

South African National Energy Research Institute – SANERI
International Energy Agency – IEA
NETWORK of Expertise in Energy Technology

***Long term energy and technology
perspectives for Africa***

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A – Energy in Africa: statistics and issues

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A1.1 – Africa energy balance, 1972 (Mtoe)

| 1972, Africa | Biomass | Coal | Crude Oil Products | Nat. Gas | Nuclear | Hydro | Electricity | TOTAL | |
|-----------------------|---------------|--------------|--------------------|--------------|-------------|-------------|-------------|-------------|---------------|
| Production | 127.01 | 36.19 | 284.35 | 0.00 | 6.48 | 0.00 | 5.46 | 0.00 | 459.50 |
| Imports | 0.00 | 1.06 | 25.72 | 11.17 | 0.00 | 0.00 | 0.00 | 0.59 | 38.53 |
| Exports | 0.00 | -1.08 | -270.46 | -5.71 | -3.45 | 0.00 | 0.00 | -0.05 | -280.74 |
| International Bunkers | 0.00 | 0.00 | 0.00 | -5.91 | 0.00 | 0.00 | 0.00 | 0.00 | -5.91 |
| Withdrawal from Sto | 0.00 | -0.23 | -0.51 | -0.10 | 0.00 | 0.00 | 0.00 | 0.00 | -0.84 |
| TPES | 127.01 | 35.95 | 39.09 | -0.55 | 3.03 | 0.00 | 5.46 | 0.54 | 210.54 |
| Plants | 0.00 | -20.63 | 0.00 | -2.98 | -0.54 | 0.00 | -5.46 | 8.62 | -20.99 |
| Refineries | 0.00 | 0.00 | -39.24 | 39.76 | 0.00 | 0.00 | 0.00 | 0.00 | 0.51 |
| Coal transformations | 0.00 | -3.43 | 0.19 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -3.24 |
| Own use | 0.00 | -0.03 | -0.04 | -1.47 | -1.92 | 0.00 | 0.00 | -0.52 | -3.98 |
| Distribution losses | 0.00 | 0.00 | 0.00 | 0.00 | -0.06 | 0.00 | 0.00 | -0.64 | -0.70 |
| Other | -119.15 | 6.13 | 0.00 | -0.46 | 0.14 | 0.00 | 0.00 | -0.33 | -113.66 |
| TFC | 7.86 | 17.99 | 0.00 | 34.30 | 0.66 | 0.00 | 0.00 | 7.67 | 68.47 |
| Agriculture | 0.00 | 0.16 | 0.00 | 1.55 | 0.00 | 0.00 | 0.00 | 0.17 | 1.88 |
| Industry | 1.26 | 10.31 | 0.00 | 7.52 | 0.55 | 0.00 | 0.00 | 4.56 | 24.20 |
| Non energy uses | 0.00 | 0.76 | 0.00 | 1.38 | 0.00 | 0.00 | 0.00 | 0.00 | 2.13 |
| Commercial | 0.00 | 0.90 | 0.00 | 0.55 | 0.02 | 0.00 | 0.00 | 0.84 | 2.31 |
| Residential | 6.60 | 2.53 | 0.00 | 5.54 | 0.09 | 0.00 | 0.00 | 1.85 | 16.60 |
| Transport | 0.00 | 3.34 | 0.00 | 17.76 | 0.00 | 0.00 | 0.00 | 0.25 | 21.35 |

(Substitution Principle)

A1.2 – Africa energy balance, 1990 (Mtoe)

| 1990, Africa | Biomass | Coal | Crude Oil | Products | Nat. Gas | Nuclear | Hydro | Electricity | TOTAL |
|-----------------------|---------------|--------------|---------------|---------------|--------------|-------------|--------------|--------------|---------------|
| Production | 196.73 | 104.62 | 324.02 | 0.00 | 61.85 | 2.20 | 11.64 | 0.84 | 701.90 |
| Imports | 0.00 | 2.82 | 27.06 | 13.54 | 0.90 | 0.00 | 0.00 | 0.22 | 44.54 |
| Exports | -0.17 | -33.82 | -239.57 | -35.17 | -30.54 | 0.00 | 0.00 | -0.38 | -339.65 |
| International Bunkers | 0.00 | 0.00 | 0.00 | -6.06 | 0.00 | 0.00 | 0.00 | 0.00 | -6.06 |
| Withdrawal from Sto | 0.00 | 0.14 | 3.44 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 3.60 |
| TPES | 196.56 | 73.75 | 114.95 | -27.68 | 32.21 | 2.20 | 11.64 | 0.69 | 404.33 |
| Plants | 0.00 | -20.63 | 0.00 | -2.98 | -0.54 | -2.20 | -11.64 | 27.57 | -10.41 |
| Refineries | 0.00 | 0.00 | -113.74 | 107.09 | 0.00 | 0.00 | 0.00 | 0.00 | -6.66 |
| Coal transformations | 0.00 | -19.83 | 4.71 | 4.69 | -1.50 | 0.00 | 0.00 | 0.00 | -11.93 |
| Own use | 0.00 | -0.05 | -0.06 | -3.96 | -12.35 | 0.00 | 0.00 | -2.01 | -18.43 |
| Distribution losses | 0.00 | -0.16 | 0.00 | 0.00 | -0.53 | 0.00 | 0.00 | -2.43 | -3.13 |
| Other | -183.87 | -13.93 | -5.86 | -5.13 | -9.62 | 0.00 | 0.00 | -1.68 | -220.09 |
| TFC | 12.69 | 19.16 | 0.00 | 72.02 | 7.66 | 0.00 | 0.00 | 22.15 | 133.69 |
| Agriculture | 0.00 | 0.24 | 0.00 | 1.50 | 0.00 | 0.00 | 0.00 | 0.64 | 2.39 |
| Industry | 2.19 | 13.18 | 0.00 | 15.11 | 6.36 | 0.00 | 0.00 | 11.80 | 48.64 |
| Non energy uses | 0.00 | 2.78 | 0.00 | 3.58 | 0.00 | 0.00 | 0.00 | 0.00 | 6.36 |
| Commercial | 0.00 | 1.09 | 0.00 | 0.38 | 0.02 | 0.00 | 0.00 | 2.09 | 3.59 |
| Residential | 10.50 | 1.69 | 0.00 | 13.95 | 1.28 | 0.00 | 0.00 | 7.23 | 34.66 |
| Transport | 0.00 | 0.18 | 0.00 | 37.50 | 0.00 | 0.00 | 0.00 | 0.38 | 38.05 |

(Substitution Principle)

A1.3 – Africa energy balance, 2004 (Mtoe)

| 2004, Africa | Biomass | Coal | Crude Oil | Products | Nat. Gas | Nuclear | Hydro | Electricity | TOTAL |
|-----------------------|---------------|---------------|---------------|---------------|--------------|-------------|--------------|--------------|---------------|
| Production | 278.84 | 140.46 | 458.91 | 0.00 | 136.60 | 3.48 | 17.12 | 2.42 | 1037.83 |
| Imports | 0.00 | 7.24 | 39.85 | 39.67 | 1.77 | 0.00 | 0.00 | 5.03 | 93.56 |
| Exports | -0.27 | -45.95 | -361.52 | -43.84 | -72.23 | 0.00 | 0.00 | -5.52 | -529.32 |
| International Bunkers | 0.00 | 0.00 | 0.00 | -6.41 | 0.00 | 0.00 | 0.00 | 0.00 | -6.41 |
| Withdrawal from Sto | 0.00 | 1.50 | -0.88 | 0.44 | 0.00 | 0.00 | 0.00 | 0.00 | 1.06 |
| TPES | 278.58 | 103.25 | 136.36 | -10.14 | 66.14 | 3.48 | 17.12 | 1.93 | 596.72 |
| Plants | -0.60 | -59.04 | -0.17 | -14.75 | -31.63 | -3.48 | -17.12 | 46.18 | -80.60 |
| Refineries | 0.00 | 0.00 | -126.86 | 122.50 | 0.00 | 0.00 | 0.00 | 0.00 | -4.35 |
| Coal transformations | 0.00 | -18.85 | 4.49 | 0.00 | -1.66 | 0.00 | 0.00 | 0.00 | -16.02 |
| Own use | 0.00 | -0.01 | -0.51 | -4.67 | -12.03 | 0.00 | 0.00 | -3.62 | -20.84 |
| Distribution losses | 0.00 | -0.14 | -0.61 | 0.00 | -1.18 | 0.00 | 0.00 | -5.14 | -7.06 |
| Other | -32.38 | -4.78 | -12.72 | 14.64 | 1.15 | 0.00 | 0.00 | -2.22 | -36.32 |
| TFC | 245.59 | 20.43 | 0.00 | 107.58 | 20.81 | 0.00 | 0.00 | 37.13 | 431.54 |
| Agriculture | 1.29 | 0.22 | 0.00 | 3.00 | 0.00 | 0.00 | 0.00 | 1.23 | 5.75 |
| Industry | 24.28 | 12.10 | 0.00 | 13.31 | 10.85 | 0.00 | 0.00 | 17.38 | 77.91 |
| Non energy uses | 0.00 | 3.55 | 0.00 | 6.36 | 4.78 | 0.00 | 0.00 | 0.00 | 14.69 |
| Commercial | 2.46 | 1.50 | 0.00 | 1.23 | 0.06 | 0.00 | 0.00 | 4.28 | 9.52 |
| Residential | 217.56 | 3.06 | 0.00 | 20.14 | 4.05 | 0.00 | 0.00 | 13.62 | 258.43 |
| Transport | 0.00 | 0.01 | 0.00 | 63.55 | 1.08 | 0.00 | 0.00 | 0.62 | 65.25 |

