

# Scénarios énergétiques

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# Equation de Saha

- Intensité énergétique

$$[I_E] = \frac{\text{Energie Primaire}}{PIB}$$

- Intensité CO2

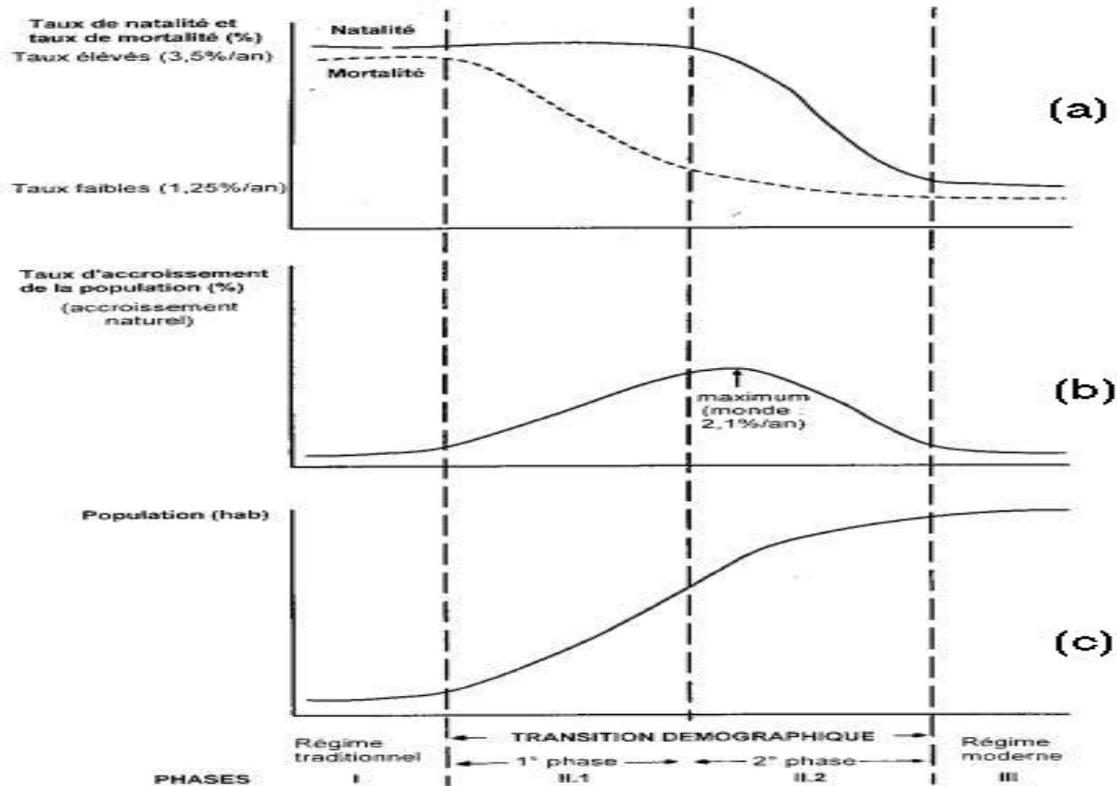
$$[I_{CO_2}] = \frac{CO_2 \text{ émis}}{\text{Energie Primaire}}$$

- Equation de Saha

$$[CO_2] = [Pop] \left[ \frac{PIB}{Pop} \right] [I_E] [I_{CO_2}]$$

# Evolution de la population

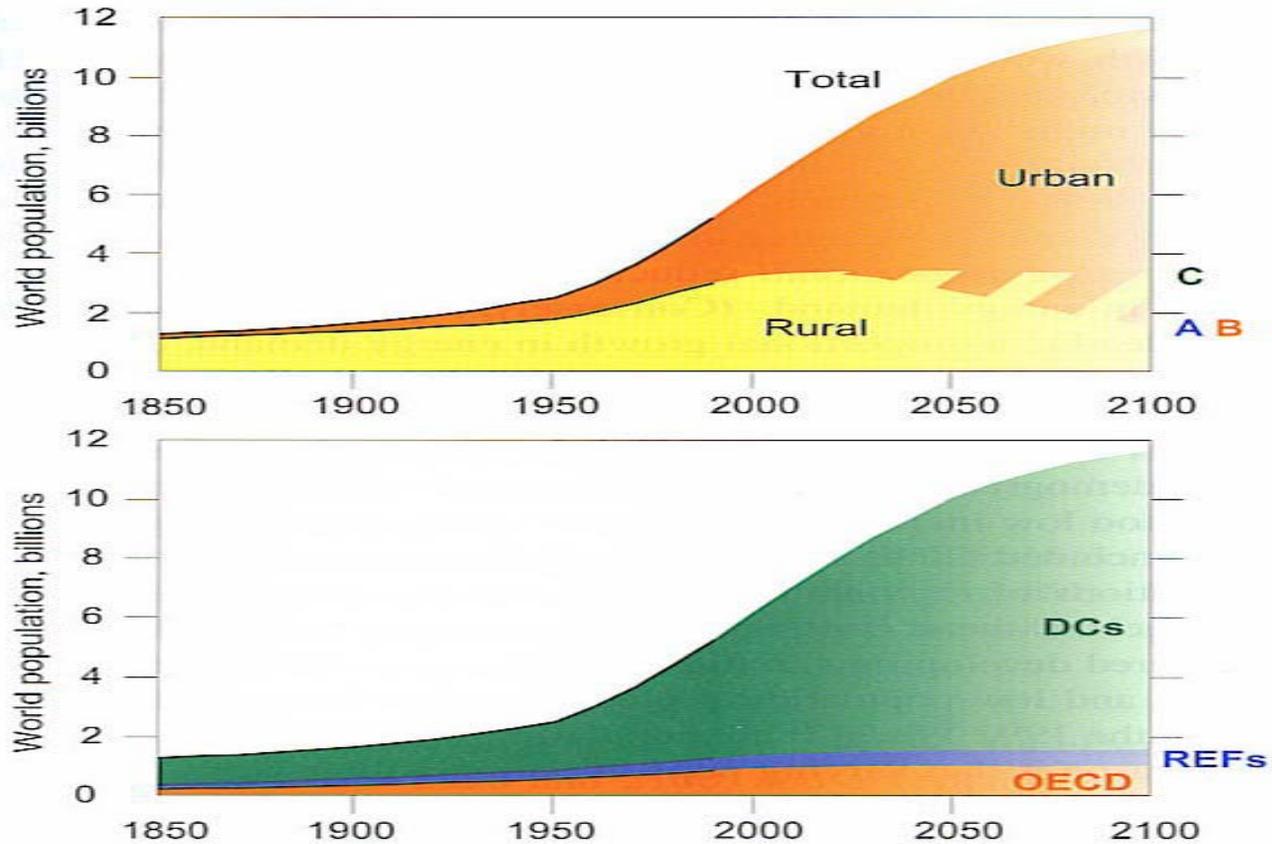
# Transition démographique



# Variables démographiques

- Par régions ou pays
- Nombre d'enfants par femme
- Espérance de vie

# Urbanisation



**Figure 4.1:** World population showing historical development from 1850 to 1990 and World Bank projection to 2100 (Bos *et al.*, 1992), (top) rural–urban and (bottom) by macroregion, in billion people. Urbanization trends are based on UN (1994) and Berry (1990).

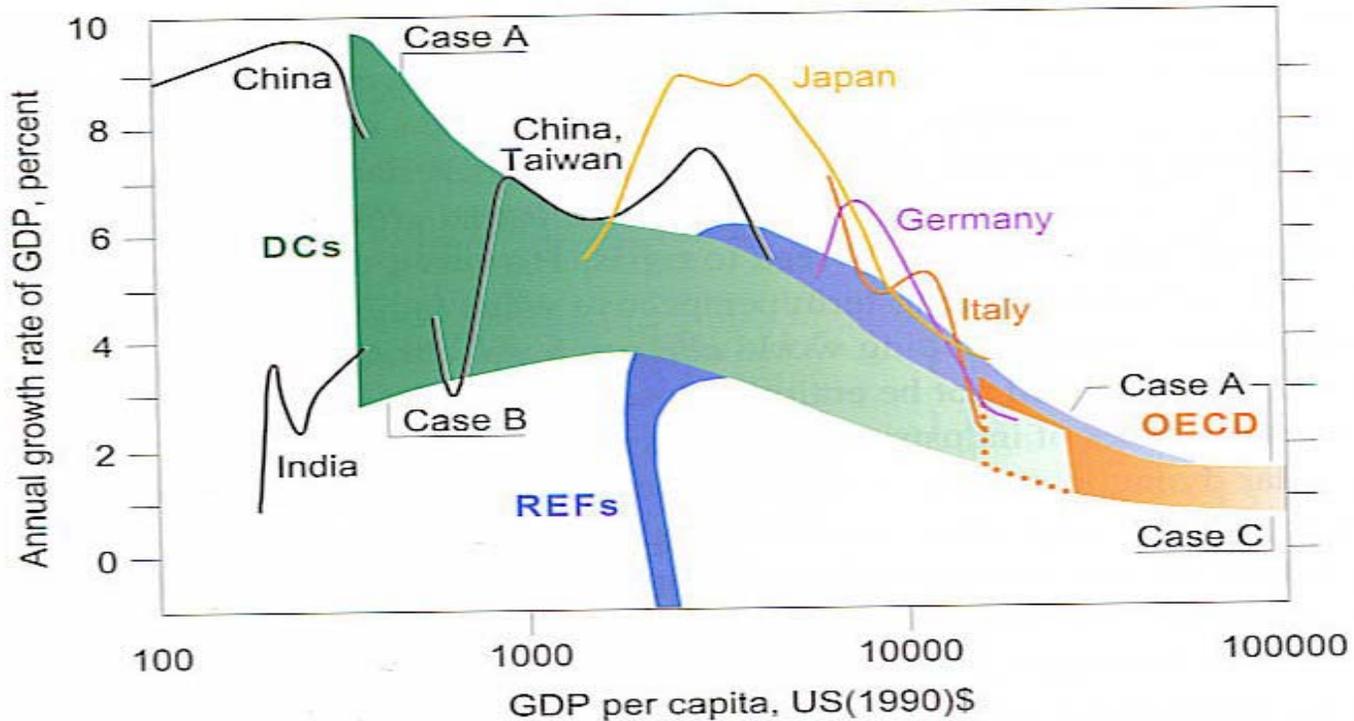
# Evolution des PIB

- Estimations en \$ 1990
- Estimations en Parité de Pouvoir d'Achat (PPP)

# Croissance économique

- Stagnation
- Décollage
- Développement accéléré
- Stabilisation

# Croissance économique

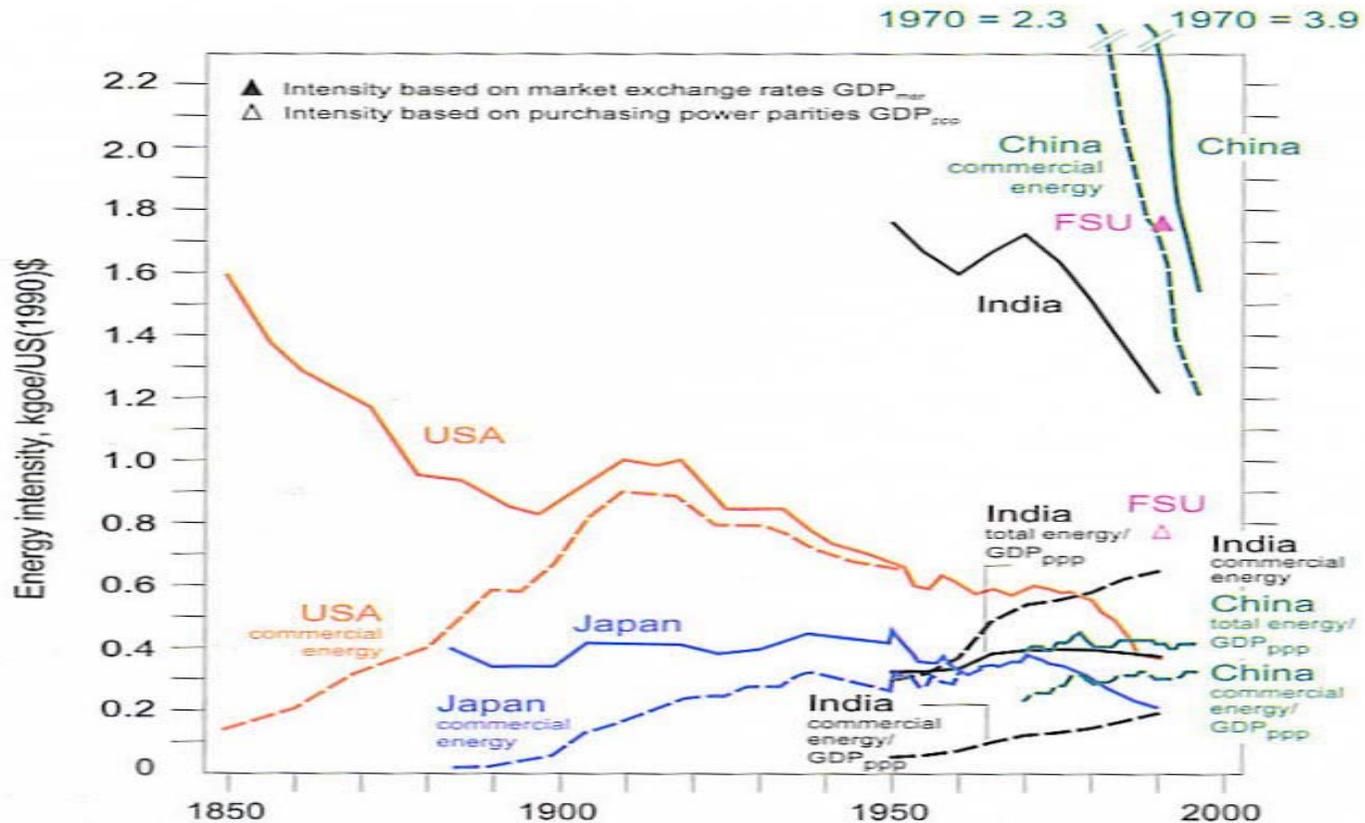


**Figure 4.3:** Economic growth rates, GDP in percent per year, versus degree of economic development, GDP per capita in US(1990)\$, illustrating “takeoff” into industrialization, peak, and declining economic growth rates of high-income economies. Historical data for selected countries (as a 10-year moving average) and range of economic growth rates assumed in the three cases are indicated for the three macroregions: DCs, REFs, and OECD countries.

