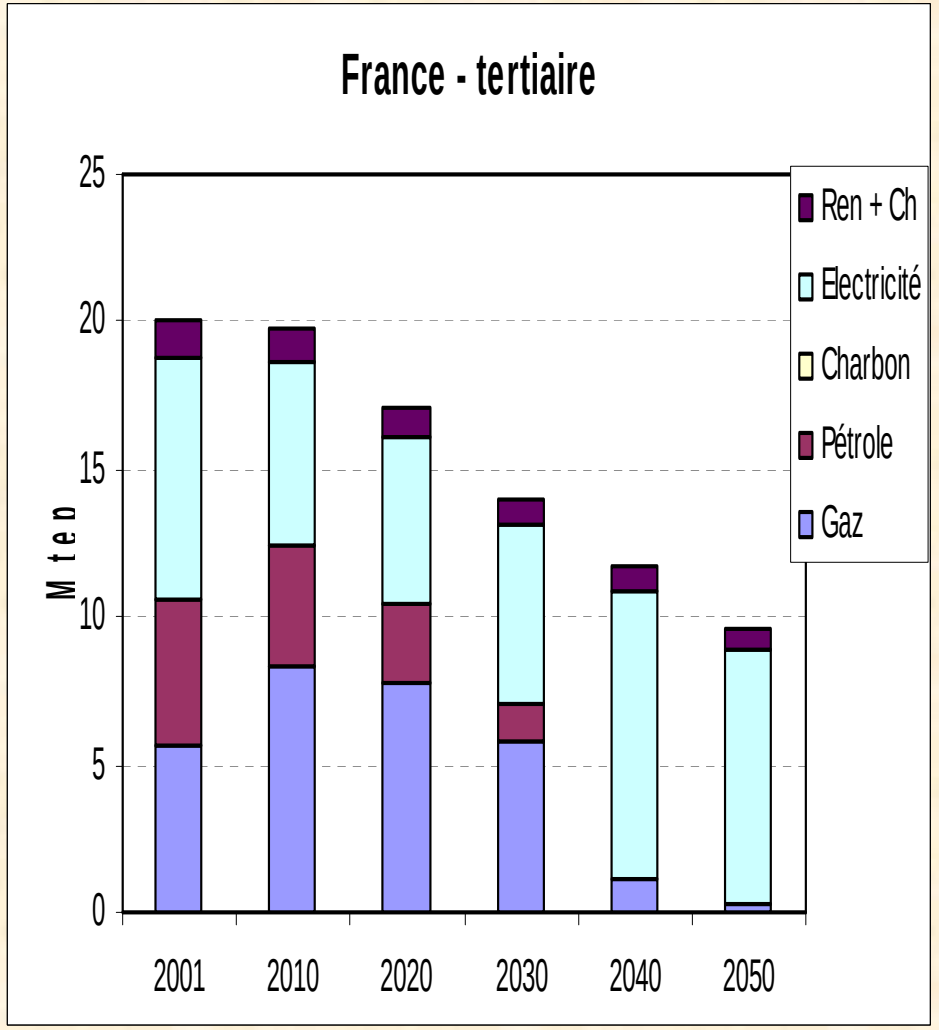
Share of VLE Buildings





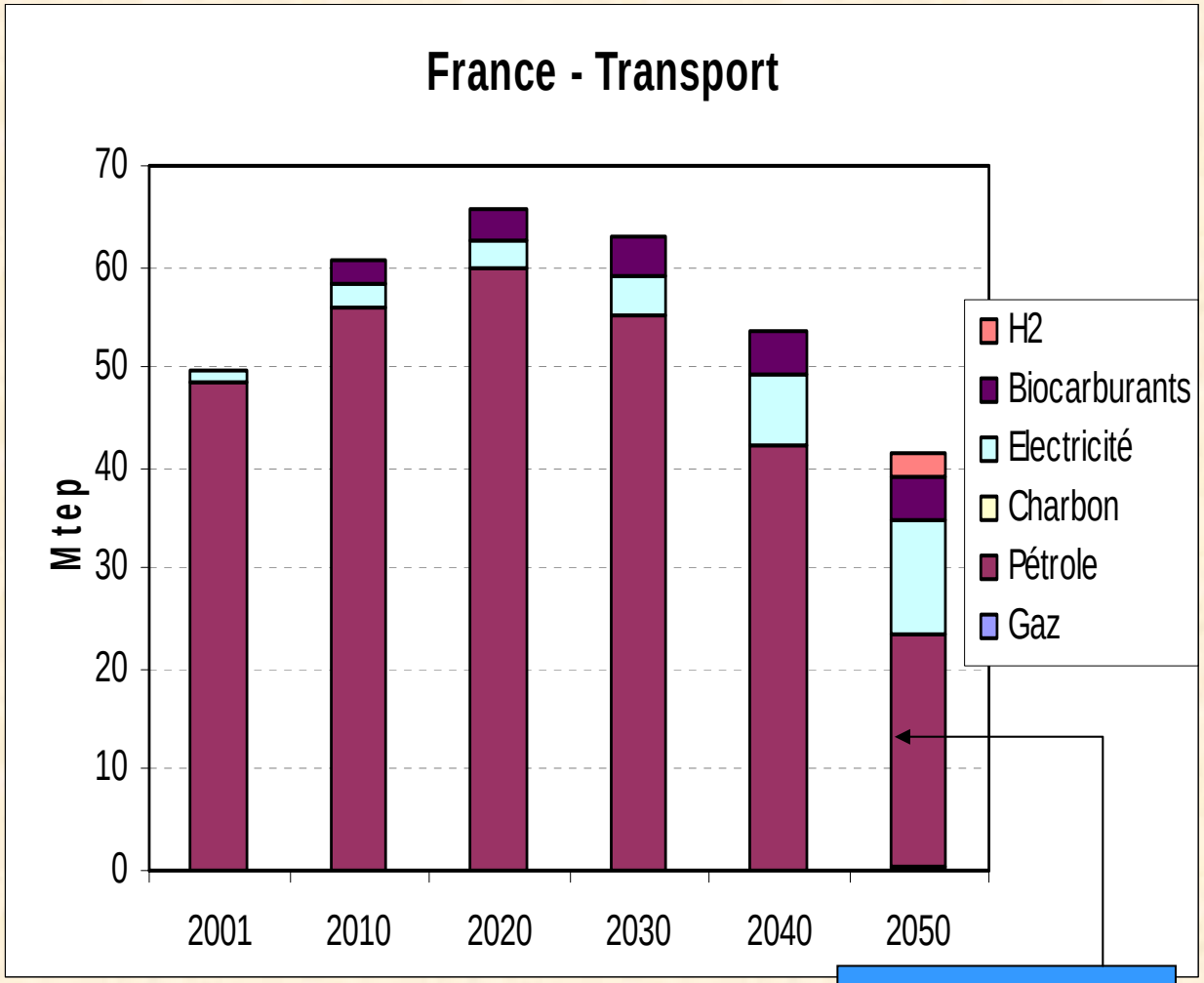
RESIDENTIAL AND SERVICE