(Substitution Principle)

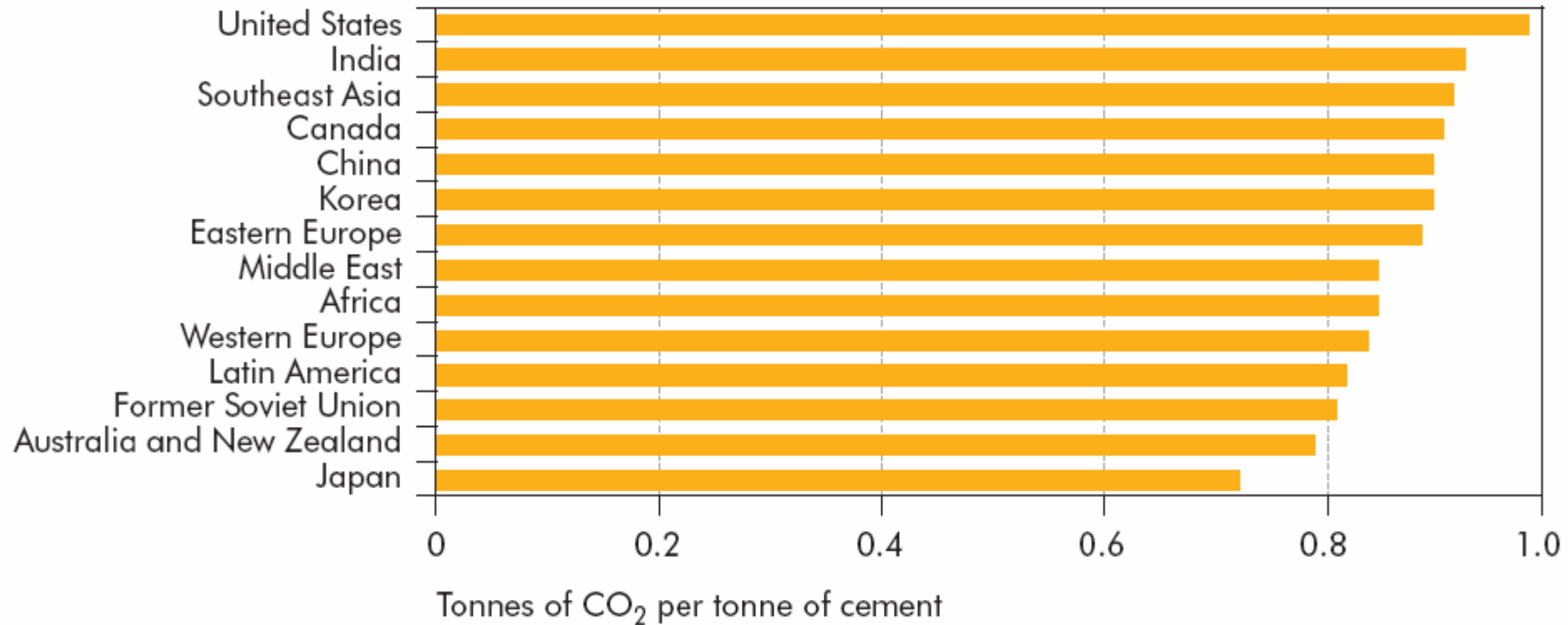
A2.1 – Comparison of energy indicators (2000)

| 2000 | TPES/ GDP ppp (toe/000 2000 US\$) | GDP ppp/ Pop (2000 USk\$ /capita) | TPES/ Pop (toe /capita) | CO2/ Pop (t CO2/ capita) | Elc/ Pop Mwh/ capita) |
|-----------|--|--|----------------------------------|-----------------------------------|--------------------------------|
| World | 0.21 | 7.75 | 1.65 | 3.79 | 2.32 |
| Africa | 0.28 | 2.26 | 0.63 | 0.91 | 0.50 |
| India | 0.18 | 2.71 | 0.50 | 0.94 | 0.41 |
| China | 0.21 | 4.17 | 0.89 | 2.43 | 1.01 |
| W. Europe | 0.16 | 24.65 | 3.91 | 8.30 | 6.77 |
| USA | 0.23 | 35.50 | 8.14 | 20.14 | 13.17 |

Source: IEA Key indicators

A2.2 – Comparison of indicators: CO₂ emissions per tonne of cement

Figure 7.10 ► Average CO₂ emissions per tonne of cement by country and region



Source: World Business Council for Sustainable Development (WBCSD), 2002.

Key point

The range of average CO₂ emissions per tonne of cement is very limited.

Reproduced from the report "Energy Technology Perspectives", IEA/ETP2006, page 406

A3 – Energy in Africa today: socio-economic issues

About 50% (60% in the seventies) of the production is exported. Mining gives about 17% of the African Value Added, against less than 5% worldwide or in India.

The present pattern reflects the existence of complex causal relationship between resources and environment on one side, and population and conflicts on the other.

According to many socio-economic studies, both scarcity and abundance of natural resources trigger conflicts, if the incentive structures are inadequate to avoid an inferior social outcome. [Luterbacher et al., 2007]

The scenarios presented hereafter assume that African researchers study these socio-economic issues and African decision makers find ways to set up appropriate regulatory frameworks.

B1 – ETSAP-TIAM long term energy scenarios

1.1 – The experts team

2.1 – Scenarios definition

2.2 – Population and GDP projections

3.1 – Total Primary Energy Supply per GDP

3.2 – Total Primary Energy Supply per capita

3.3 – CO2 emissions per capita

3.4 – Electricity use per capita

4.1 – TPES in Africa by scenario

4.2 – Electricity generation in Africa by scenario

B1.1 – The team and the tools

The scenarios presented hereafter have been compiled through the 15-region global TIMES Integrated Assessment Model (TIAM), a technical-economic equilibrium development model of the energy system as a whole, from supply to end-uses.

ETSAP-TIAM has been originally developed by the Canadian team at GERAD (Richard Loulou, Amit Kanudia, Maryse Labriet), more recently also by Uwe Remme and Markus Blesl (IER, Stuttgart) and Antti Lehtila (VTT, Finland). ETSAP-TIAM has several similarities with the global MARKAL model used by the IEA in the Energy Technology Perspective project.

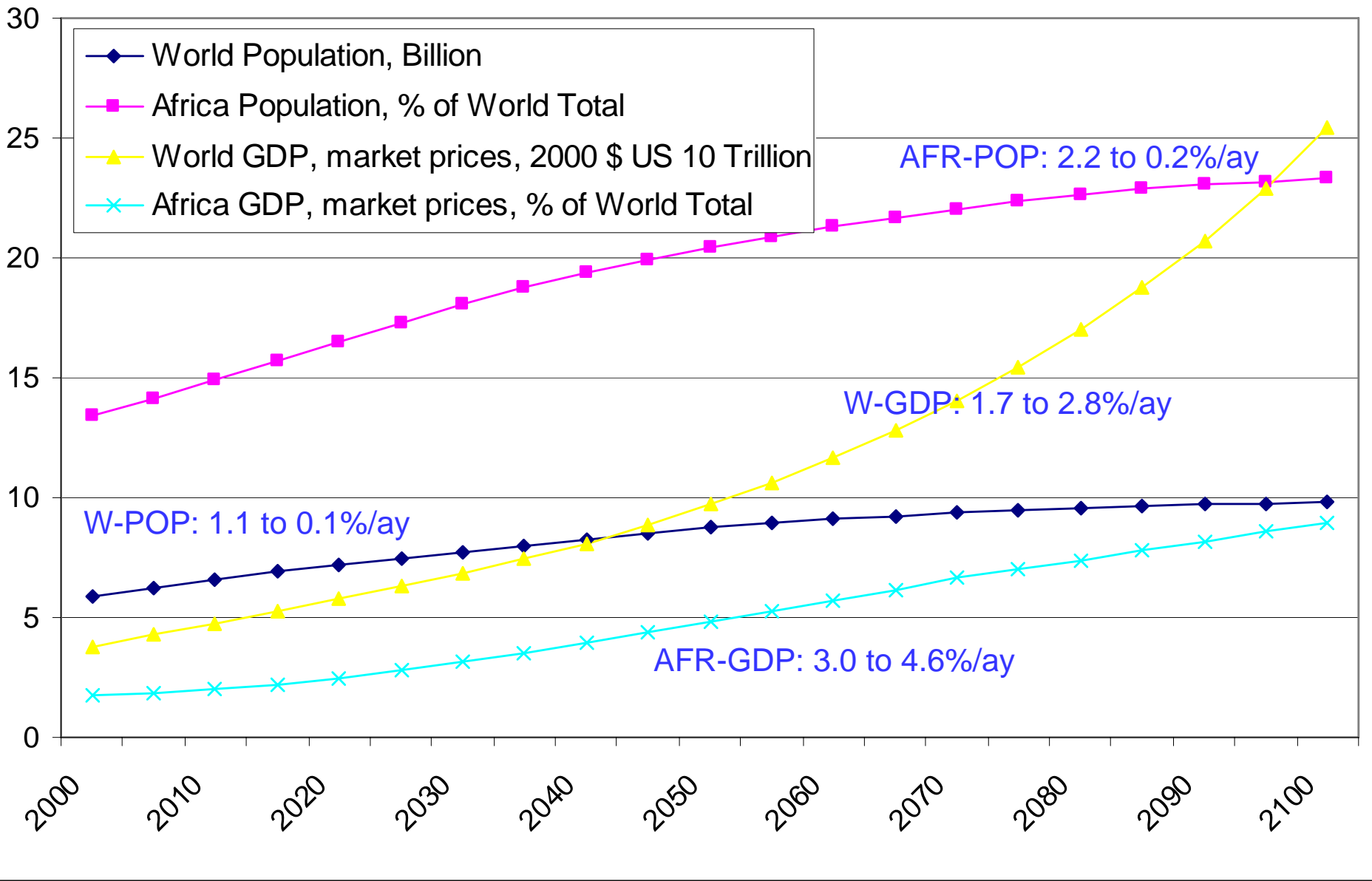
ETSAP has developed the MARKAL models generator and recently improved it to The Integrated MARKAL EFOM System (TIMES).