# Intensité énergétique

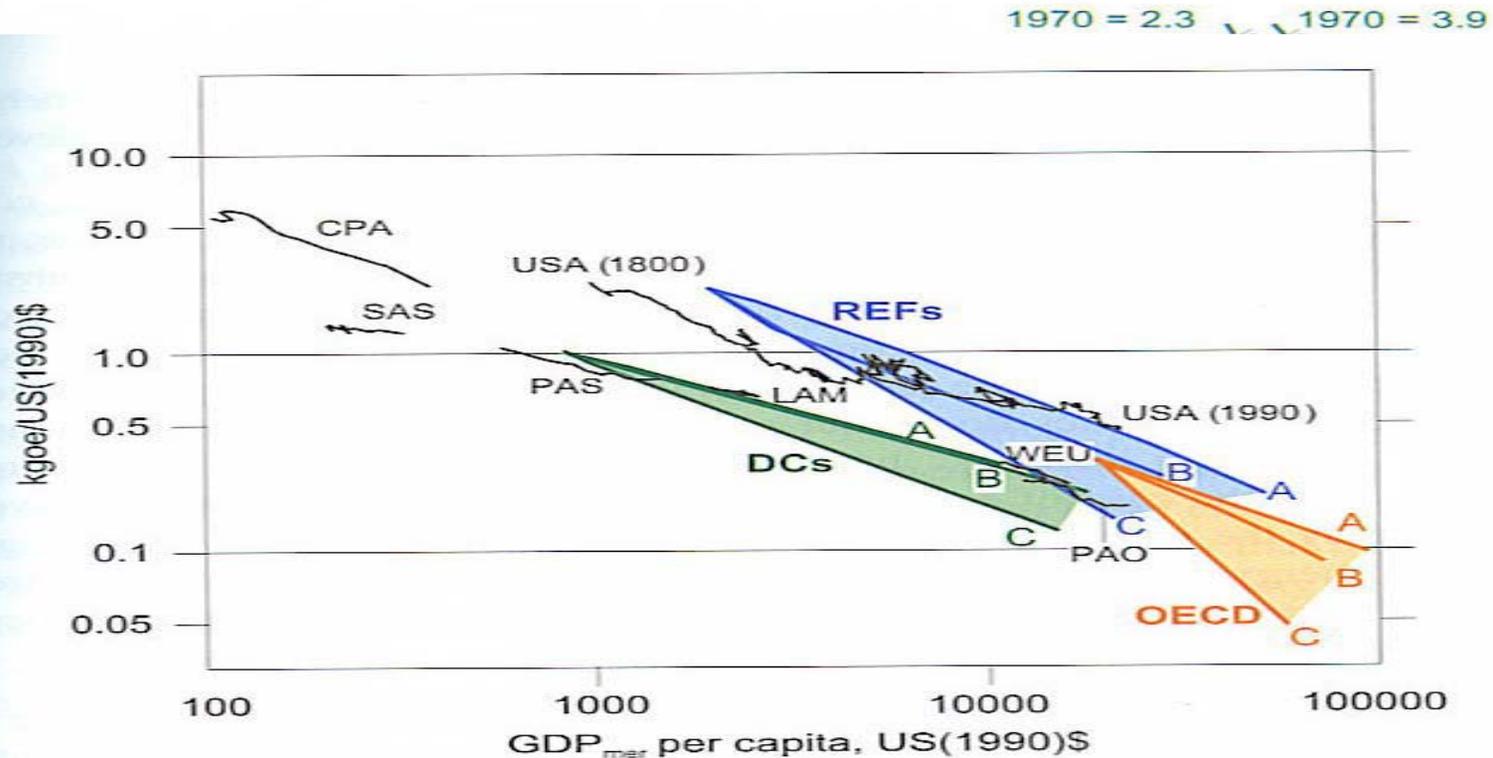
- Tyrannie des PIB?

# Intensités énergétiques Passé



**Figure 4.5:** Primary energy intensity for four selected countries and FSU, total (solid lines) and commercial energy (dashed lines), in kgoe, per GDP, in US(1990)\$ . Unless otherwise specified, GDP refers to GDP<sub>mer</sub>. For China, India, and FSU intensities based on GDP<sub>ppp</sub> are also given. Data sources: Nakićenović, 1987; Martin, 1988; TERI, 1994.

# Intensités énergétiques Projections



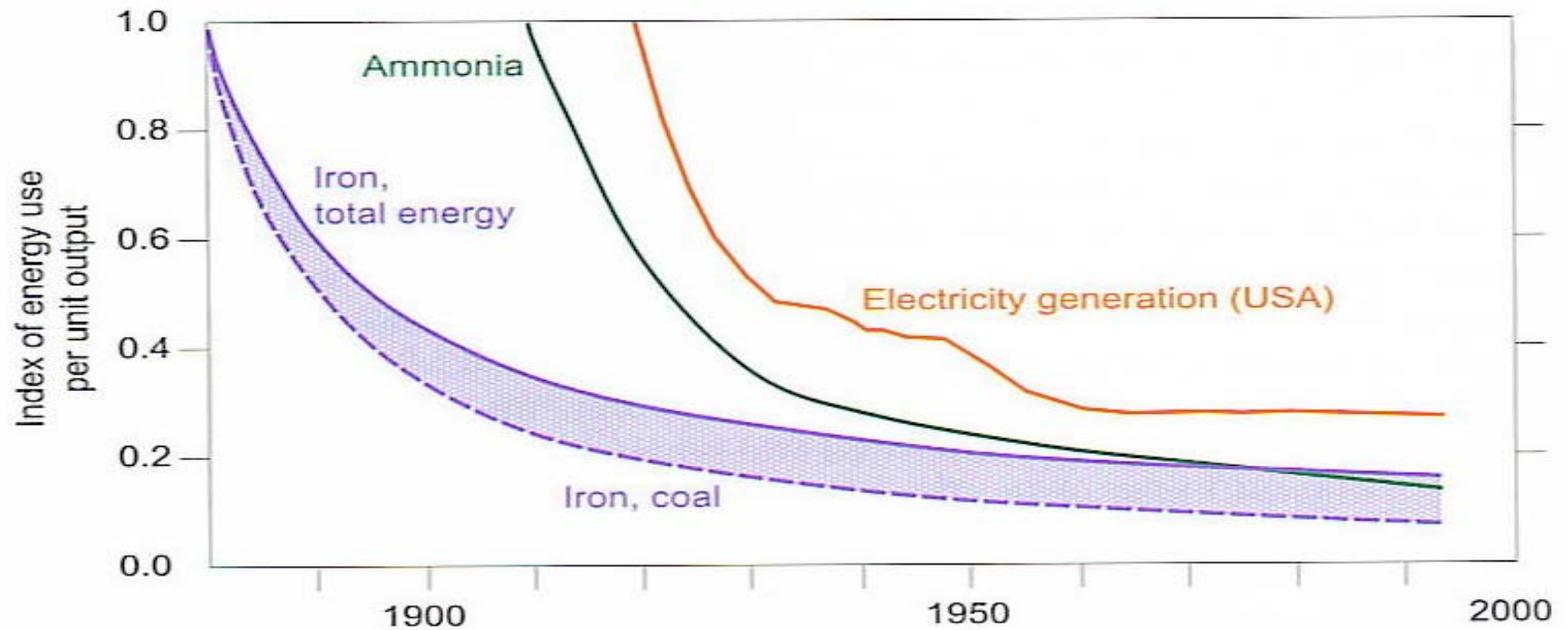
**Figure 4.7:** Energy intensities, in kgoe per US(1990)\$, as a function of degree of economic development, in GDP<sub>mer</sub> per capita in US(1990)\$ . Historical data (black) and Cases A, B, and C (color).

US(1990)\$ . Unless otherwise specified, GDP refers to GDP<sub>mer</sub> . For China, India, and FSU intensities based on GDP<sub>ppp</sub> are also given. Data sources: Nakićenović, 1987; Martin, 1988; TERI, 1994.

# Processus d'innovation

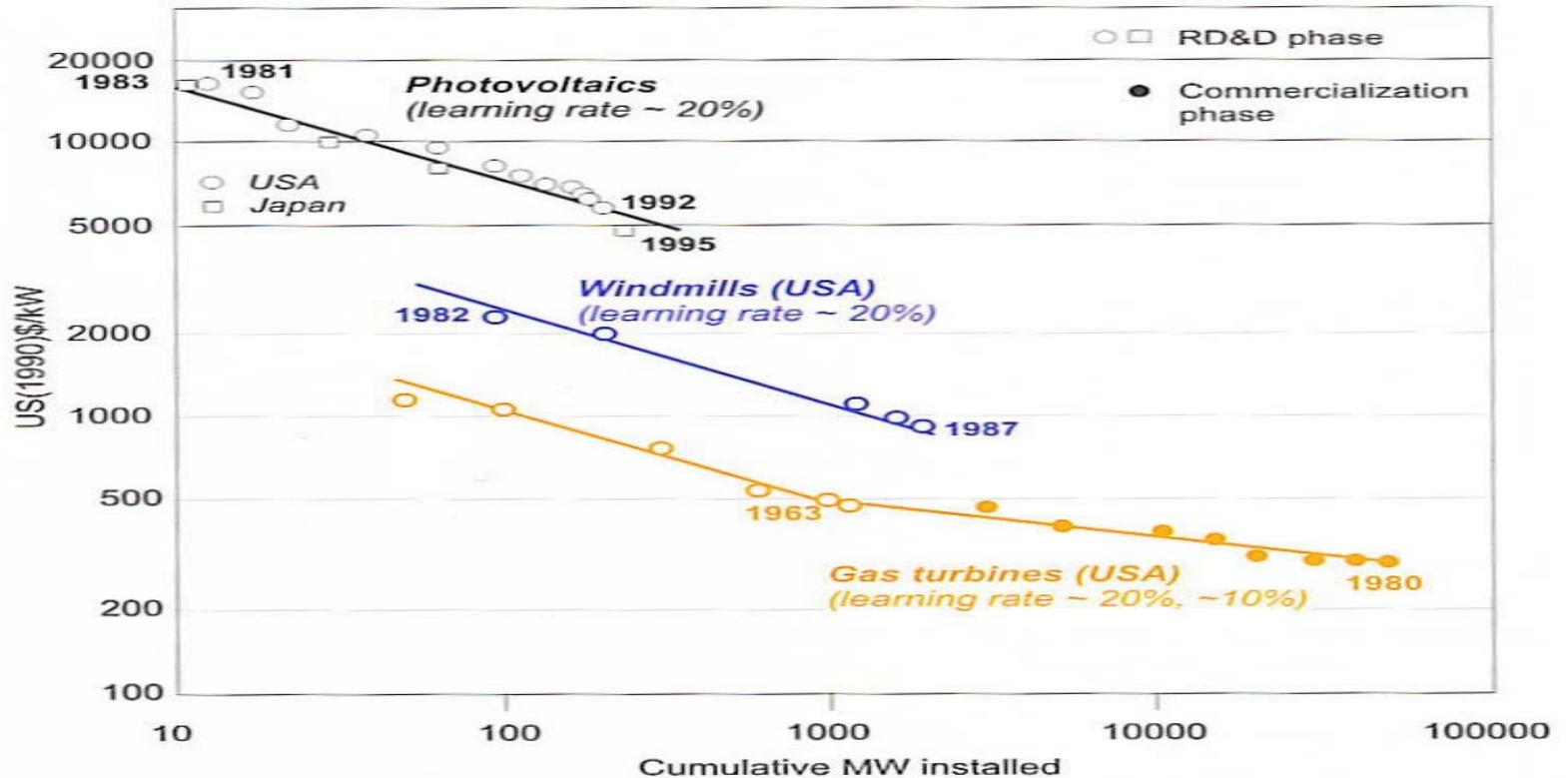
- Invention
- Développement dans une niche (applications militaires, recherche fondamentale): le coût ne compte pas
- Diffusion « grand public »
- Saturation
- Obsolescence (ordinateurs, téléphones portables)

# Efficacités énergétiques



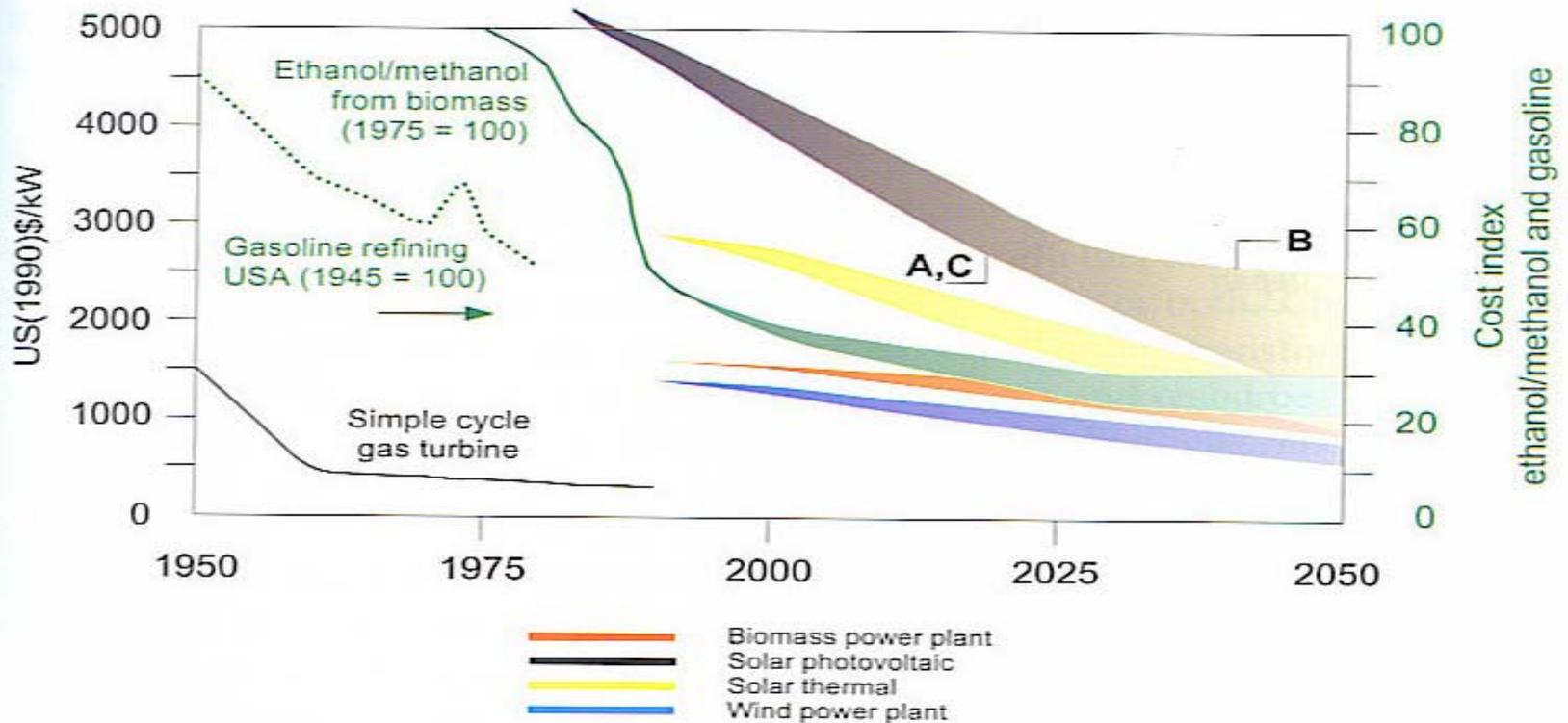
**Figure 4.9:** Technology improvements: The example of energy input for production of iron, ammonia, and electricity shown as an index with energy input at introduction equal to 1. Sources: adapted from USDOC, 1975 and consecutive volumes; Marchetti, 1978; Grübler, 1990.

