Modeling Technological Change

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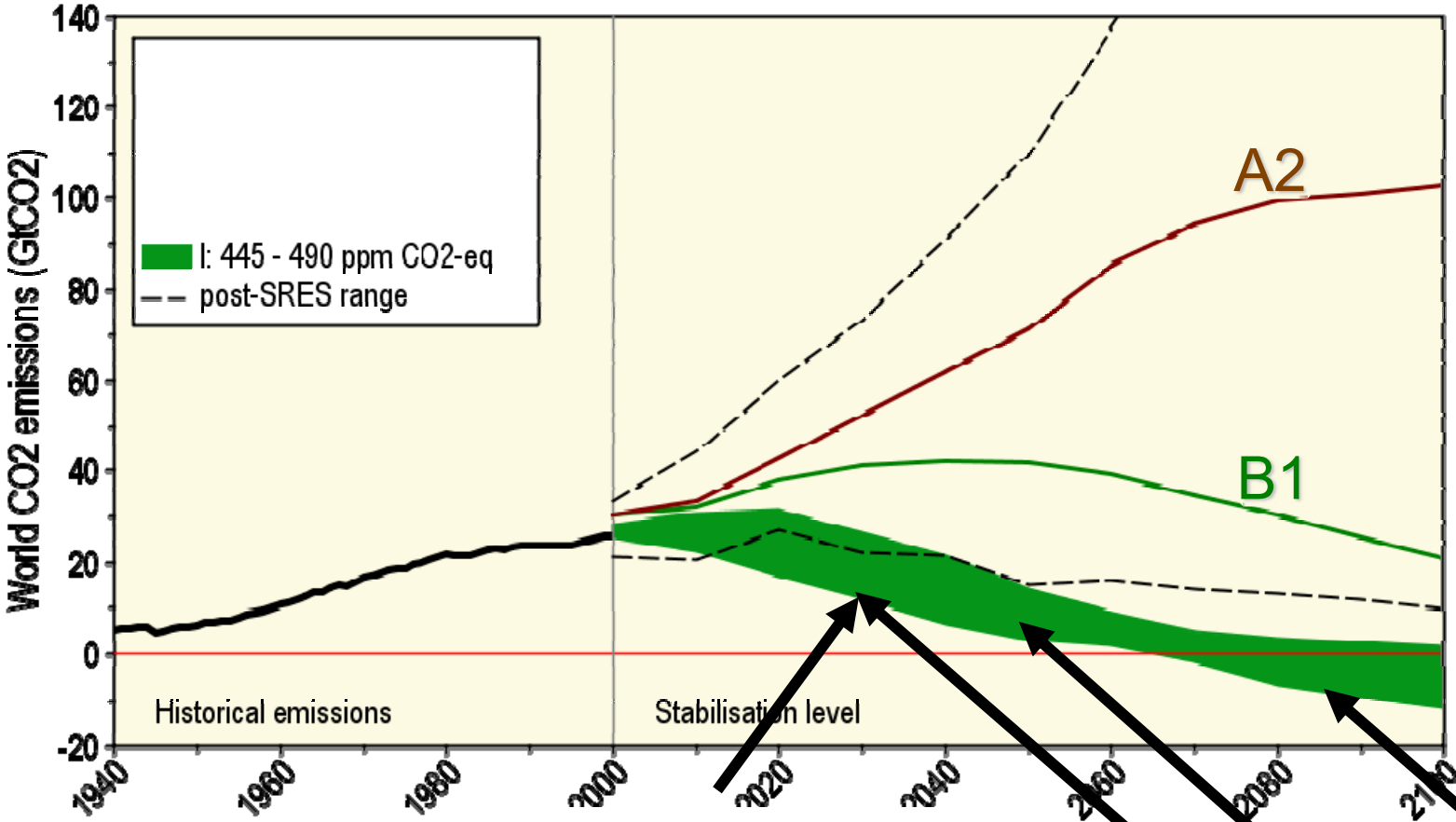
Astronaut Sunita Williams


