Preliminary approach

Scenarios with an Intensive Contribution of Nuclear Energy to the World Energy Supply

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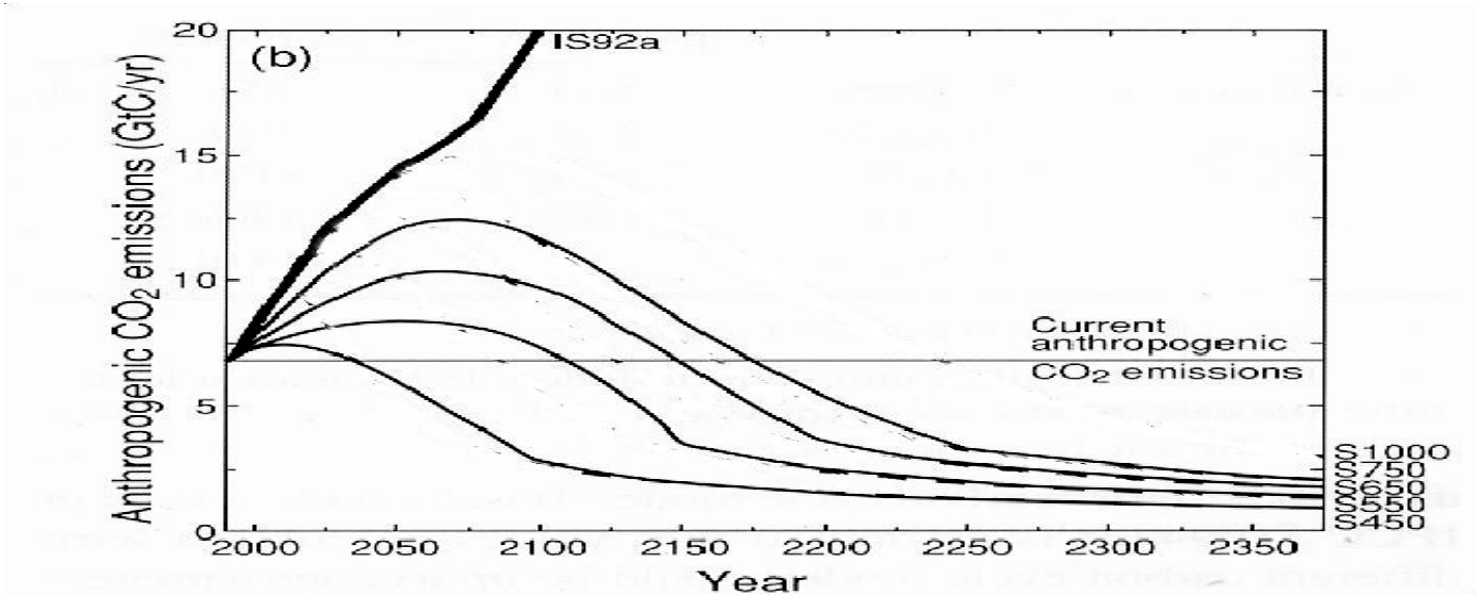
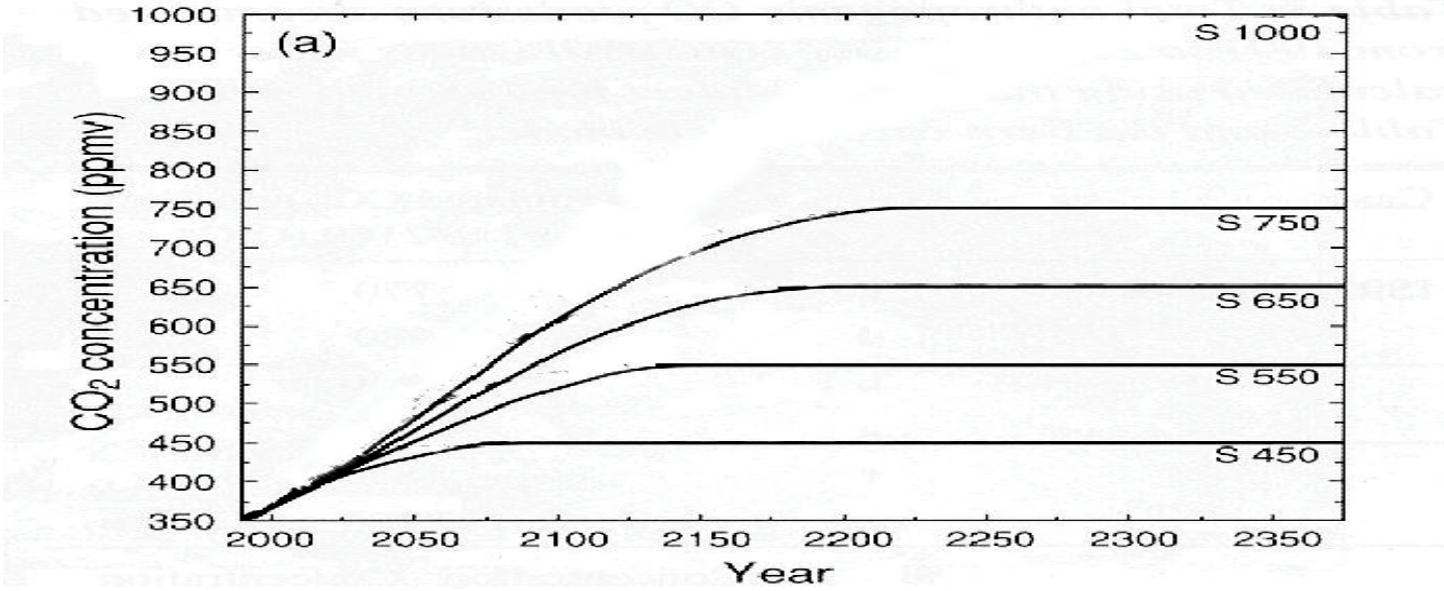
Global Heating Challenge

Models for emission (a) and concentrations of CO2 (b)

(a)



(b)



Global Warming

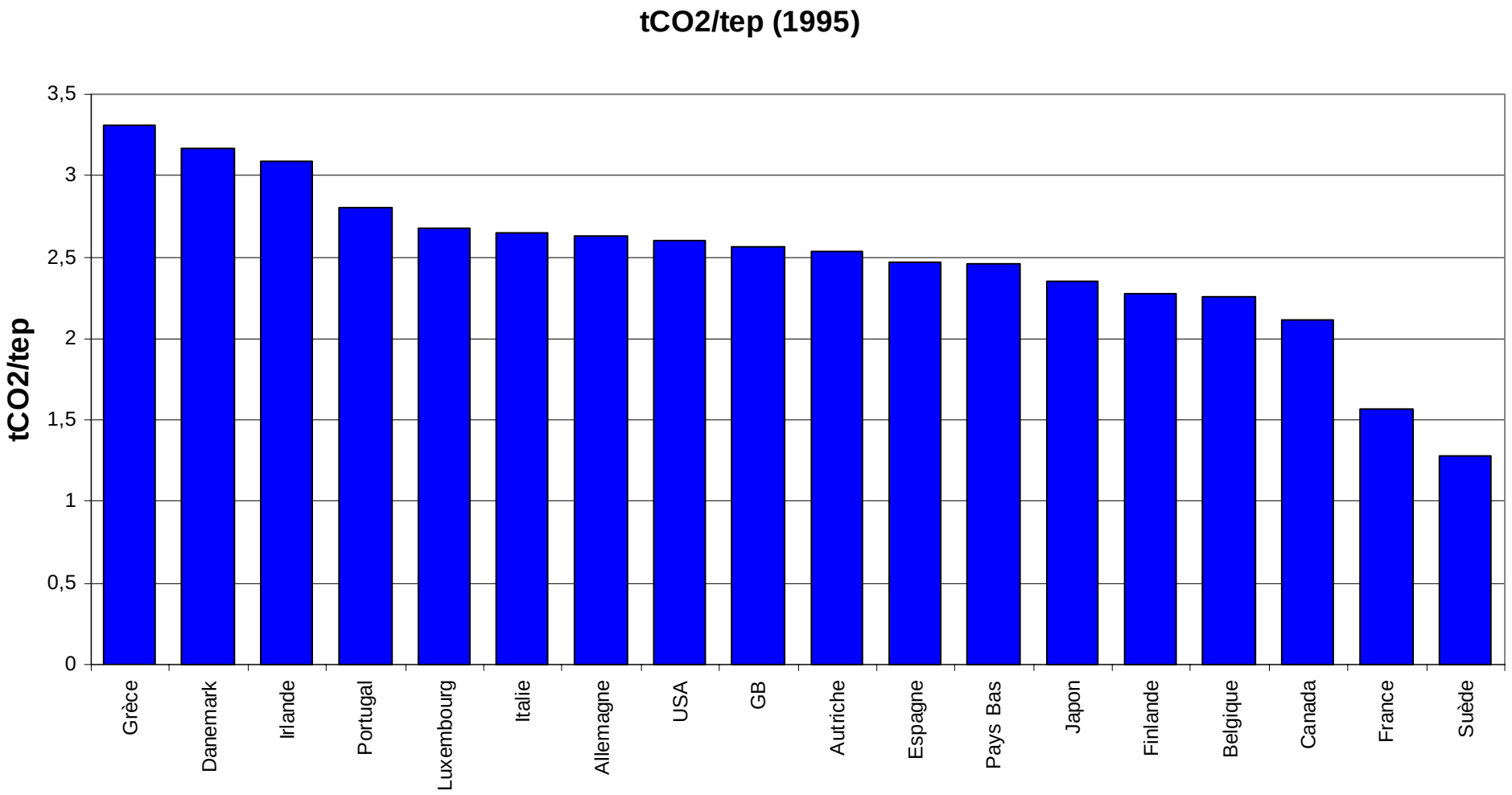
- Present Emissions : 6GtC
- World population: 6 Billions
- Emission/capita: 1 Ton C

Max. emission for temperature stabilization: **3GtC**

- Objective for **2050**
- World Population(minimum) : 9 Billions
- Emission/capita: 0.33 Ton