# Courbes d'apprentissage



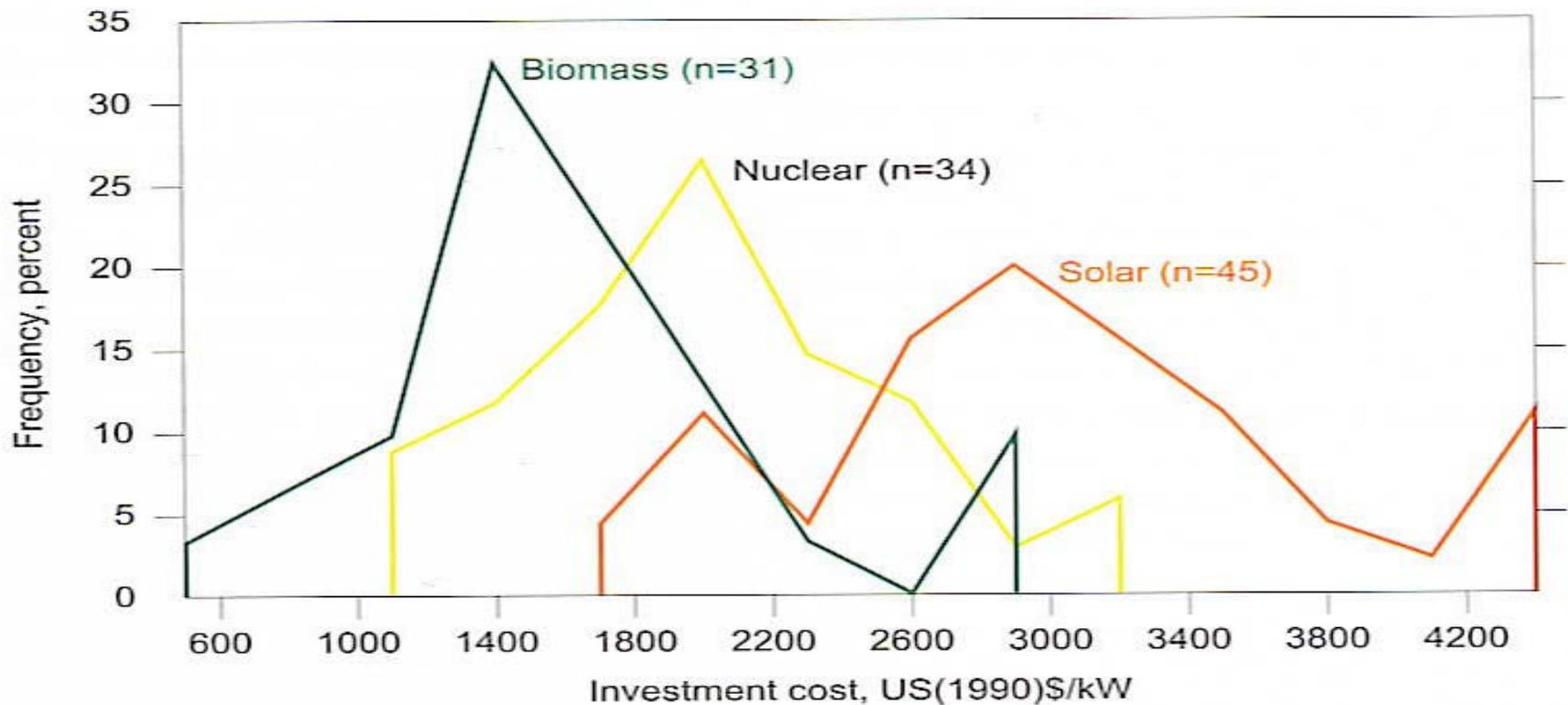
**Figure 4.11:** Technology learning curves: Cost improvements per unit installed capacity, in US(1990)\$ per kW, versus cumulative installed capacity, in MW, for photovoltaics, wind, and gas turbines. Sources: adapted from MacGregor *et al.*, 1991; Christiansson, 1995.

# Amélioration des coûts



**Figure 4.10:** Technology cost improvements, in US(1990)\$ per kW. Past achievements for US gasoline refining (Fisher, 1974) and Brazilian ethanol/methanol (Goldemberg, 1994) and range for biomass, solar, and wind electricity generation assumed for the three cases.

# Incertitudes sur les coûts

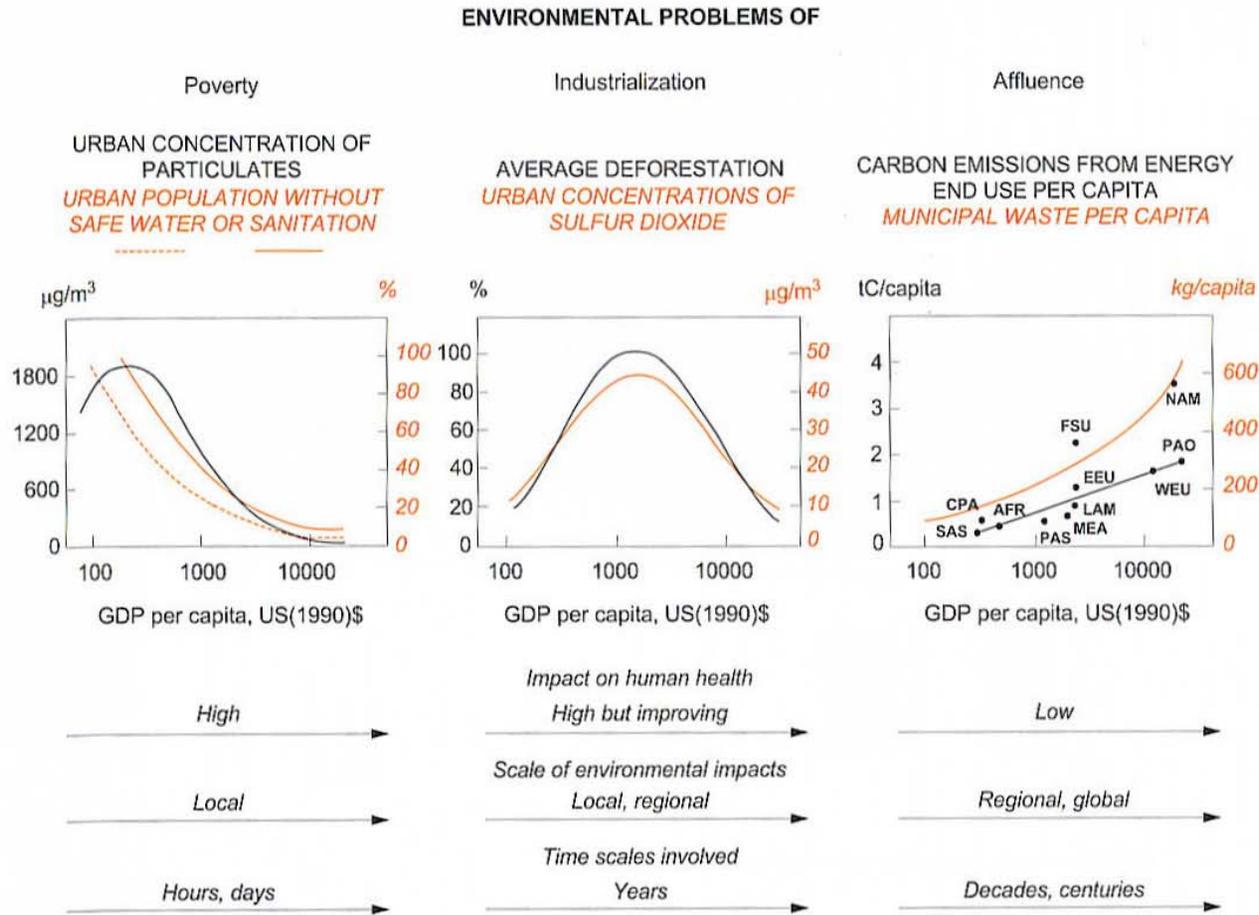


**Figure 4.8:** Range of investment cost distributions from the IIASA technology inventory for biomass, nuclear, and solar electricity generation used as input to assess costs of current and future energy systems, in US(1990)\$ per kW.

# Pollutions et CO2

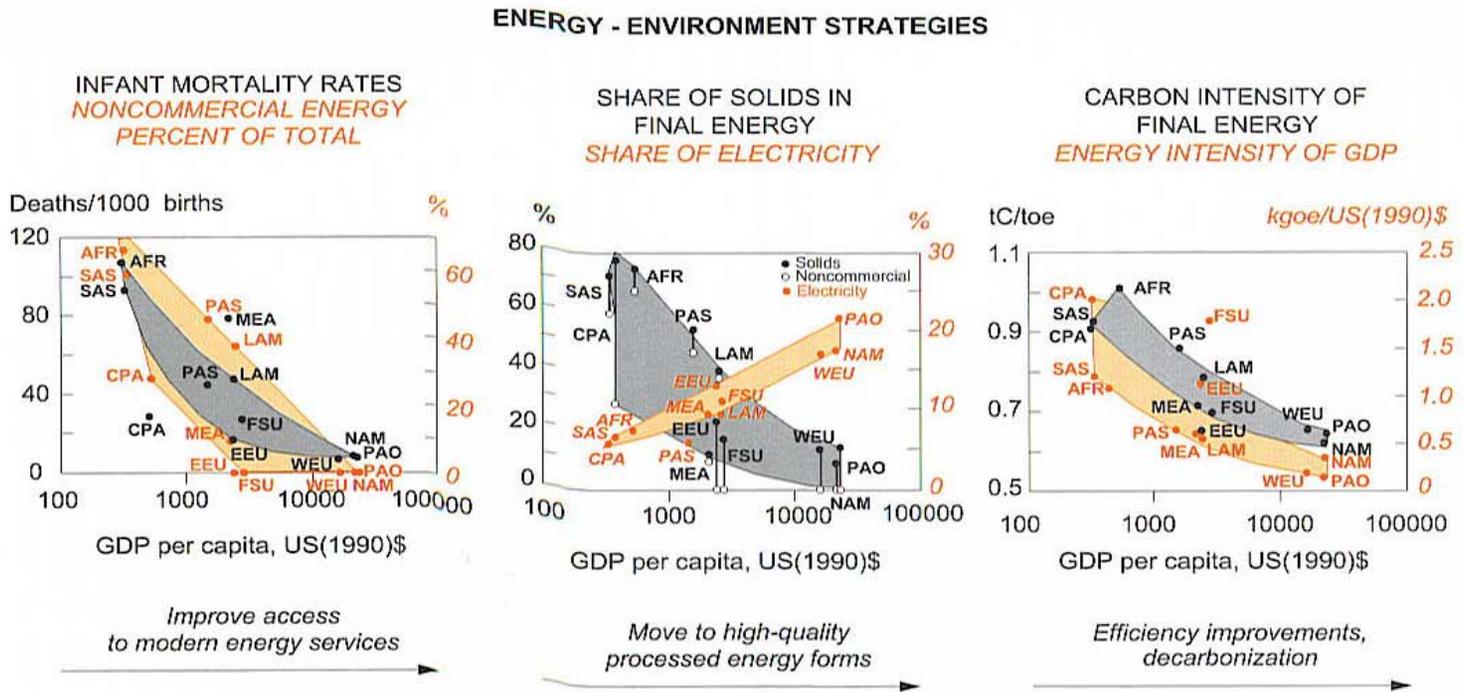
# Richesse et pollution

Figure 4.14: A typology of environmental problems as they evolve with economic development. Source: adapted from World Bank, 1992.

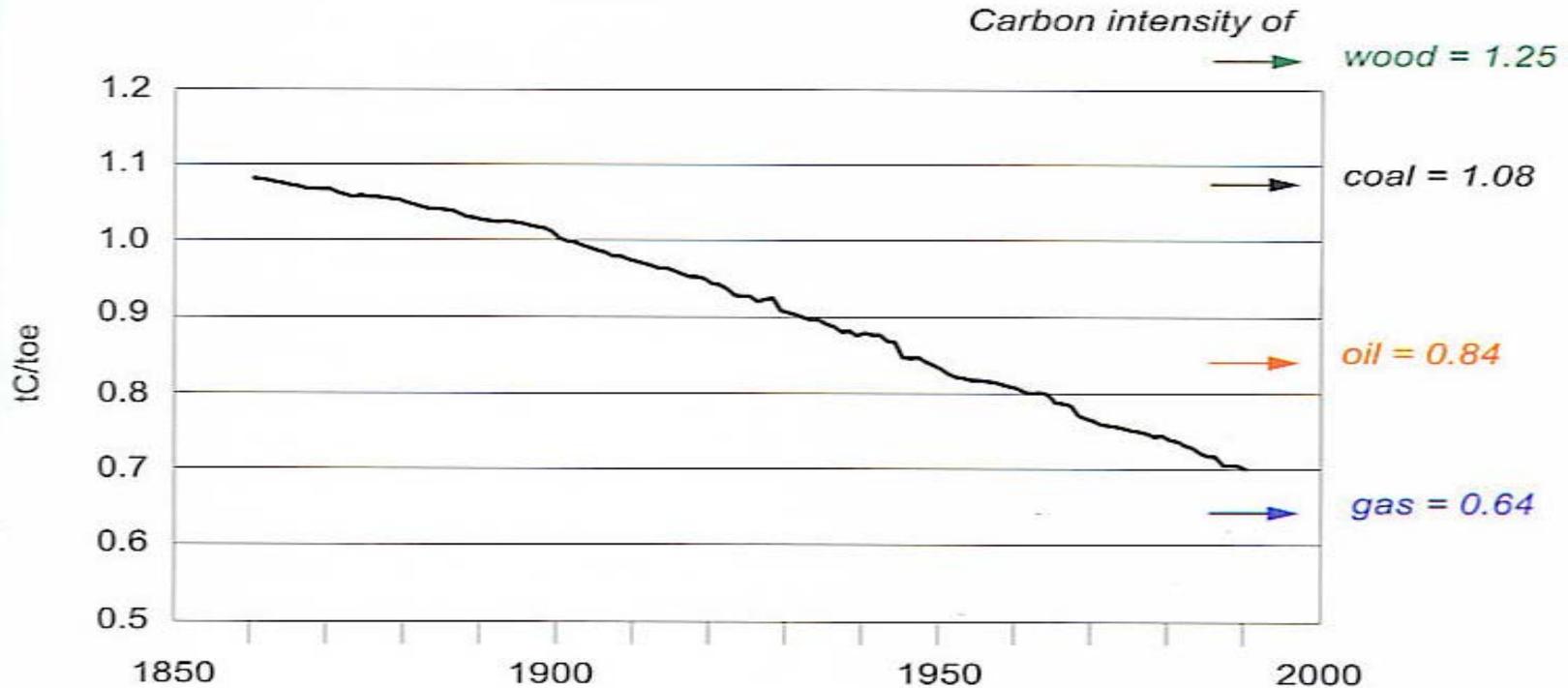


# Richesse et pollution

Figure 4.15: Energy strategies to address environmental problems of poverty, industrialization, and affluence. Improvements in energy efficiency and structural change in energy systems toward cleaner energy carriers ("decarbonization") are important generic long-term strategies to tackle environmental problems.