Scenario definition

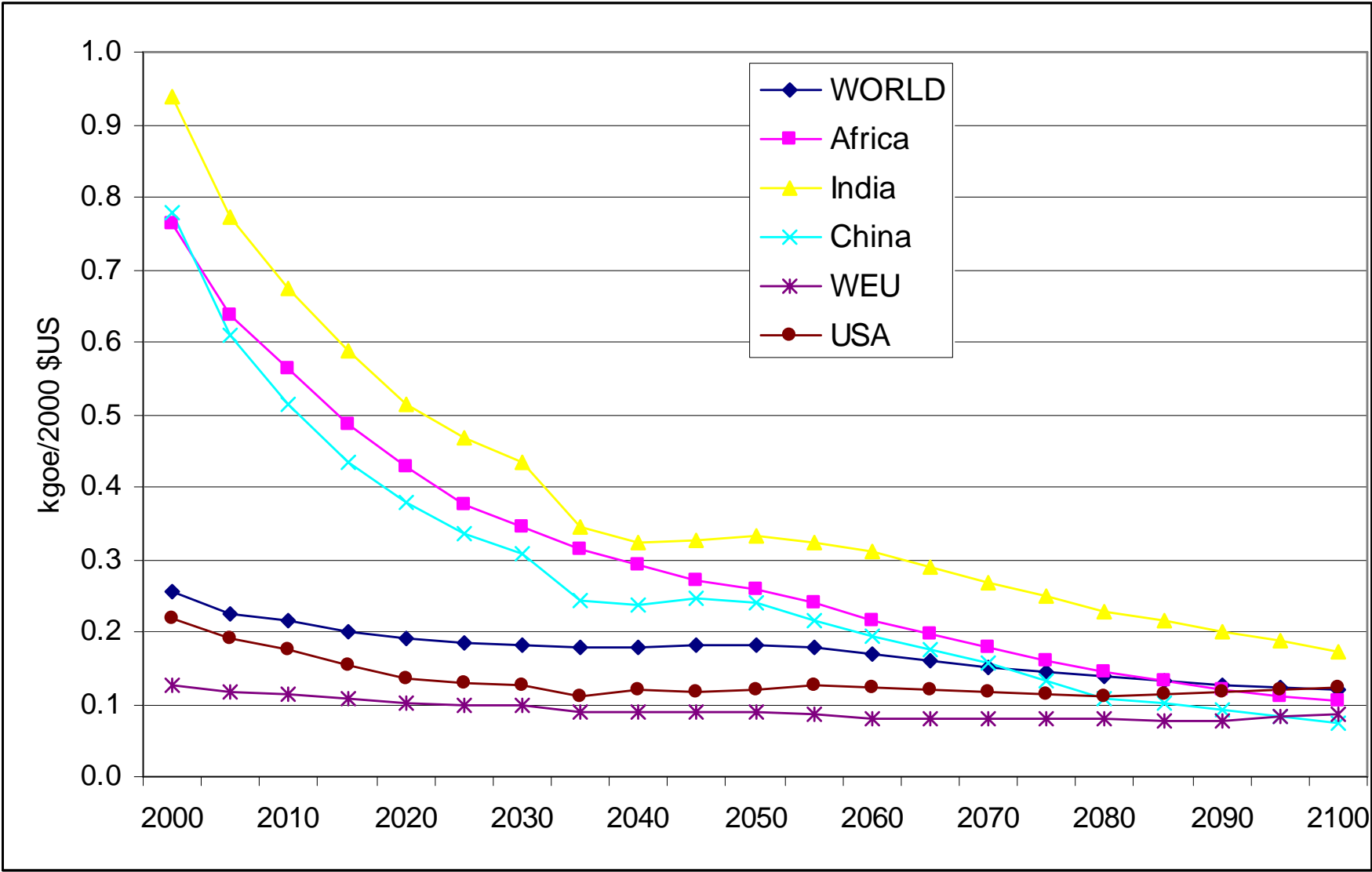
- Base scenario (BASE) oriented towards the IPCC B2 scenario:
 - i. No CO₂ mitigation policy in place
 - ii. No restriction on coal use in electricity generation
- CO₂ price scenario (CO₂):
 - i. CO₂ price of 5 \$/t CO₂ in 2010 escalating with 5 %/yr (i.e. a price of 404 \$/t CO₂ in 2100)

B2.2 - Population and GDP projections



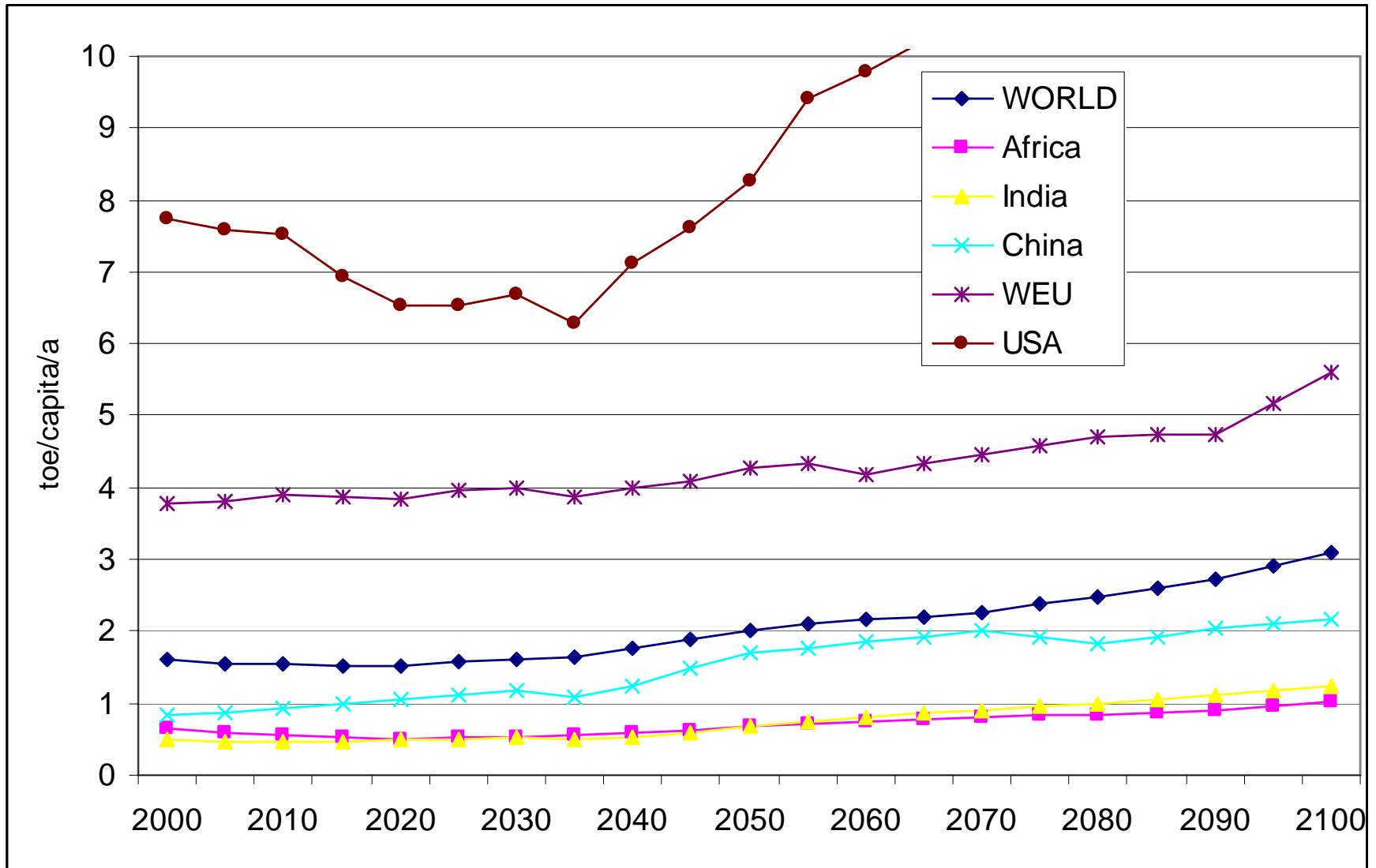
B3.1-CO2 scenario: Primary Energy Supply per GDP