Astronaut Sunita Williams

Long-Term Stabilization Profiles

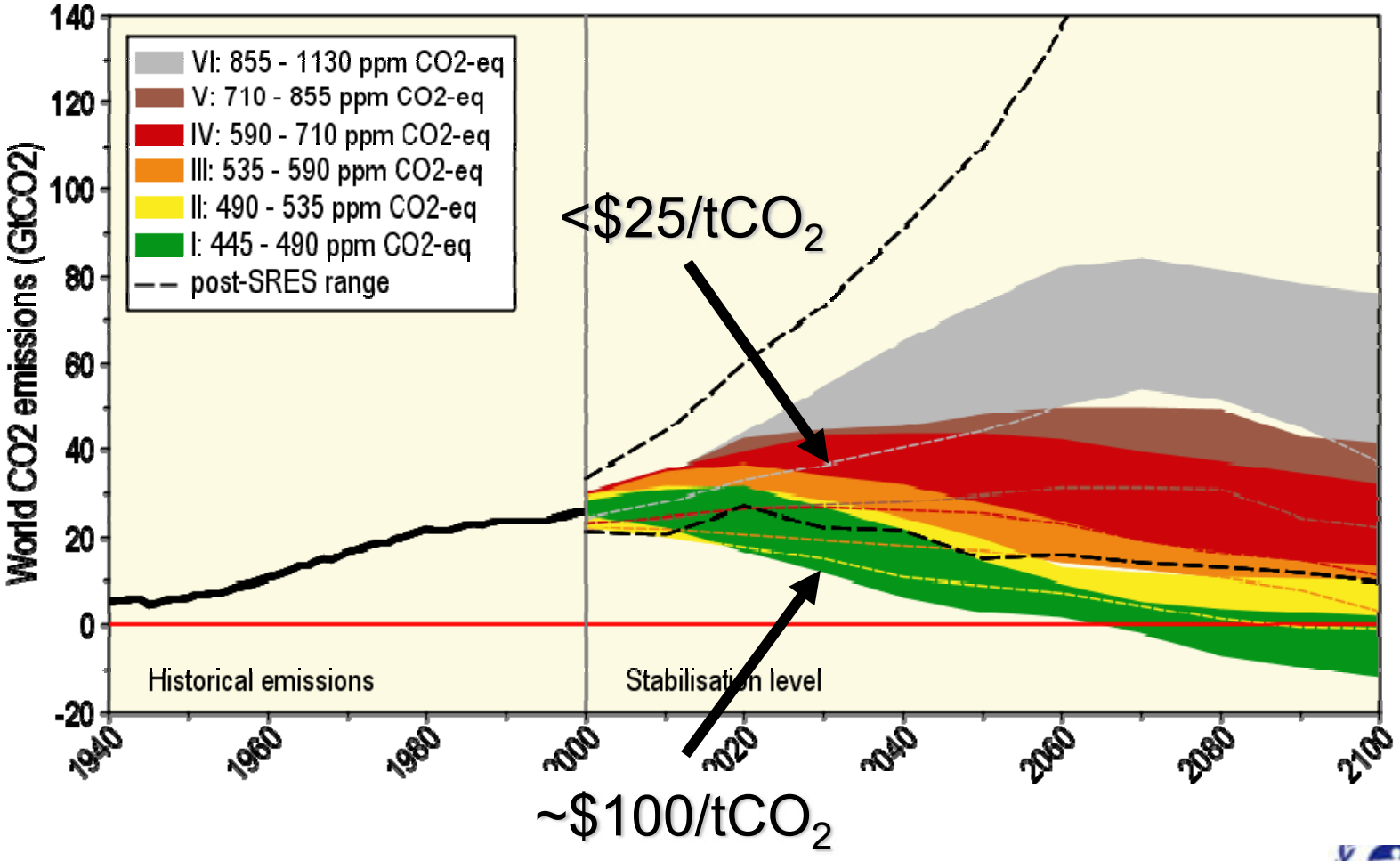


~$100/tCO$_2$

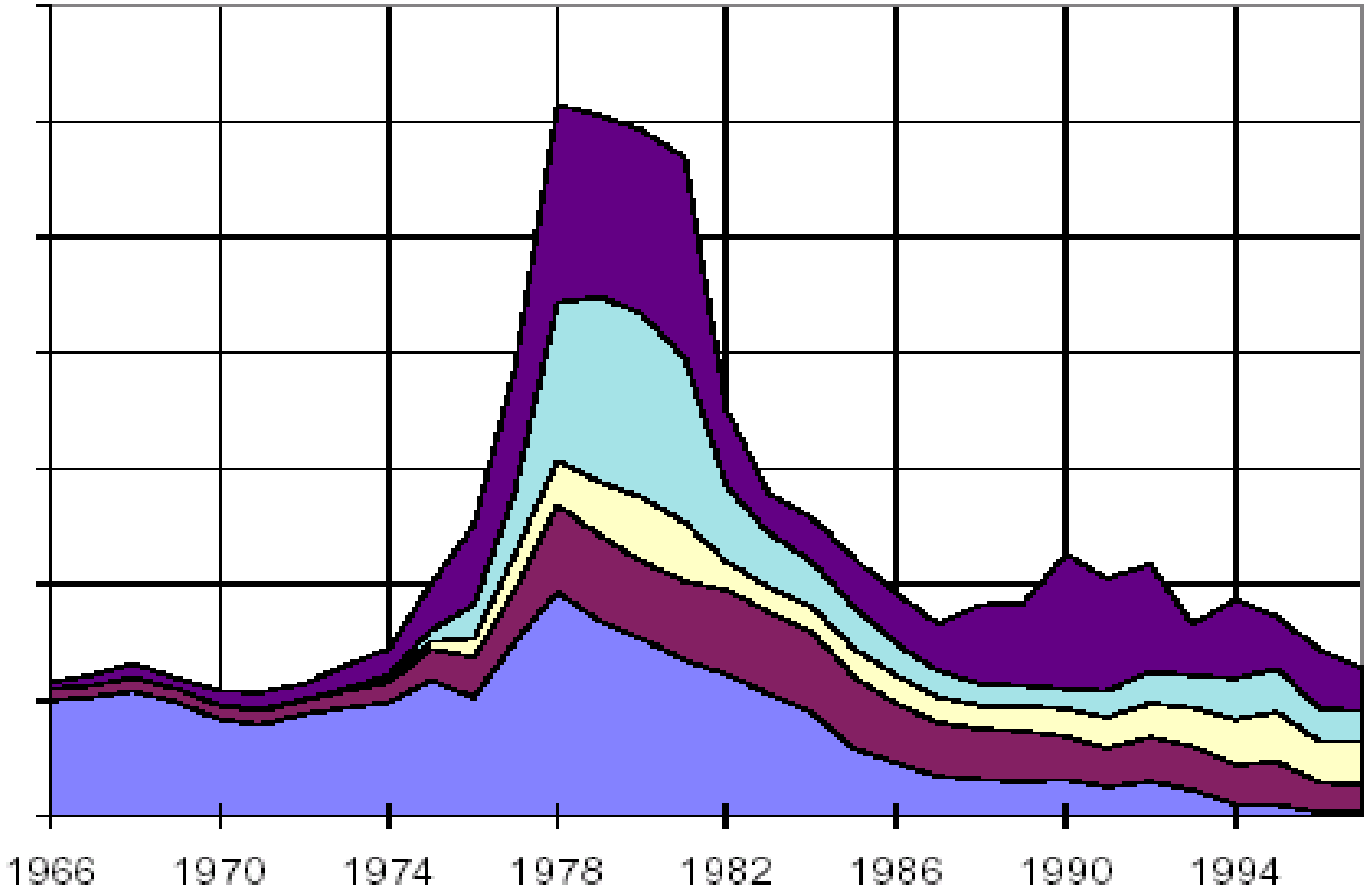
WMO

UNEP

Long-Term Stabilization Profiles

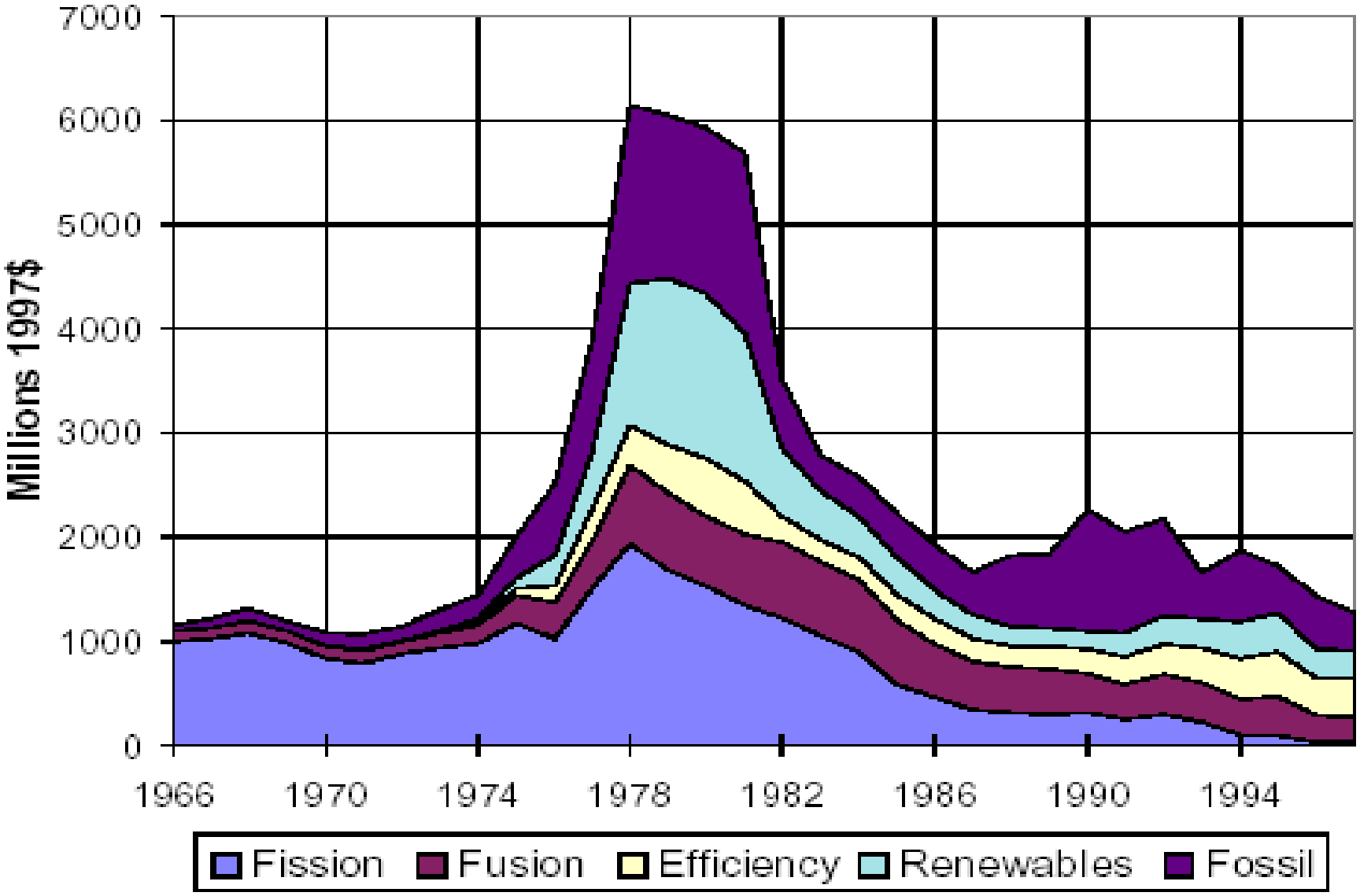


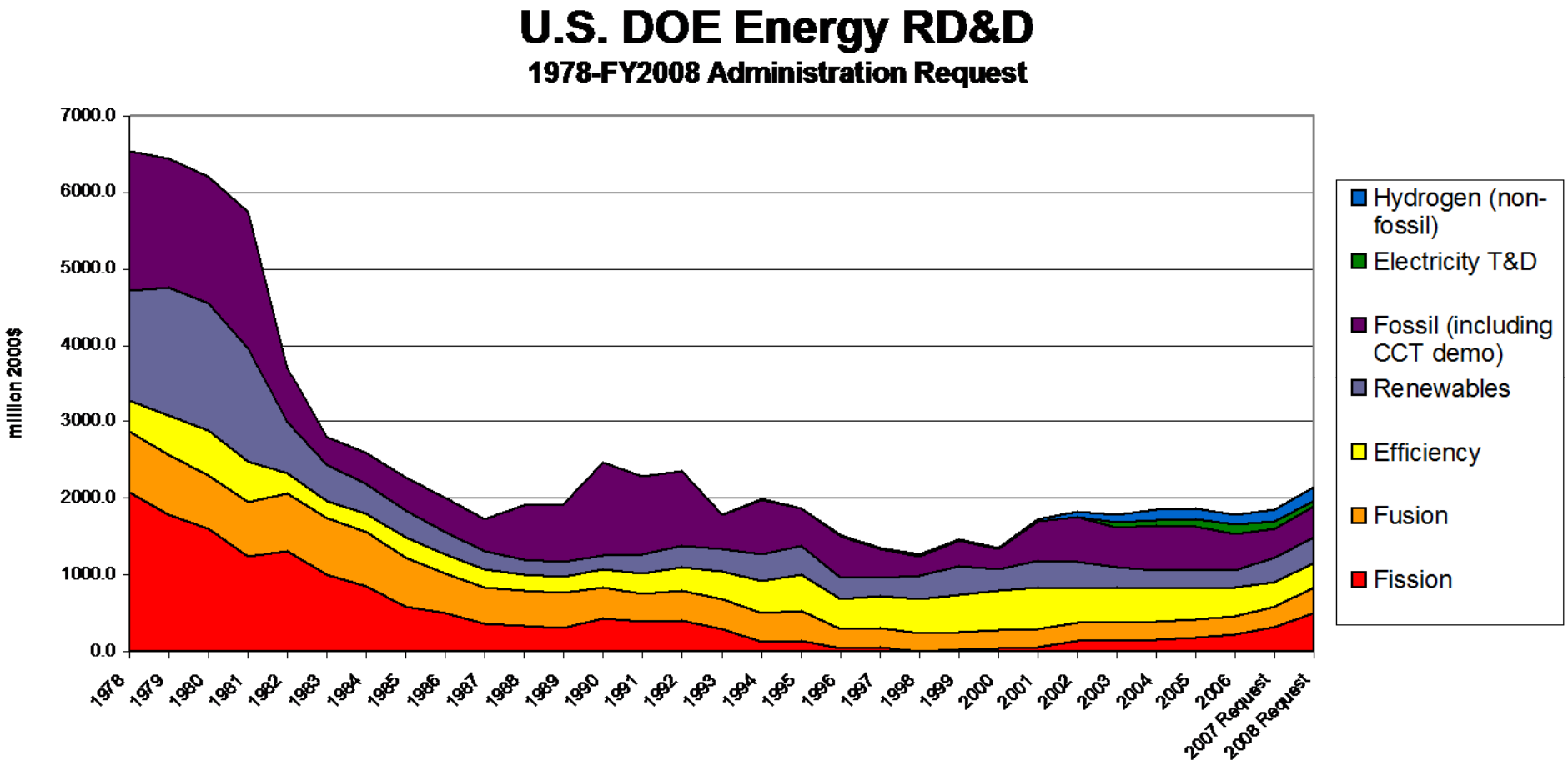
What kind of energy indicator is this?



US DOE Applied Energy-Technology RD&D

(from PCAST, 1997)



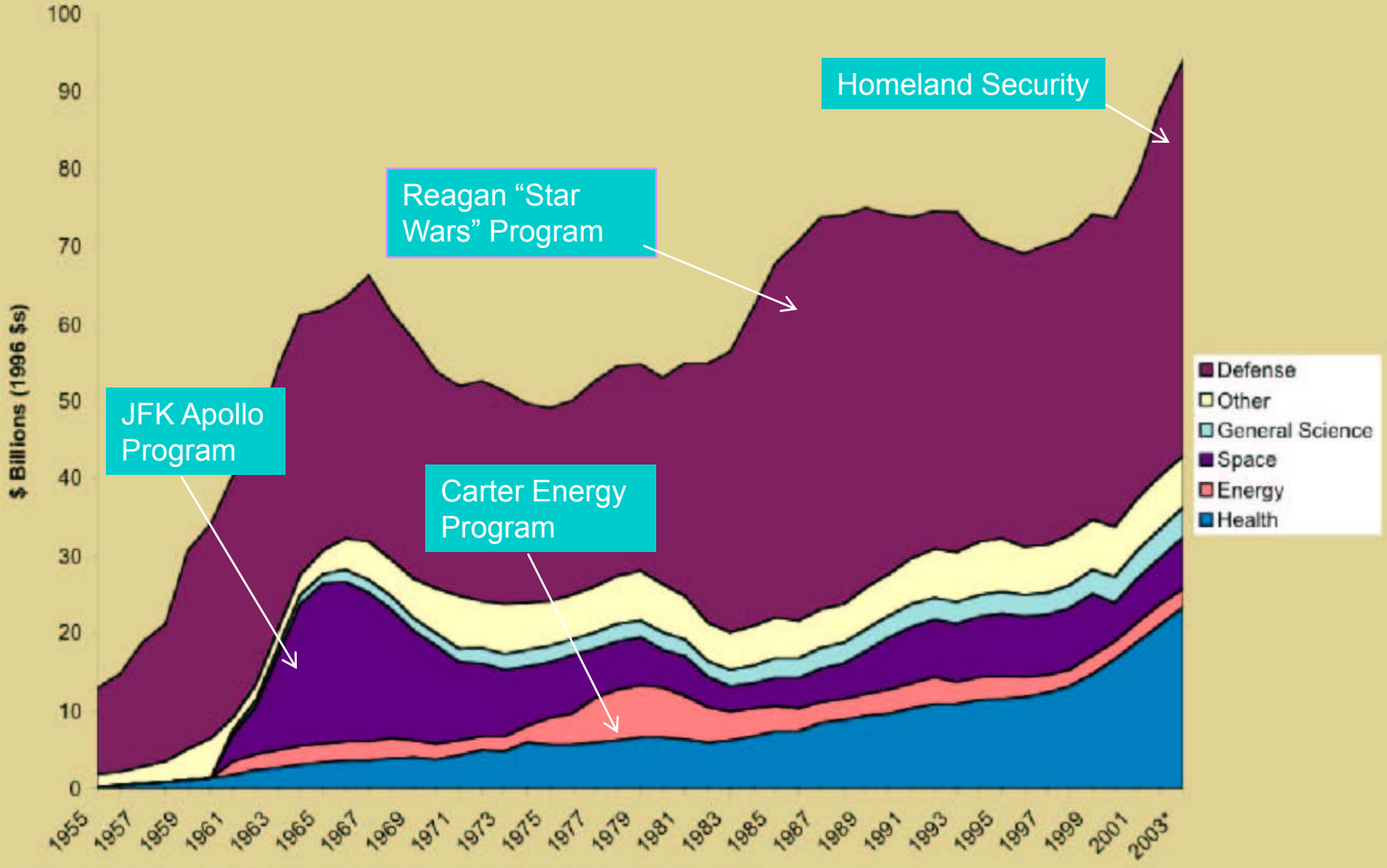


Source: K. Gallagher 2007

"Energy RD&D programs are not commensurate in scope and scale with the energy challenges & opportunities the 21st century will present."

Stylized Fact I:
Vigorous R&D a prerequisite for technological change?