# Décarbonation



**Figure 4.16:** Carbon intensity of world primary energy mix, 1850 to 1990, in tC per toe, including emissions from unsustainable uses of fuelwood. Source: Nakićenović *et al.*, 1996.

# Trois types de scénarios IIASA

- A: croissance rapide

  - A1: Pétrole

  - A2: Charbon

  - A3:Gaz

- B: Intermédiaire

- C: Faible intensité énergétique. Forte électricité

  - C1: Ren.+Gaz

  - C2: Ren.+Nucléaire

# Exemple: natalité

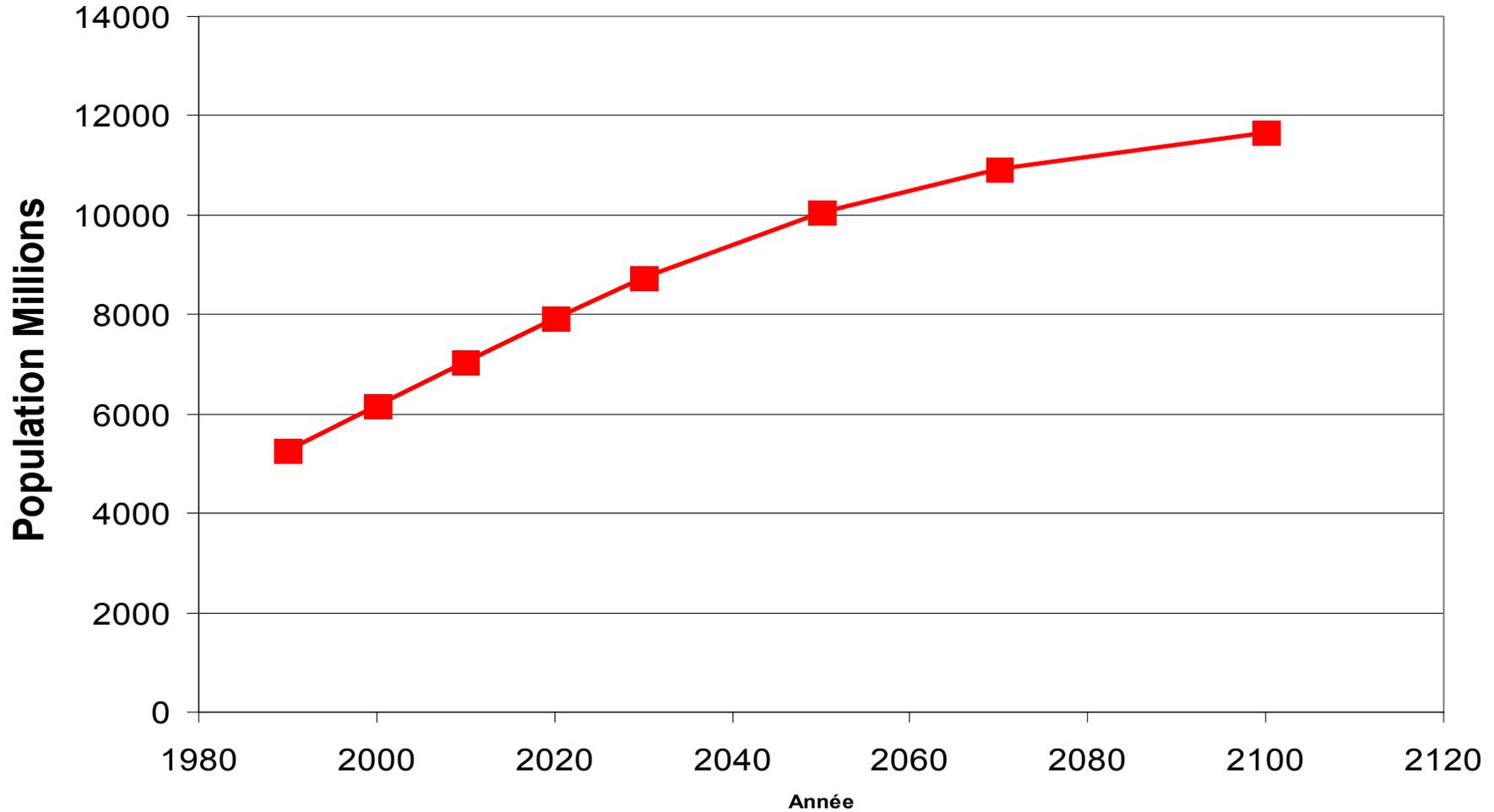
Région	1995	Nombre d'enfants par femme (IIASA 2030 médian)
Afrique		
Afrique du Nord	4,35	3,00
Afrique Sub-Saharienne	6,18	3,00
Asie de l'Est		
Chine et Pays planifiés	2,00	2,25
Asie Pacifique	2,88	2,35
Asie OCDE	1,53	1,70
Asie de l'Ouest		
Asie Centrale	3,35	3,00
Moyen Orient	5,47	3,00
Asie du Sud	3,77	2,35
Europe		
Europe de l'Est	1,66	1,70
Russie	1,50	1,70
Europe de l'Ouest	1,67	1,70
Amérique latine	3,10	2,35
Amérique du Nord	1,97	1,85

# Espérance de vie

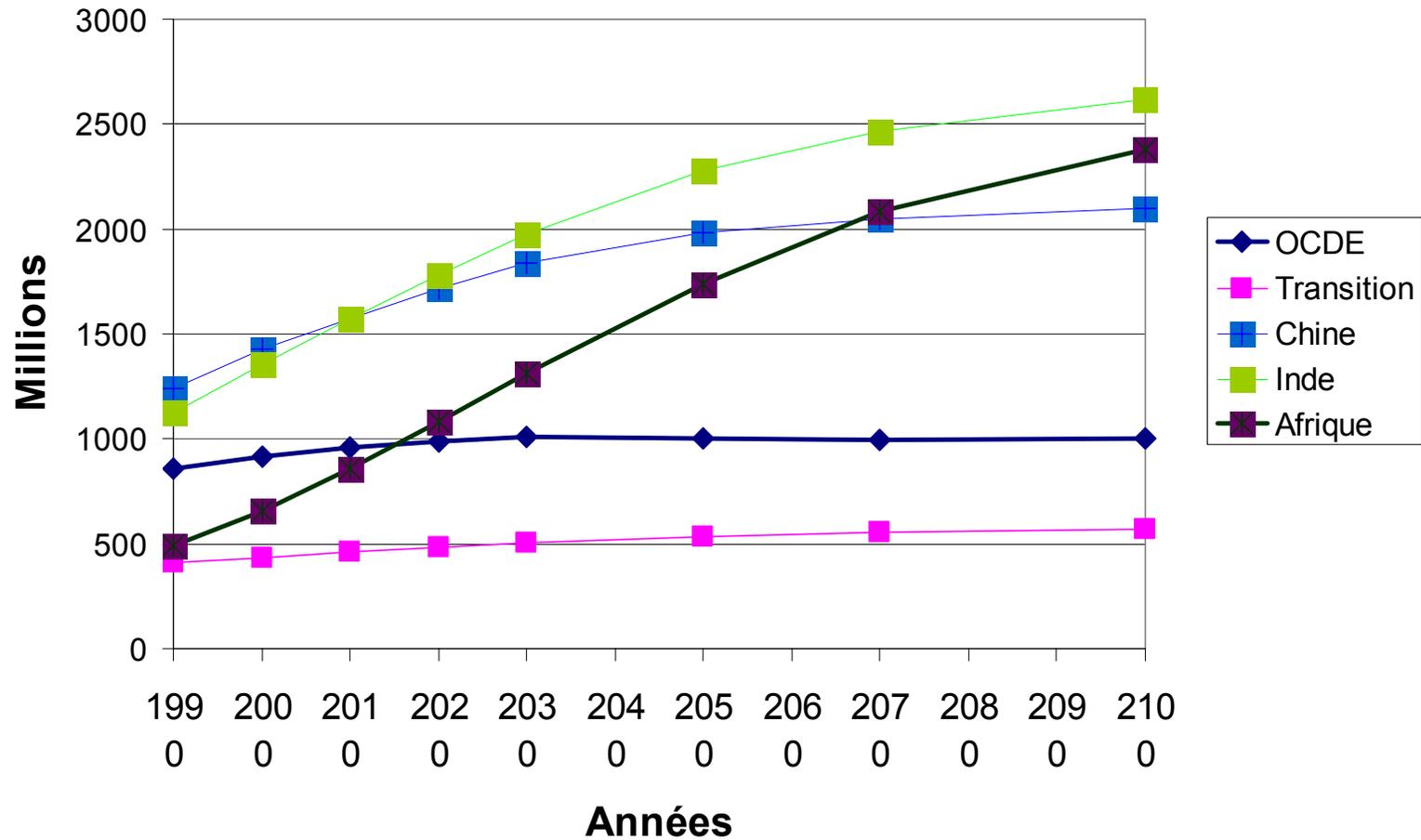
Région	Espérance de vie 1995		Allongement de l'espérance de vie Années par décade (2030) Médian	
	Hommes	Femmes		
<b>Afrique</b>				
Afrique du Nord	62,7	65,3		2,3
Afrique Sub-Saharienne	50,6	53,9		1,0
<b>Asie de l'Est</b>				
Chine et Pays planifiés	66,4	70,1	Hommes	1,5
			Femmes	2,0
Asie Pacifique	63,1	67,4		2,0
Asie OCDE	76,1	82,2		2,0
<b>Asie de l'Ouest</b>				
Asie Centrale	65,1	72,5		2,0
Moyen Orient	65,6	68,0		2,3
Asie du Sud	59,7	59,7	Hommes	1,5
			Femmes	2,0
<b>Europe</b>				
Europe de l'Est	67,3	75,0		2,0
Russie	61,1	72,8	Hommes	2,0
			Femmes	2,0
Europe de l'Ouest	72,1	78,1		2,0
<b>Amérique latine</b>	66,3	71,8		2,0
<b>Amérique du Nord</b>	72,3	79,1		2,0