Present emissions

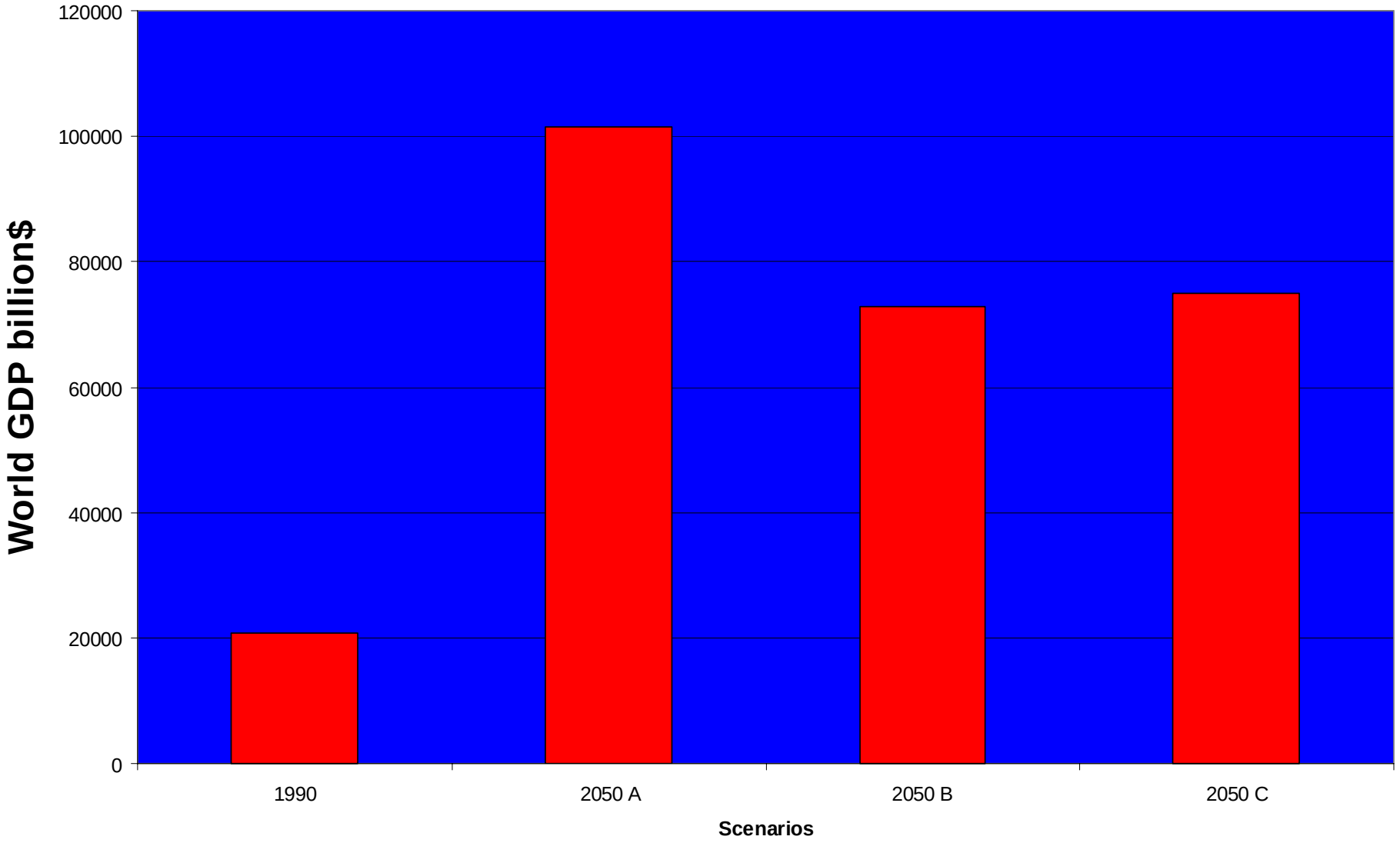
- World average: 1 ton C/capita
- USA: 6 tons C/capita
- Germany : 3.5 tons C/capita
- France: 1.9 tons C/capita
- China: 0.7 tons C/capita


tCO2/tep (1995)
tCO2/tep
3,5
3
2,5
2
1,5
1
0,5
0
Grèce
Danemark
Irlande
Portugal
Luxembourg
Italie
Allemagne
USA
GB
Autriche
Espagne
Pays Bas
Japon
Finlande
Belgique
Canada
France
Suède

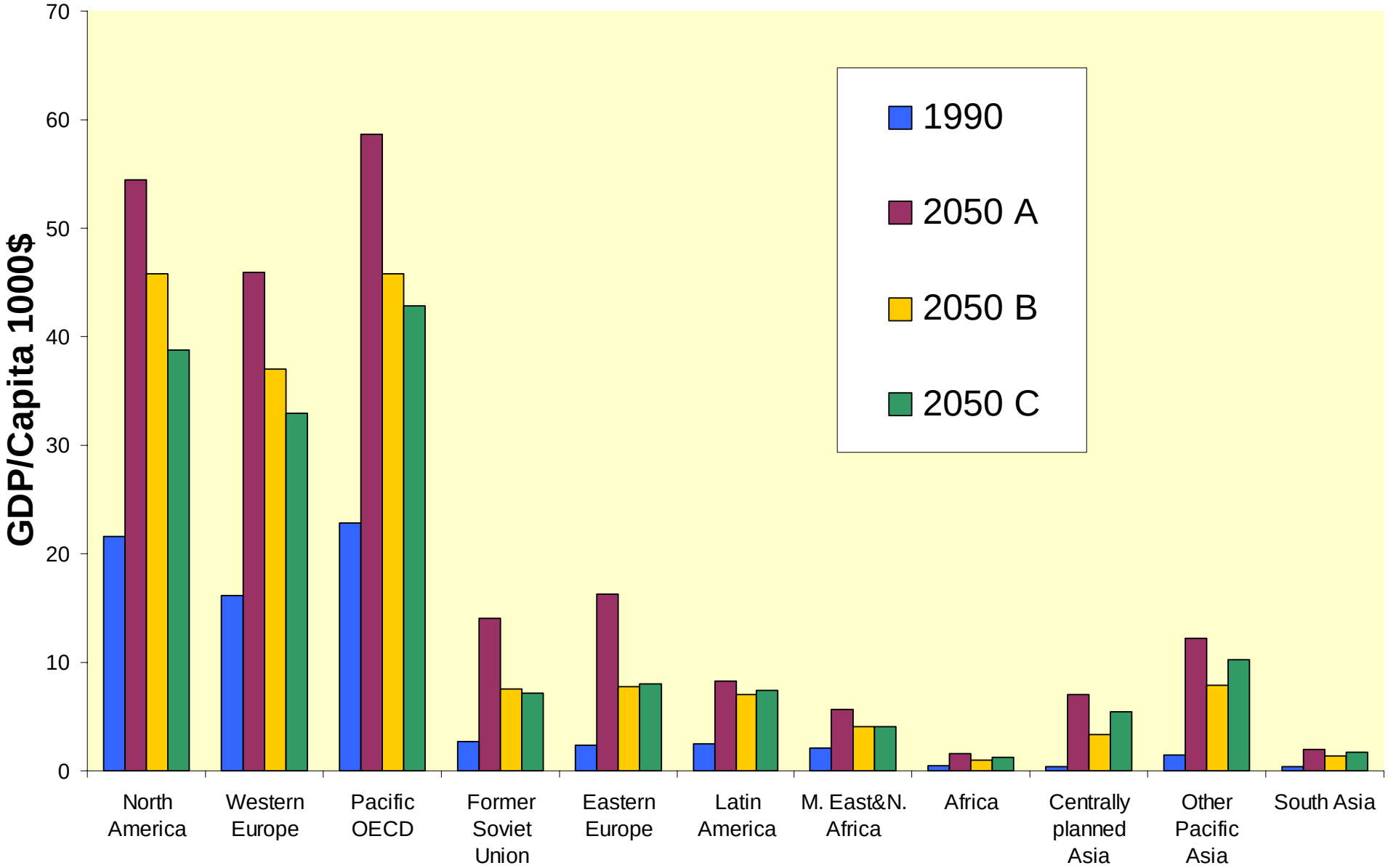
IIASA-WEC Scenarios

- A: strong growth
  - A1: Oil
  - A2: Coal
  - A3:Gaz
- B: Middle of the road
- C: Low energy intensity. High electricity
  - C1: Ren.+Gaz
  - C2: Ren.+Nuclear