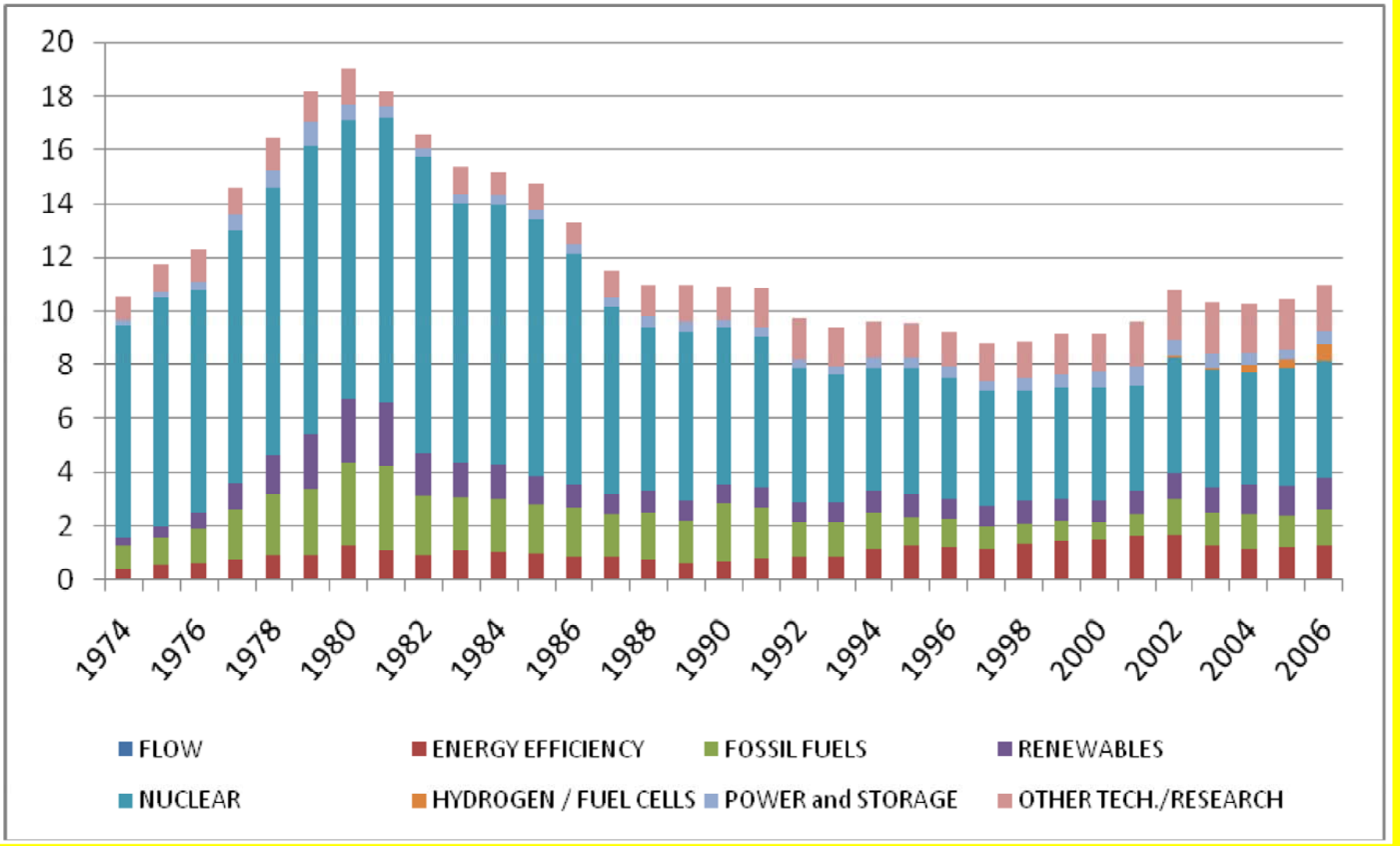
History of US Federal Government R&D



Source: National Science Foundation, Federal R&D Funding by Budget Function, Fiscal Years 2001-03.
** 2002 figures are preliminary, 2003 figures are proposed.*

Government R&D in IEA countries

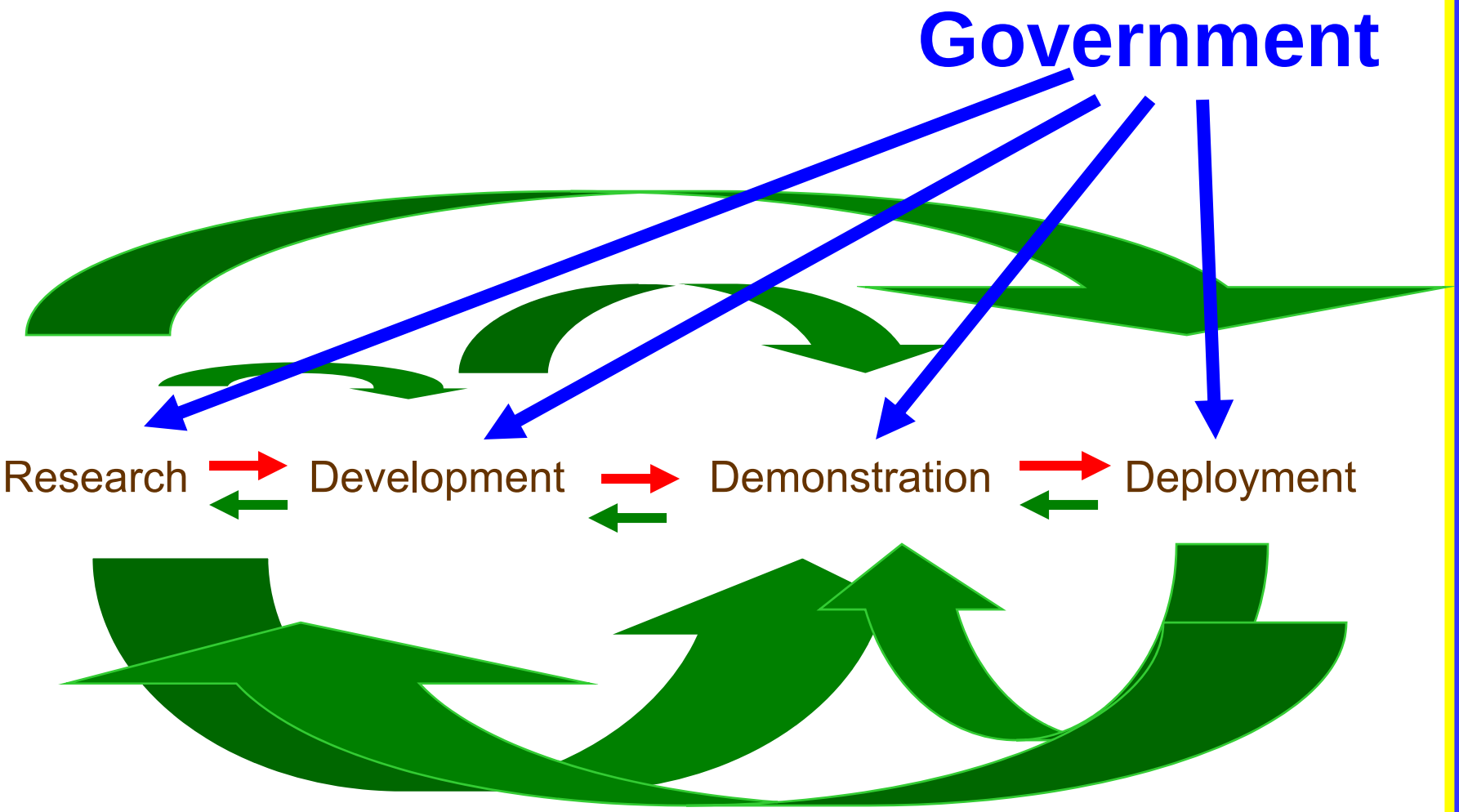
in billion US$ (2006)