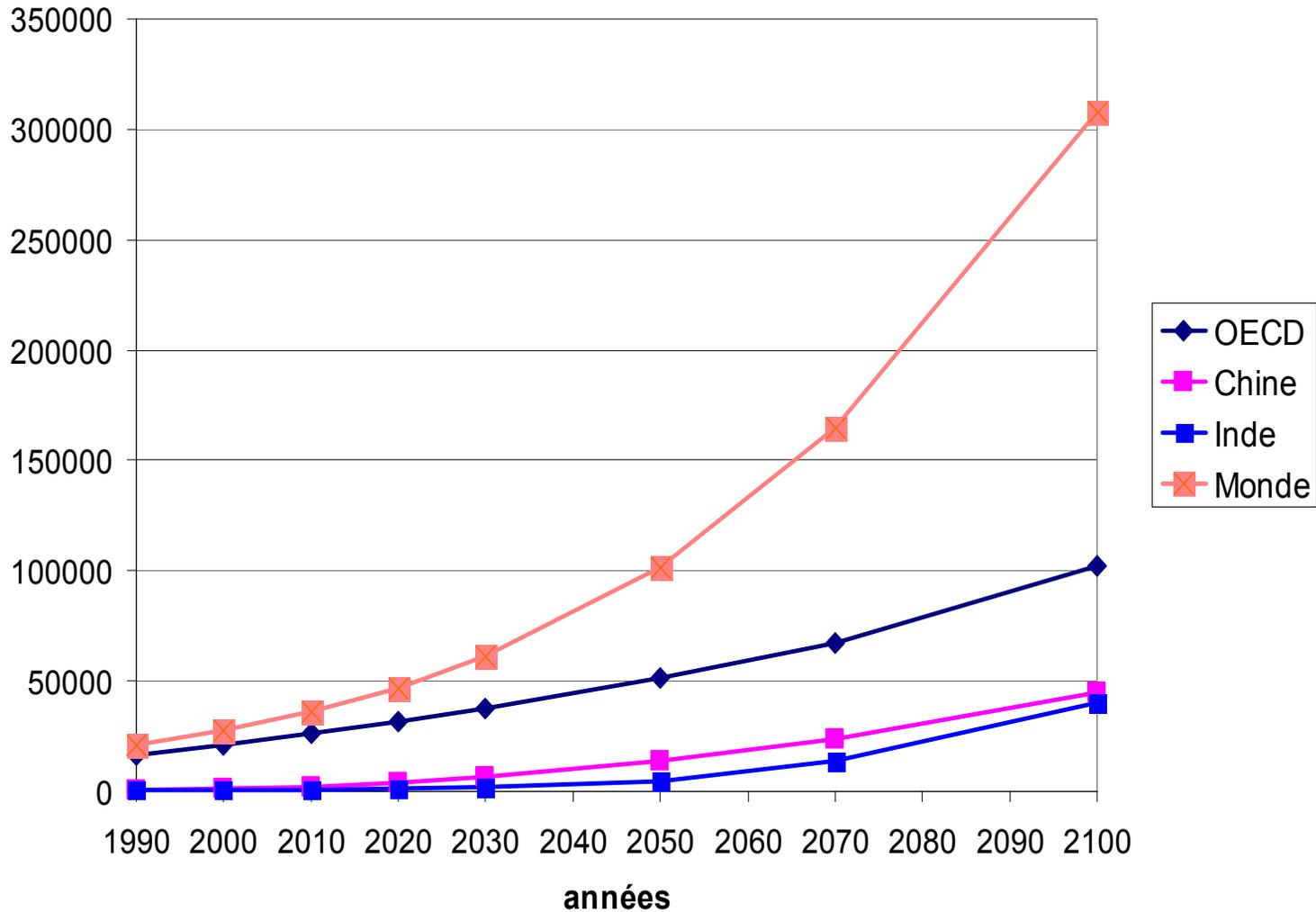
# Projections IIASA



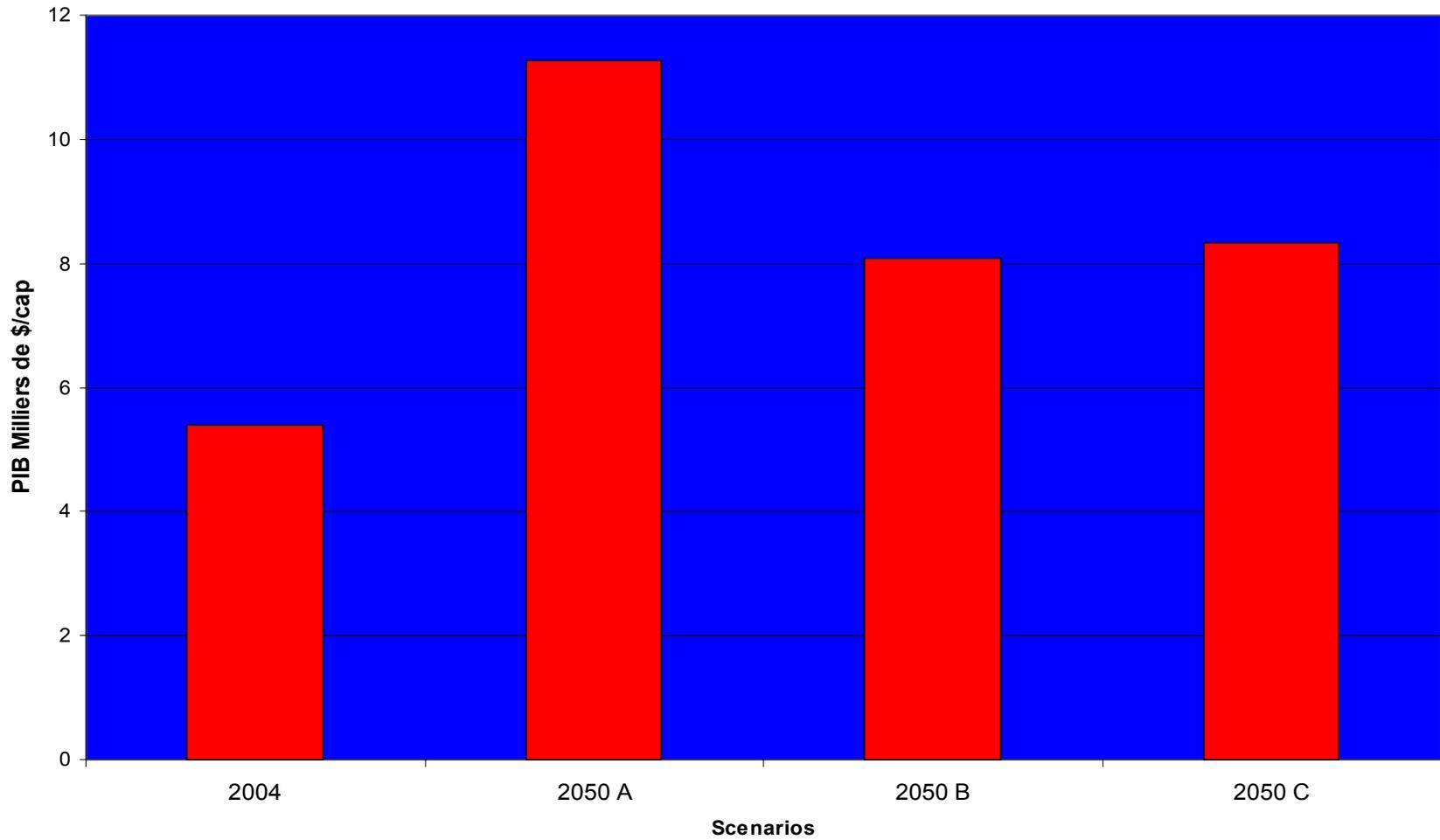
# Projections régionales



# PIB Régionaux

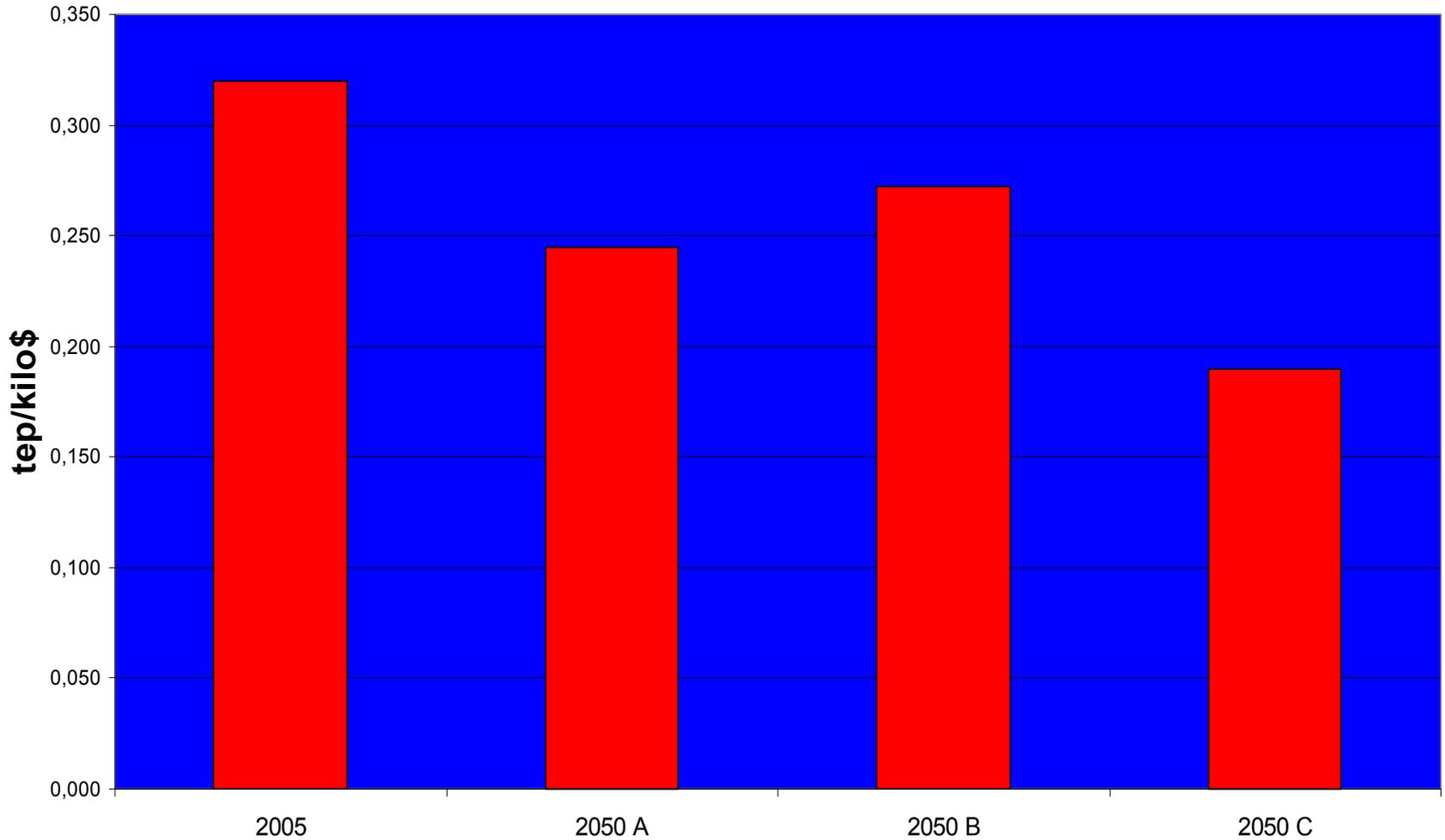


## PIB/cap Mondial

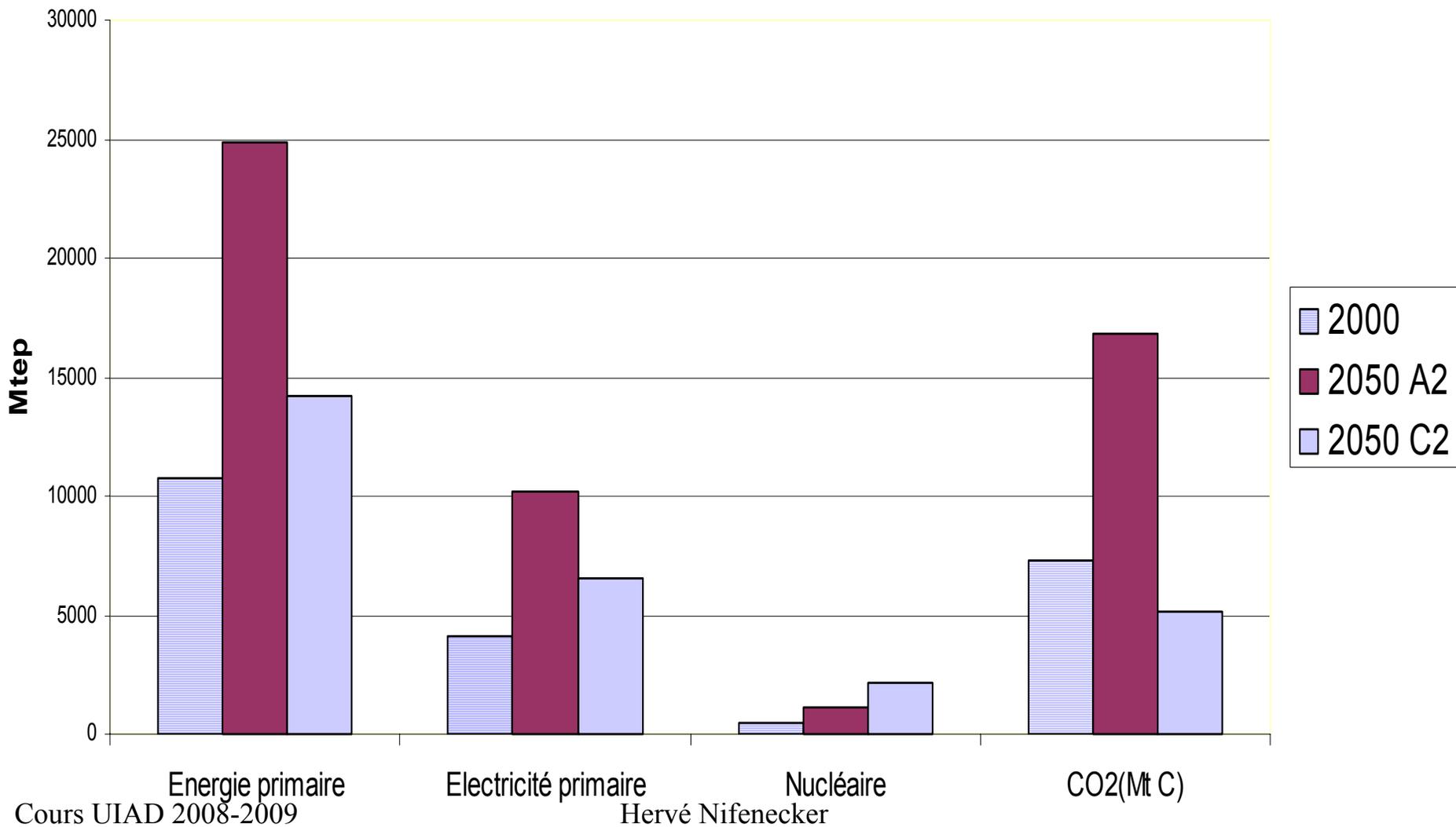


France 2004 22 k\$/cap

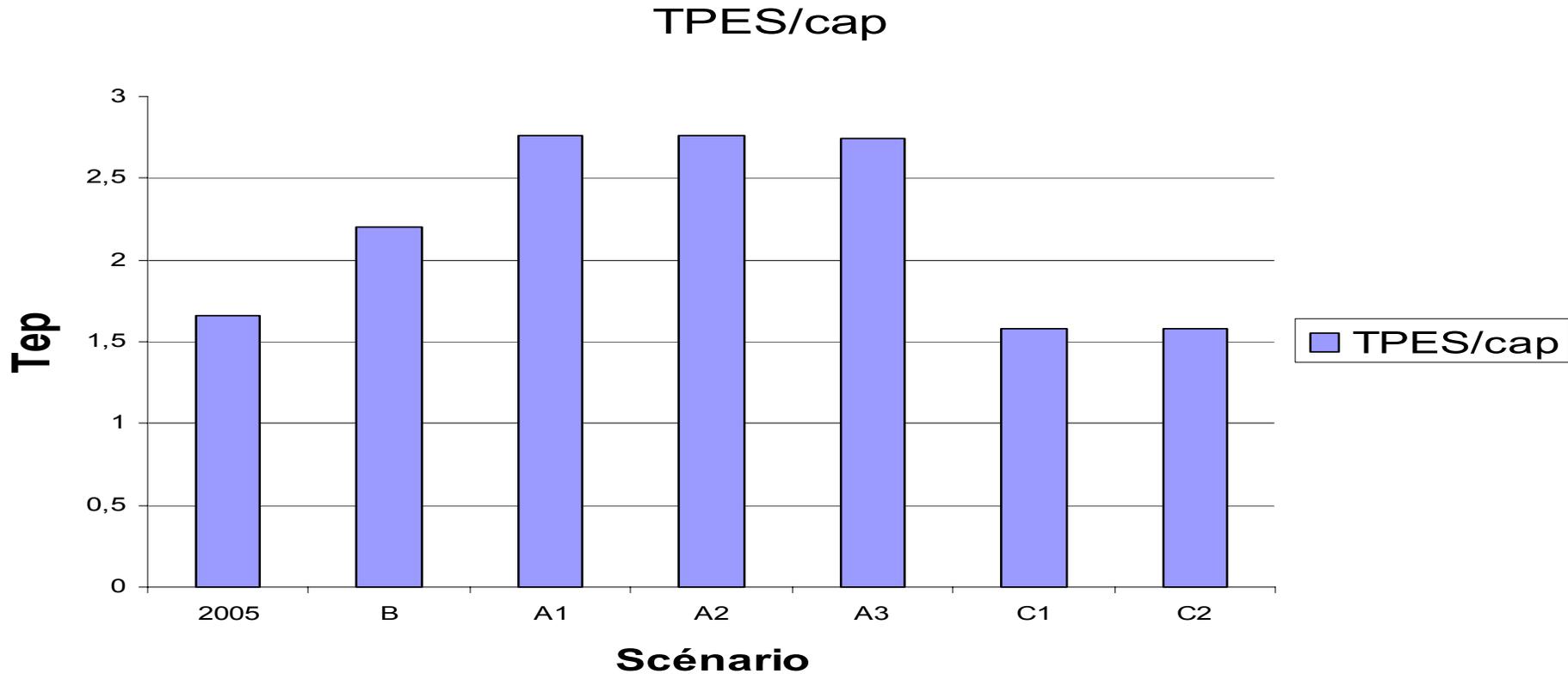
## Intensités énergétiques



# Emissions de CO2

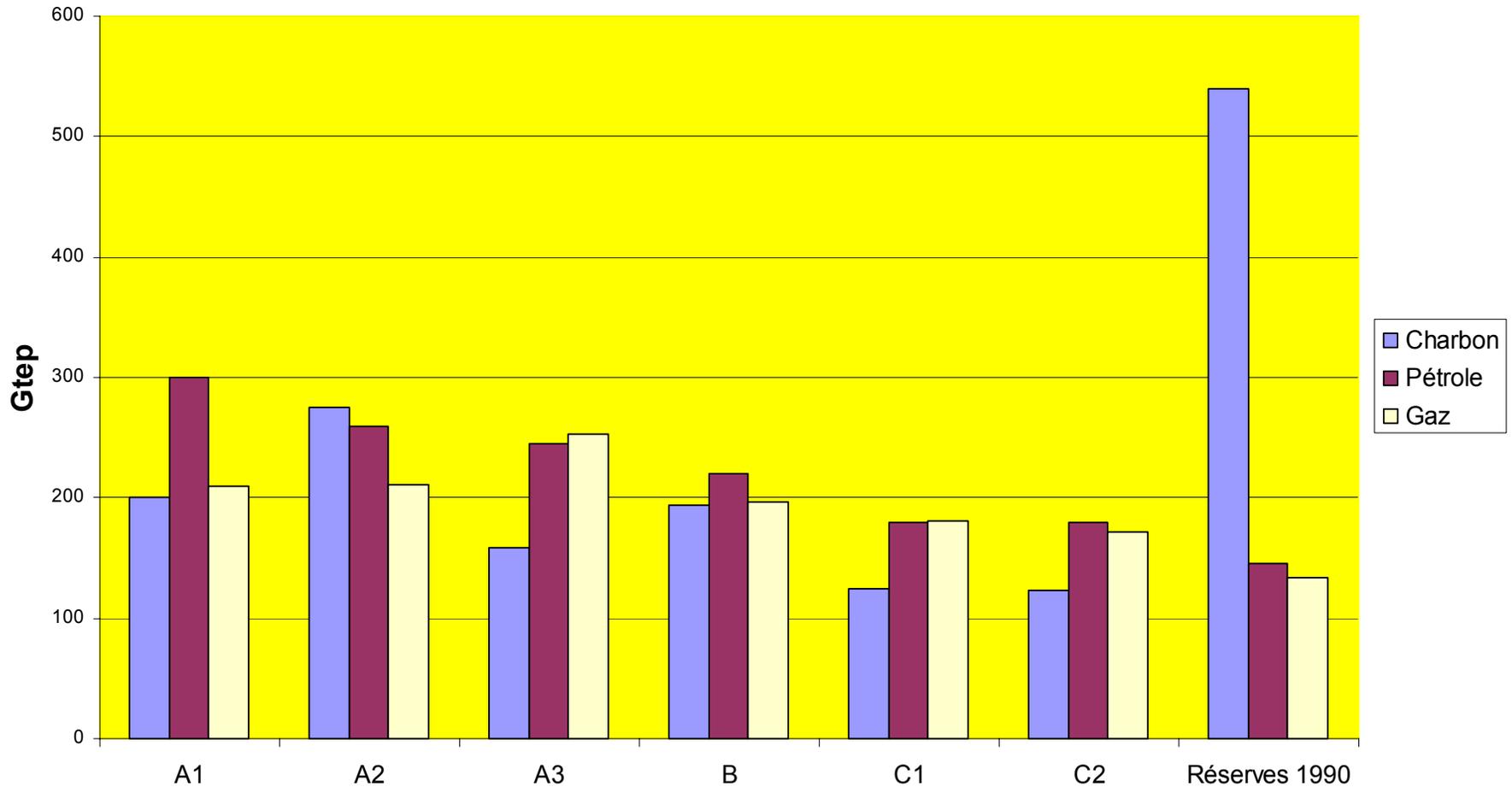


# Production par tête

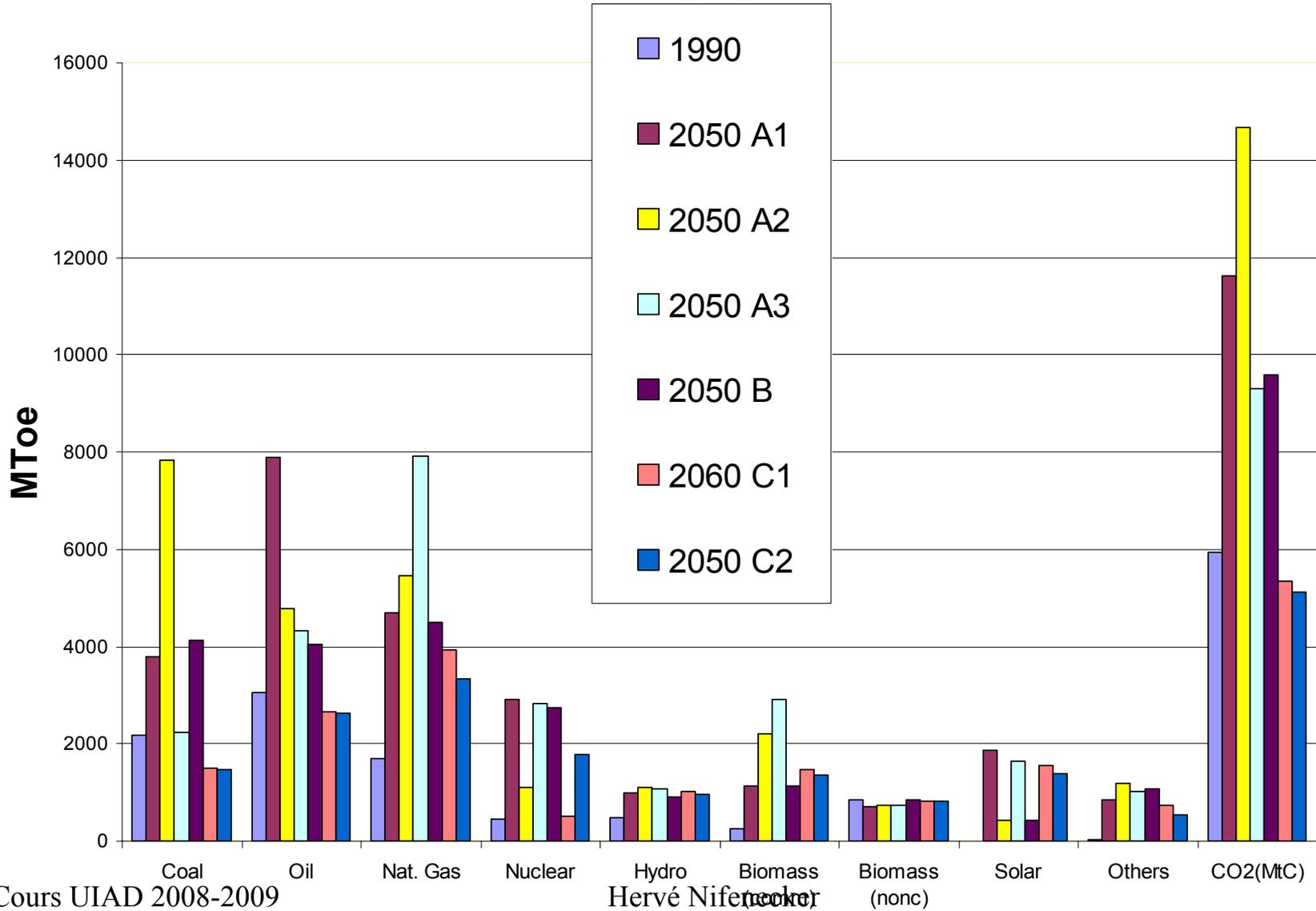