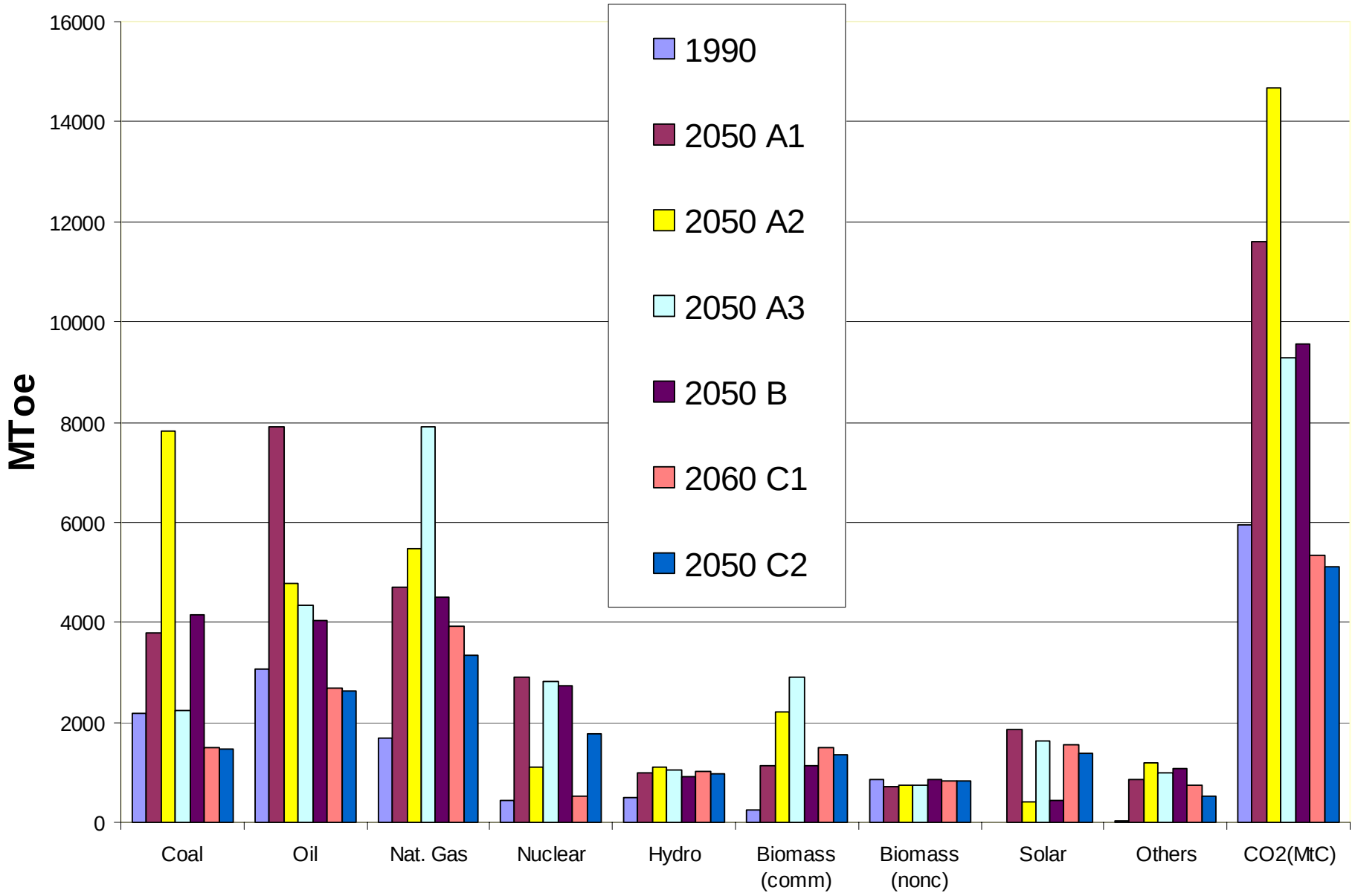
World GDP


120000
100000
80000
60000
40000
20000
0
World GDP billion$
1990
2050 A
2050 B
2050 C
Scenarios

GDP/capita 1000$



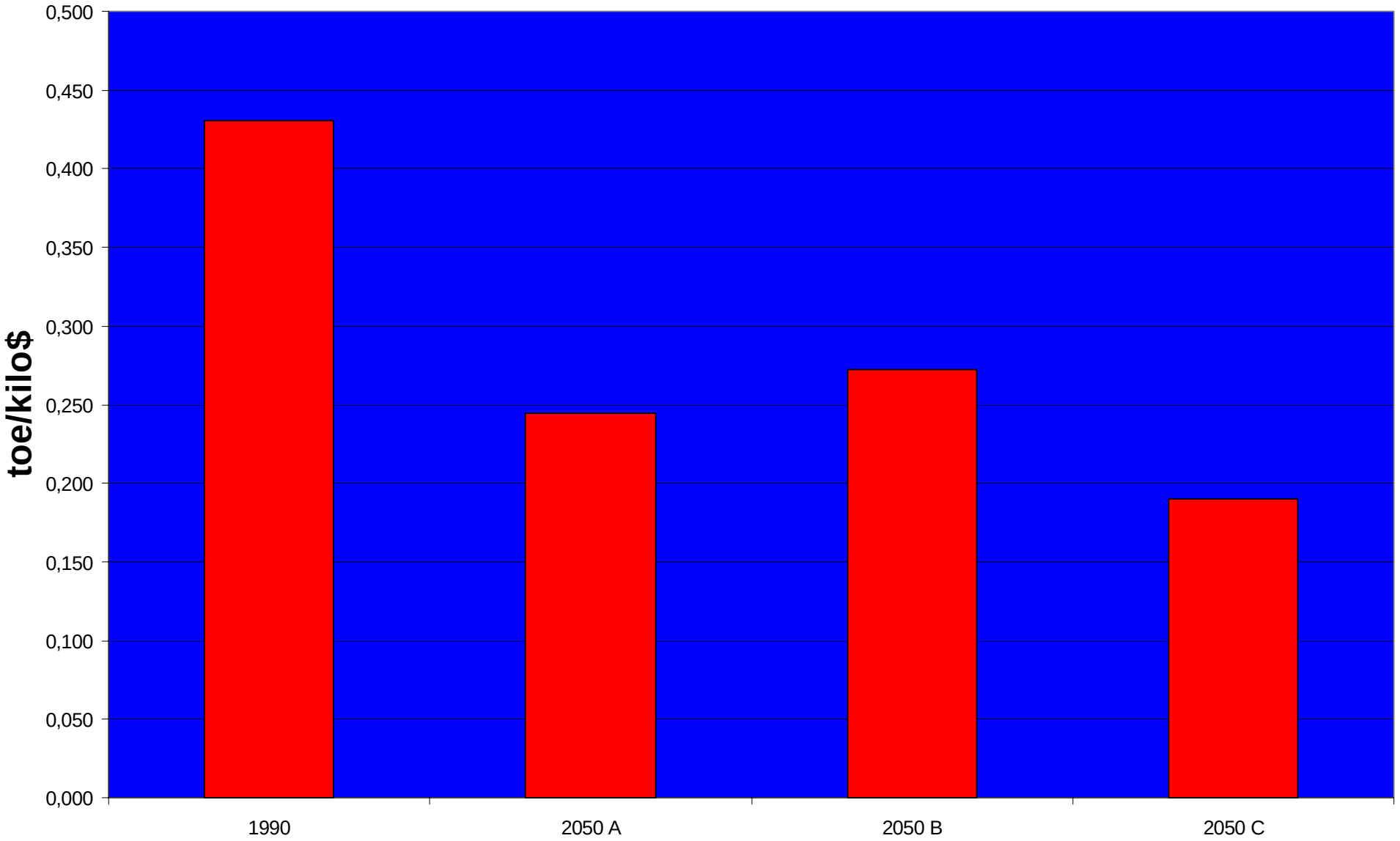
Primary energy per fuel MToe



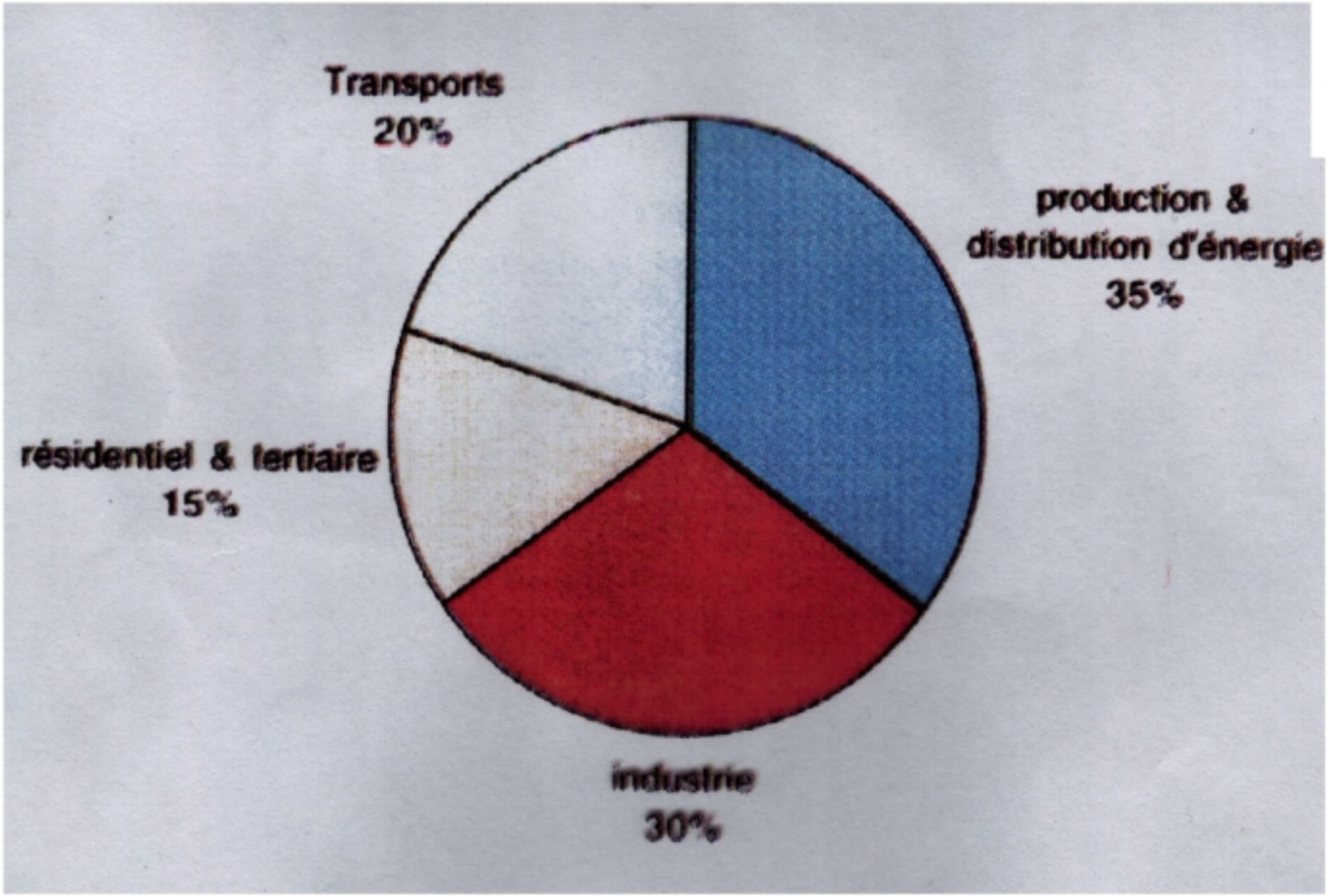
Exhaustion of fossile reserves (Gtoe)