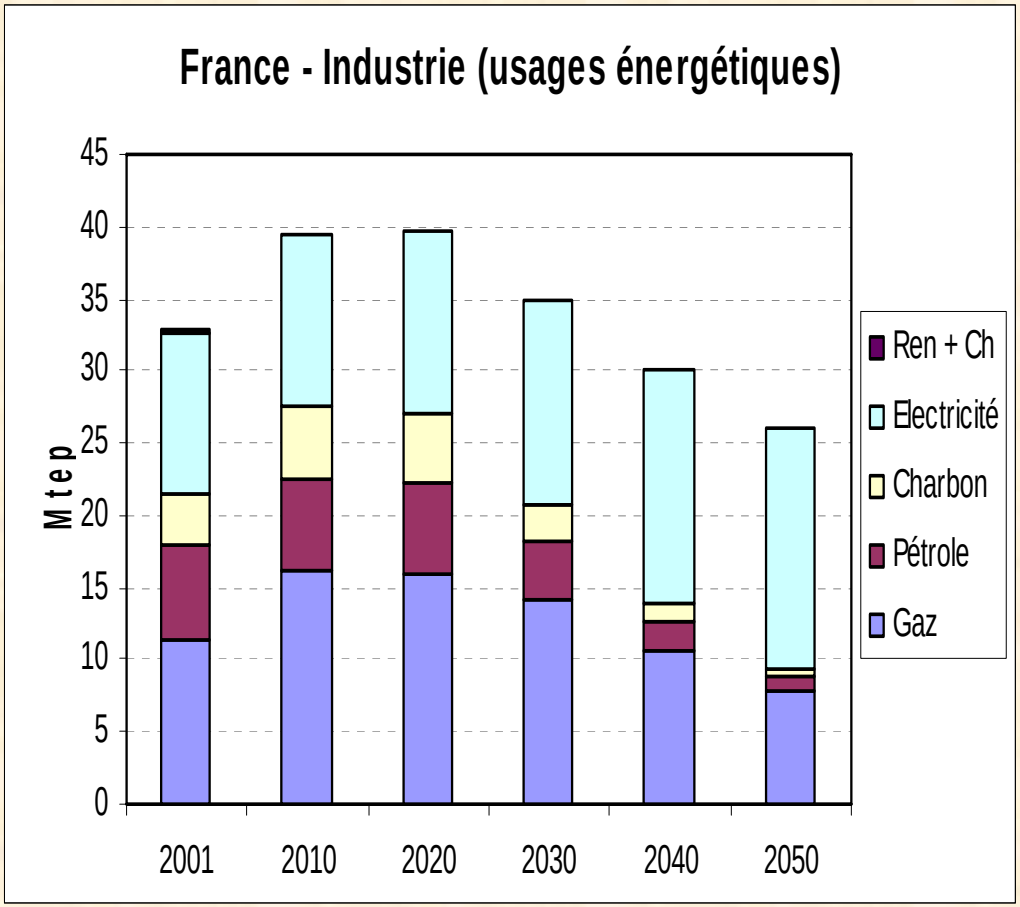
Transports

- Consumption increase until 2020
- Fast diffusion of new vehicles after 2030

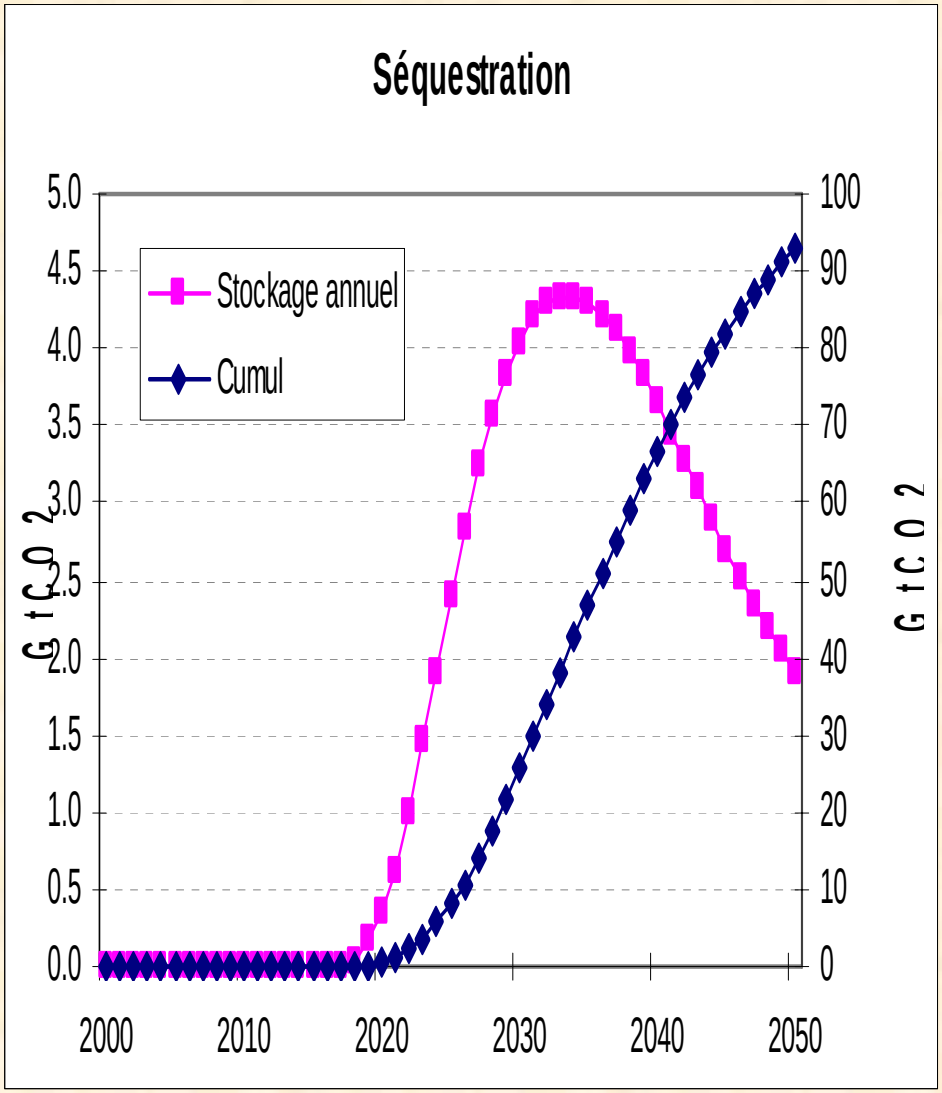