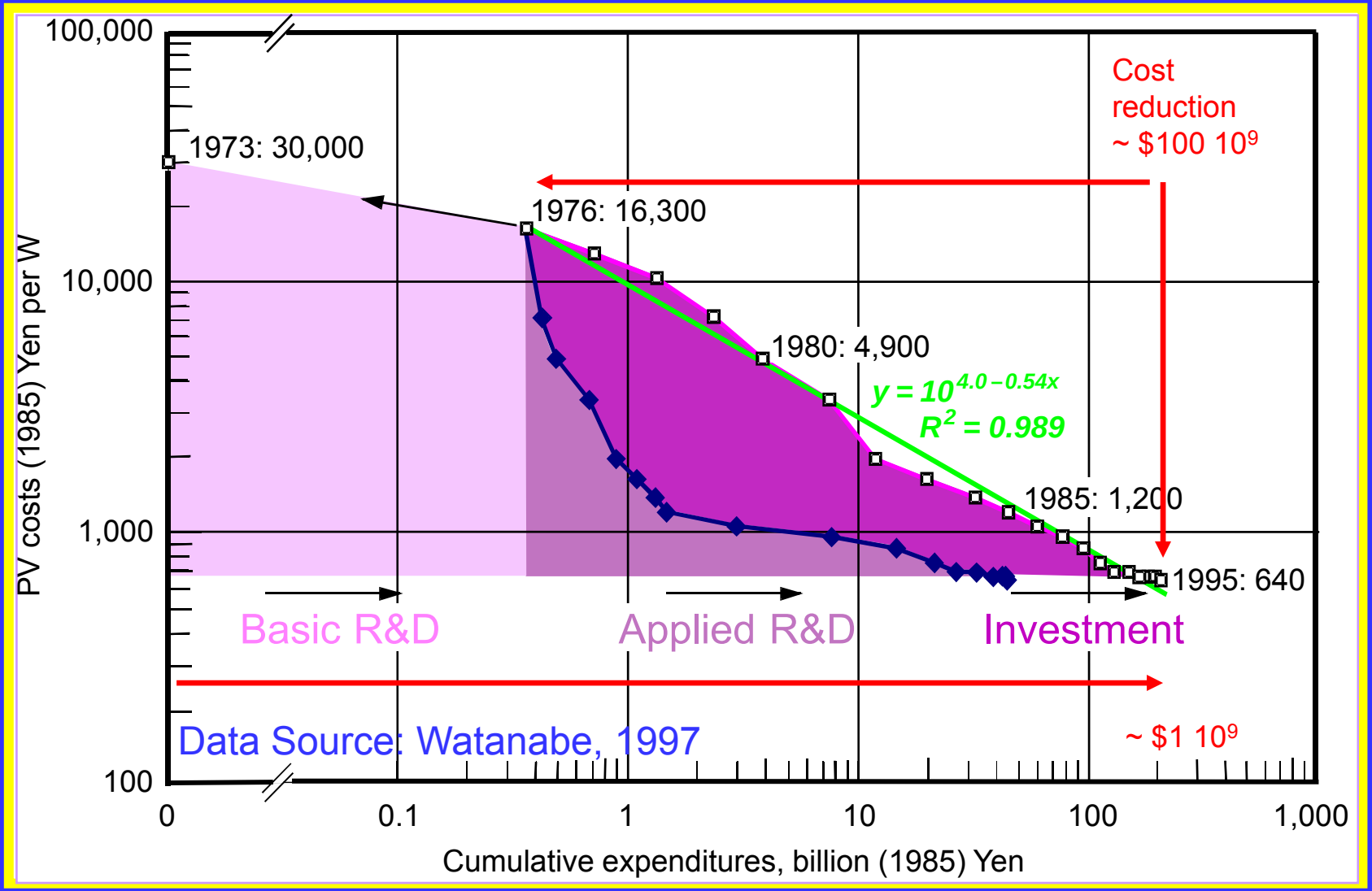
What we don't know

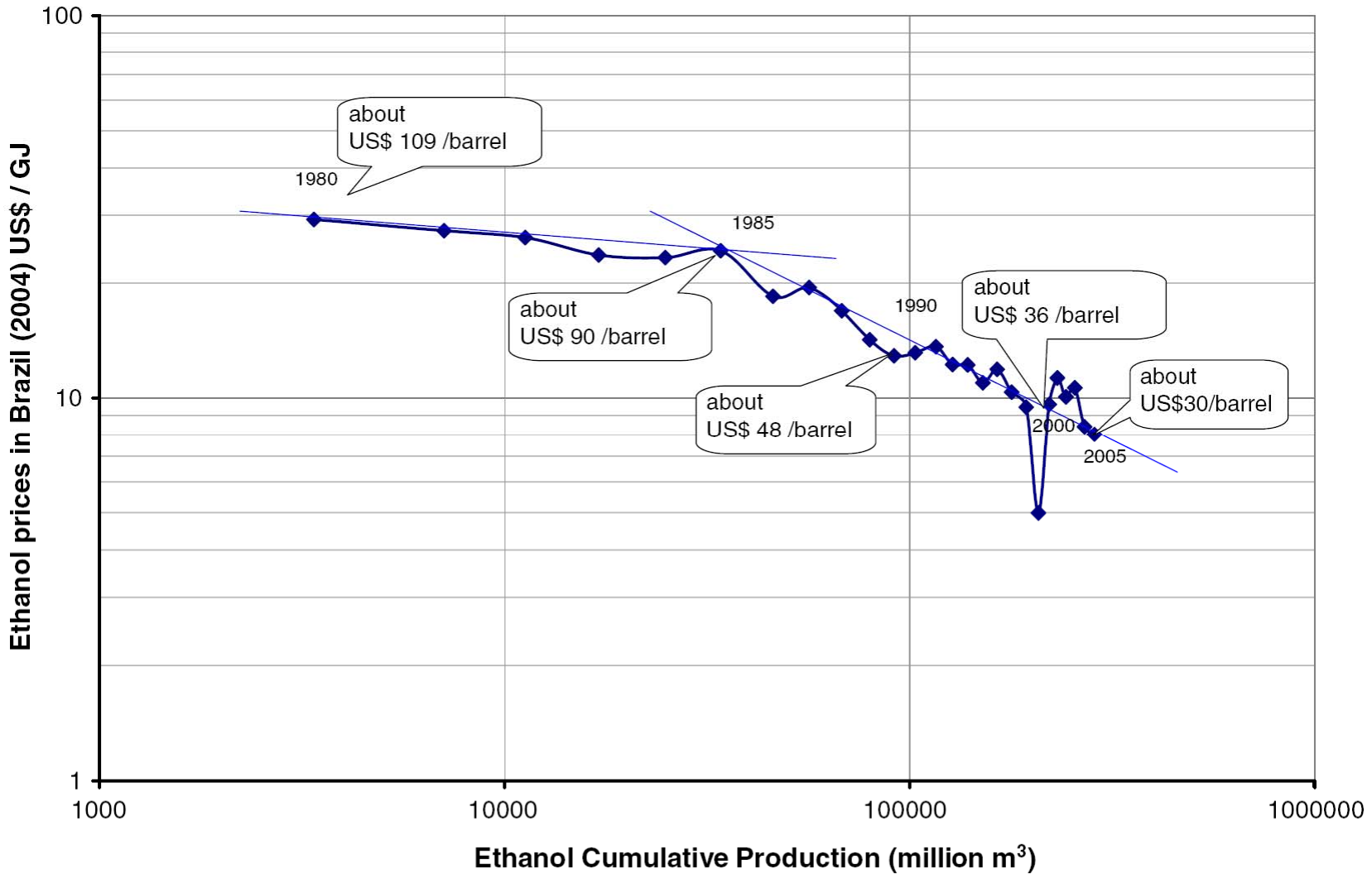
- The simplest measure of "inputs" to the innovation process is outlays for energy R&D, but even these are poorly characterized – boundaries are fuzzy, private-sector data are incomplete.
- "Output" measures for R&D – publications, patents, performance measures for technologies, sales – are often difficult to correlate with specific inputs.
- The innovation "chain" – basic research, applied research, development, demonstration, diffusion – is more complex than once thought because of feedbacks and blurred boundaries.
- The phenomena embodied in "learning curves", whereby unit costs decline as a logarithmic function of cumulative production or cumulative investment in RD^3, are not well understood.
- Progress from basic research to technology diffusion increasingly involves partnerships & interactions, within and among sectors (firms, governments, universities, NGOs) that have scarcely been mapped, not to say analyzed and understood.

Innovation Chain: Dynamic & Complex



Japan - PV Costs vs. Expenditures




100
10
1
Ethanol prices in Brazil (2004) US$ / GJ
about
US$ 109 /barrel
1980
1985
about
US$ 90 /barrel
1990
about
US$ 36 /barrel
about
US$ 48 /barrel
2000
about
US$30/barrel
2005
1000
10000
100000
1000000
Ethanol Cumulative Production (million m3)

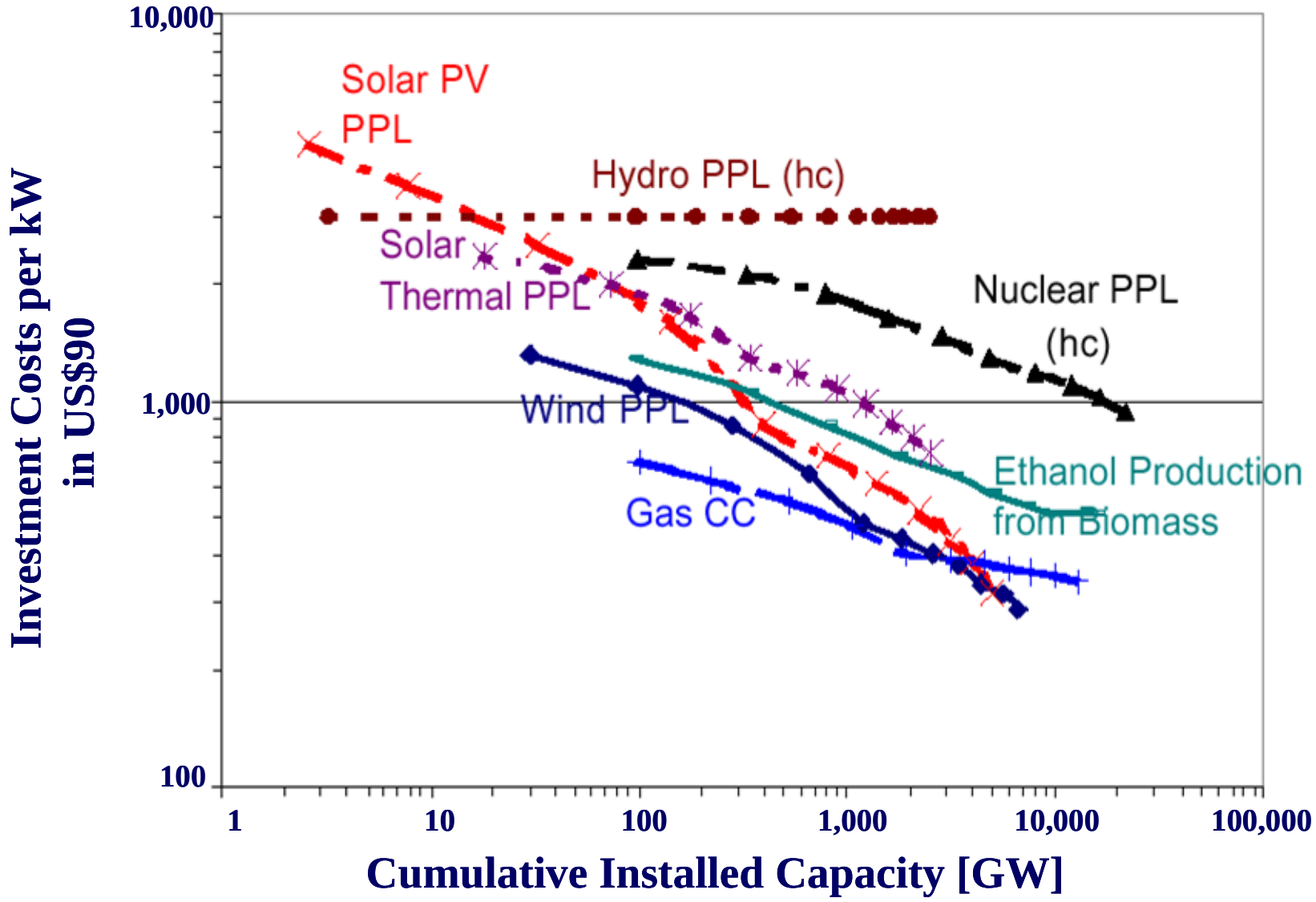
The Brazilian Ethanol Story

(a part thereof)

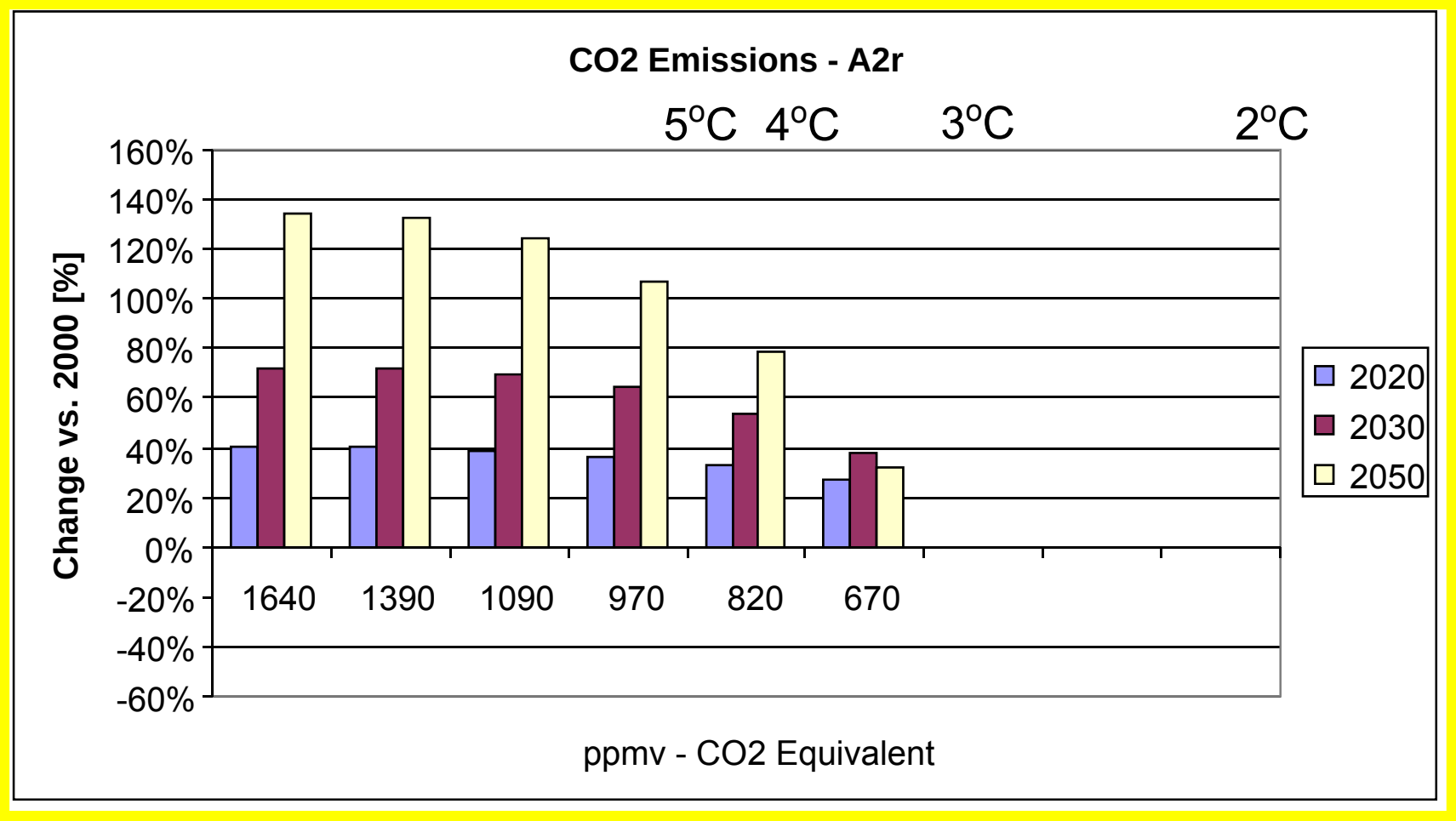
- Essential is a long-term and sustained commitment to promote advanced technology while it is costlier and often also inferior to the more conventional alternatives.
- Cumulative additional investment (based on the difference between ethanol and gasoline price) was about US $2 billion (Gruebler, 2002).
- Total investment in the agricultural and industrial sectors for automotive ethanol is estimated at some US $5 billion (Goldemberg, 2006).
- Total savings from avoided oil import accrued to more than US $50 billion (Goldemberg, 2006)!

Stylized Fact II: Endogenize “buy-downs” along the learning curves?