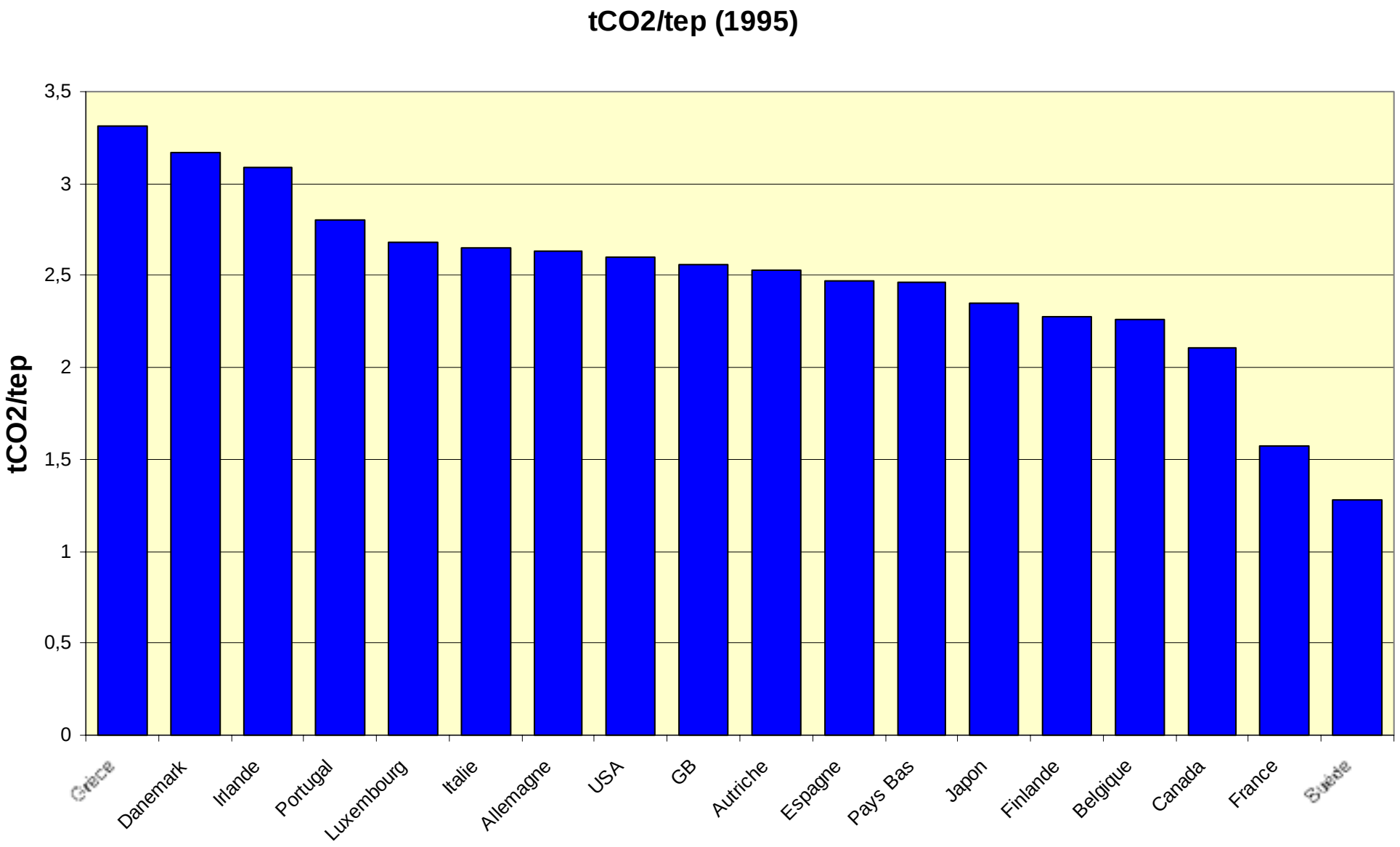
	A1	A2	A3	B	C1	C2	Reserves 1990
Coal+Lignite	200	275	158	194	125	123	540
Oil	300	260	245	220	180	180	146
Gas	210	211	253	196	181	171	133

Energy Intensities



Nuclear Intensive Scenarios


Transports
20%
production &
distribution d'énergie
35%
résidentiel & tertiaire
15%
industrie
30%


tCO2/tep (1995)
tCO2/tep
3,5
3
2,5
2
1,5
1
0,5
0
Grèce
Danemark
Irlande
Portugal
Luxembourg
Italie
Allemagne
USA
GB
Autriche
Espagne
Pays Bas
Japon
Finlande
Belgique
Canada
France
Suède

2030

- Minimize use of fossiles for **Electricity**
- « Reasonable » implementation of **Nuclear Power**
  - OECD: 85%
  - Transition: 50%
  - China, India, Latin Am.: 30%

3000 GWe Nuclear Power

2050

Manage ^{235}U Reserves

1st Scenario

- No more use of fossiles for electricity

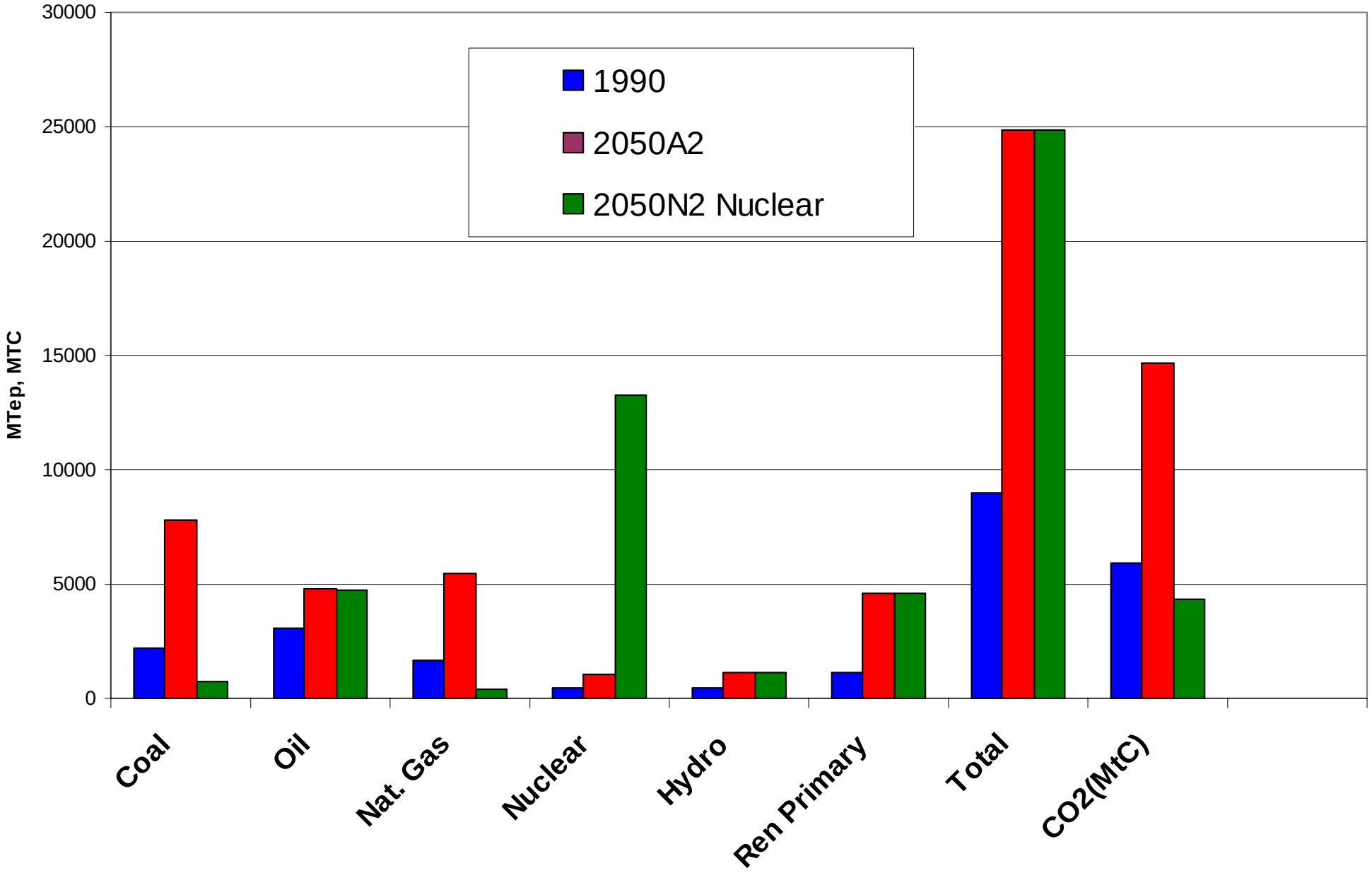
4500 GWe Nuclear Power

2nd Scenario

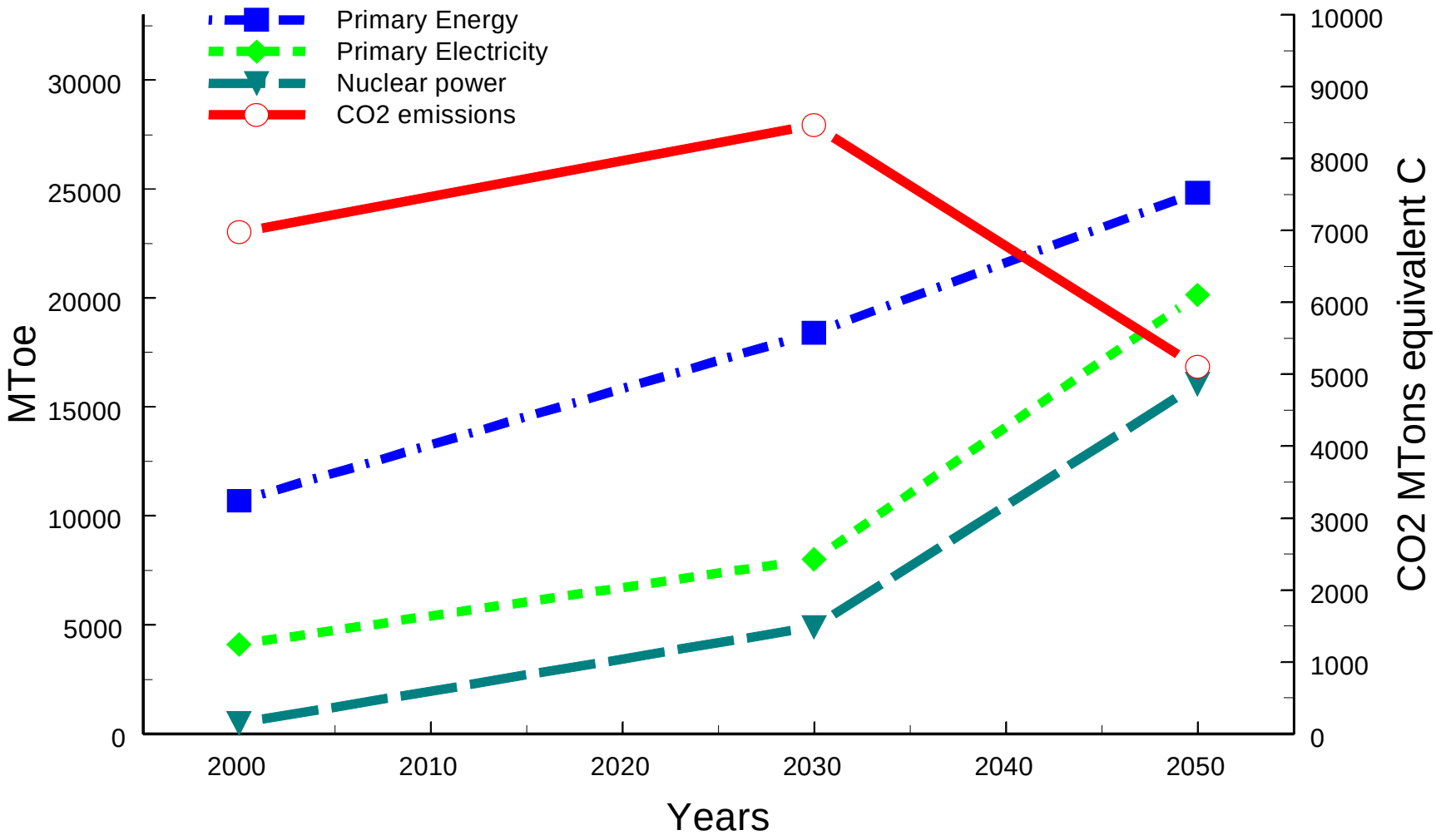
- Generalized use of Electrolytic Hydrogen
- Increased share of Electricity:
  - OECD: 90%
  - Transition: 85%
  - S.E.Asia: 80%
  - Rest of the World: 70%