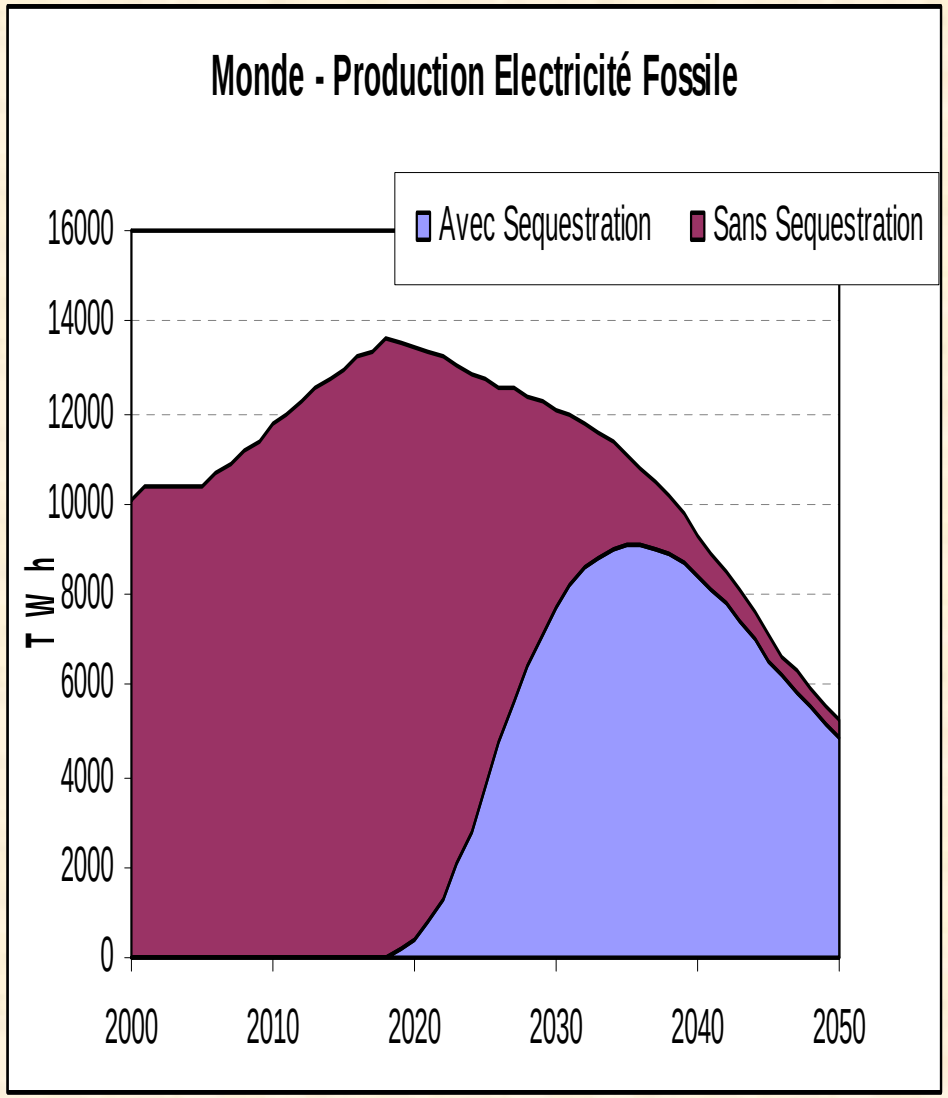
INDUSTRY

- Stabilisation of Industry consumption after 2010
- A mix of Gas and Electricity