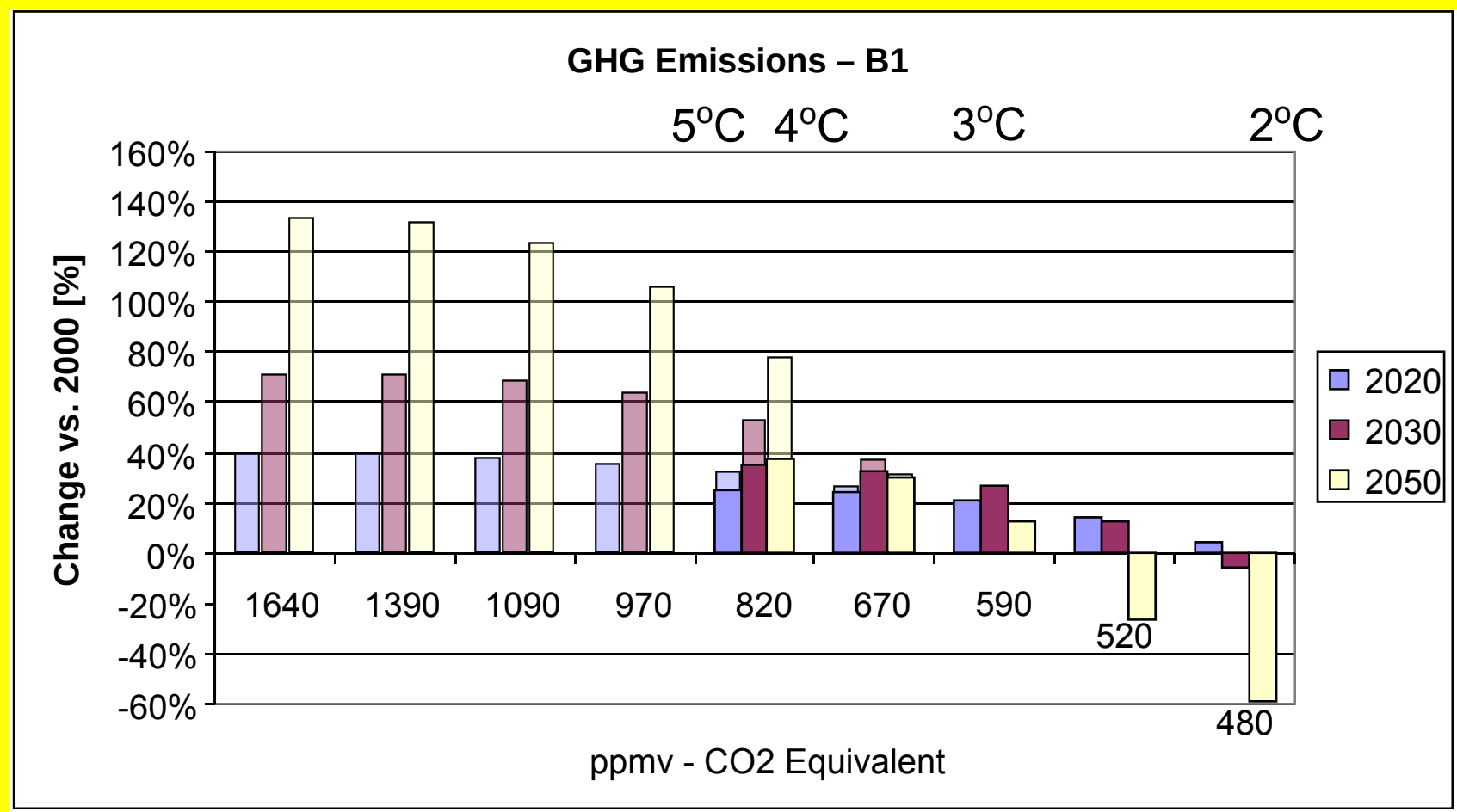
Technology Learning in SRES



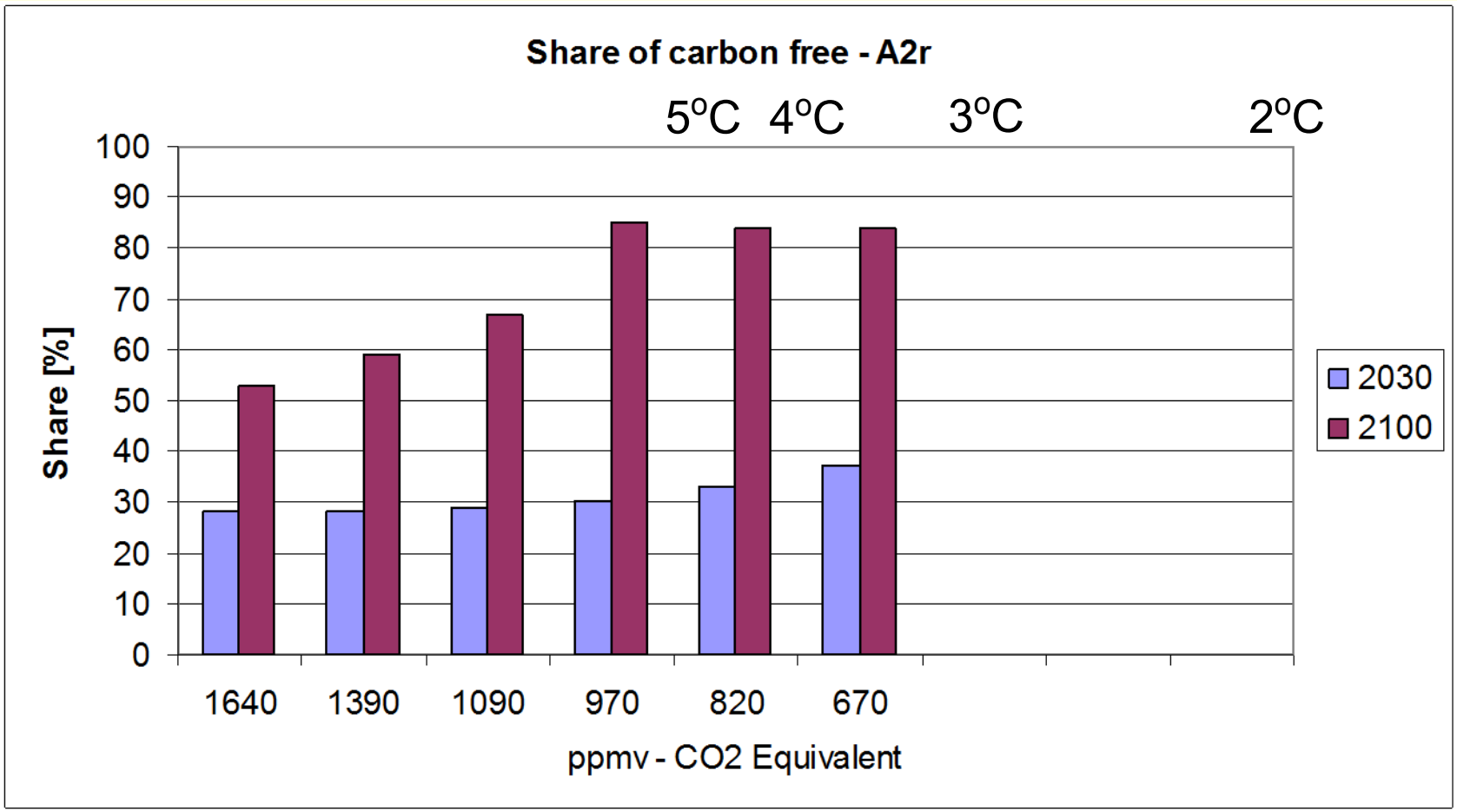
Change in GHG emissions in A2r



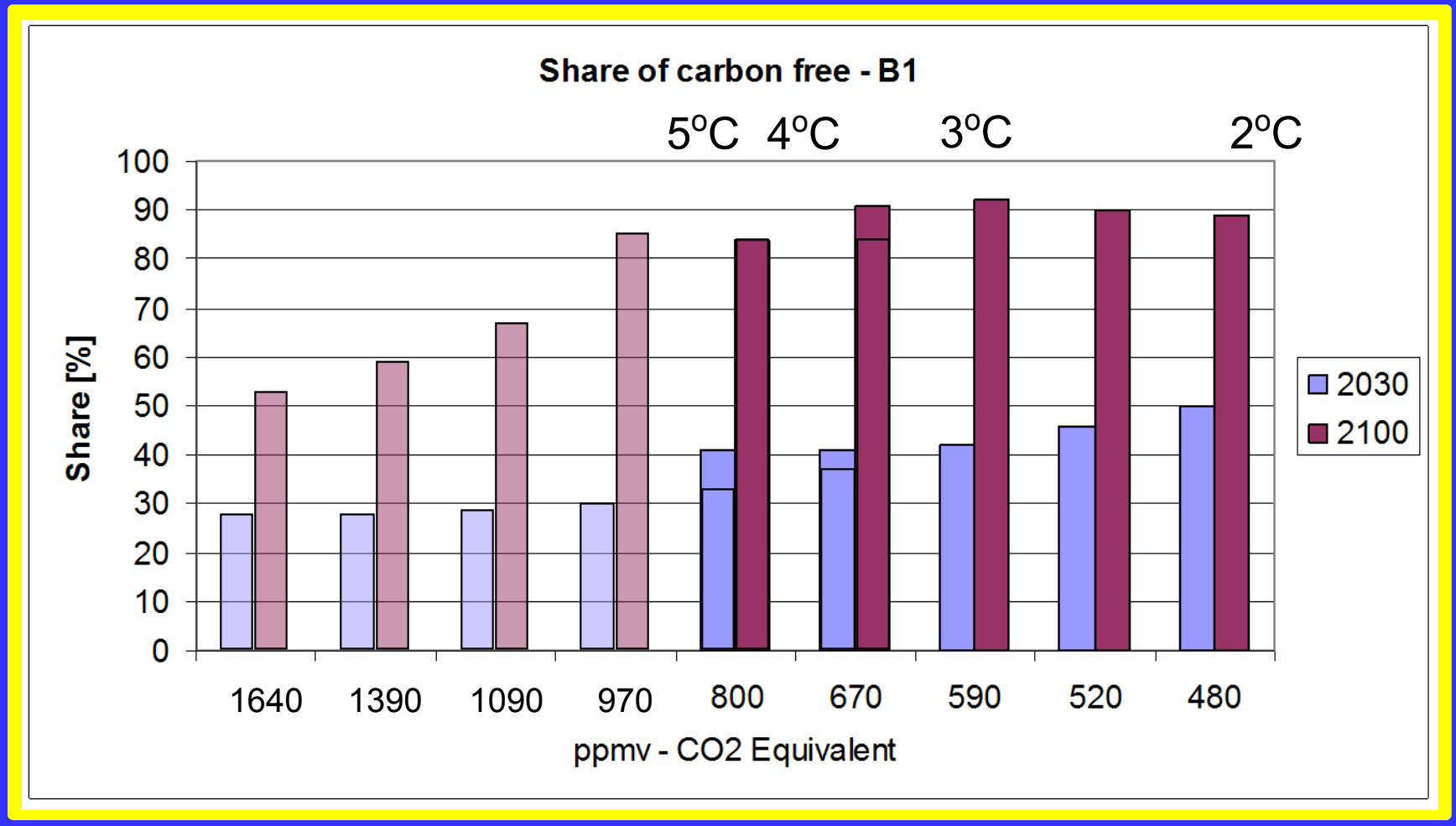
Change in GHG emissions in B1



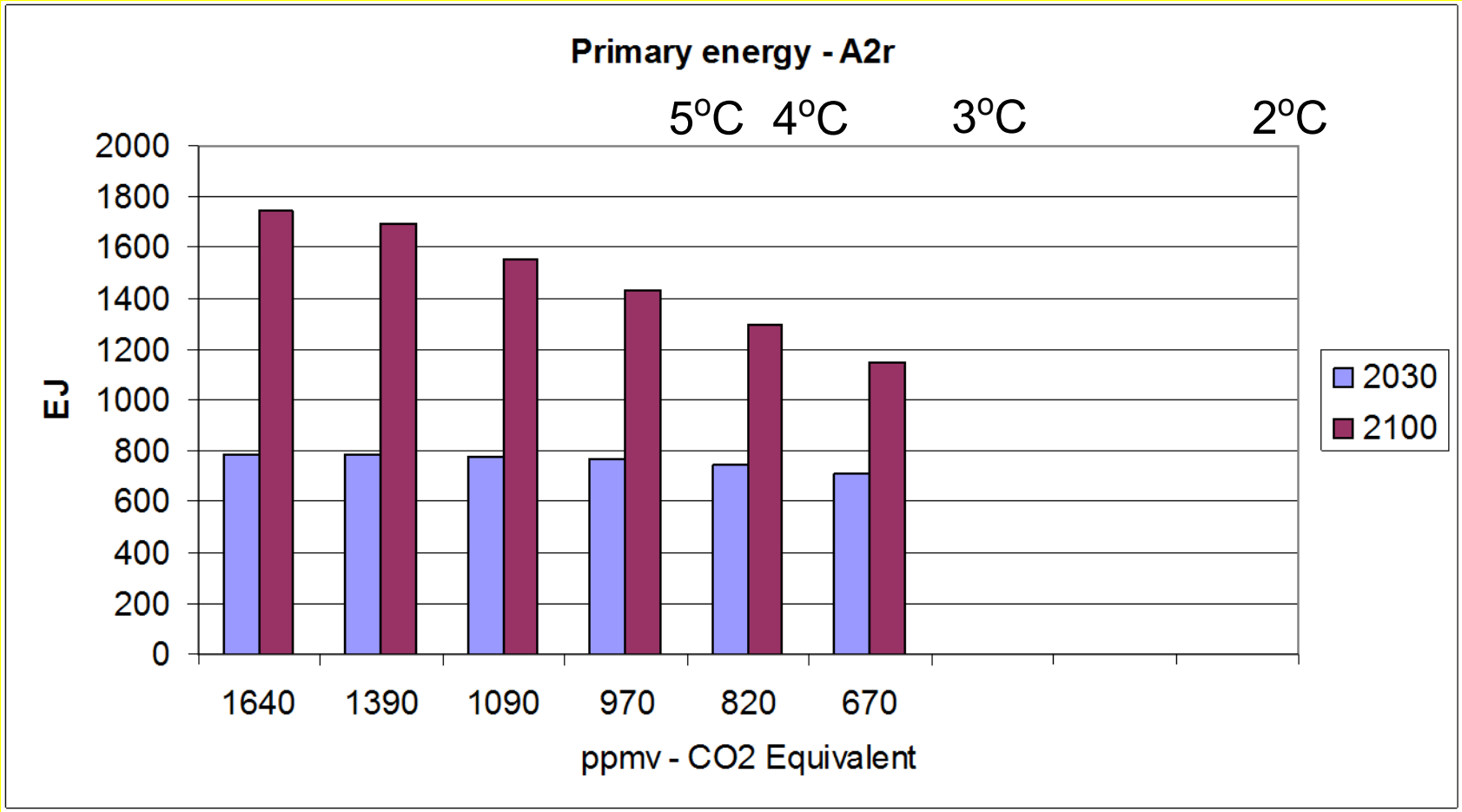
Share of Carbon-Free in A2r



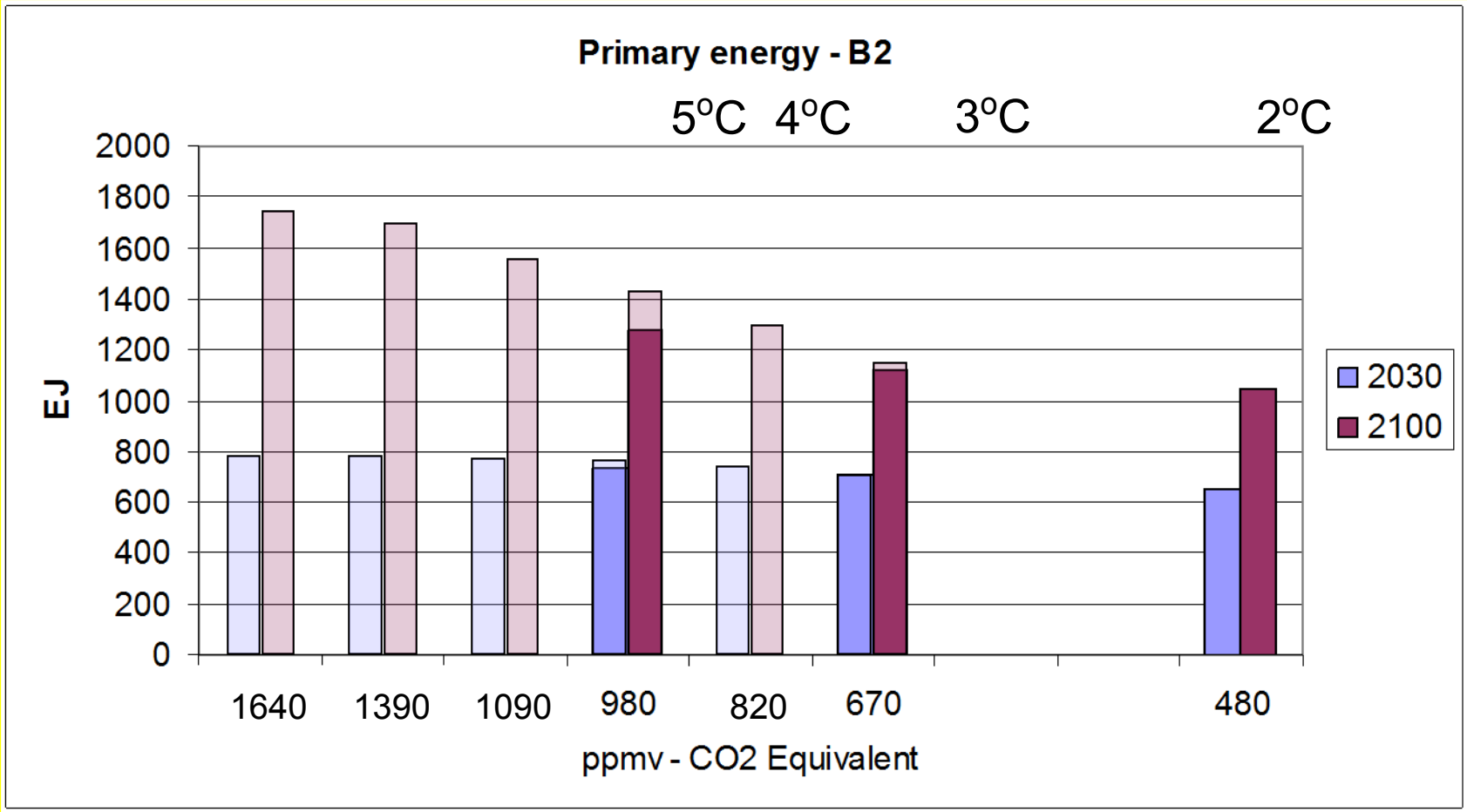
Share of Carbon-Free in B1



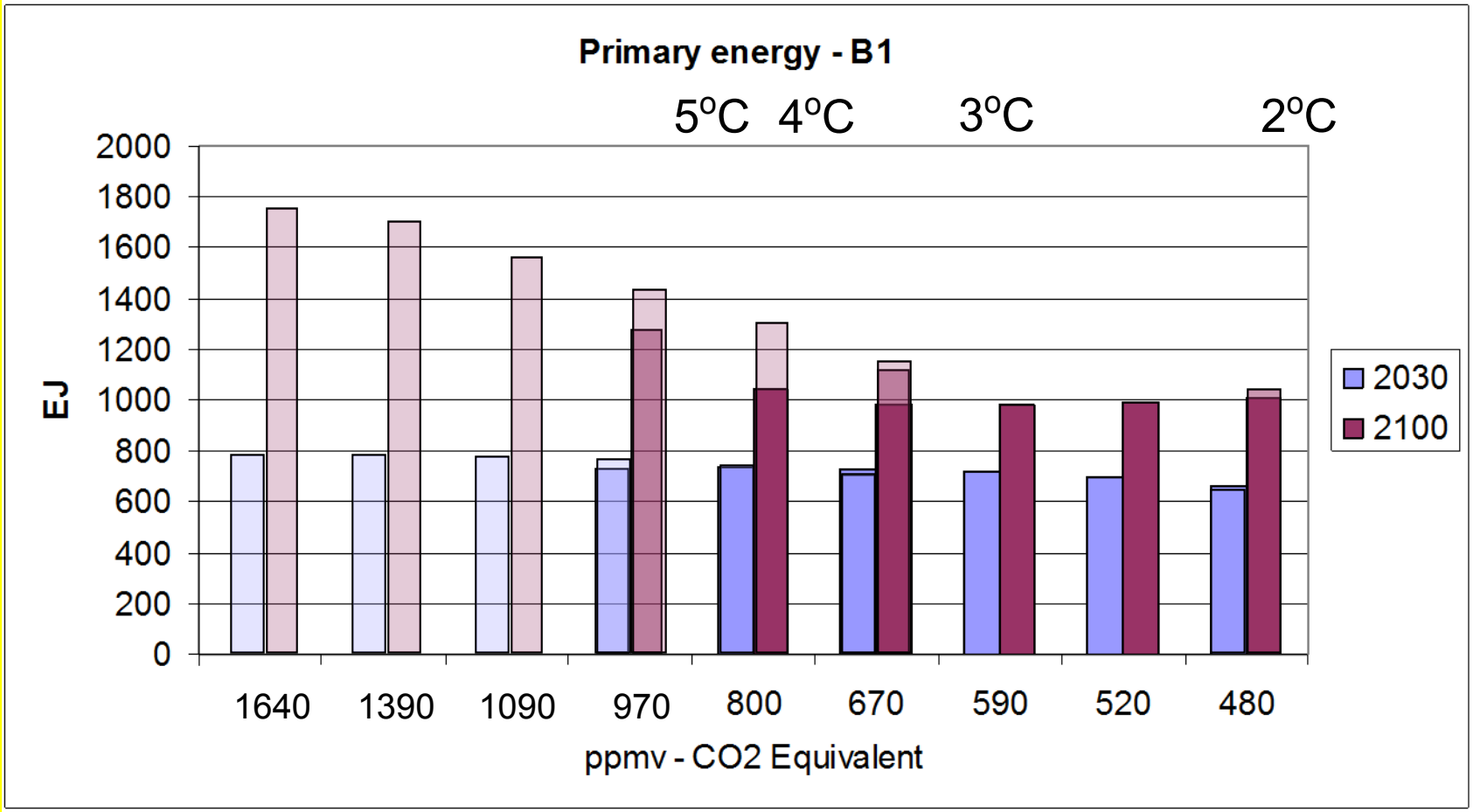
Primary Energy in A2r



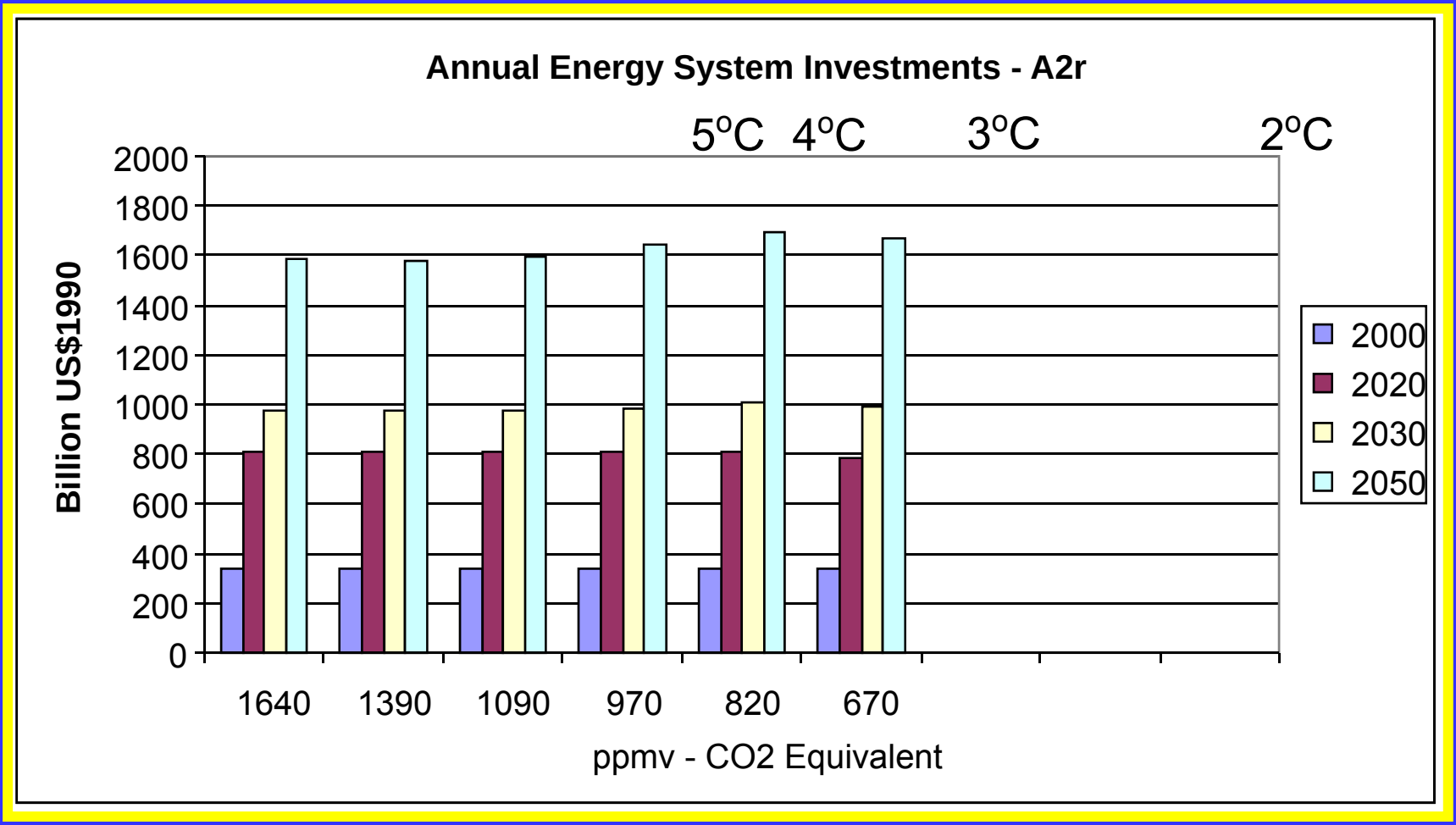