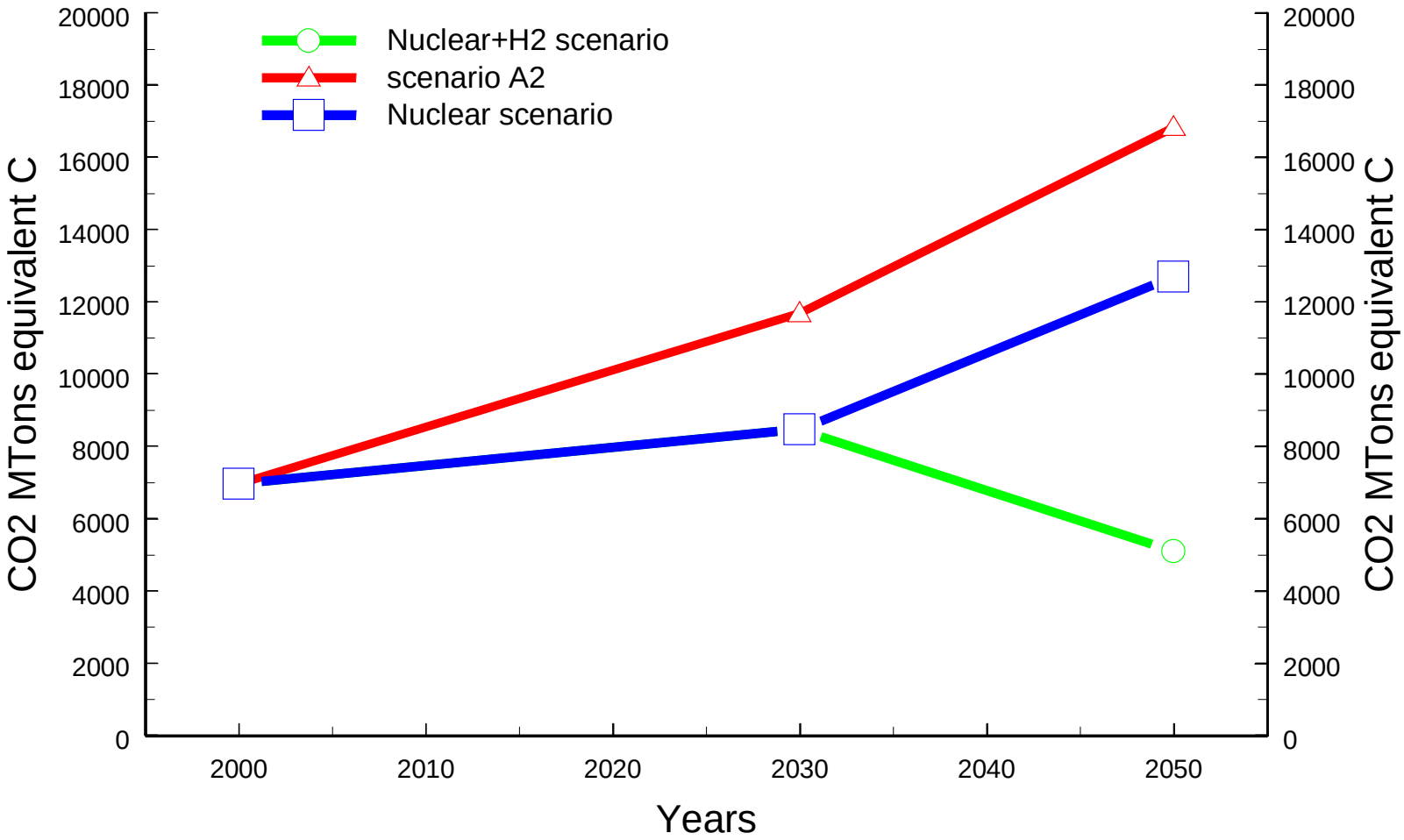
9000 GWe Nuclear Power

Scenario no coal no gas in 2050

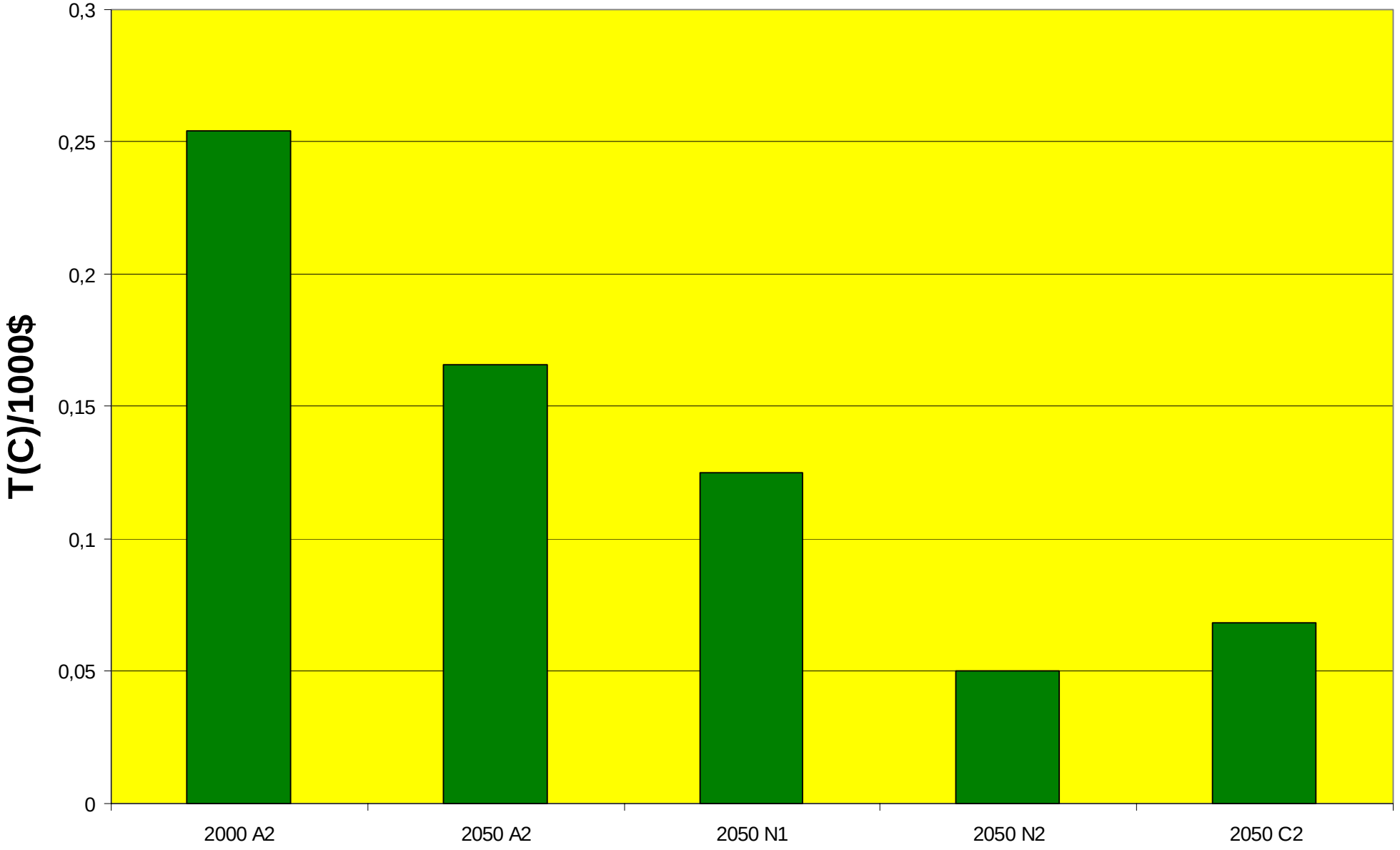


1	3	4	5	6	7
	IIASA(A2)	Nuclear intensive	IIASA(A2)	Nuclear intensive	Hydrogen
Year	2030	2030	2050	2050	2050
Population(Millions)	8751	8751	10056	10056	10056
GDP(G$)	61597	61597	101519	101519	101519
Primary Energy(Mtoe)	**18408**	**18408**	**24840**	**24840**	**24840**
Primary Electricity(Mtoe	**8060**	**8021**	**10231**	**10231**	**20154**
Nuclear(Mtoe)	**684**	**4902**	**1092**	**7034**	**16047**
Fossil elec.	5894	1638	6409	467	1378
Nuclear+renewables	2165	6383	3822	9764	18776
% Electricity	**43,78**	**43,78**	**41,19**	**41,19**	**81,14**
Nuclear %El.	8,49	61,12	10,68	68,75	79,62
Renewable% El.	18,38	18,38	26,68	26,68	13,54
Fossil elec.%	**73,13**	**20,42**	**62,64**	**4,57**	**6,84**
Nuclear(Gwe)	**376**	**3387**	**607**	**4466**	**8915**
Nuclear(% total)	3,72	26,63	4,4	28,32	64,6
CO2(Mt C)	**11693**	**8465**	**16838**	**12695**	**5106**
CO2(Mt C)**OECD**	3973	1648	4266	2040	746
Cumulative tons U nat	**1,39E+06**	**4,10E+06**	**2,45E+06**	**1,13E+07**	**1,64E+07**