(at Market Prices)

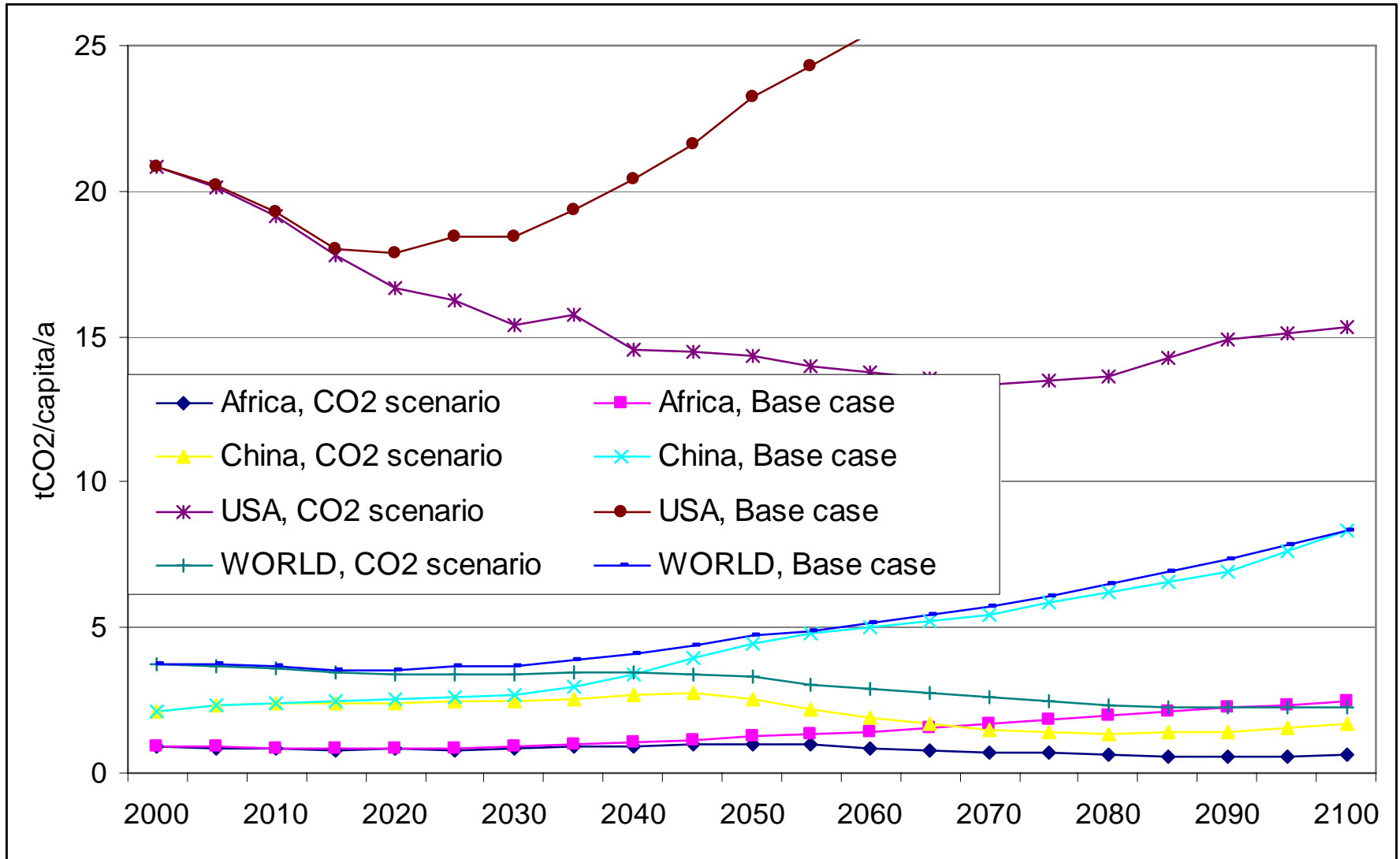


B3.2 – CO2 price scenario: TPES per capita

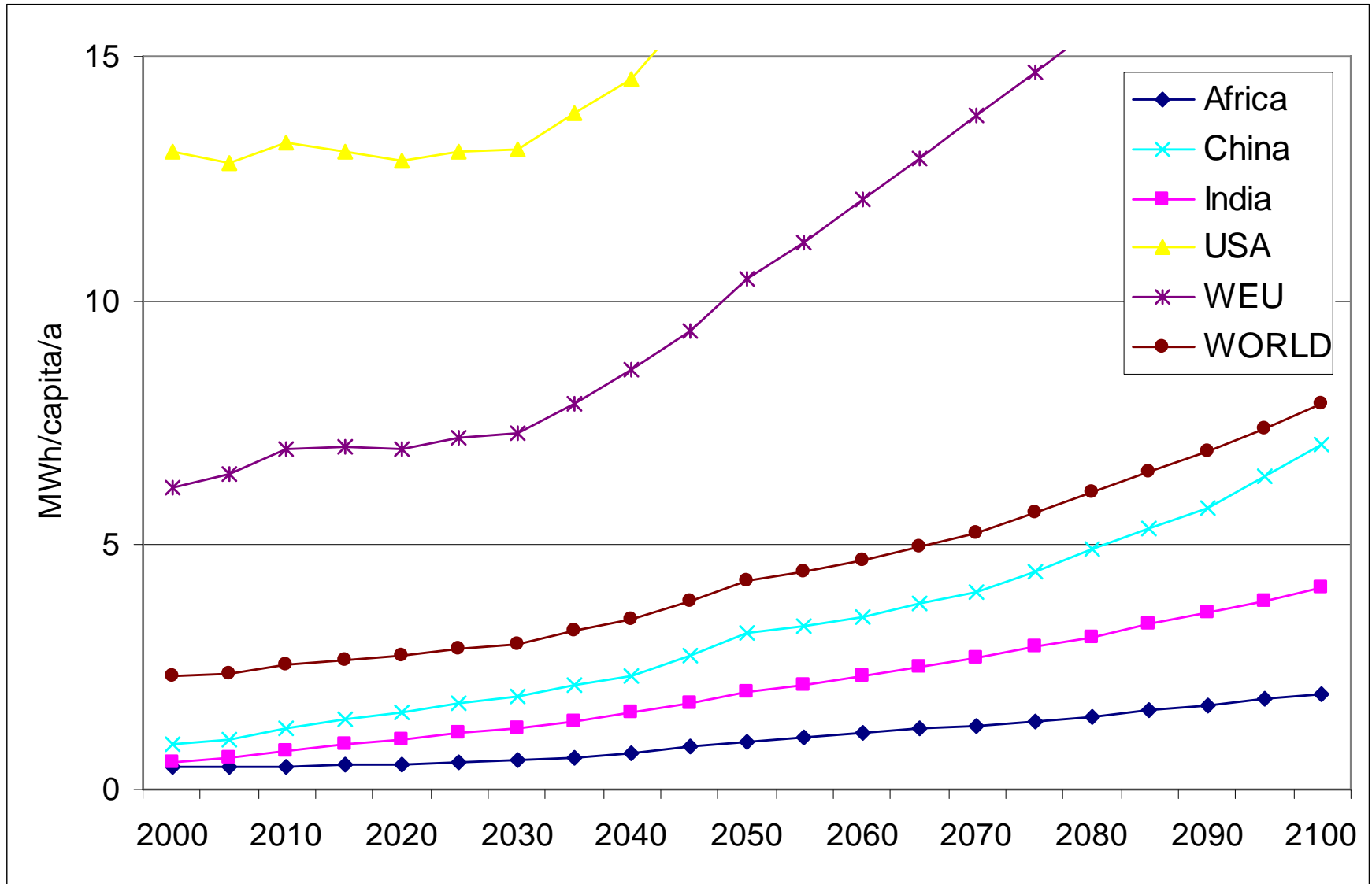
(TPES = Total Primary Energy Supply)