Primary Energy in B2



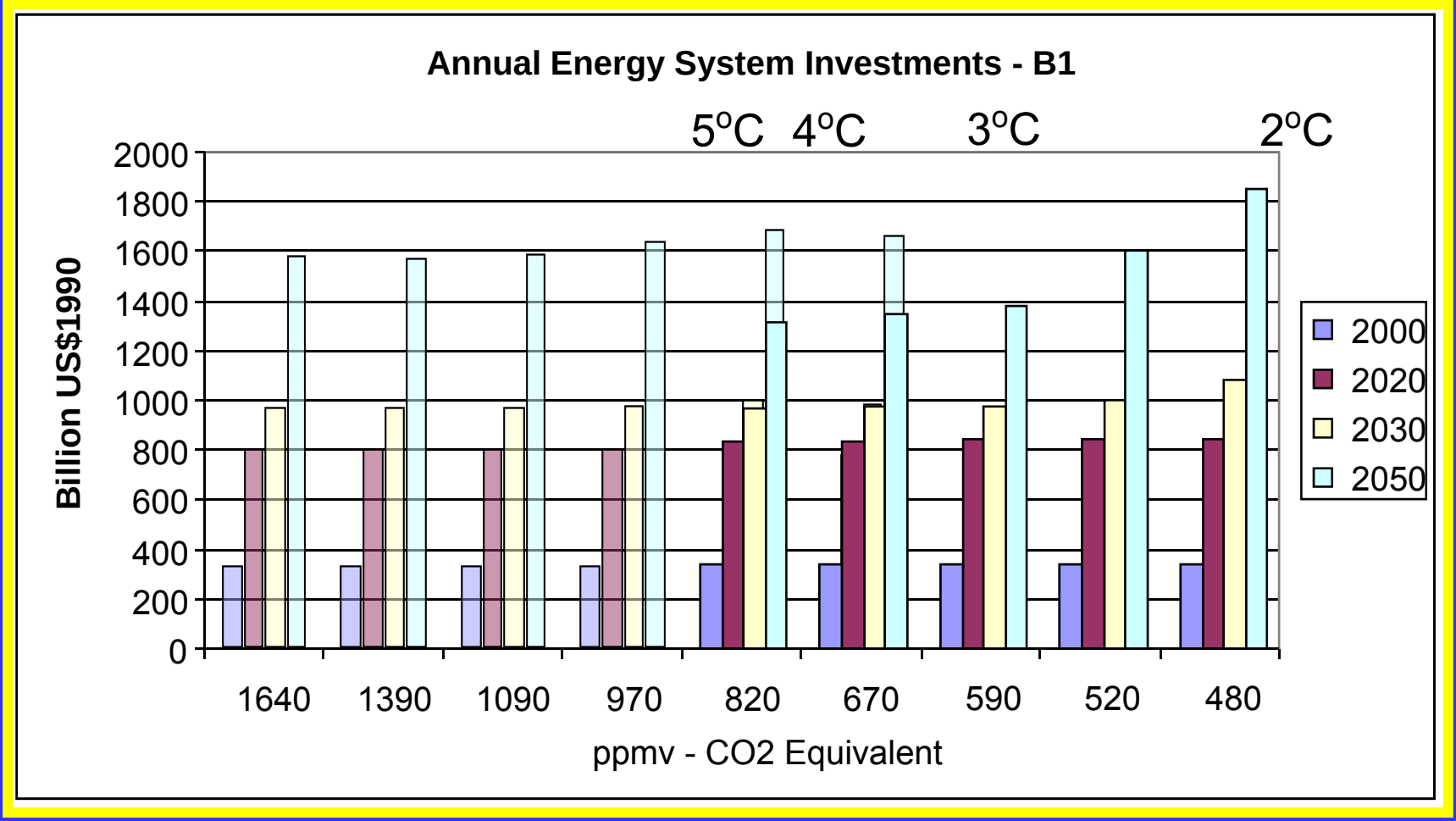
Primary Energy in B1



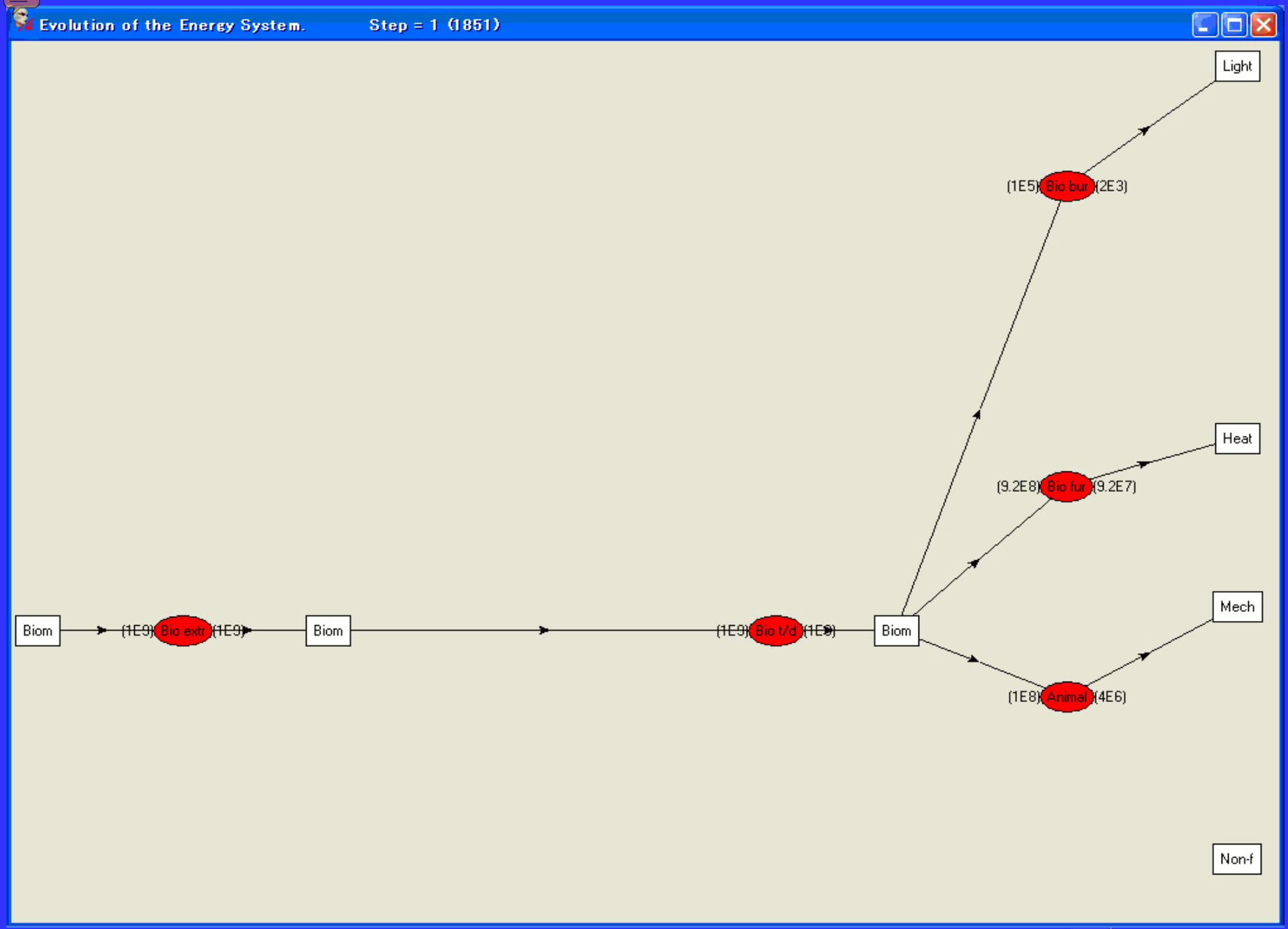
Energy Systems Investments in A2r

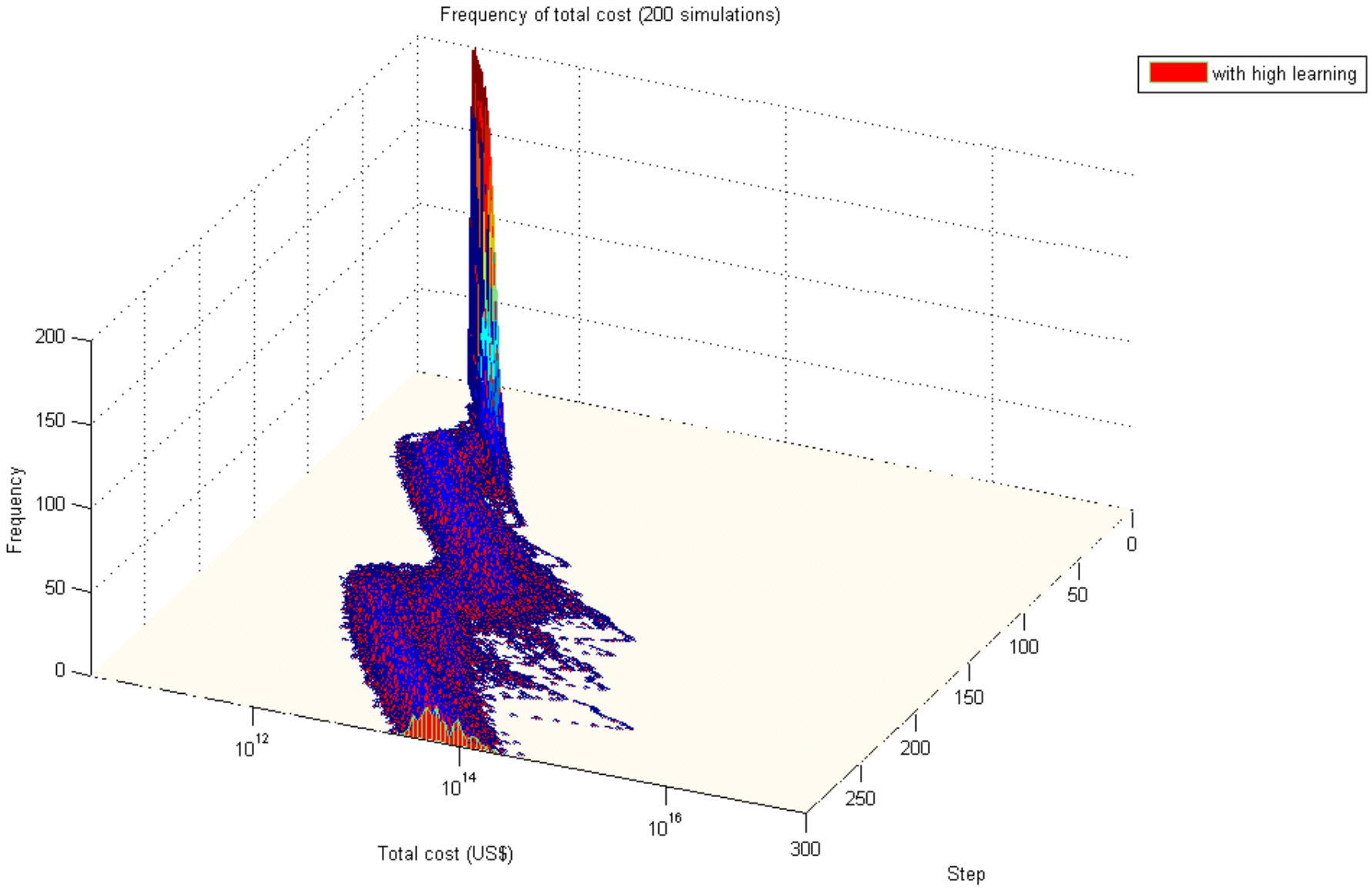


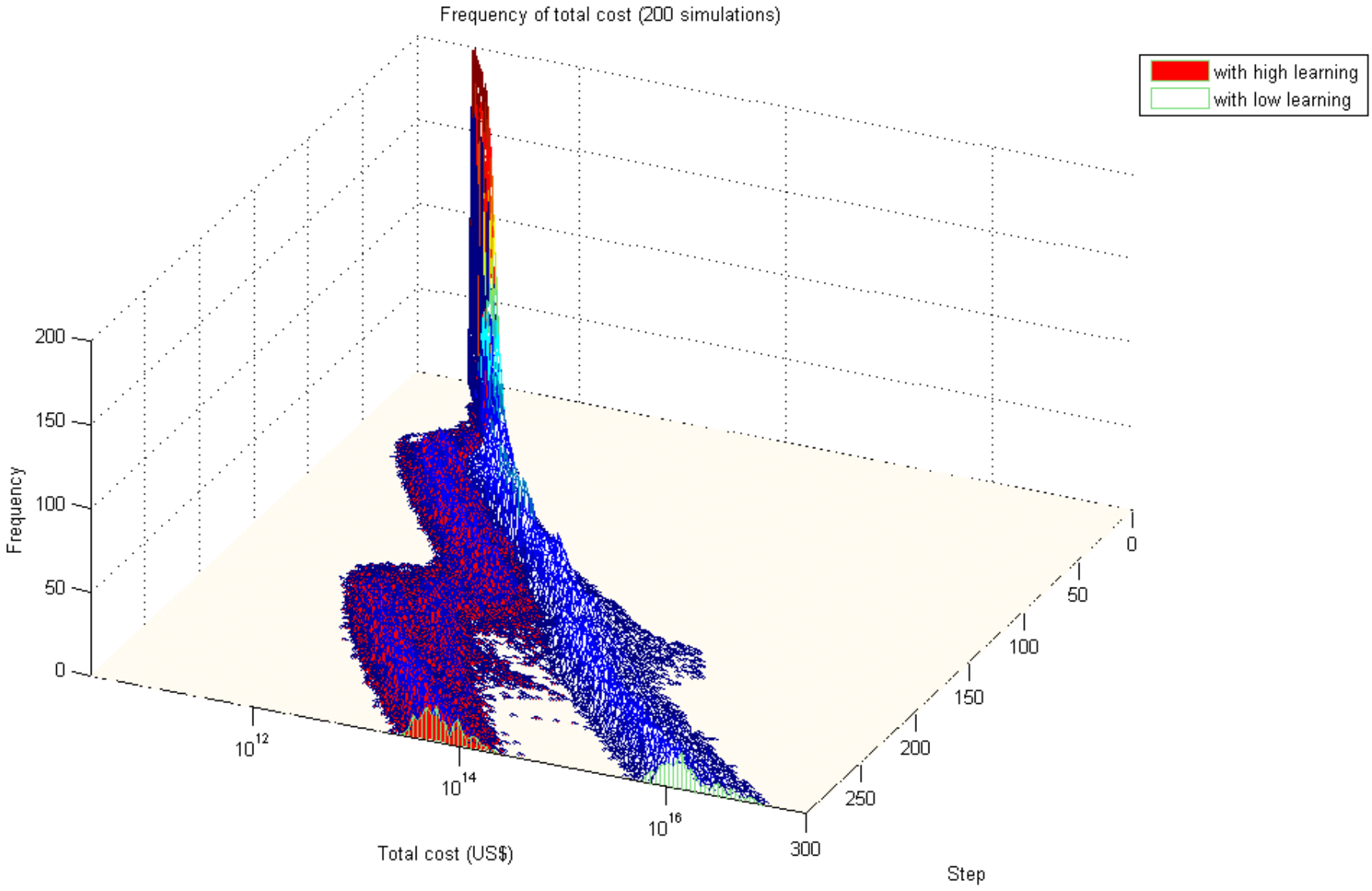
Energy Systems Investments in B2

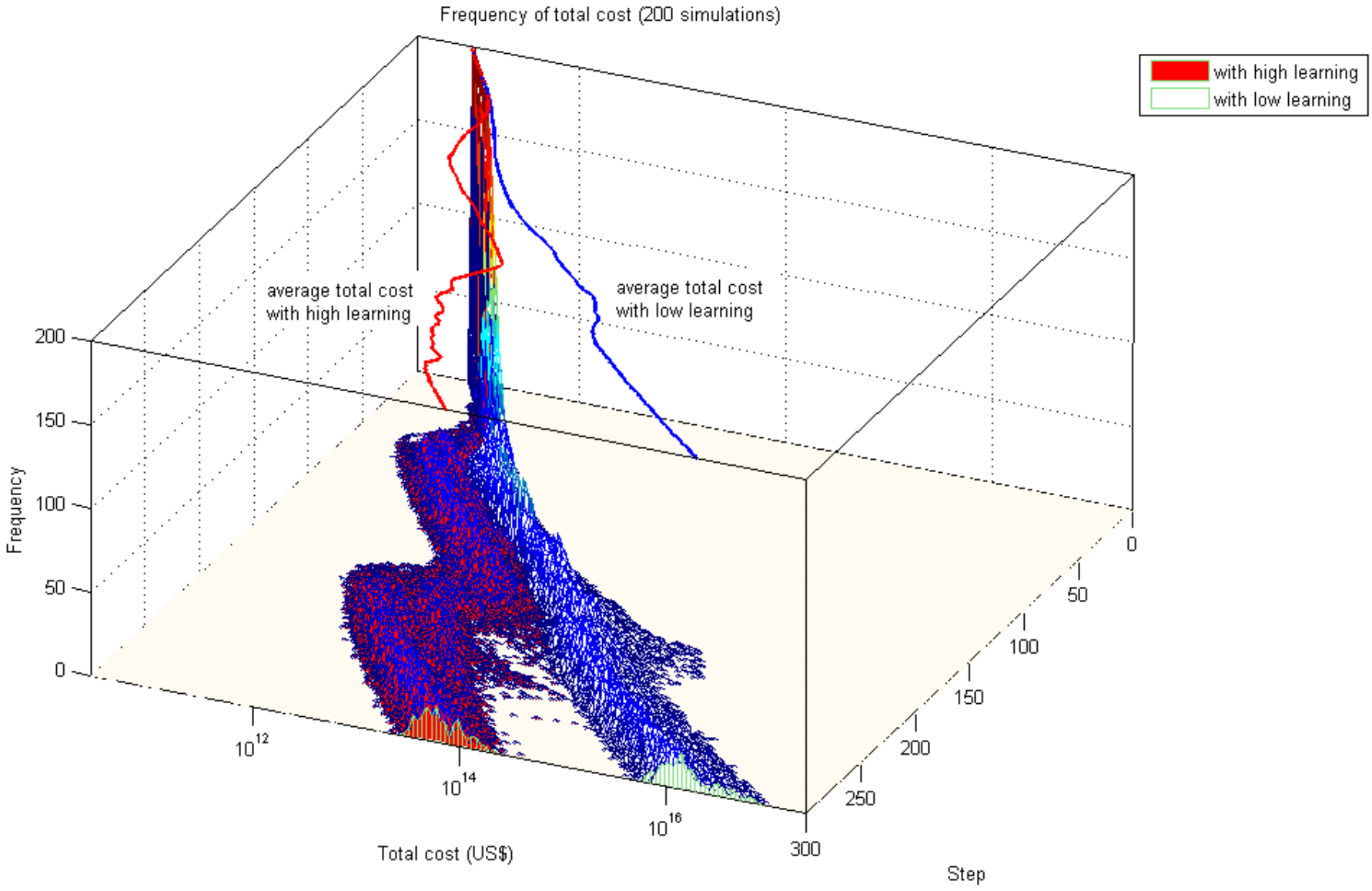


Stylized Fact III:
Model dynamic, cumulative, systemic and uncertain nature of technology?


Evolution of the Energy System.
Step = 1 (1851)
Light
(1E5) Bio bur (2E3)