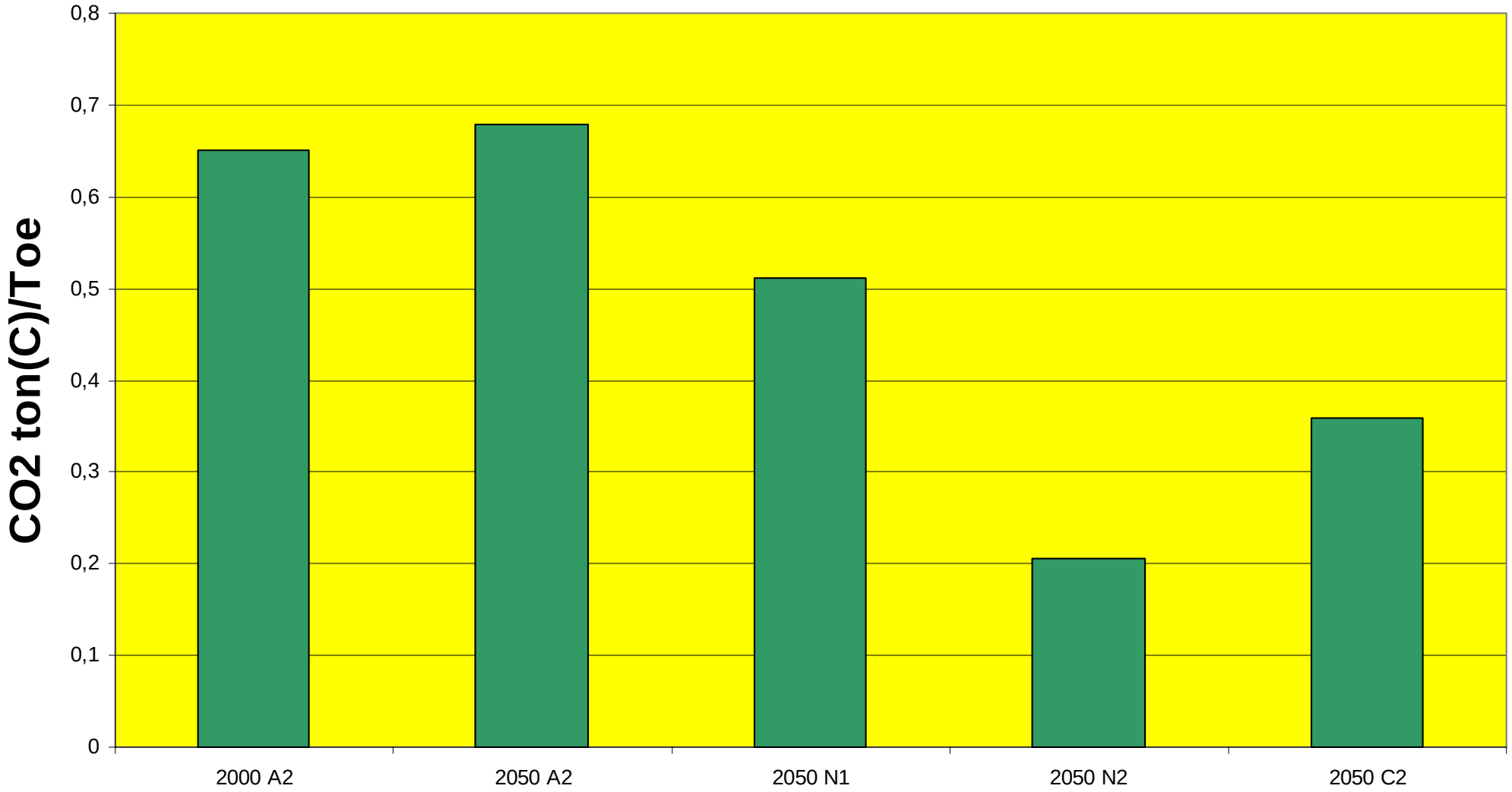

Primary Energy
Primary Electricity
Nuclear power
CO2 emissions
MToe
CO2 MTons equivalent C
Years
0
5000
10000
15000
20000
25000
30000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
2000
2010
2020
2030
2040
2050


Nuclear+H2 scenario
scenario A2
Nuclear scenario
CO2 MTons equivalent C
CO2 MTons equivalent C
Years
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
2000
2010
2020
2030
2040
2050

CO2/GDP

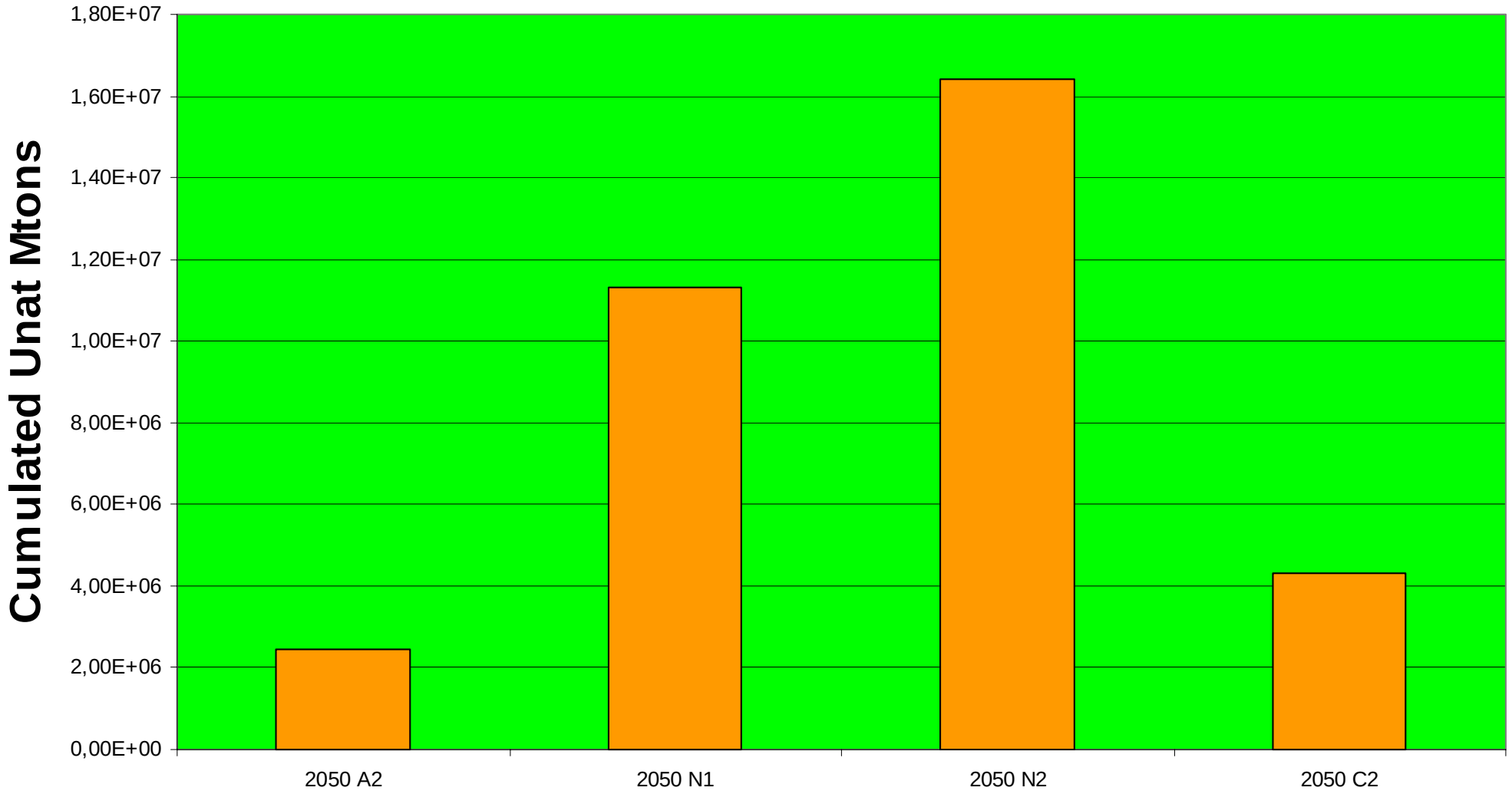

T(C)/1000$
0,3
0,25
0,2
0,15
0,1
0,05
0
2000 A2
2050 A2
2050 N1
2050 N2
2050 C2

CO2/primen


CO2 ton(C)/Toe
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
2000 A2
2050 A2
2050 N1
2050 N2
2050 C2

