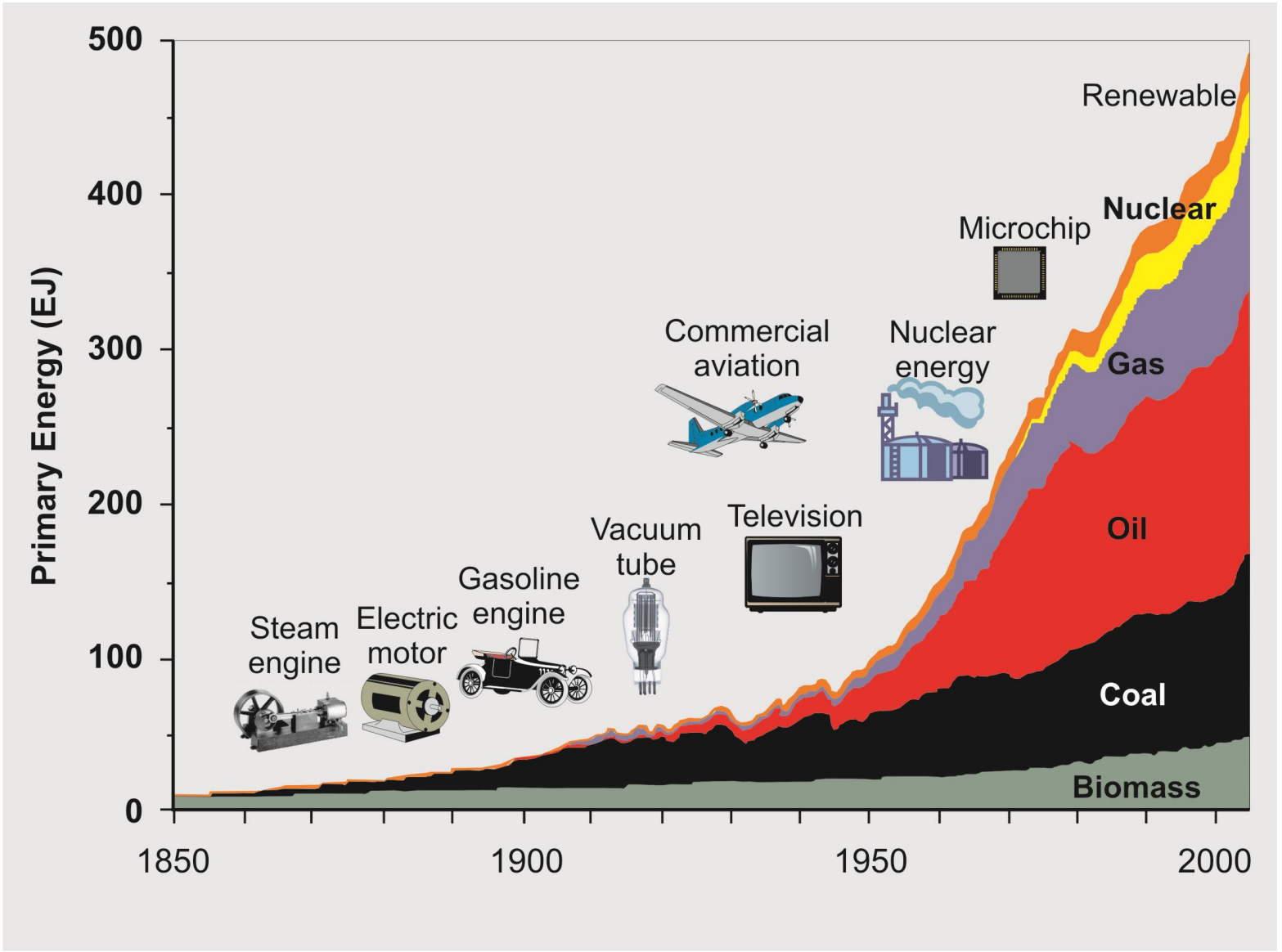
1st USP Conference in Engineering

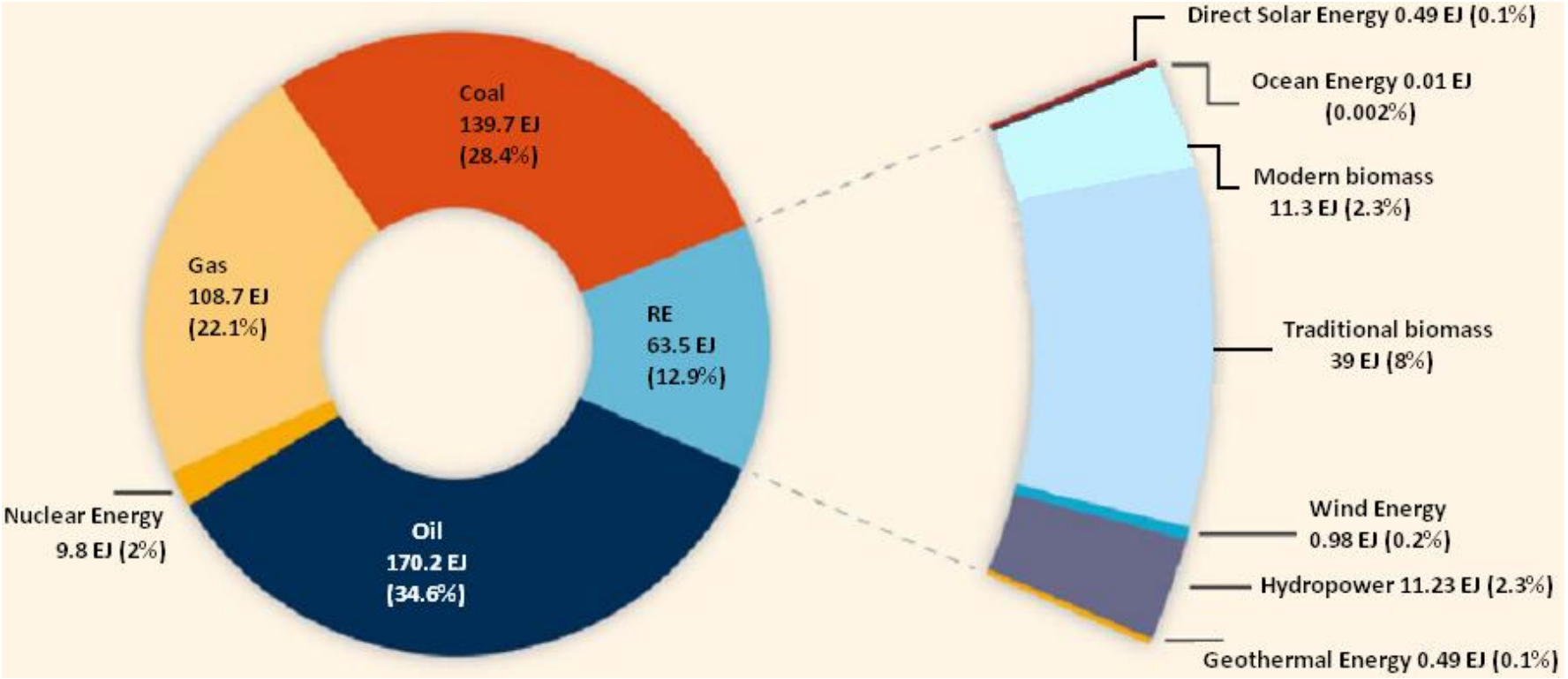
Energy in Brazil and the world

Escola Politécnica

Prof. José Goldemberg

26/10/2011


Primary Energy (EJ)
500
400
300
200
100
0
1850
1900
1950
2000
Renewable
Nuclear
Microchip
Gas
Commercial aviation
Nuclear energy
Oil
Television
Vacuum tube
Gasoline engine
Electric motor
Steam engine
Coal
Biomass


Coal
139.7 EJ
(28.4%)
Gas
108.7 EJ
(22.1%)
RE
63.5 EJ
(12.9%)
Nuclear Energy
9.8 EJ (2%)
Oil
170.2 EJ
(34.6%)
Direct Solar Energy 0.49 EJ (0.1%)
Ocean Energy 0.01 EJ
(0.002%)
Modern biomass
11.3 EJ (2.3%)
Traditional biomass
39 EJ (8%)
Wind Energy
0.98 EJ (0.2%)
Hydropower 11.23 EJ (2.3%)
Geothermal Energy 0.49 EJ (0.1%)