B3.3 – CO2 emissions per capita by scenario

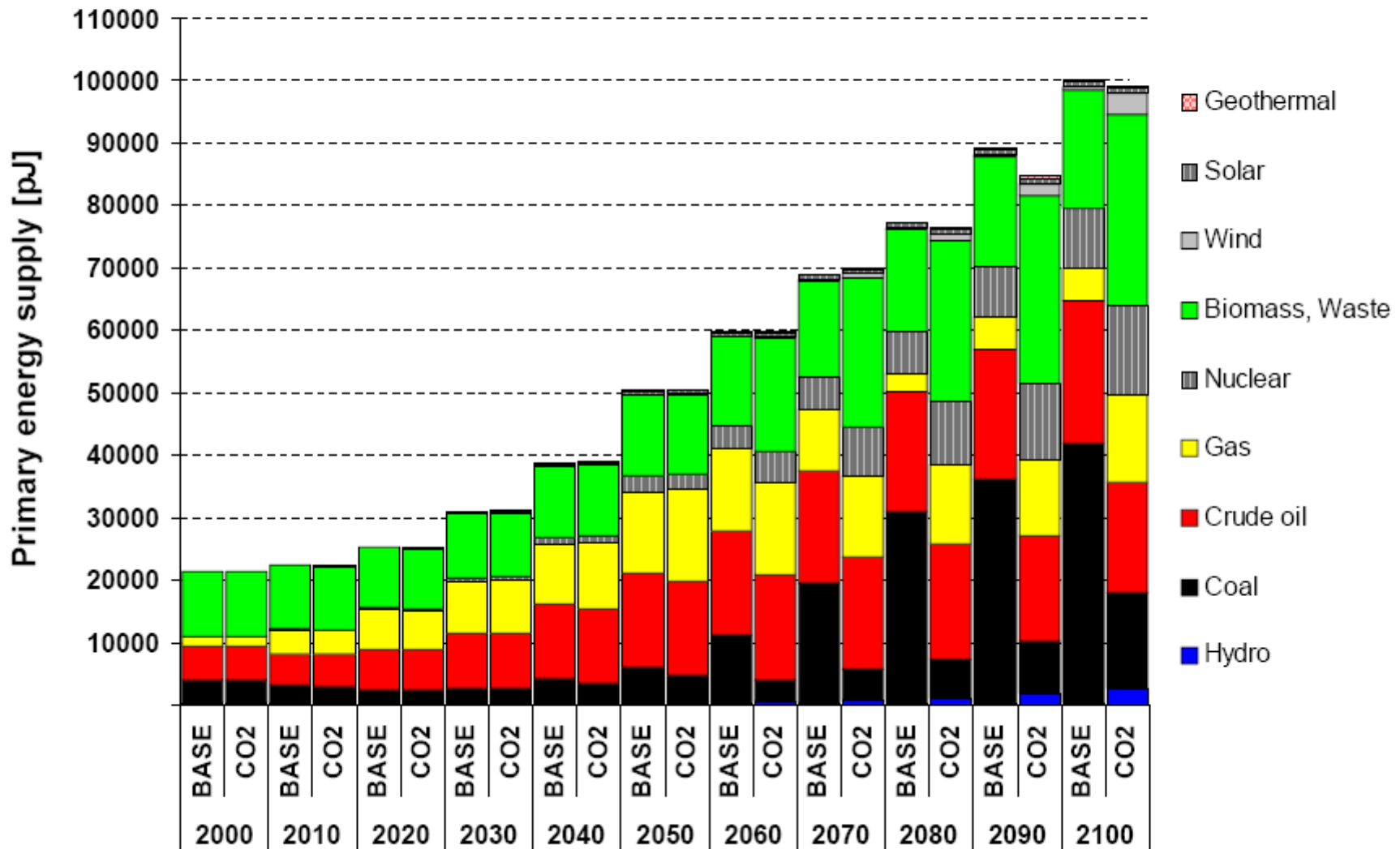


B3.4 – Electricity use per capita (base case)

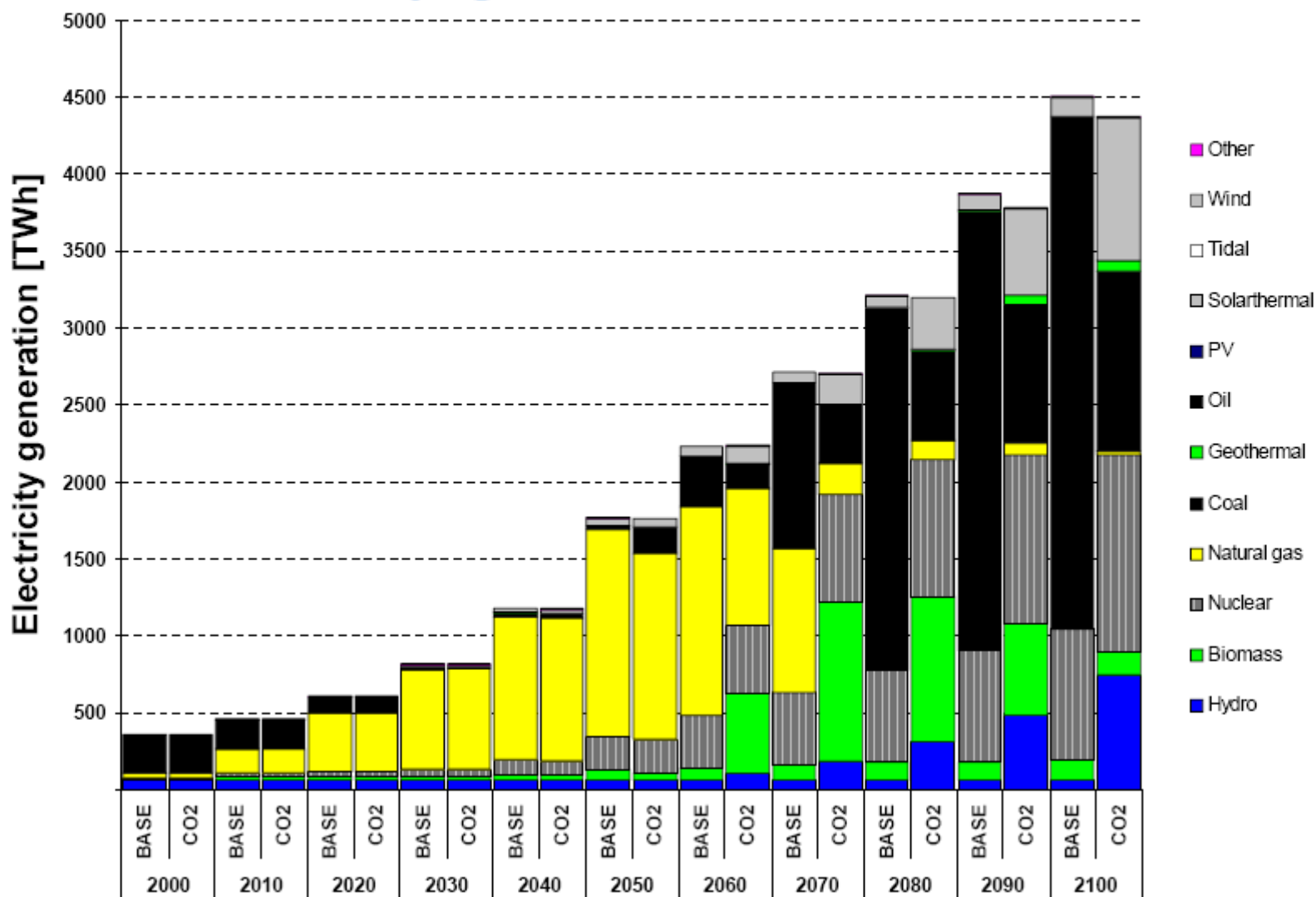




Africa: TPES (Total Primary Energy Supply) by scenario



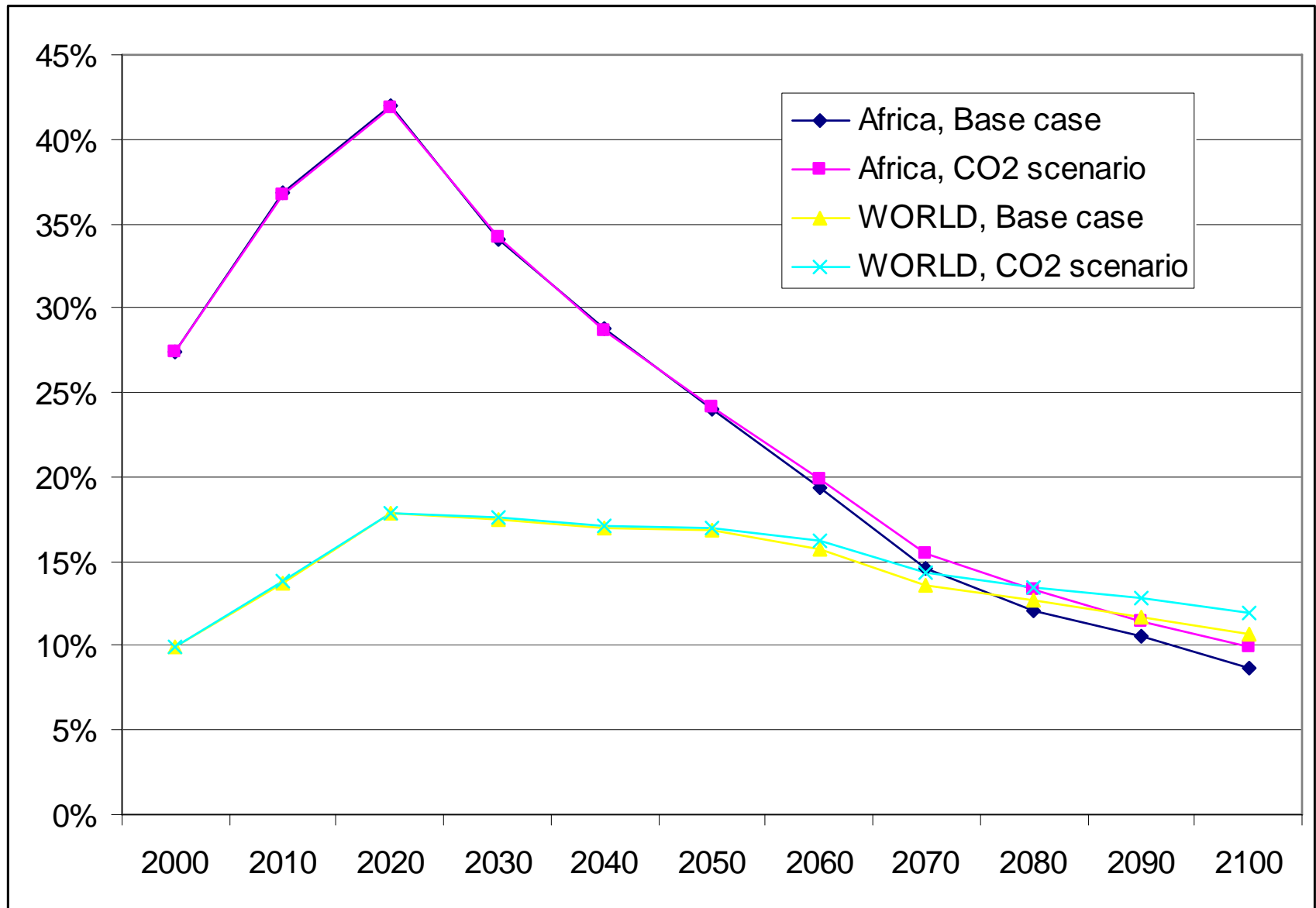
Africa: Electricity generation by scenario – B4.2