CCS takes almost all thermal generation between 2020 and 2030 …





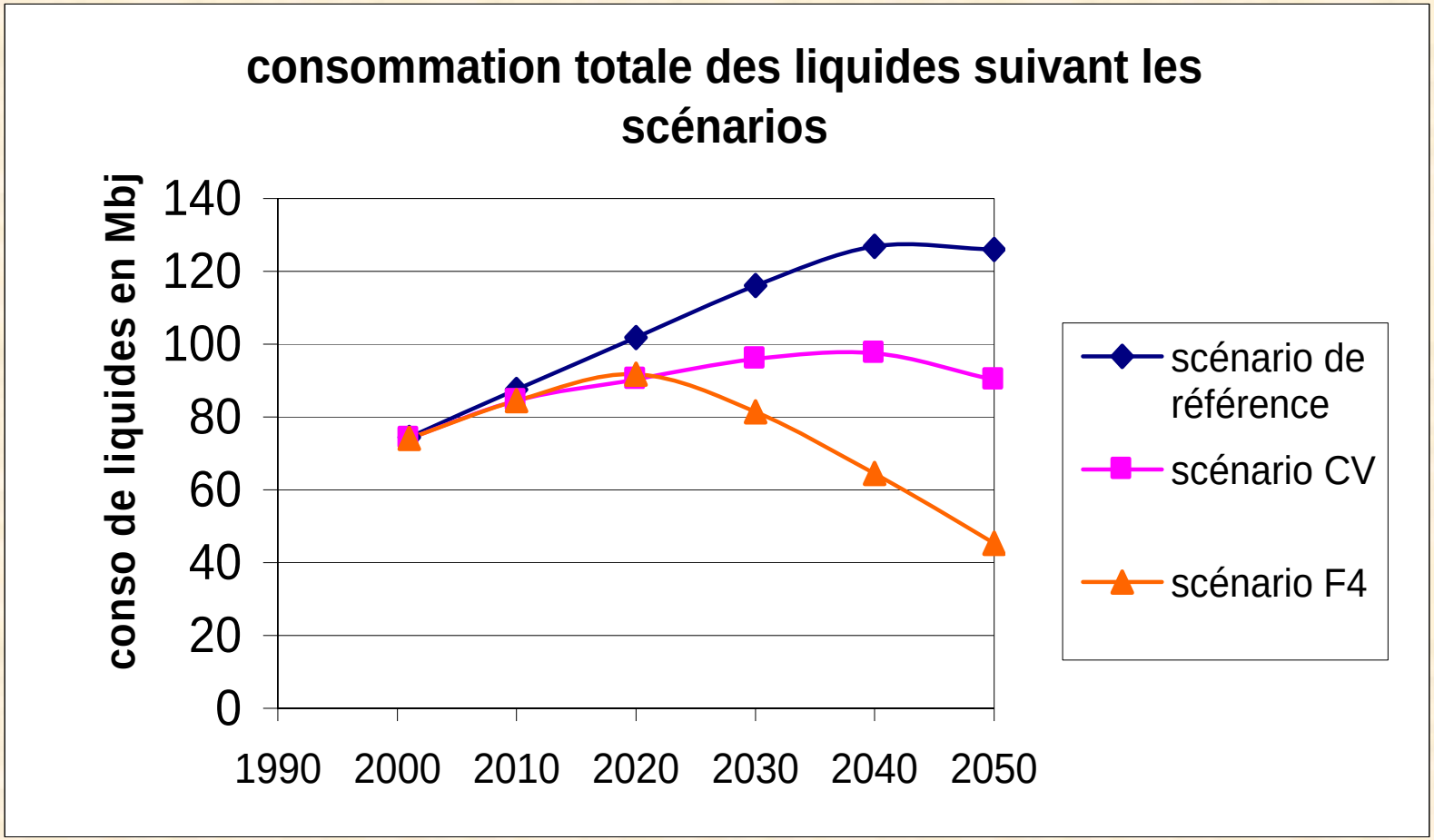
… but in current scenarios, the extra cost limits the competitiveness compared to renewables and nuclear

from Techs DB and for 2025

€/MWh	Pulverised Coal	Pulverised Coal + CCS	Wind	Nuclear
0 €/tCO2	30	42	39	35
20 €/tCO2	46	46	39	35

Impacts on the international markets:

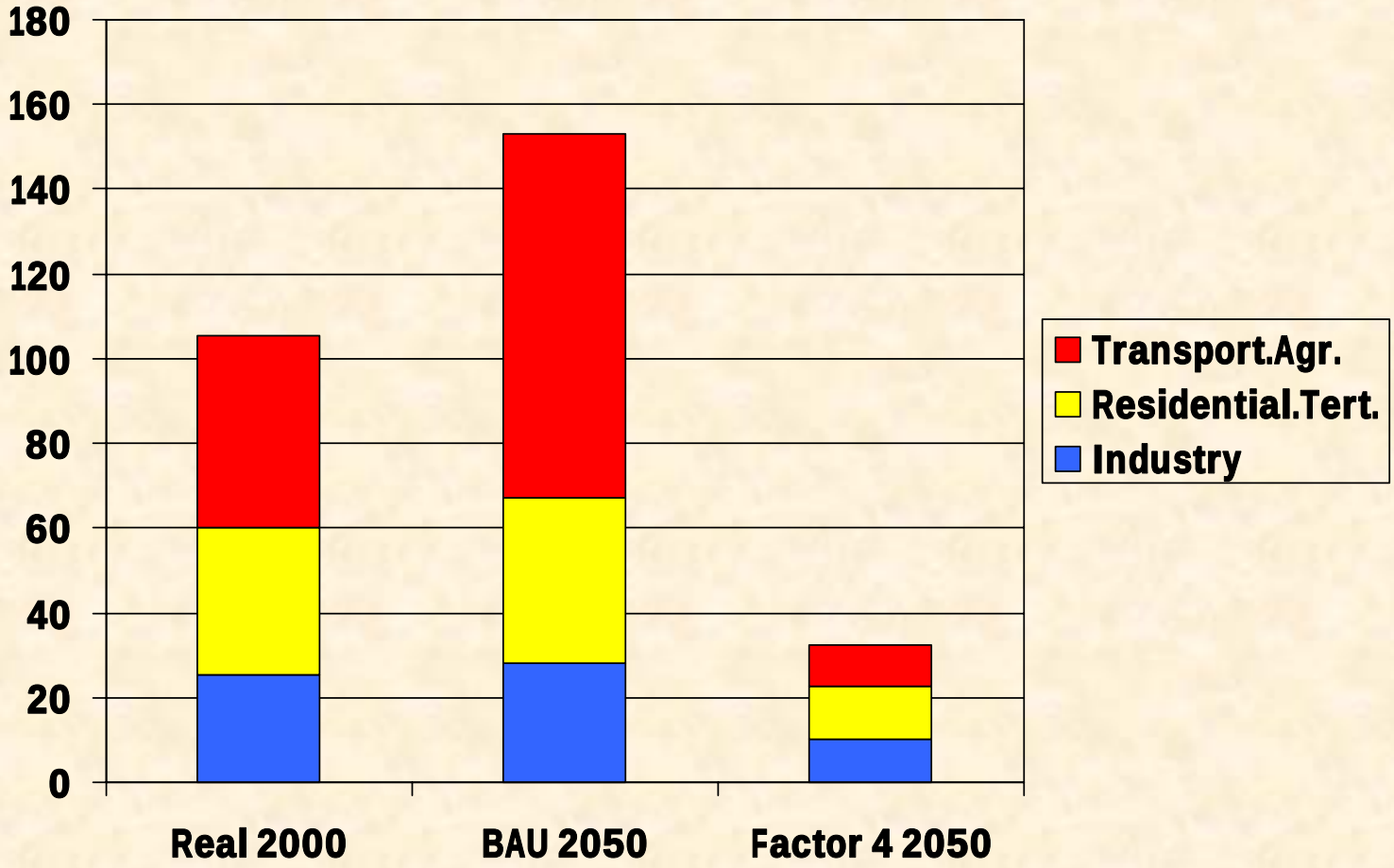
- **Significant mitigation action will also have significant impacts on international markets … e.g. the oil market**