The role of modern biomass in the world`s energy supply

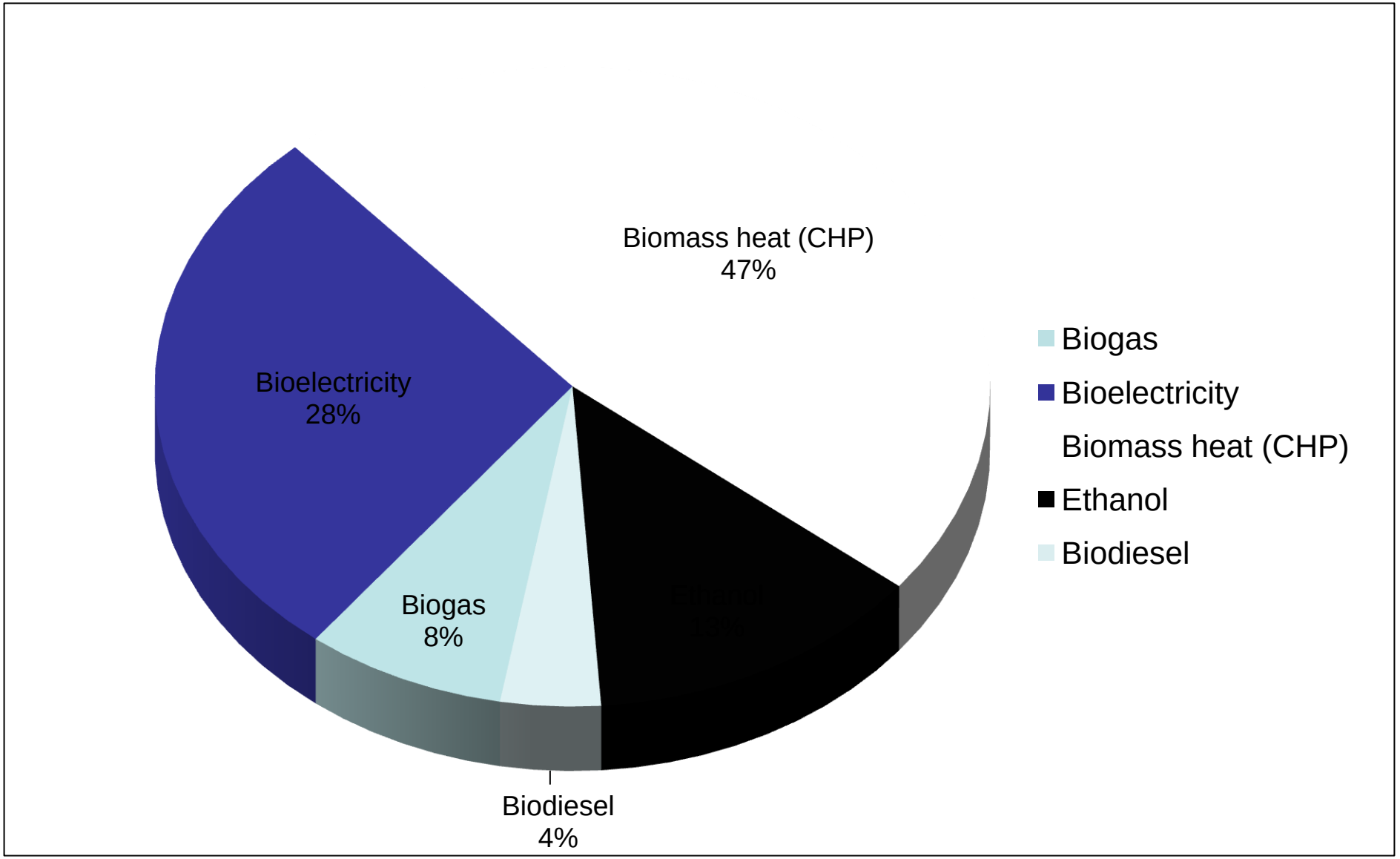