Gestion of
Natural Uranium Reserves

Unat exhaustion

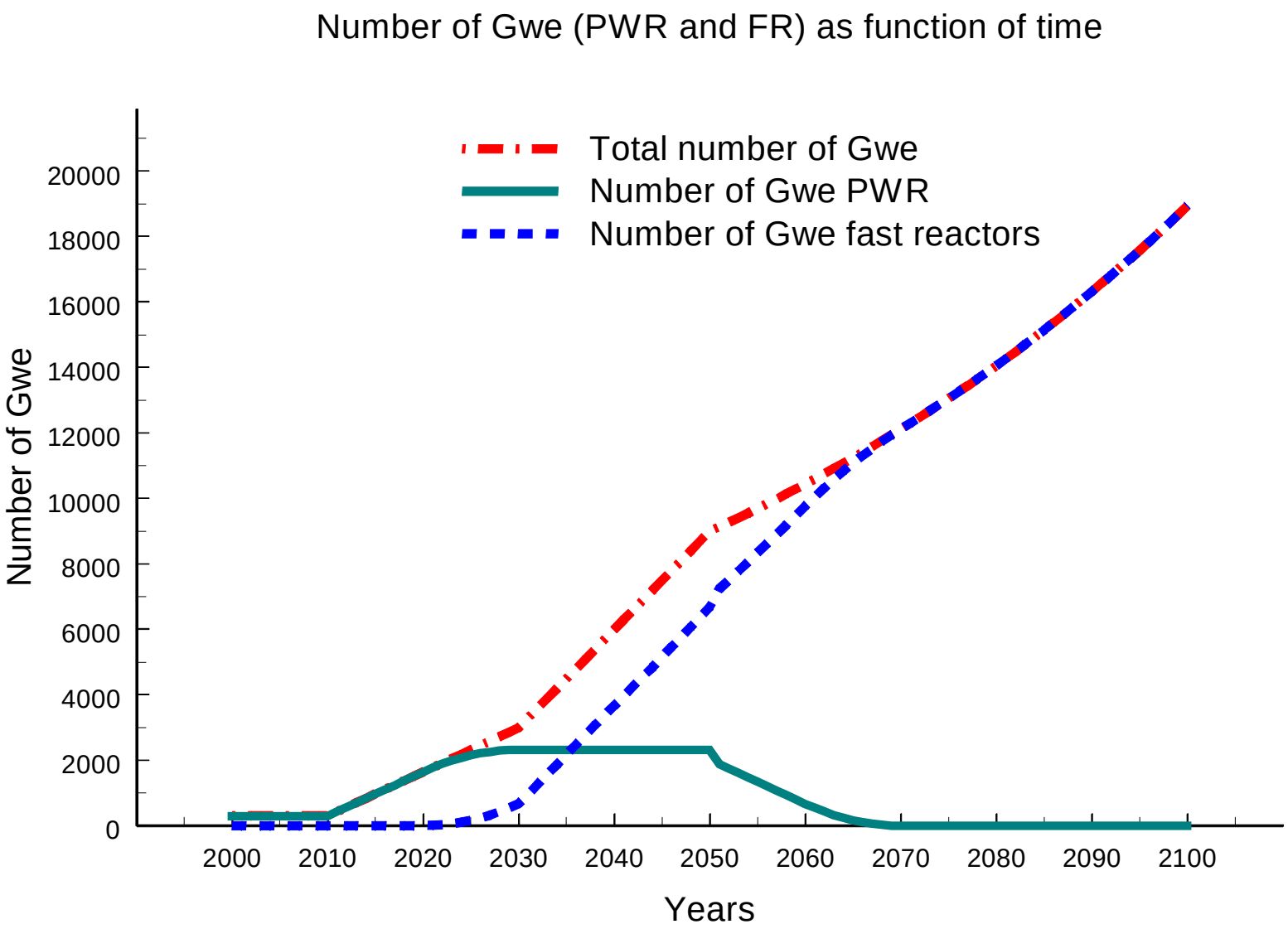


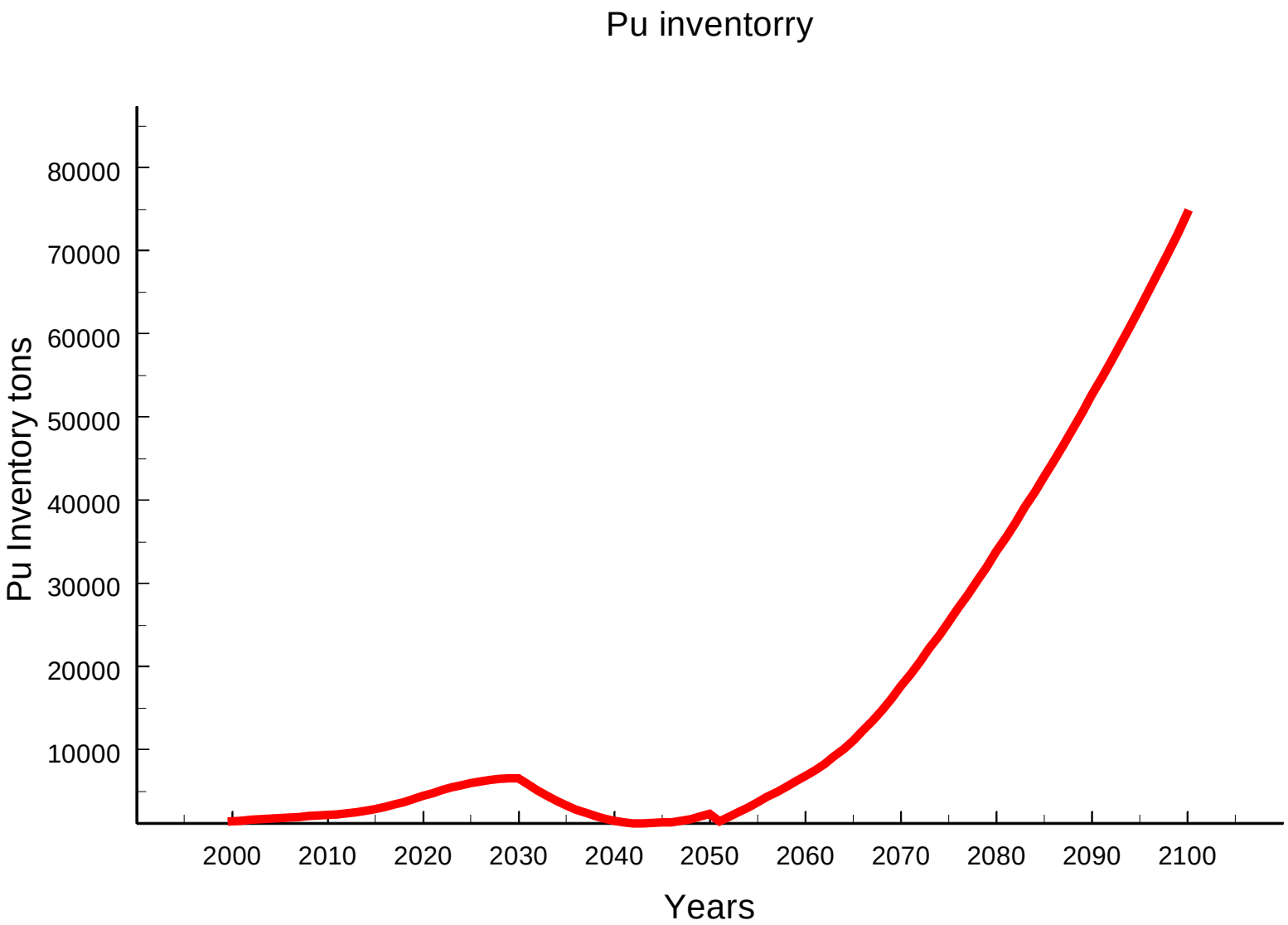
Breeding Cycles

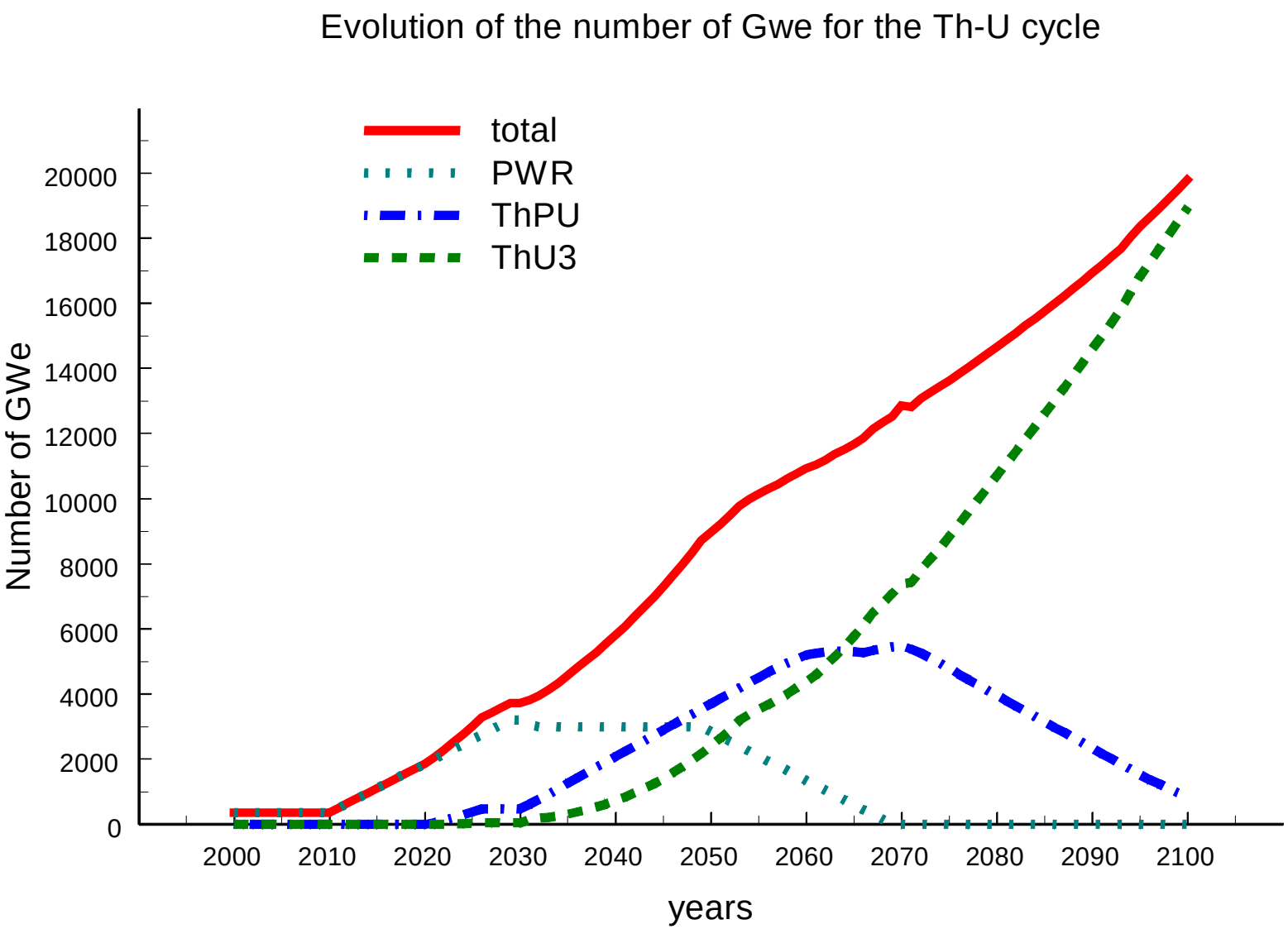
U-Pu versus Th-U cycles

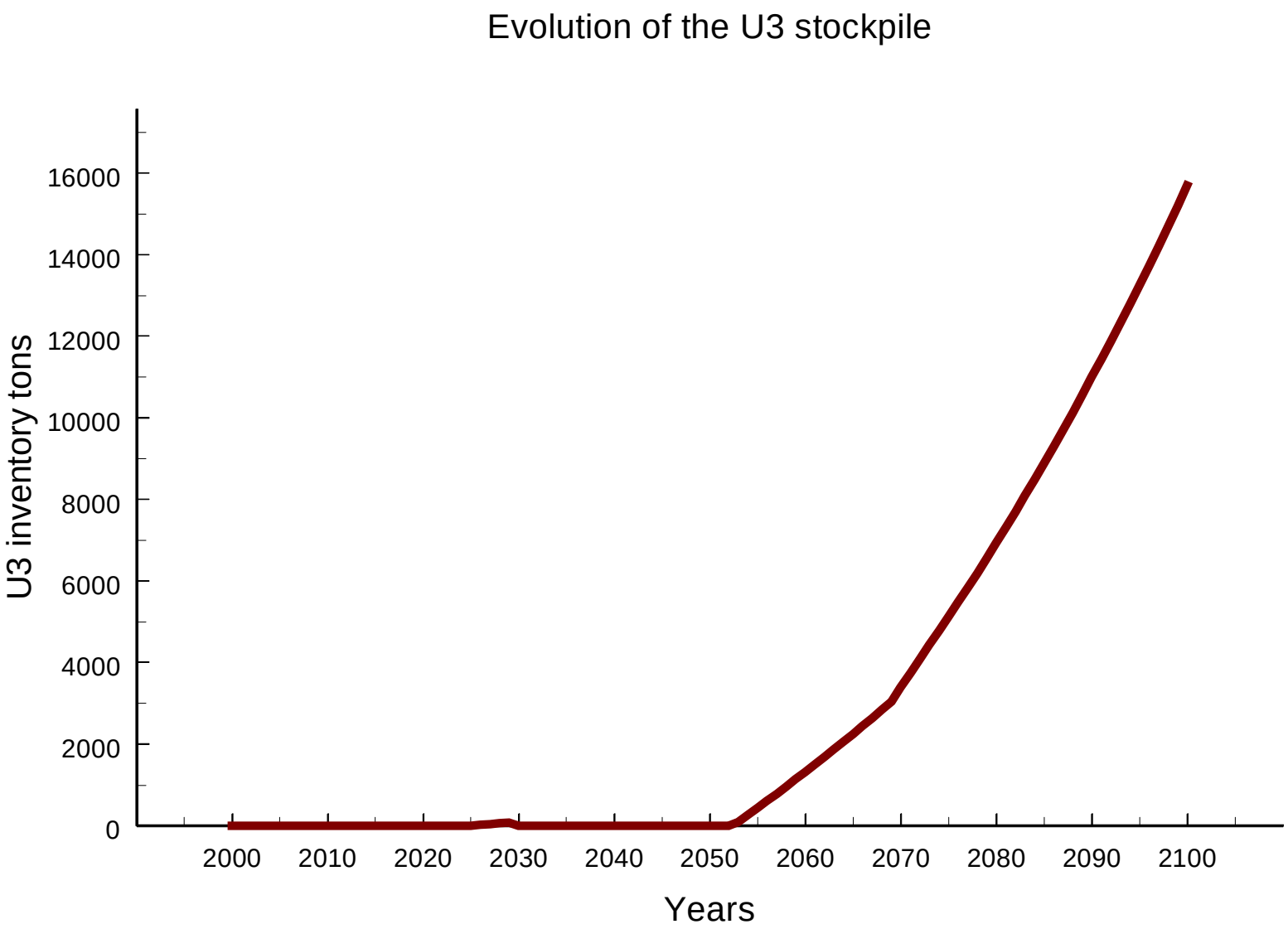
- U-Pu
  - Fast Spectra
  - Pu fuel
  - 1.2 GWe reactors
  - Solid fuels
  - 1 year cooling
  - 25 years doubling time

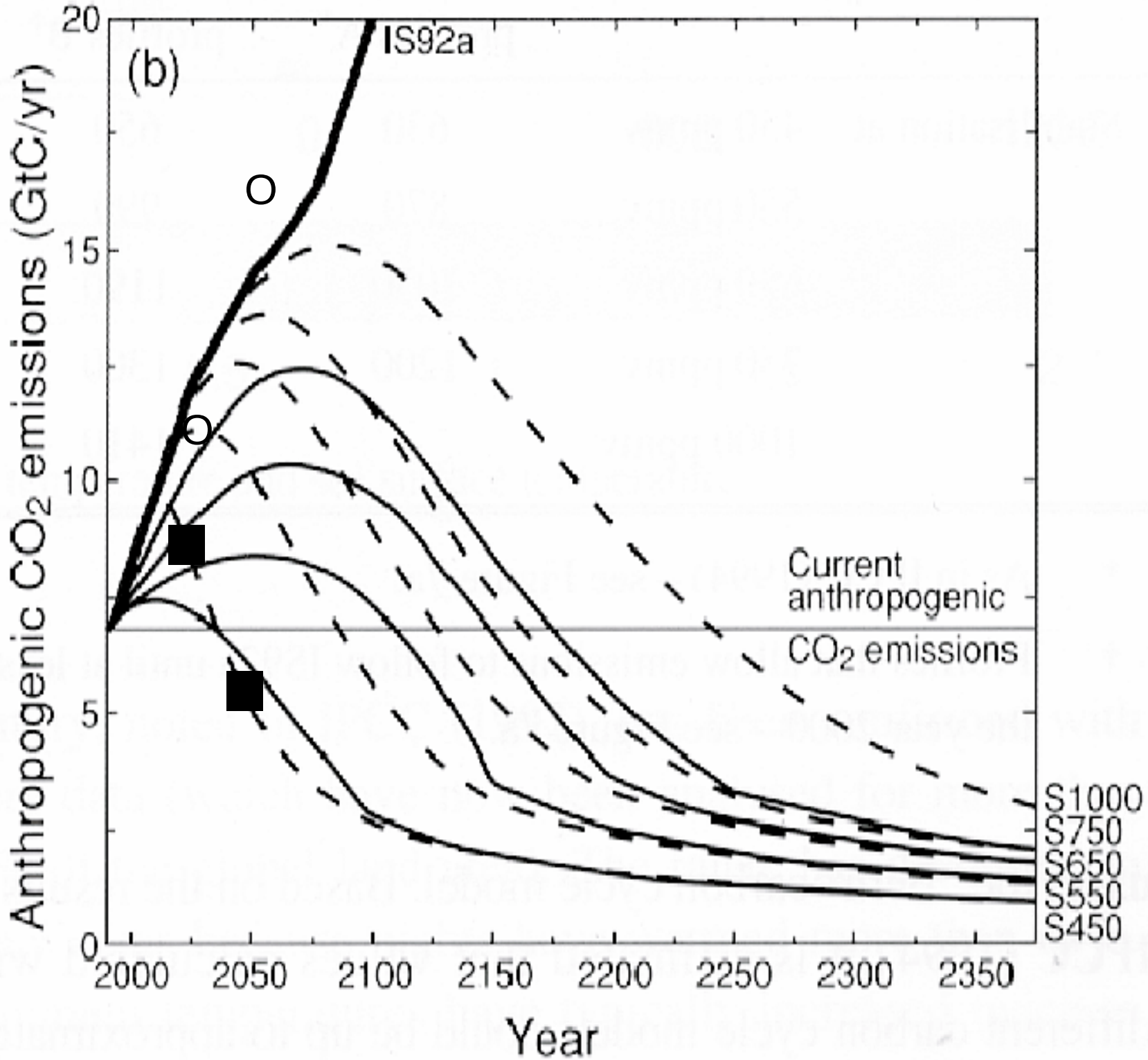
- Th-U
  - Thermal Spectra
  - Pu, then ^{233}U fuel
  - 1 GWe reactors
  - Molten Salts fuel
  - 10 days fuel cycling
  - 25 years doubling time


Number of Gwe (PWR and FR) as function of time
Total number of Gwe
Number of Gwe PWR
Number of Gwe fast reactors
Number of Gwe
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Years


Pu inventorry
Pu Inventory tons
80000
70000
60000
50000
40000
30000
20000
10000
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Years


Evolution of the number of Gwe for the Th-U cycle
total
PWR
ThPU
ThU3
Number of GWe
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
years


Evolution of the U3 stockpile
U3 inventory tons
16000
14000
12000
10000
8000
6000
4000
2000
0
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Years


(b)
IS92a
Anthropogenic CO_2 emissions (GtC/yr)
20
15
10
5
0
2000
2050
2100
2150
2200
2250
2300
2350
Year
Current anthropogenic CO_2 emissions
S1000
S750
S650
S550
S450

World total

	1	2	3	4	5	6	7	8