France: 4 tep/cap

# Epuisement des réserves fossiles



# Primary energy per fuel MToe





# Scénarios riches en nucléaire

2030

- Minimiser l'utilisation des fossiles pour l'Electricité
- Développement « Raisonable » du Nucléaire
  - OECD: 85%
  - Transition: 50%
  - Chine, Inde, Am. Latine: 30%

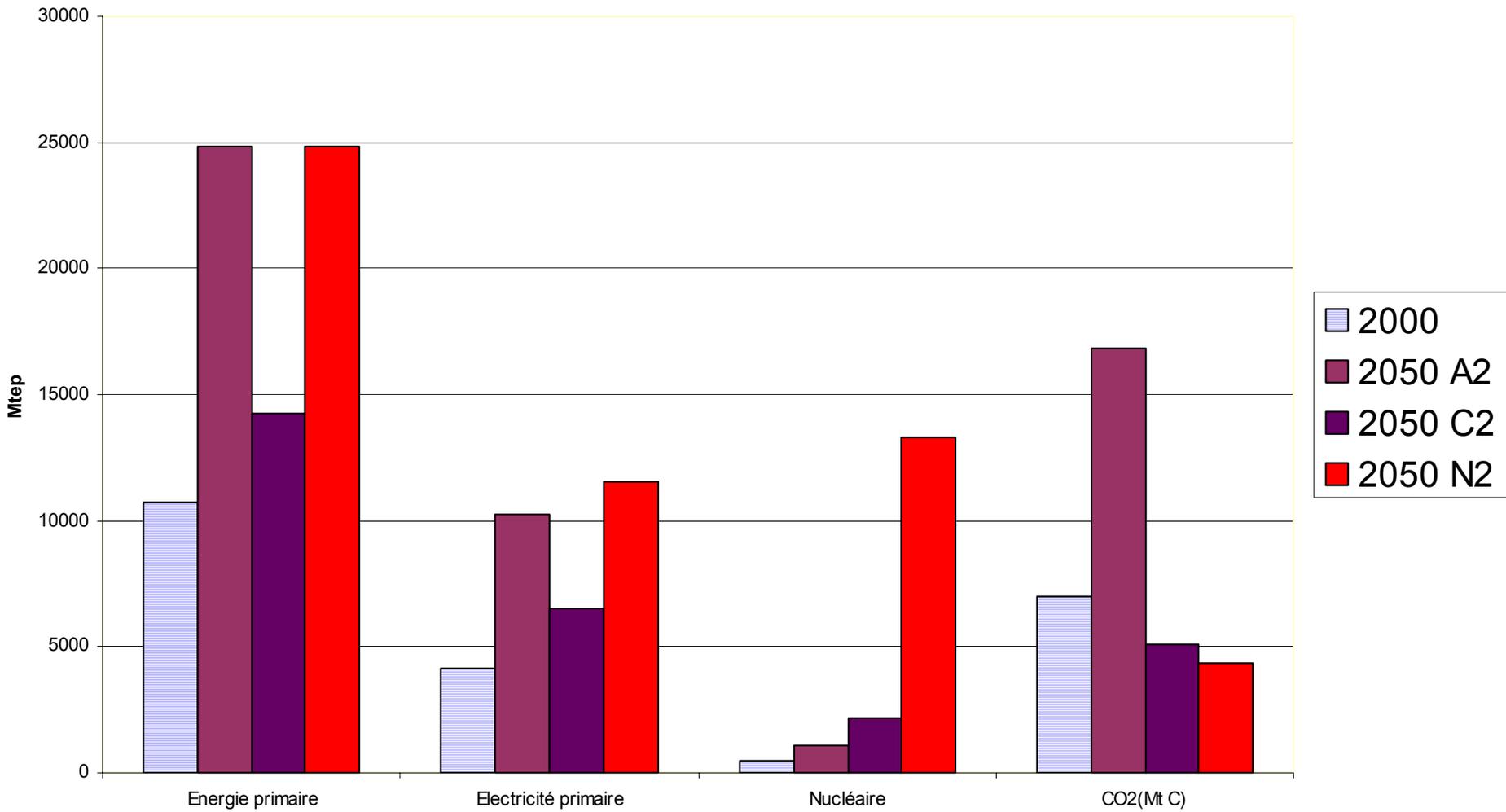
3000 GWe Nucléaire

2050

- Minimiser l'utilisation du charbon et du gaz
- 30% charbon Chine, Inde; 30% gaz Russie; 100% Afrique