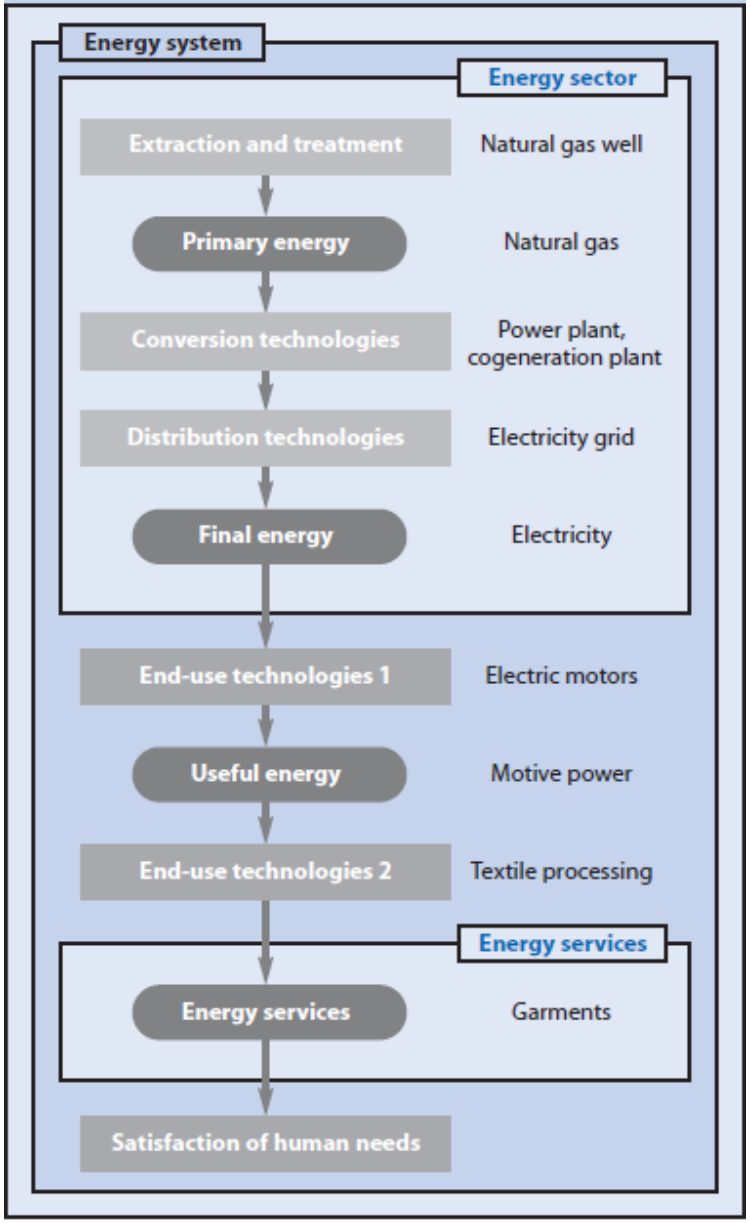
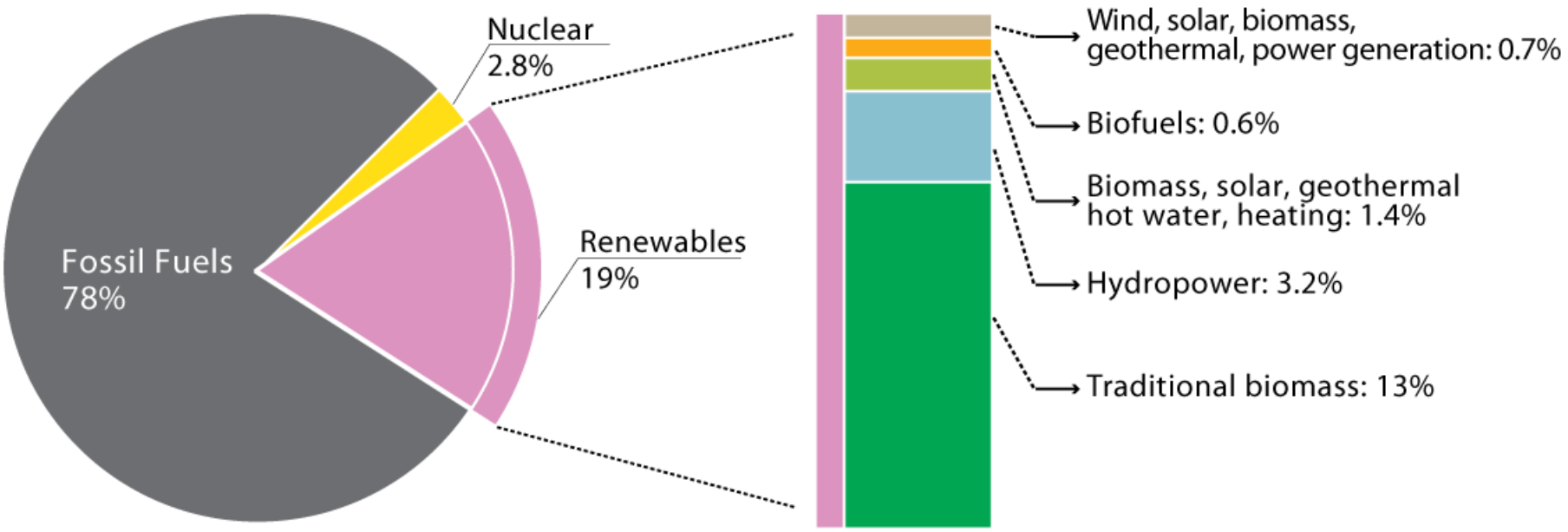
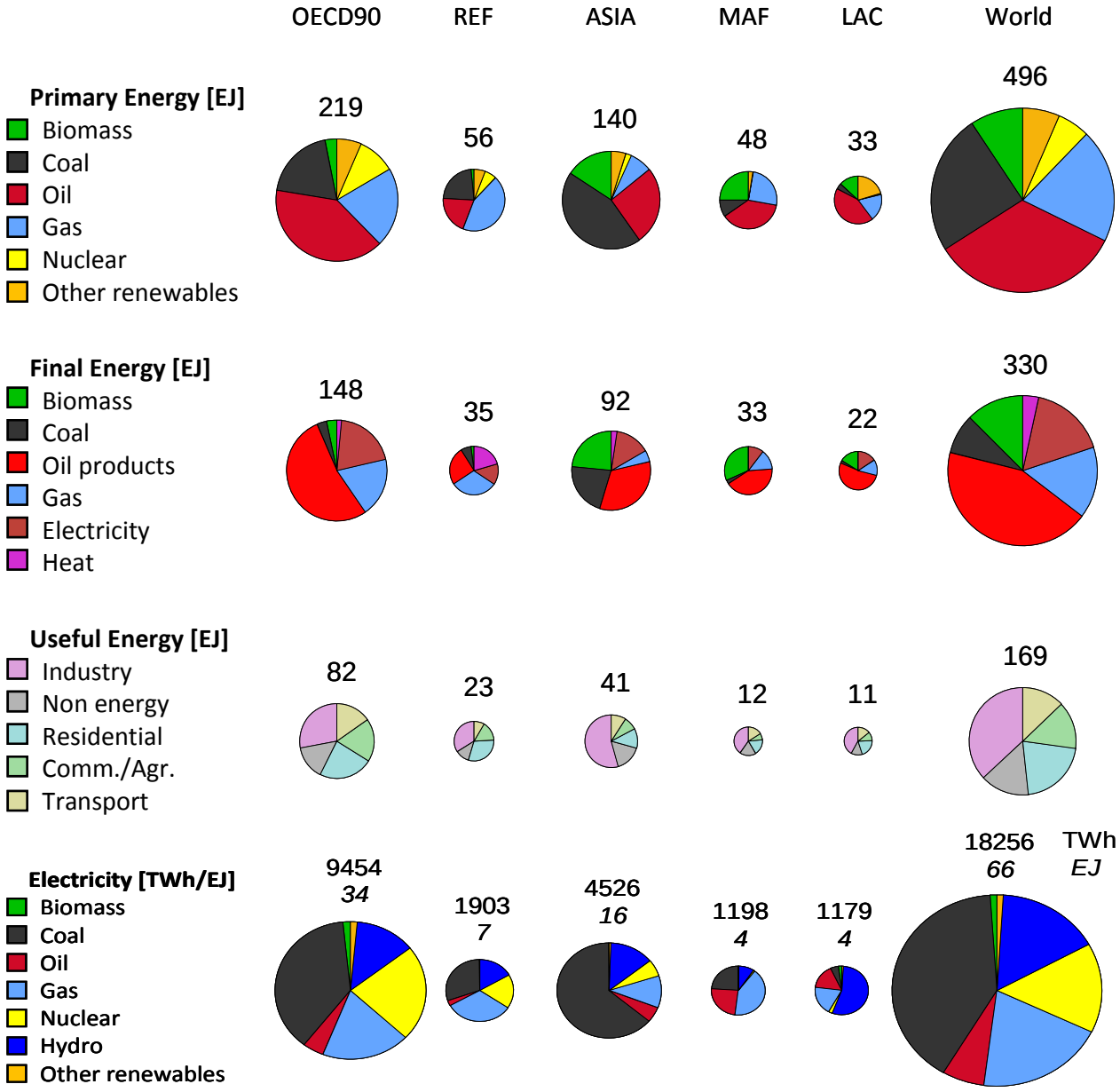