Heat
(9.2E8) Bio fur (9.2E7)
Mech
(1E8) Animal (4E6)
Non-f
Biom
(1E9) Bio extr (1E9)
Biom
(1E9) Bio t/d (1E9)
Biom


Frequency of total cost (200 simulations)
with high learning
Frequency
200
150
100
50
0
10^{12}
10^{14}
10^{16}
Total cost (US$)
0
50
100
150
200
250
300
Step


Frequency of total cost (200 simulations)
with high learning
with low learning
Frequency
200
150
100
50
0
10^{12}
10^{14}
10^{16}
Total cost (US$)
0
50
100
150
200
250
300
Step


Frequency of total cost (200 simulations)
with high learning
with low learning
average total cost
with high learning
average total cost
with low learning
Frequency
200
150
100
50
0
10^{12}
10^{14}
10^{16}
Total cost (US$)
300
250
200
150
100
50
0
Step

TATA Nano

TATA Nano

Toyota Prius CNG

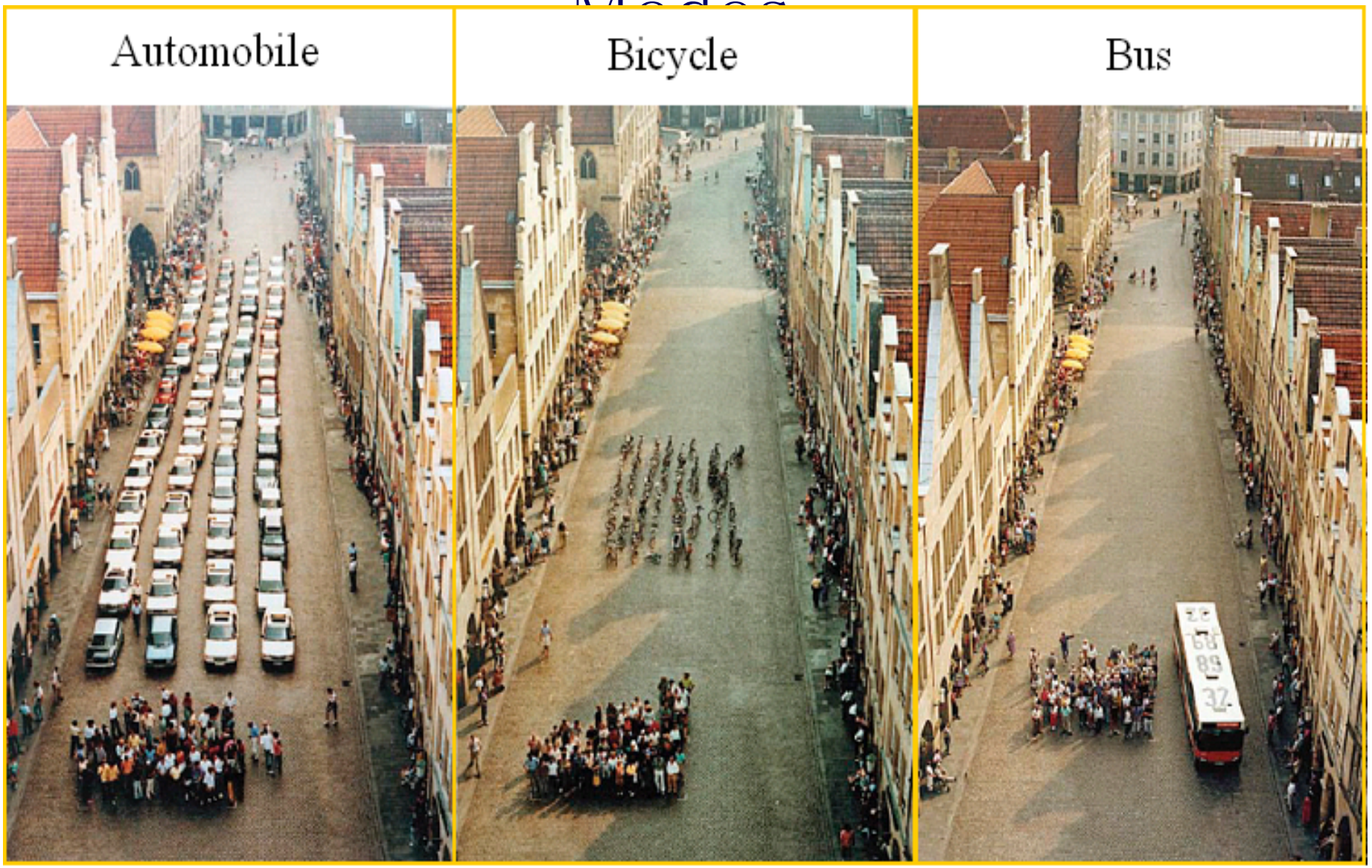
Tesla Electric Roadster

Source: www.fuel-efficient-vehicles.org

Toyota – “I-Unit”

CITARO H_2 Fuel Cell Bus

Area Occupied by Various Transport Modes



UN-SUTP module3a(2005)