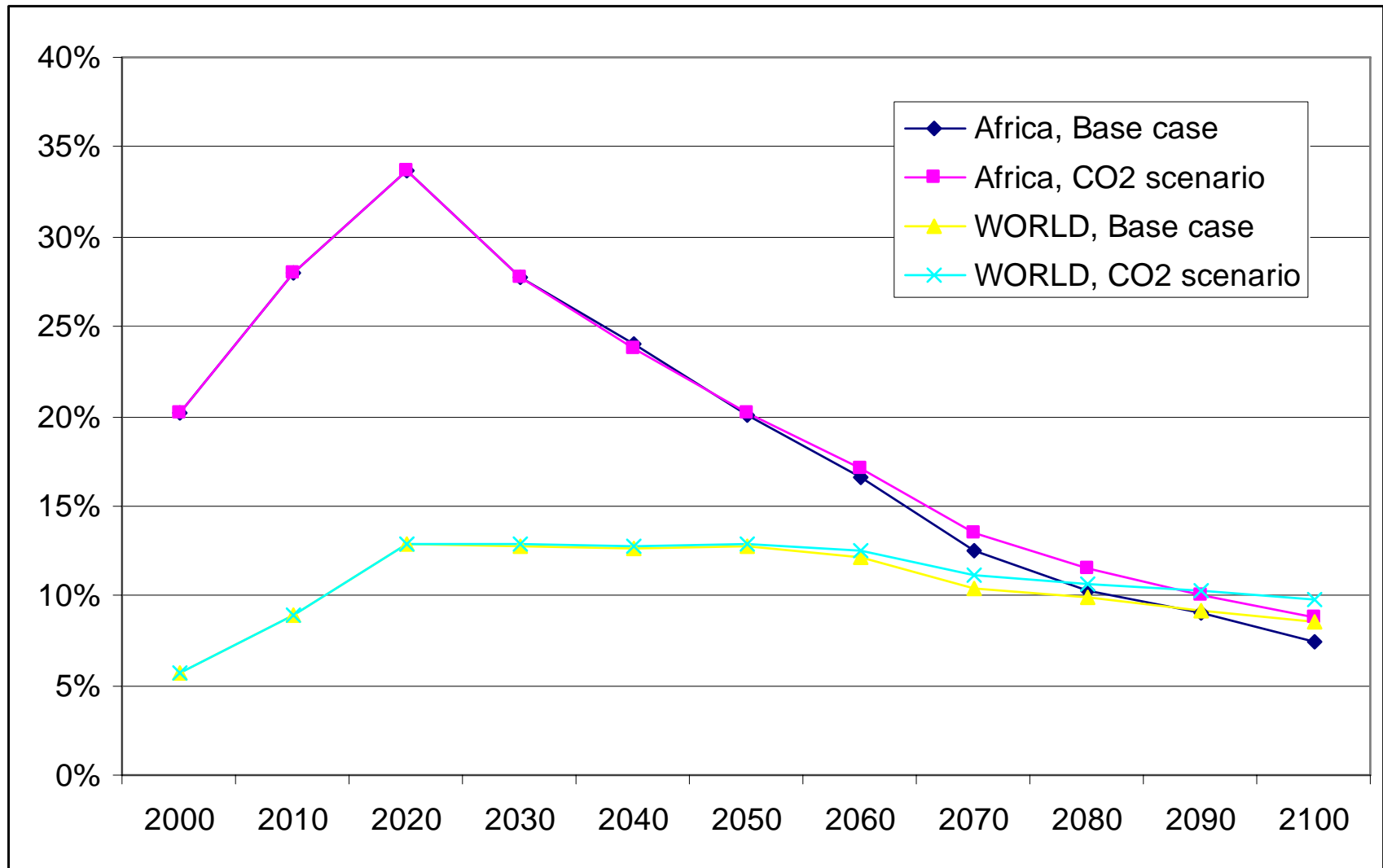
C – Investment opportunities

- 1.1 – Energy system cost as percentage of GDP
- 1.2 – Investments in energy technologies / GDP
- 1.3 – Share of energy investments by sector
- 2.1 – New plants capacity to be built
- 3.1 – CO2 emission reduction: possible roles of Climate Change Mitigation and CO2 Capture & Sequestration
- 4.1 – Observations

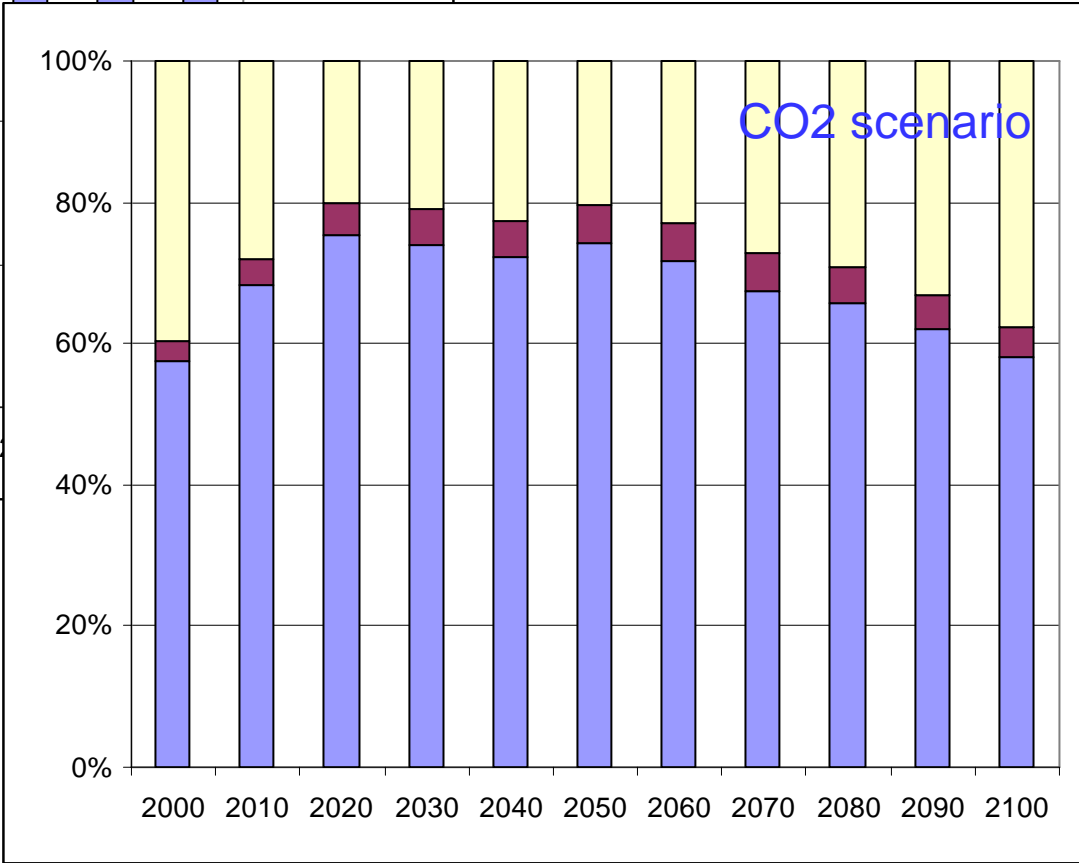
C1.1 – Energy system cost as percentage of GDP