FIGURE 2. AN EXAMPLE OF THE ENERGY CHAIN FROM EXTRACTION TO SATISFACTION OF NEEDS




Nuclear
2.8%
Fossil Fuels
78%
Renewables
19%
Wind, solar, biomass,
geothermal, power generation: 0.7%
Biofuels: 0.6%
Biomass, solar, geothermal
hot water, heating: 1.4%
Hydropower: 3.2%
Traditional biomass: 13%


OECD90
REF
ASIA
MAF
LAC
World
Primary Energy [EJ]
Biomass
Coal
Oil
Gas
Nuclear
Other renewables
219
56
140
48
33
496
Final Energy [EJ]
Biomass
Coal
Oil products
Gas
Electricity
Heat
148
35
92
33
22
330
Useful Energy [EJ]
Industry
Non energy
Residential
Comm./Agr.
Transport
82
23
41
12
11
169
Electricity [TWh/EJ]
Biomass
Coal
Oil
Gas
Nuclear
Hydro
Other renewables
9454
34
1903
7
4526
16
1198
4
1179
4
18256
66
TWh
EJ

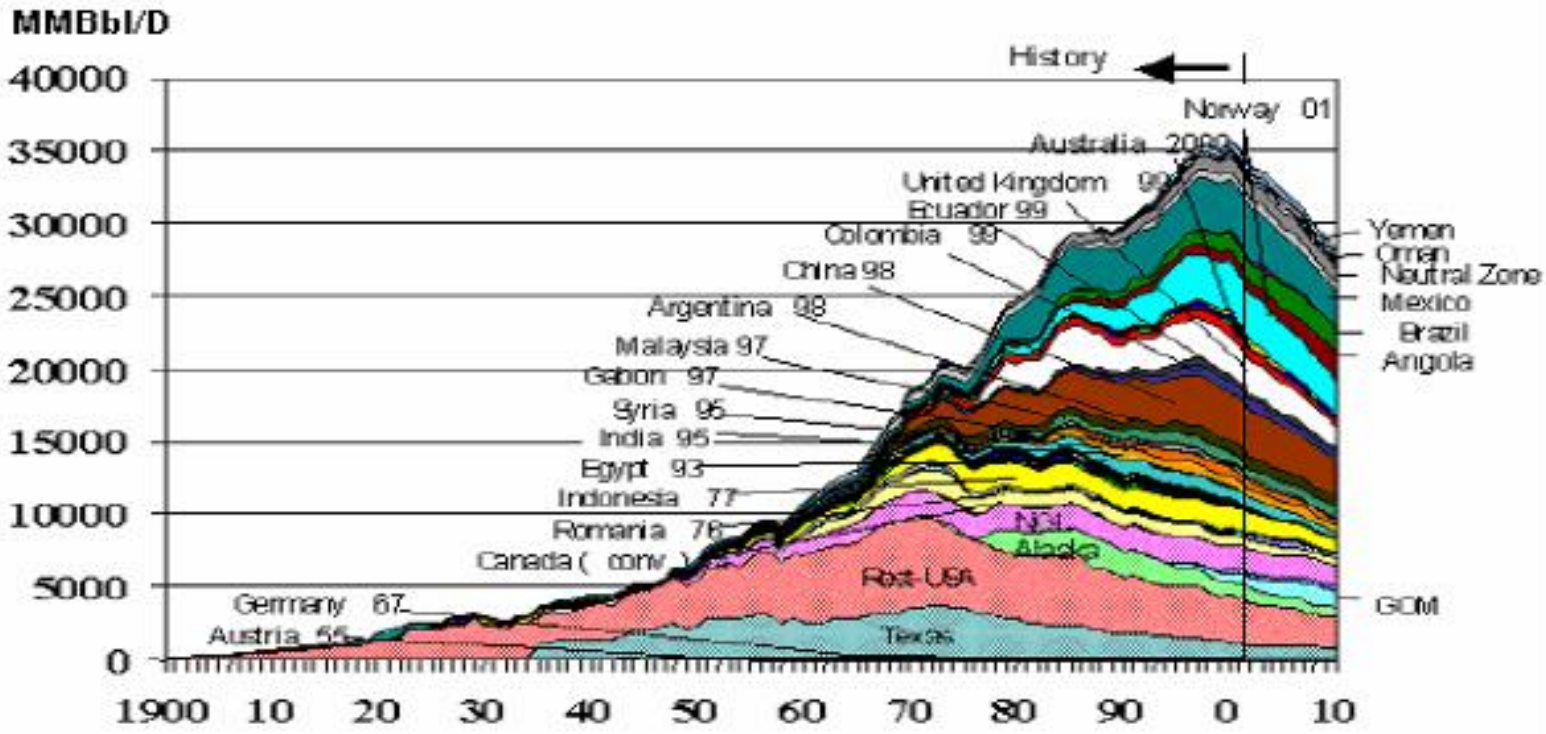
Problems with the present energy system

i. Exhaustion of fossil resources

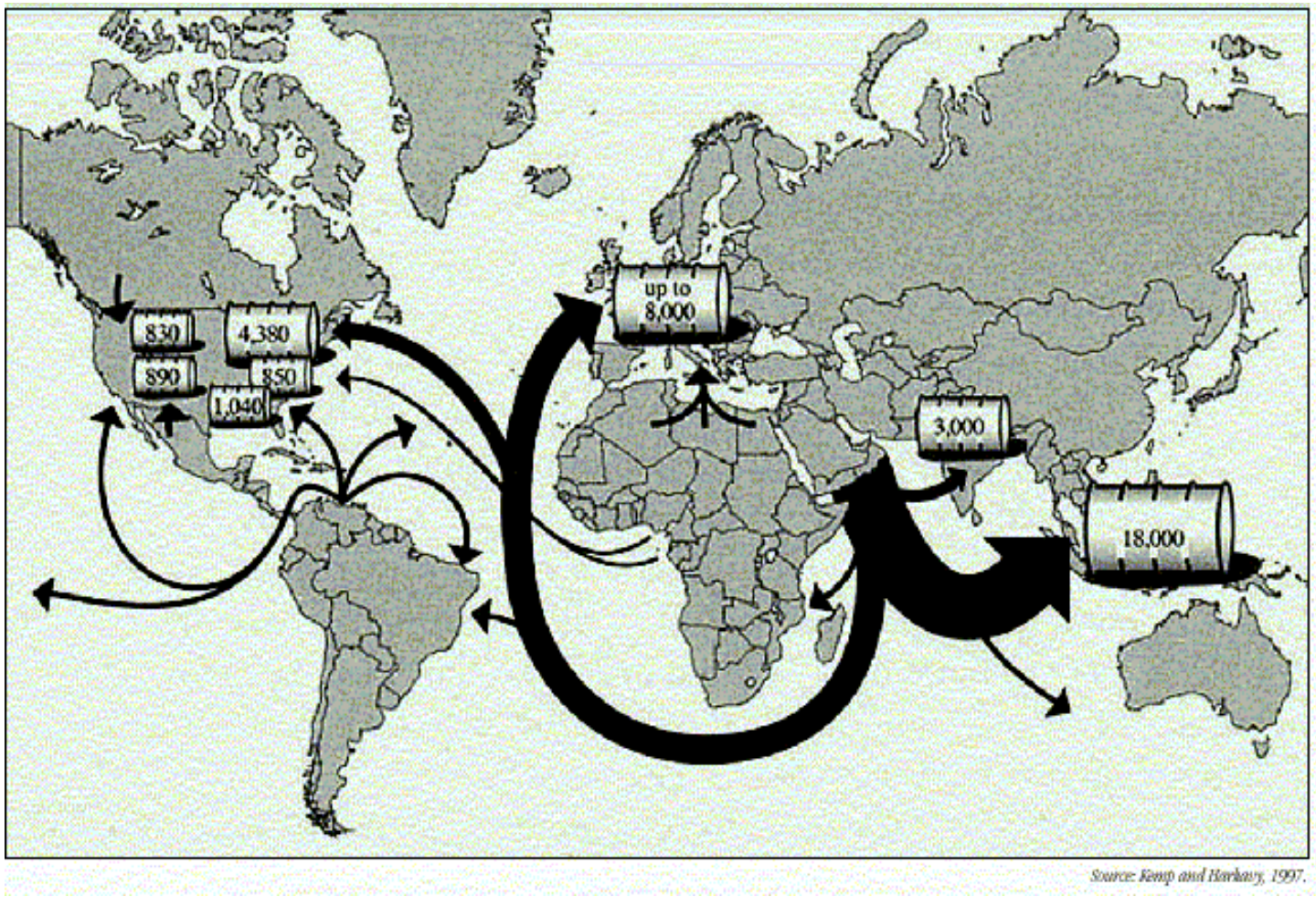
ii. Security of supply

iii. Environmental impacts