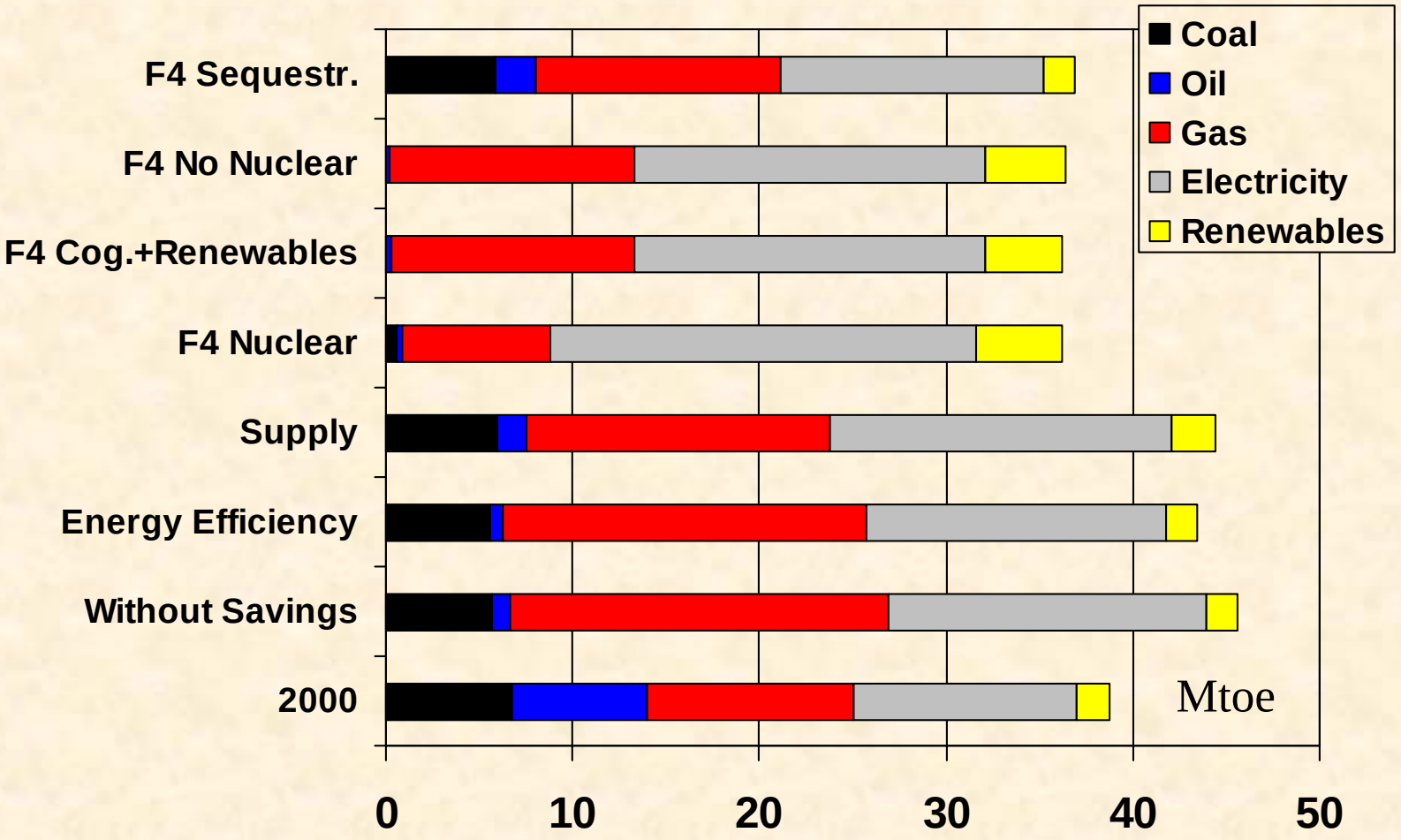
« Factor four » MIES study

- **Objective : to reduce by 75% the GHG emissions in 2050 / 1990**
- **Aim of the study : understand the mix of policies needed, the choices in competition**
- **2 steps :**
  - **Sensitivity analysis (SUP, EnE, WiS)**
  - **Consistent Scenarios (Nuc, NNuc, CoRe, Seq)**

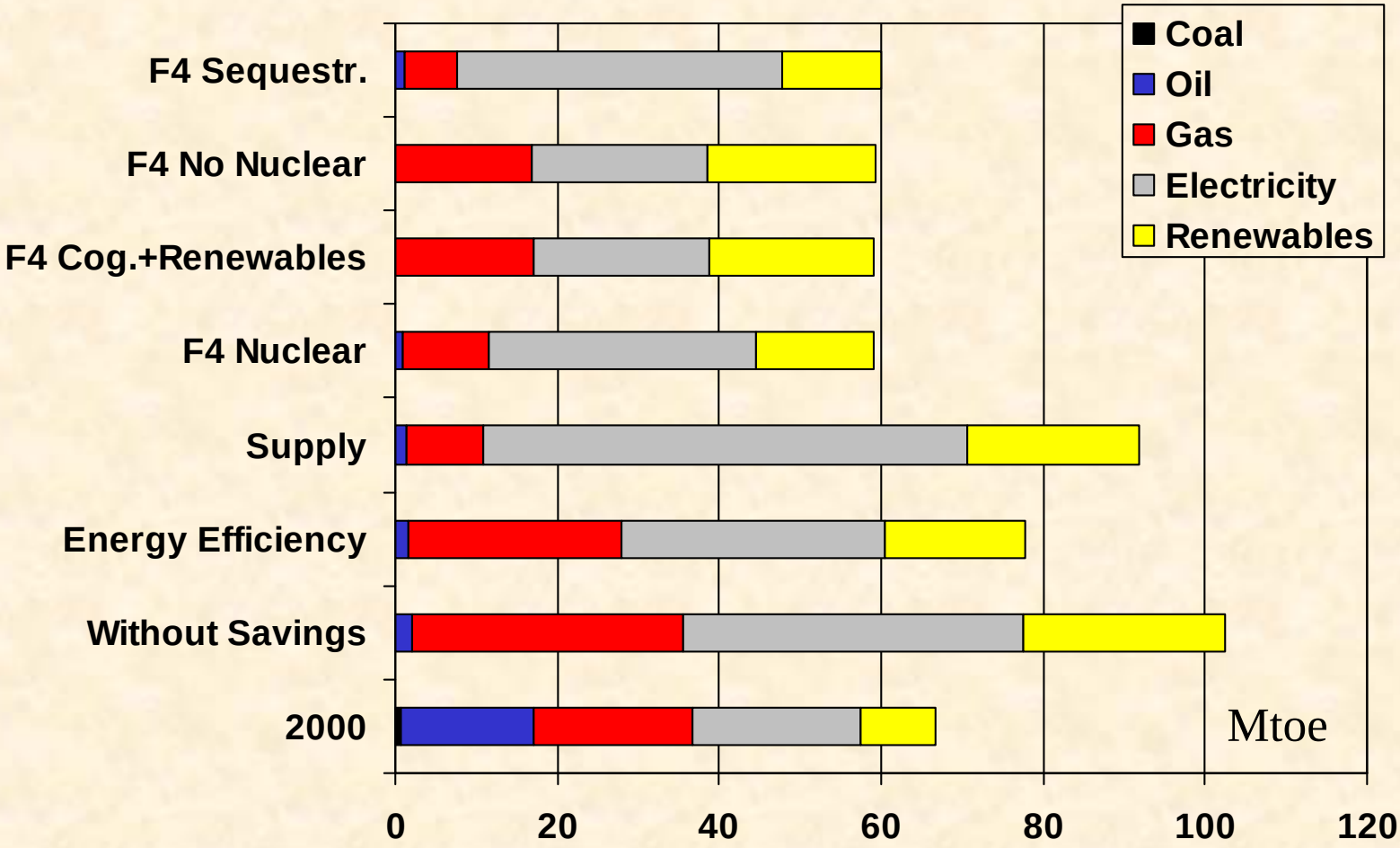
What is at stake?