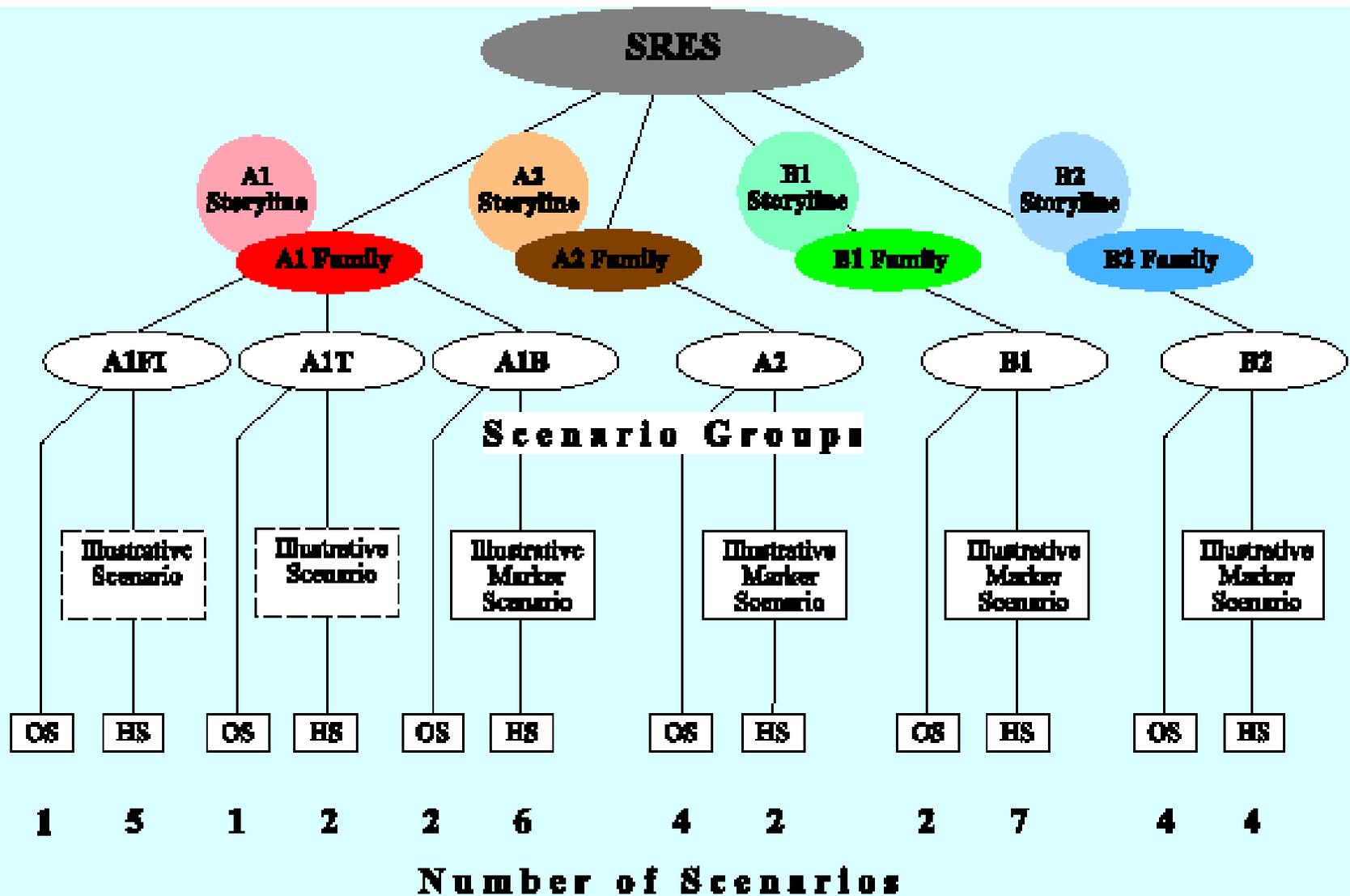
7500 GWe Nucléaire

# Scénario ni charbon ni gaz en 2050

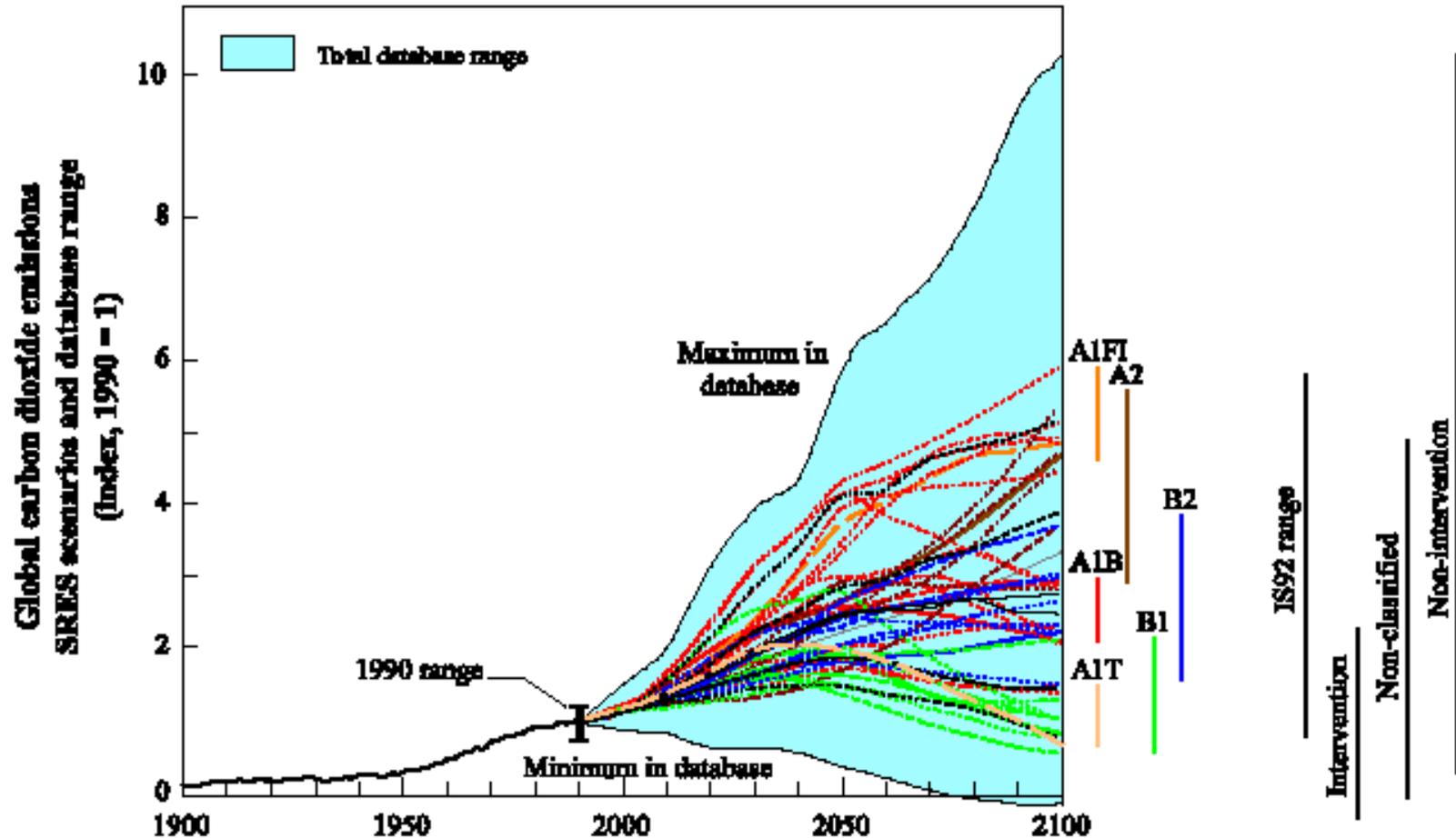




# Scenarios GIEC



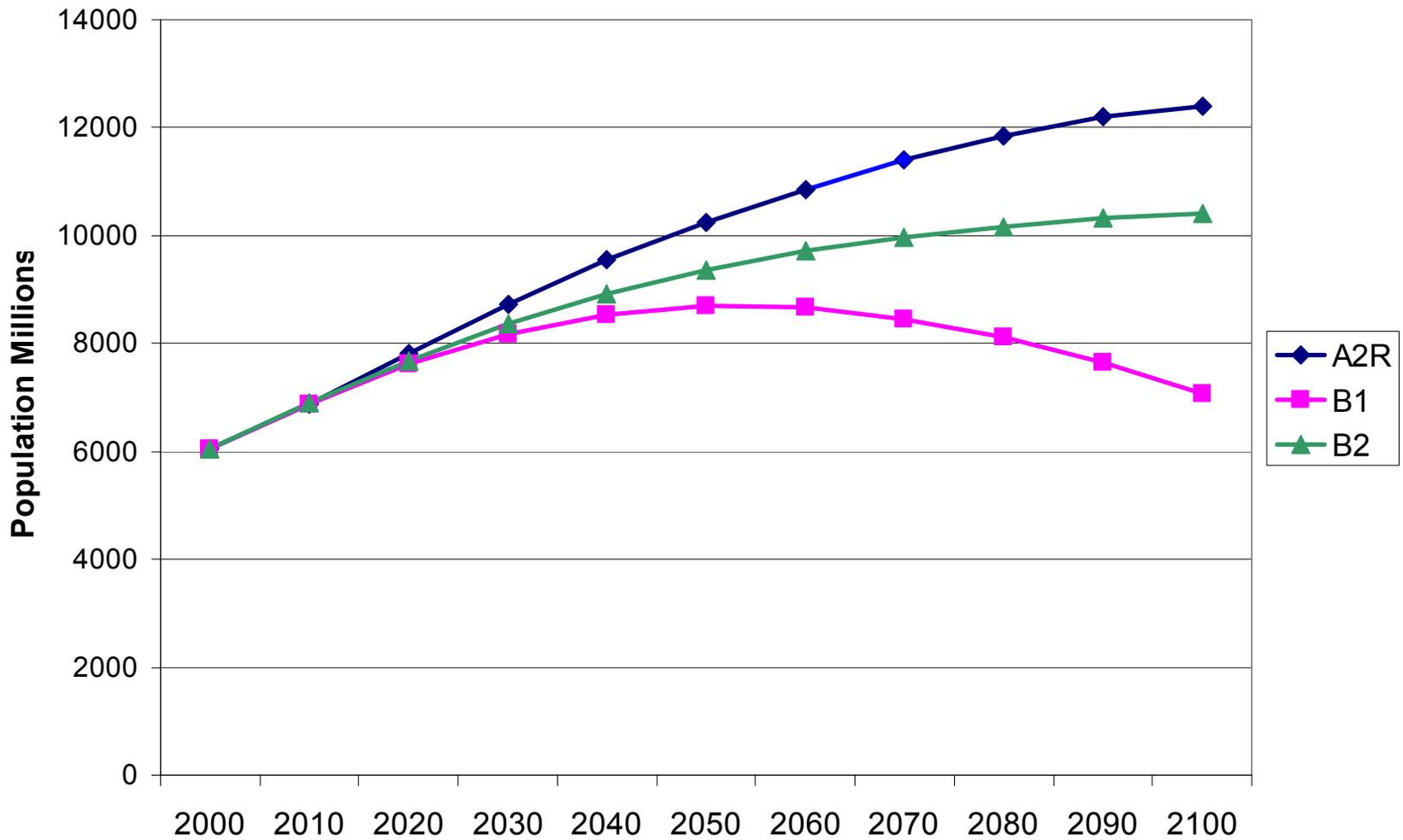
# Evolution des émissions CO2



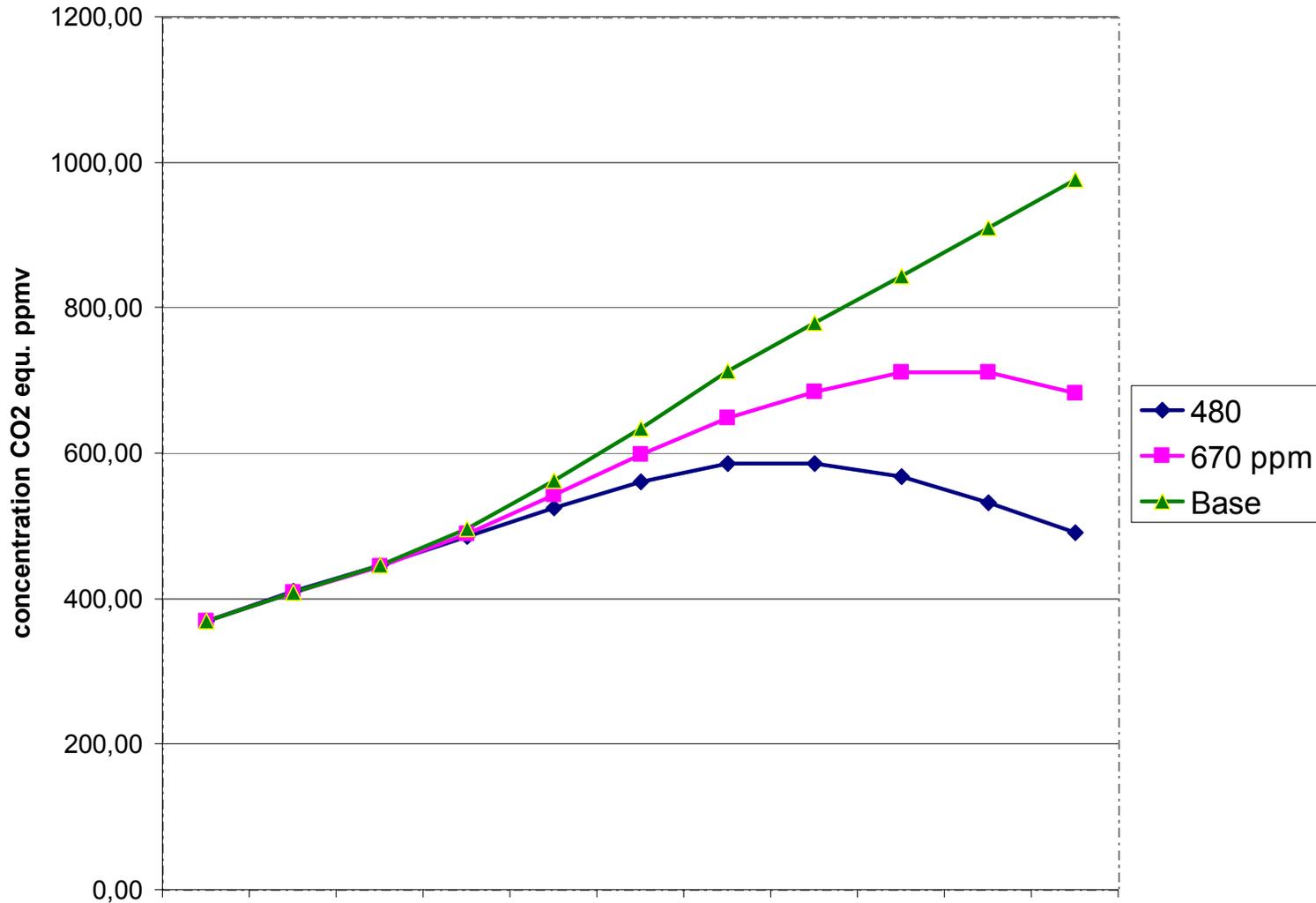


# Scénario IIASA B2 contraint à 470 ppm CO<sub>2</sub>

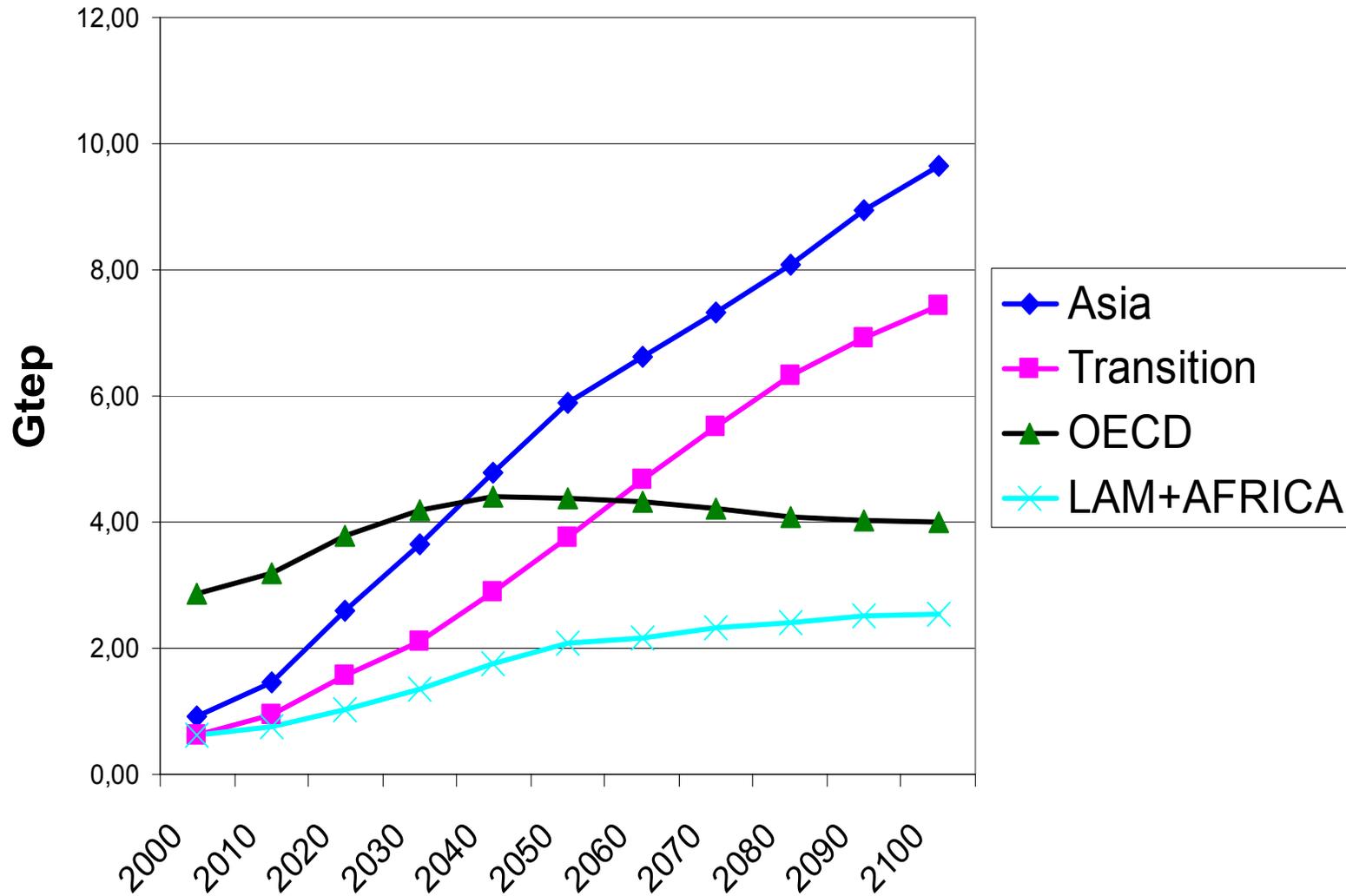
# Population



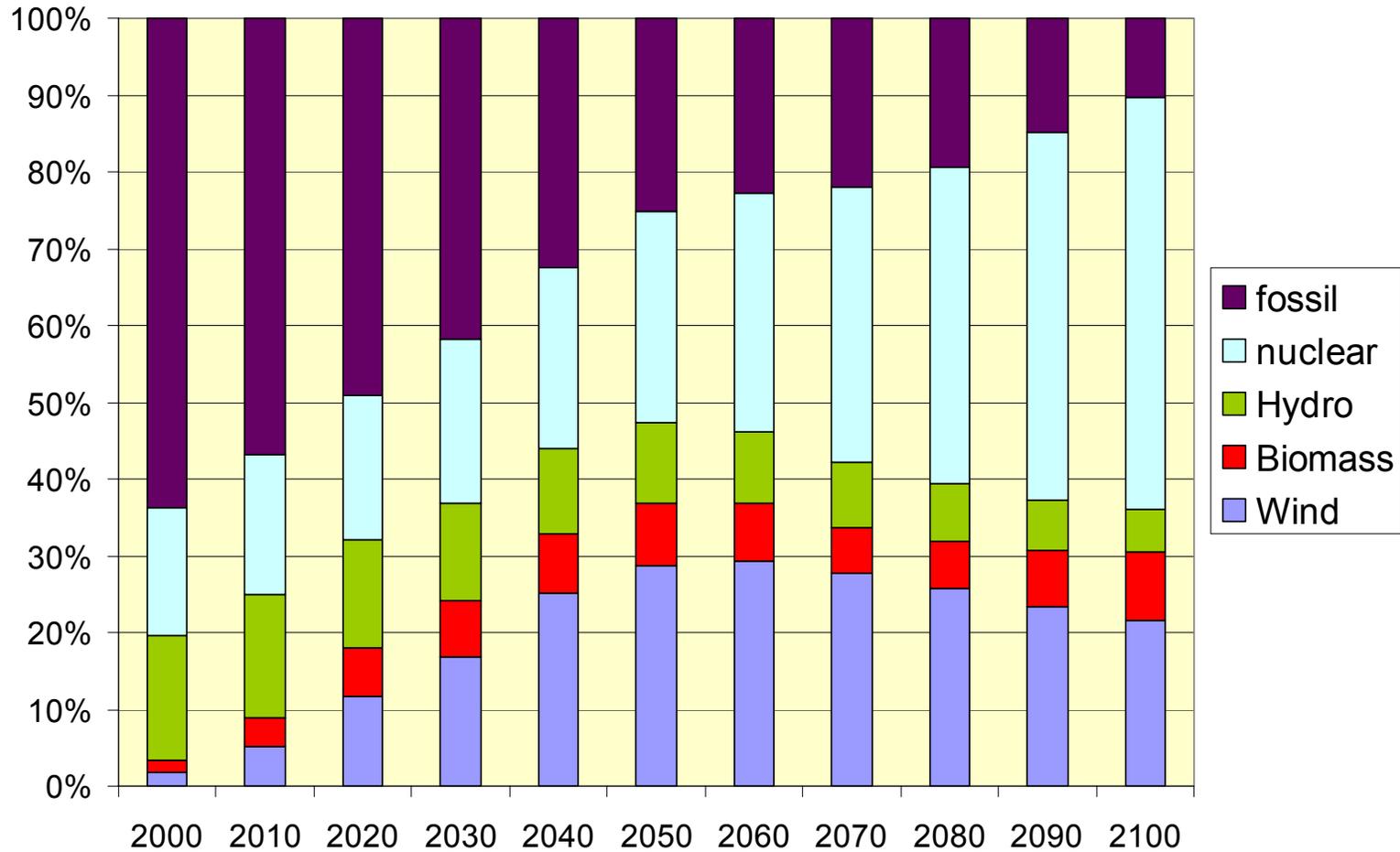
# CO2 concentrations



# Demande d'énergie par agrégat



# Mix électrique pour B2 470 ppm





# France

Négatep (Acket-Bacher)  
versus  
Négawatt

# RENOUVELABLES PERSPECTIVES 2050

<b>A ce jour</b>	<b>29 Mtep (12 %)</b>	<b>Obj. 2050 x 2 à 3</b>
◆Hydraulique	16 Mtep (70 TWh )	≅ 16 Mtep
◆Bois Déchets	12 Mtep	24 Mtep
◆Biocarburants	0.5 Mtep	5 à 15 Mtep
◆Solaire thermique		6 Mtep