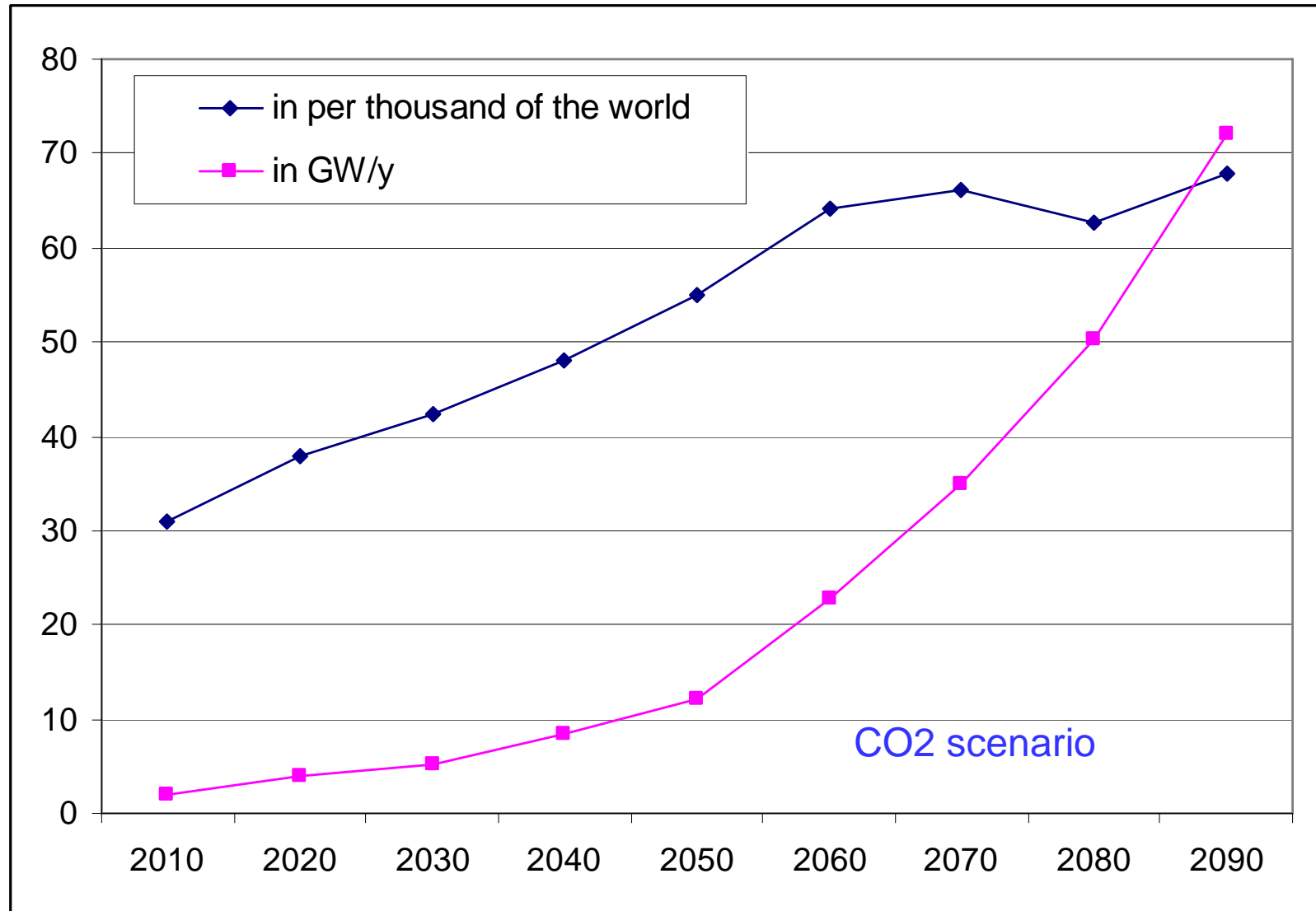
C1.2 – Energy Investment as percentage of GDP



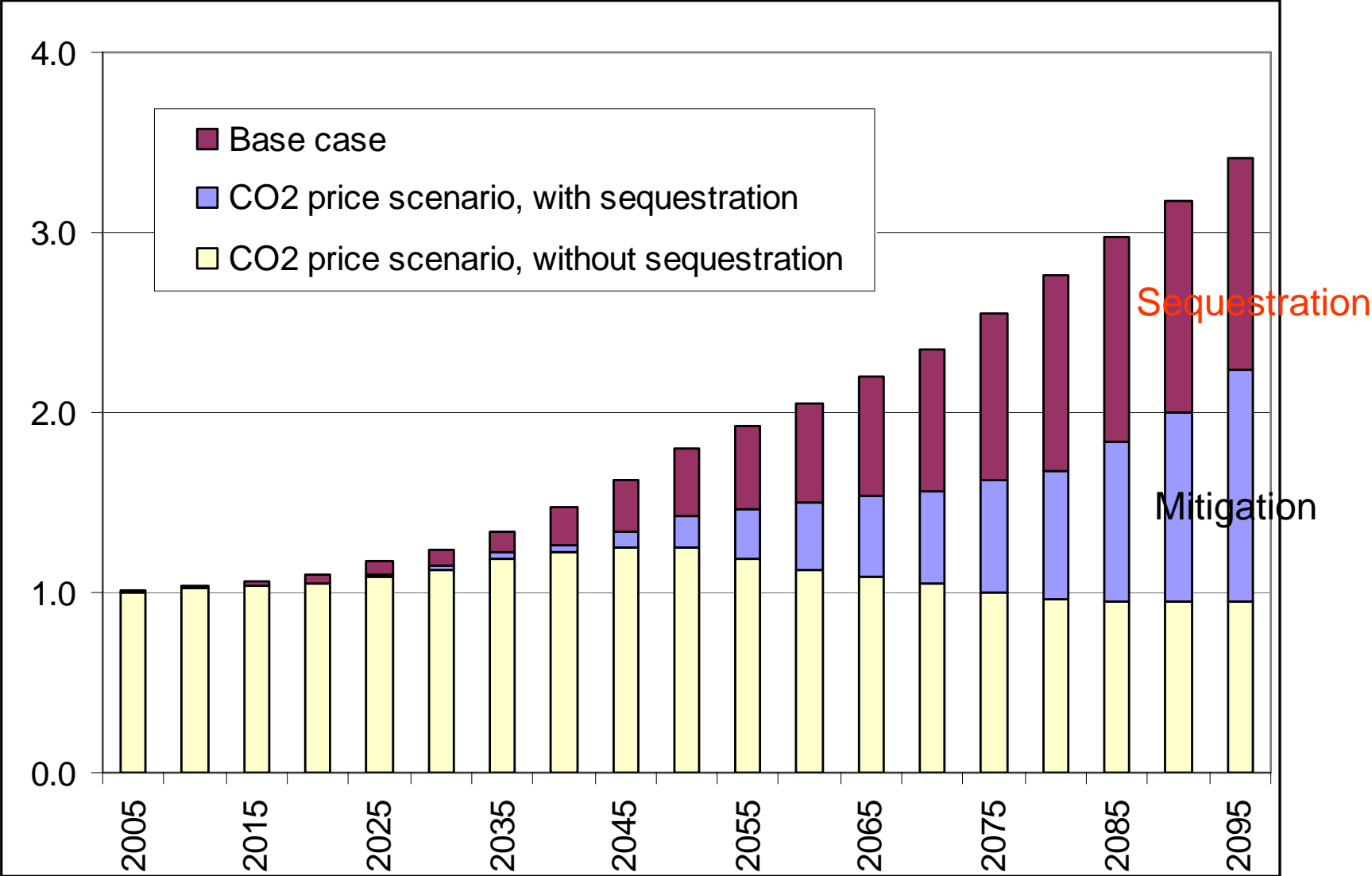
C1.3 – Share of energy investment by sector: Africa



C2.1 – New plant capacity to be built yearly in Africa



C3.1 – CO2 emission reduction: possible roles of CC Mitigation and CO2 Capture & Sequestration



C4 – Observations

The demand for energy services continues to grow: capturing this market is worth investing. In the decades to come Africa could spend for its energy system 0.5-1.0 US\$ trillion yearly (10 US\$ trillion worldwide). Investments amount to about 70% of the total cost. If they are domestic, they transform domestic energy demands into domestic economic development.