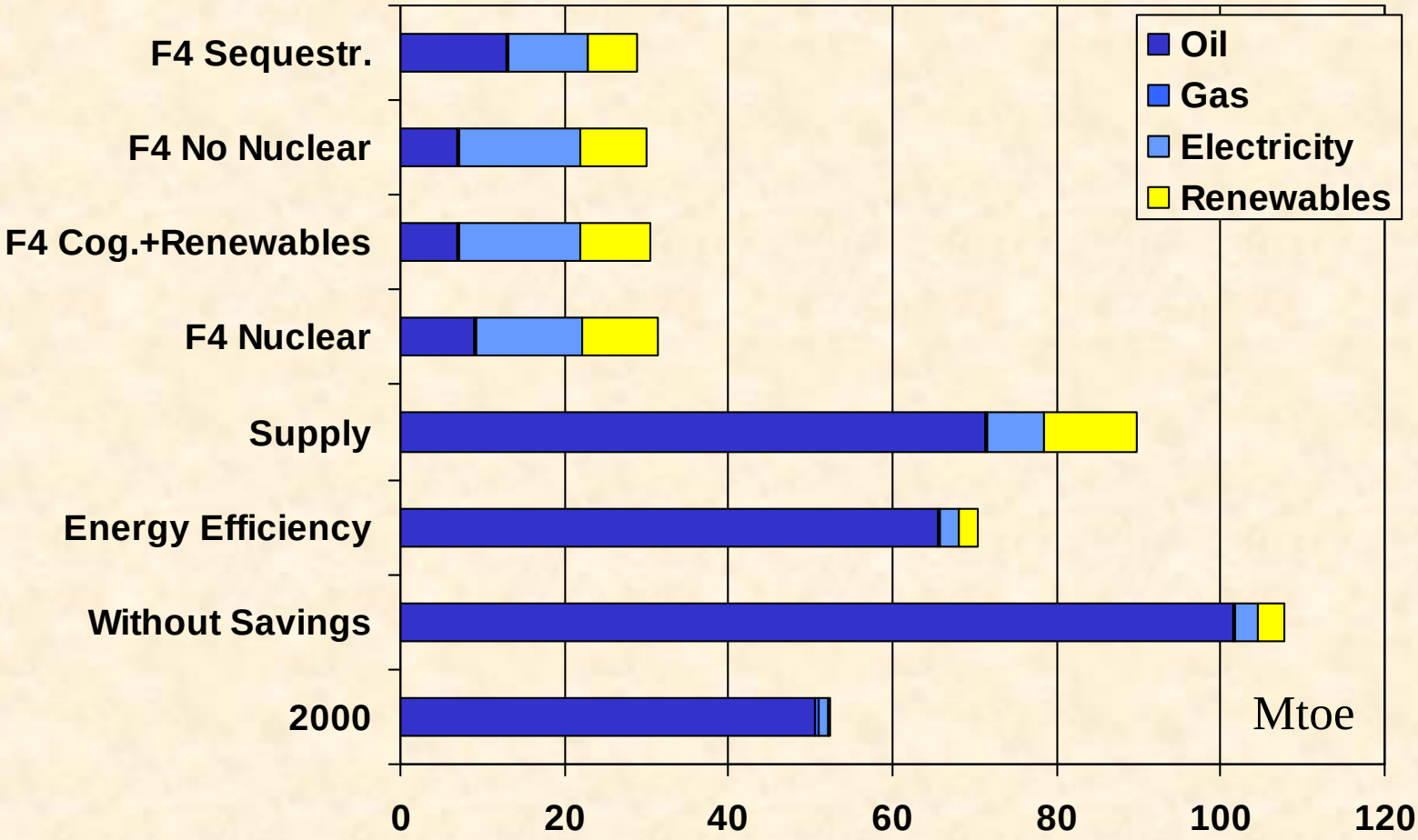
End-use energy consumption industry



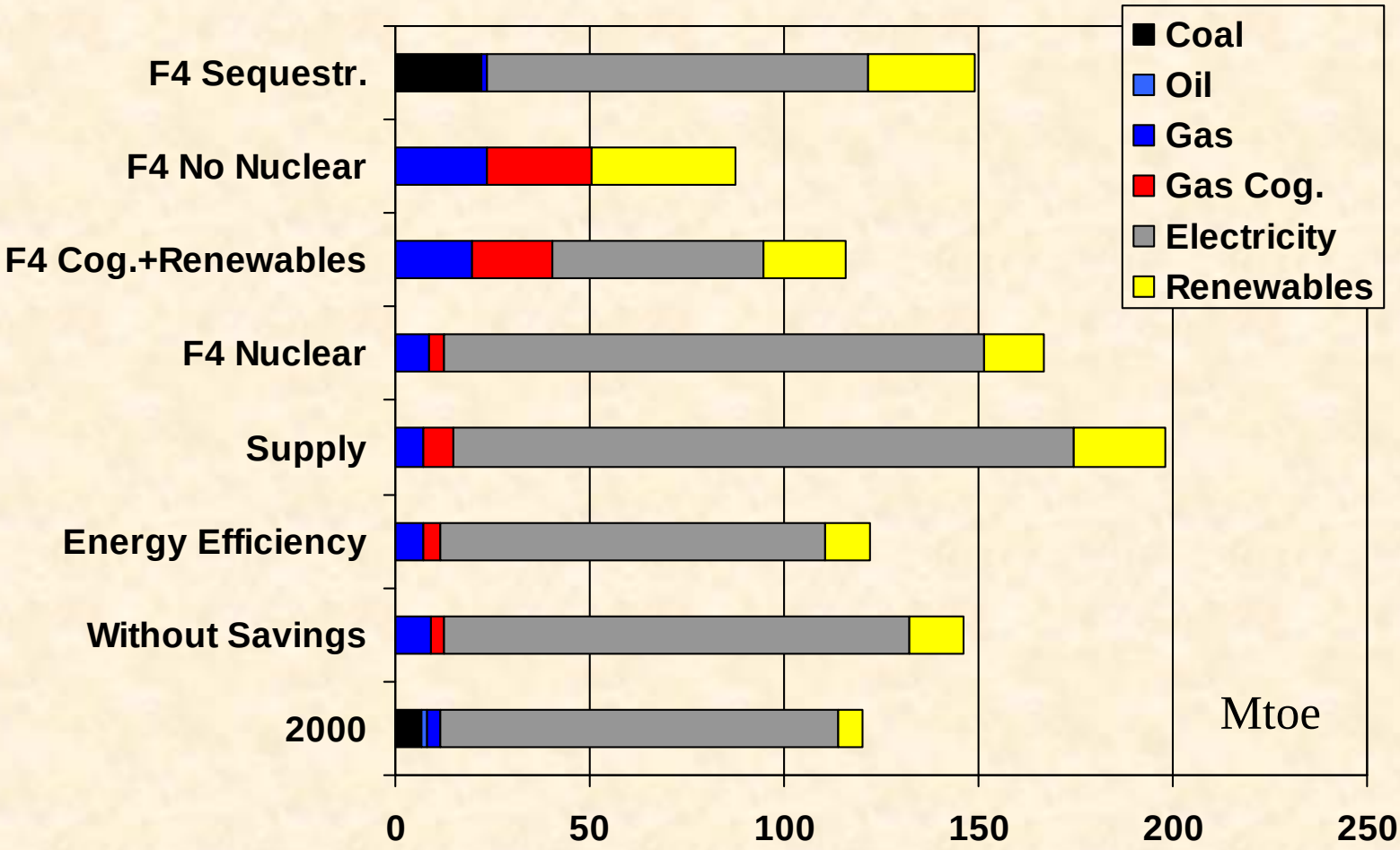