		IIASA(A2)	IIASA(A2)	Nuclear intensive	IIASA(A2)	Nuclear intensive	Hydrogen	IIASA(C2)
1	Year	2000	2030	2030	2050	2050	2050	2050
2	Population(Millions)	6168	8751	8751	10056	10056	10056	10056
3	GDP(G$)	27436	61597	61597	101519	101519	101519	75050
4	GDP/Capita k$	4,4	7	7	10,1	10,1	10,1	7
5	**Primary Energy(Mtoe)**	**10710**	**18408**	**18408**	**24840**	**24840**	**24840**	**14250**
6	**Primary Electricity(Mtoe**	**4107**	**8060**	**8021**	**10231**	**10231**	**20154**	**6524**
7	**Nuclear(Mtoe)**	**493**	**684**	**4902**	**1092**	**7034**	**16047**	**2163**
8	Fossil elec.	3008	5894	1638	6409	467	1378	952
9	Nuclear+renewables	1099	2165	6383	3822	9764	18776	5573
10	**%Electricity**	**38,35**	**43,78**	**43,78**	**41,19**	**41,19**	**81,14**	**45,79**
11	Nuclear %El.	12	8,49	61,12	10,68	68,75	79,62	33,15
12	Renewable% El.	14,75	18,38	18,38	26,68	26,68	13,54	**52,26**
13	**Fossil elec.%**	**73,25**	**73,13**	**20,42**	**62,64**	**4,57**	**6,84**	**14,58**
14	**Nuclear(Gwe)**	**275**	**376**	**3387**	**607**	**4466**	**8915**	**1202**
15	Nuclear(% total)	4,6	3,72	26,63	4,4	28,32	64,6	15,18
16	**CO2(Mt C)**	**6976**	**11693**	**8465**	**16838**	**12695**	**5106**	**5114**
17	Saved CO2 %			27,61		24,61	69,68	69,63
18	CO2(Mt C)**OECD**	3146	3973	1648	4266	2040	746	
19	Unat tons/year	31690	43983	315142	62414	401957	916951	115360
20	**Cumulative tons U nat**		**1,39E+06**	**4,10E+06**	**2,45E+06**	**1,13E+07**	**1,64E+07**	**4,31E+06**

TABLE 1