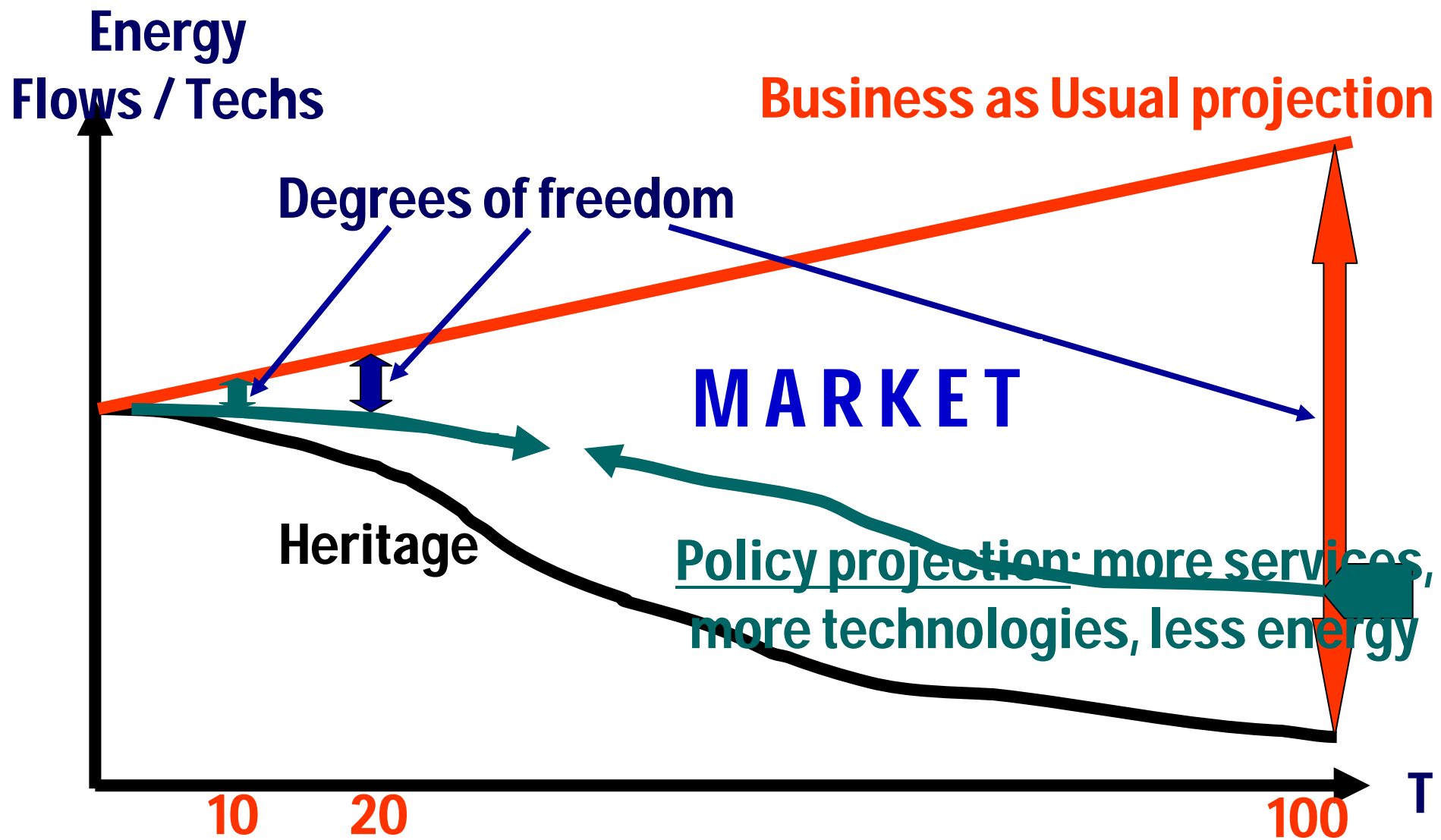
Intermediate goods (for personal transport, cooling, cooking, etc.) are the largest part of energy related investments. Experts who know the local conditions have more chances to provide the winning products.

In the long term, CO₂ Capture & Sequestration could become as important as energy supply technologies.

D – Energy markets and Energy R&D

- 1.1 – The concept: unfolding future markets of energy and technology
- 2.1 – How much is the global market of energy and technology worth?
- 3.1 – Energy R&D investments: absolute amounts, weights and trends
- 3.2 – Energy R&D expenditures: new vs. existing technologies
- 4.1 – Observations

D1.1 – The concept: unfolding the future market of energy and technologies



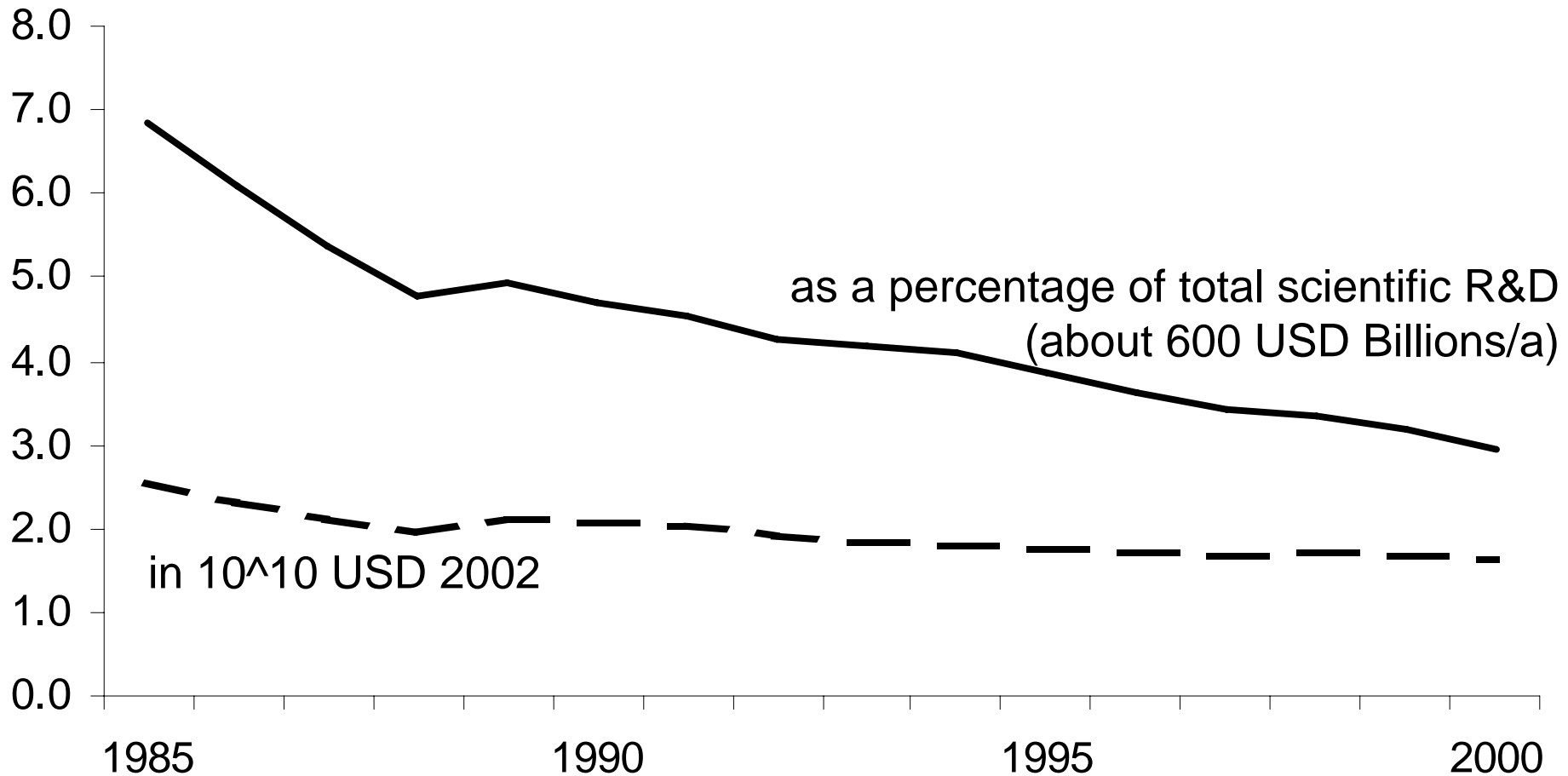
D2.1 – How much is the global market of energy and technologies worth? (2002, US\$ Billions)

| 2002 | | Crude | Oil | Nat. | | | Bio- | Elec. | | |
|------------------|-------------|--------------|--------------|-------------|--------------|--------------|-------------|---------------|--|--------------|
| USD bill. | Coal | Oil | Prod. | Gas | Nucl. | Hydro | Mass | Other* | | TOTAL |
| TPES | 192 | 1056 | 0 | 456 | 47 | 46 | 112 | 6 | | 1915 |
| Transf | -136 | -1053 | 2372 | 132 | -47 | -46 | 80 | 1259 | | 2562 |
| TFC | 56 | 3 | 2372 | 589 | | | 192 | 1265 | | 4477 |
| <i>Industry</i> | 39 | 3 | 317 | 206 | - | - | 24 | 333 | | 922 |
| <i>Transport</i> | 1 | 0 | 1702 | 34 | - | - | 2 | 12 | | 1751 |
| <i>Other</i> | 16 | 0 | 353 | 348 | - | - | 166 | 920 | | 1804 |

TPES = Total Primary Energy Supply; TFC = Total Final Consumption;
 Transf. = transformations, such as power&CHP plants, refineries, coke ovens,
 Other indicates renewable sources: wind, solar, geothermal, etc.
 Prices: oil=40\$/bbl; coal=50\$/t; n.gas=5\$/GJ; elec=100\$/MWh R&C, 50 ind, ...

D3.1 – Energy R&D investment: absolute amounts, weights and trends

Energy R&D investments of USA, Japan, EU15 (www.izt.de/eurendel/)



D3.2 – Energy R&D expenditures: new vs. existing technologies

In 1985-2000, about 25% of energy R&D was spent for:

- Photovoltaics, Wind, Biofuels for transport, Biomass technologies, Geothermal energy, Ocean technologies, Other Renewable Energy Sources, Energy storage in RES,
- Hydrogen carrier, Fuel cells,
- Distributed energy systems, Other power generation,
- Fusion, Superconductivity,

About 75% was used to improve existing chains and techs:

- Coal, Oil and gas, Natural gas infrastructure, Other fossil fuels infrastructure, CO2 sequestration
- Fission reactors & fuel cycle, Nuclear safety & waste disposal,
- Miscellaneous energy savings, Industry, Buildings, Freight on rail, Other transport
- High voltage grids, Miscellaneous

D4 – Observations

- More complete and reliable data on energy technology use, investments and R&D expenditures are necessary to improve analyses and policies.
- Present energy R&D expenditures for improving existing chains seems low compared to the market.
- Is there a relation between the one fourth energy R&D budget devoted to new technologies and the low expected contribution from them in scenarios?
- Existing techs, with more R&D funds and expanding markets, “learn” more than new techs, with less R&D funds and low/no markets. Has the present unbalance of R&D funds the affect of “locking in” existing techs and “locking out” new techs?