End-use energy consumption residential & commercial



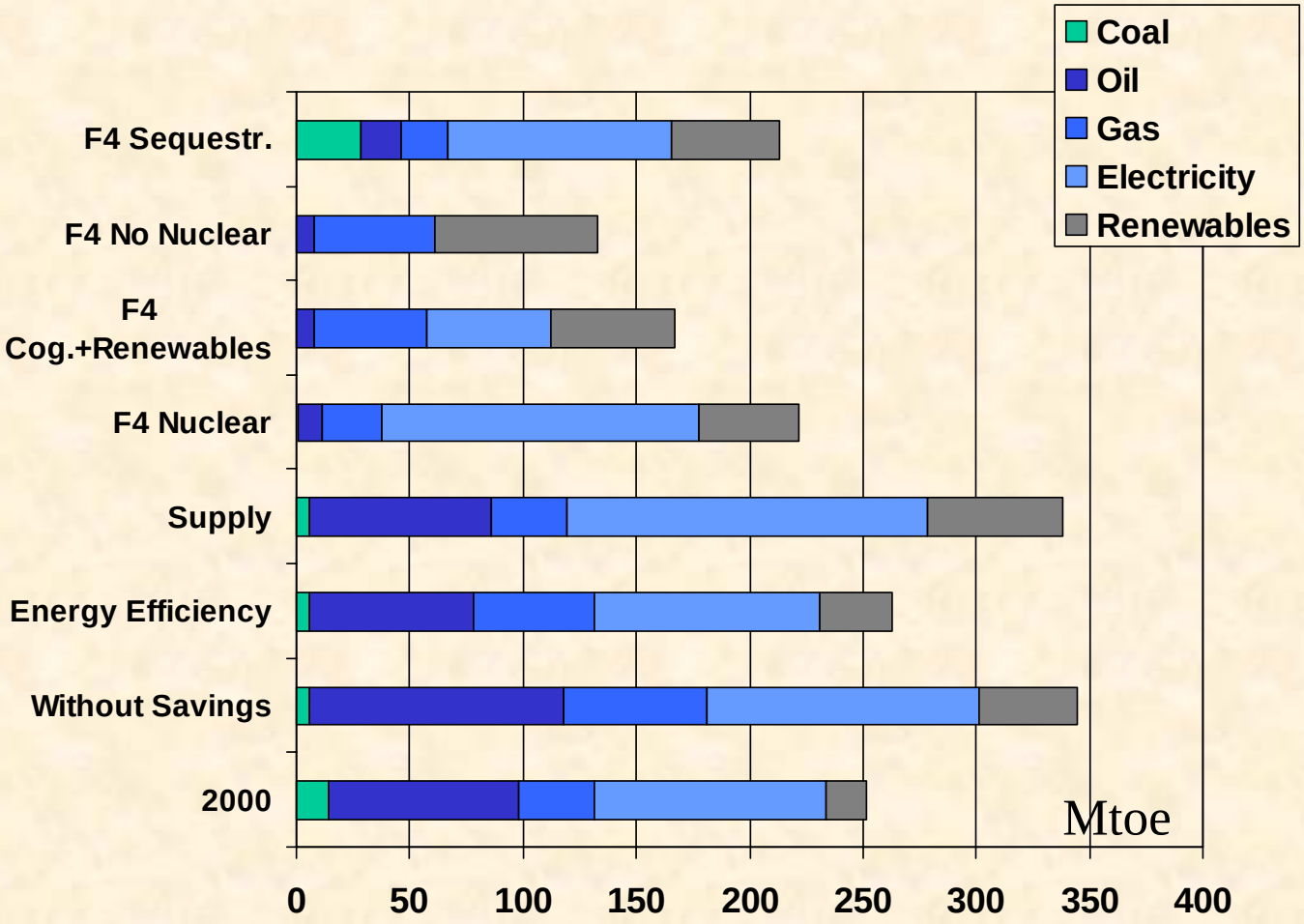
End-use energy consumption agriculture and transportation