◆Géothermie		9 Mtep
◆Éolien		5 à 20 Mtep (22 à 88 TWh ) <i>10.000 à 40.000 MWe P.inst</i>

*Mtep : Millions de tonne ~ pétrole*

*TWh : Tera Watt heure : 1.000 Milliards de Wh*

*Hydraulique 1 TWh = 0.222 Mtep et non 0.086*

# Production électrique 2050

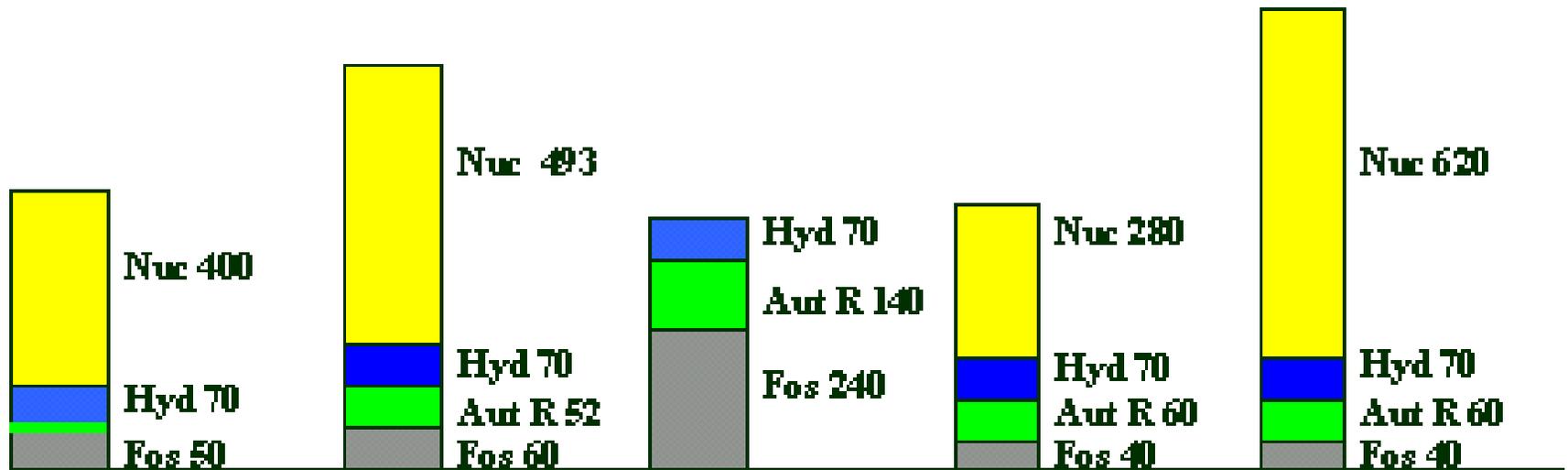
Auj: 525 TWh  
(exp 75)

B: 675 TWh

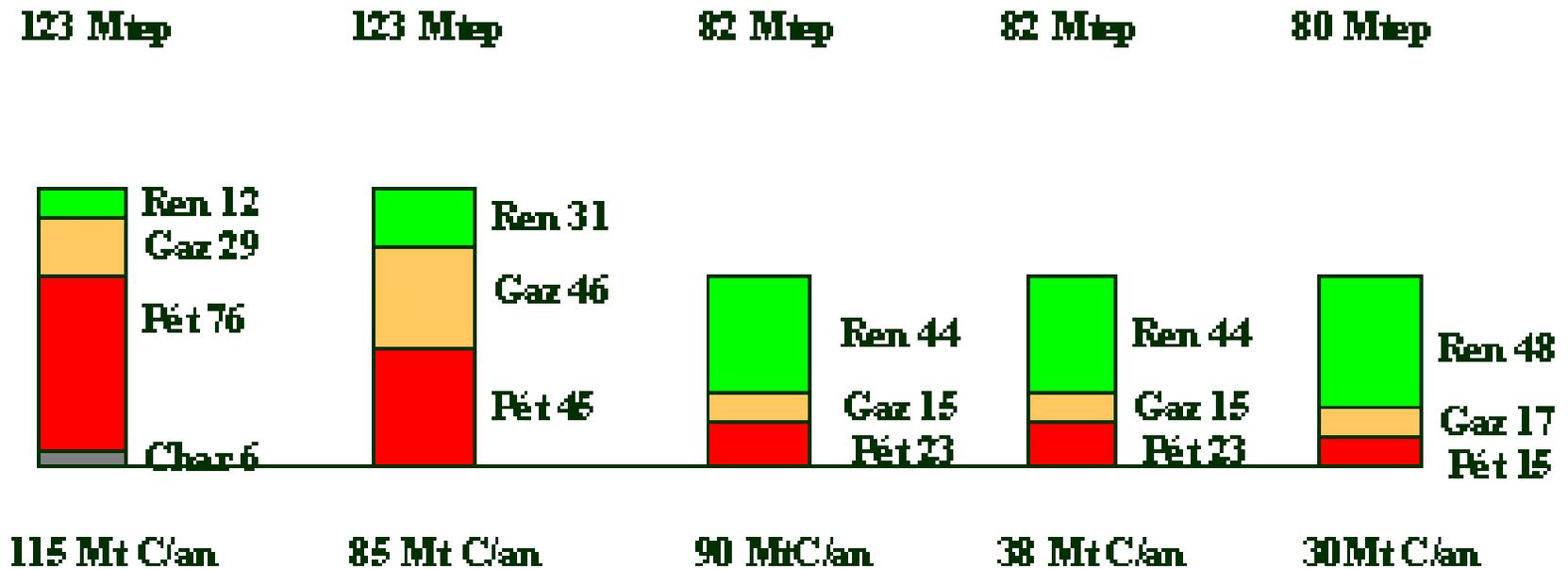
Cs: 450 TWh

Cn: 450 TWh

F4: 790 TWh



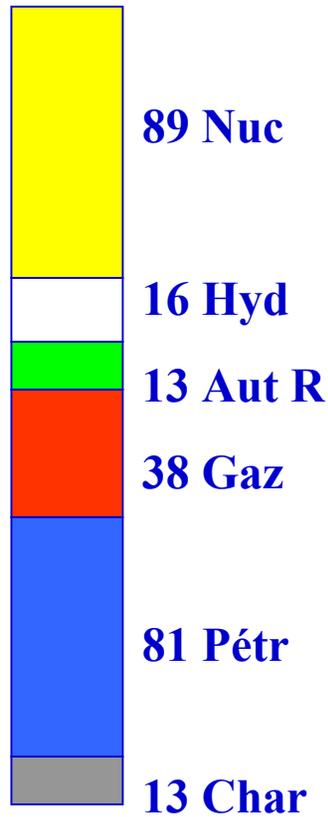
# Chaleur Mobilité



# SCENARIO Négatep (Acket, Bacher)

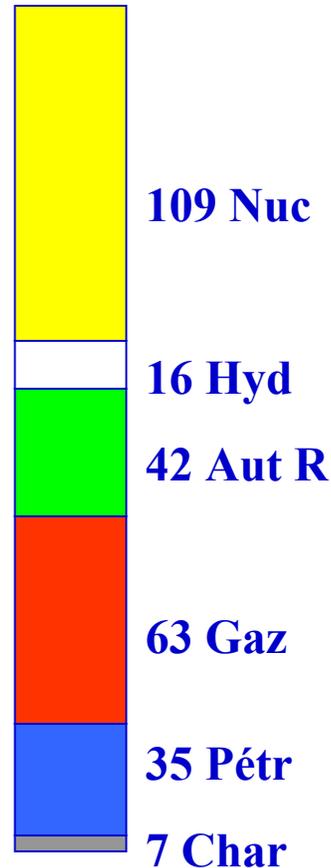
**2000**

**250 Mtep**



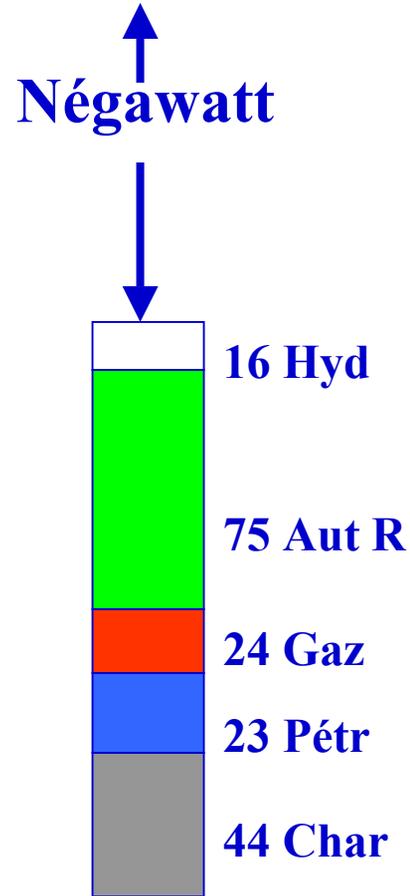
**2050 TB**

**272 Mtep**



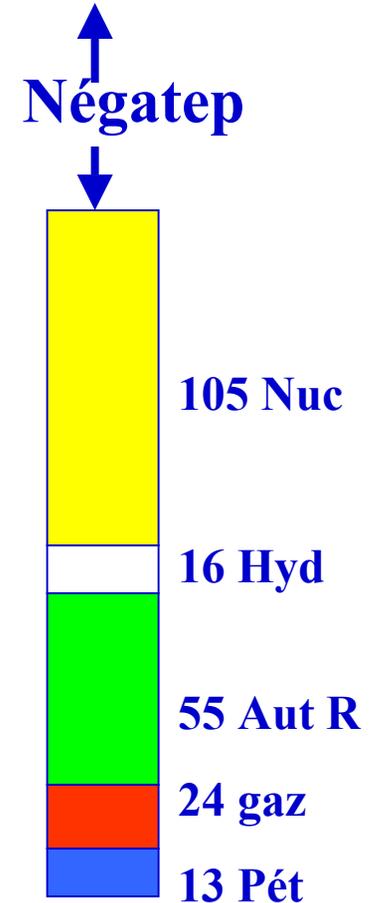
**2050 Sn**

**182 Mtep**



**2050 Sf**

**213 Mtep**



**C: 115 Mt/an**

**85 Mt/an**

**89 Mt/an**

**29 Mt/an**