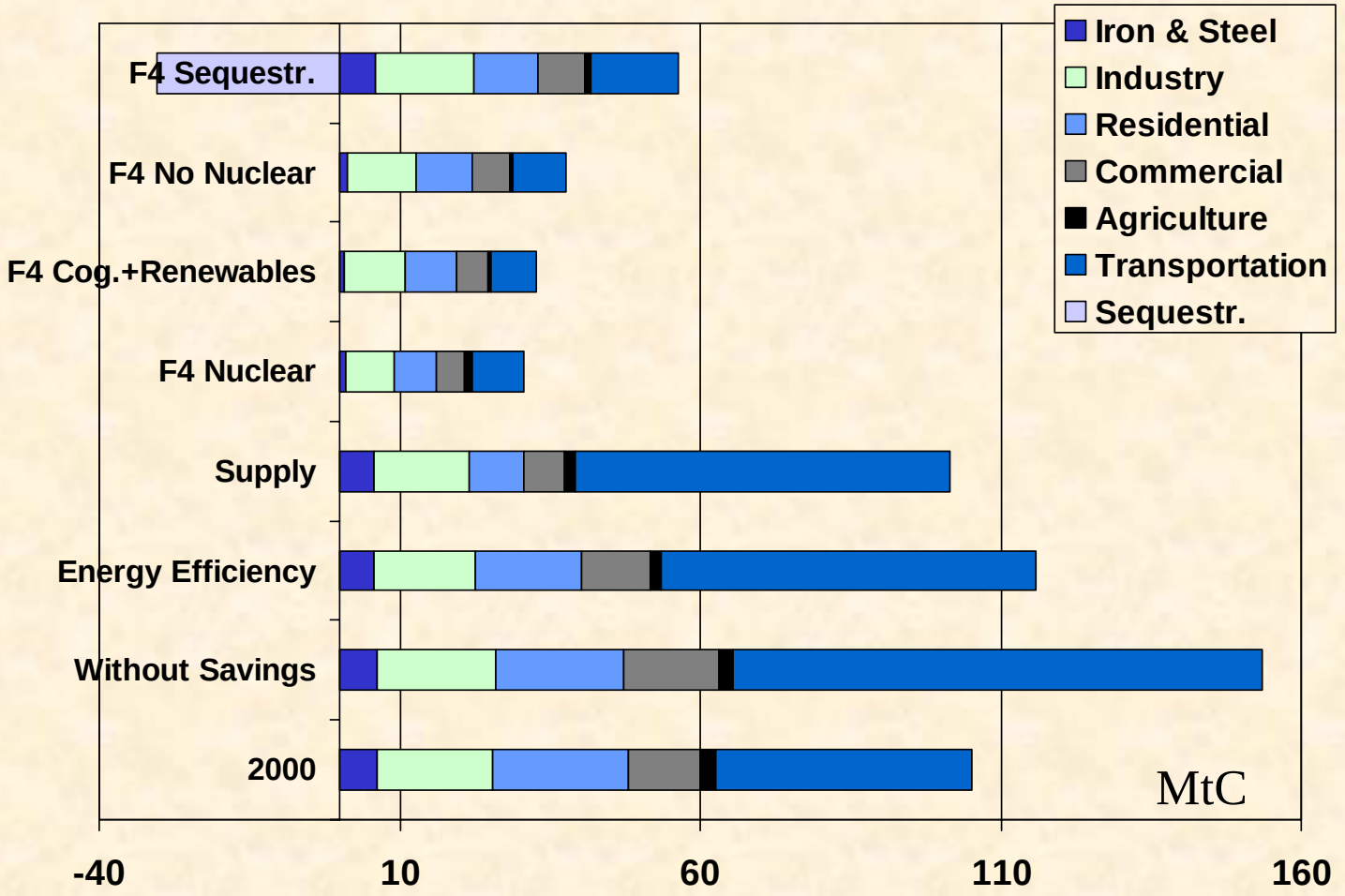
Structure of Electricity generation



Primary Energy Consumption



CO2 Emissions



Lessons for policy makers (ST and MT)

- Forbidden Paths
- **Power generation based on fossil fuels without cogeneration.**
- **A transportation sector essentially based on oil.**
- **Buildings heated with fossil fuels at low efficiency.**
- **An industrial production with a massive use of fossil fuels (steam, furnaces…).**
- **Waiting. The crucial sectors for further evolutions are the building stock, transportation infrastructures, urban planning, jobs localization**
- **Avoid early replacement and stranded assets**

Lessons for policy makers (ST and MT)

- Common Obligations
- **High Efficiency end uses**
- **Advanced Technologies portfolio .**
- **Investing in building stock retrofit.**
- **Switch of industrial processes to electricity.**
- **Raw materials recycling**
- **Transportation : urban planning, modal switch, fast train to replace SD flights, bits instead of km**

Expected good news

- Consumers behavior will be facilitated by new tech. Development
- Electricity storage (grid renewable integration, vehicles)
- CO2 sequestration
- Hydrogen ?

Research

- Simulation of dynamic inter-technology competition is key to energy modelling
- Endogenous technology is increasingly taken into account in energy models … but remains an issue for basic research
- Dynamics of assets, infrastructure versus consumption patterns poorly described in current models

Research

- A new IDDRI research programme
  - With strong involvment of the industry sector
  - Based on both sectoral (POLES LEPII-EPE) and general equilibrium (IMACLIM CIRED) models
  - Low carbon scenarios for industry taking into account changes in infrastructures and products, and capital turnover