Figure 7. Non-OPEC, non-FSU Oil Production Has Peaked and is Declining (Ref. 17

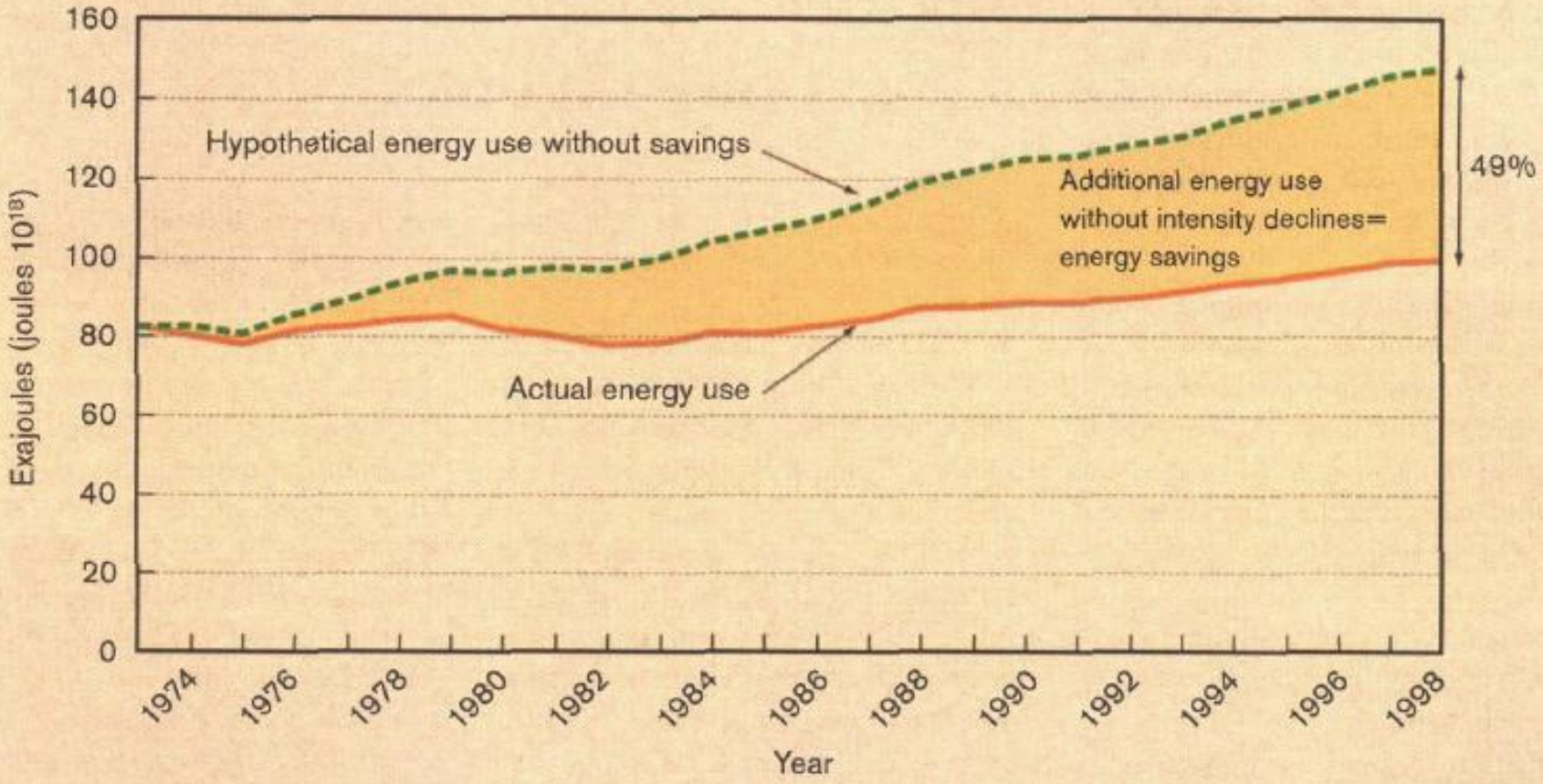


Segurança de Abastecimento

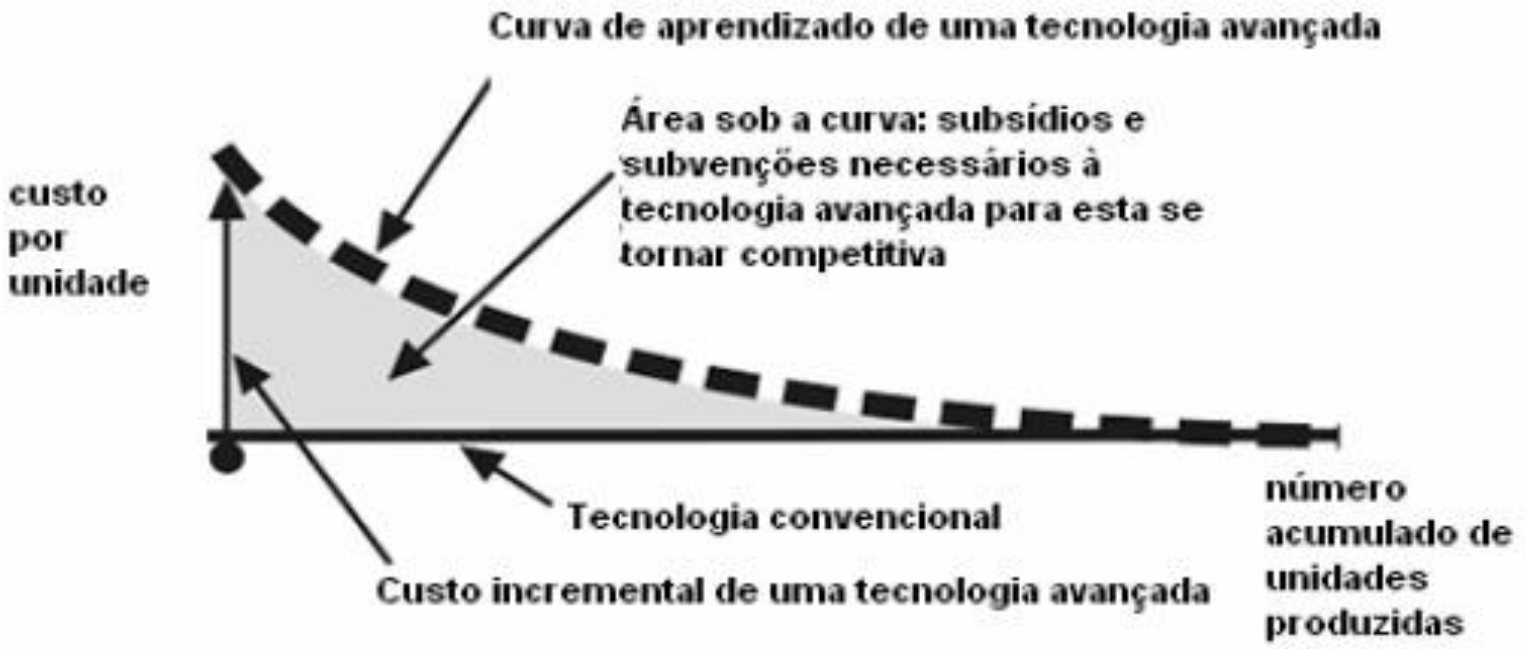


Fluxos de petróleo

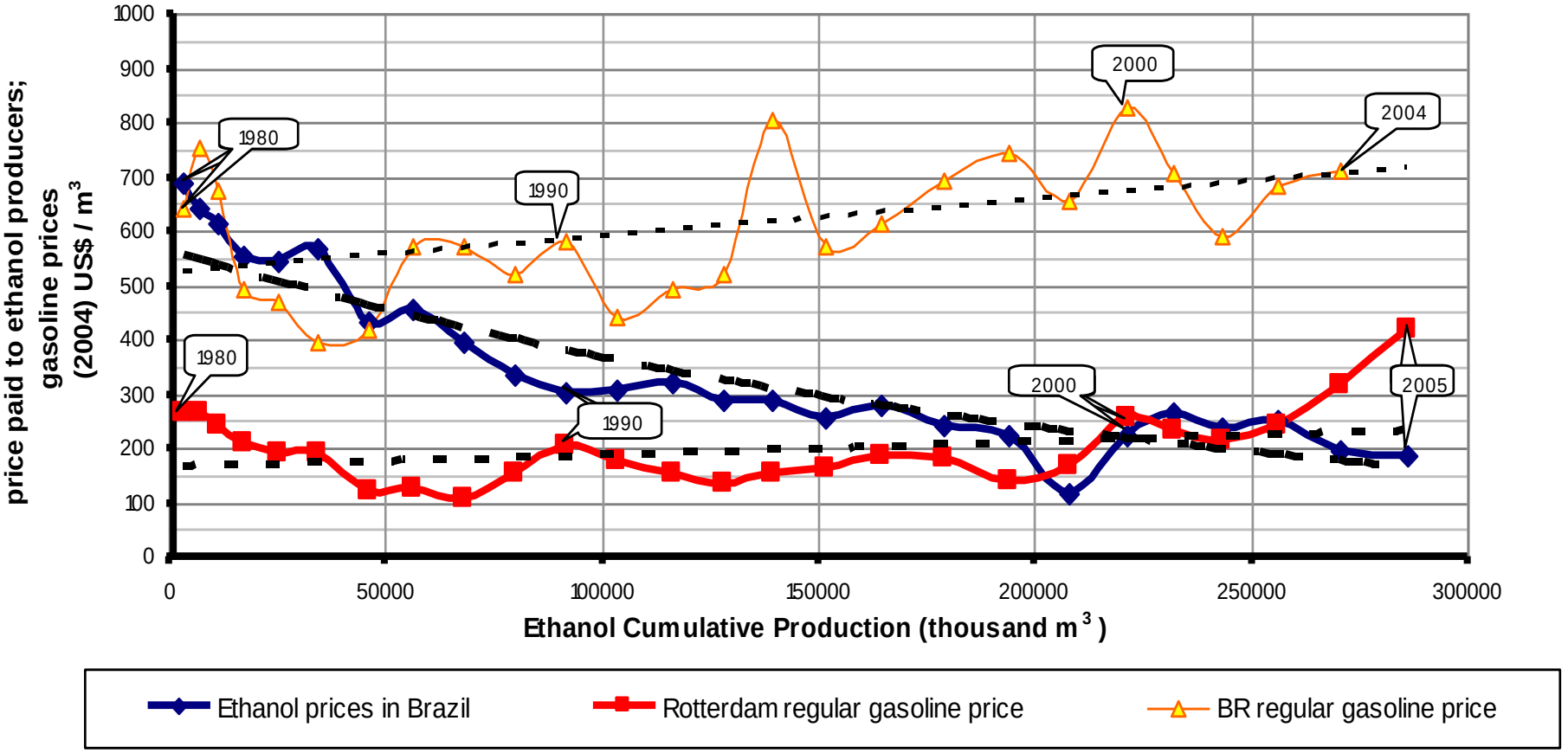
Figure 2. Energy savings in the OECD (1973–1988)

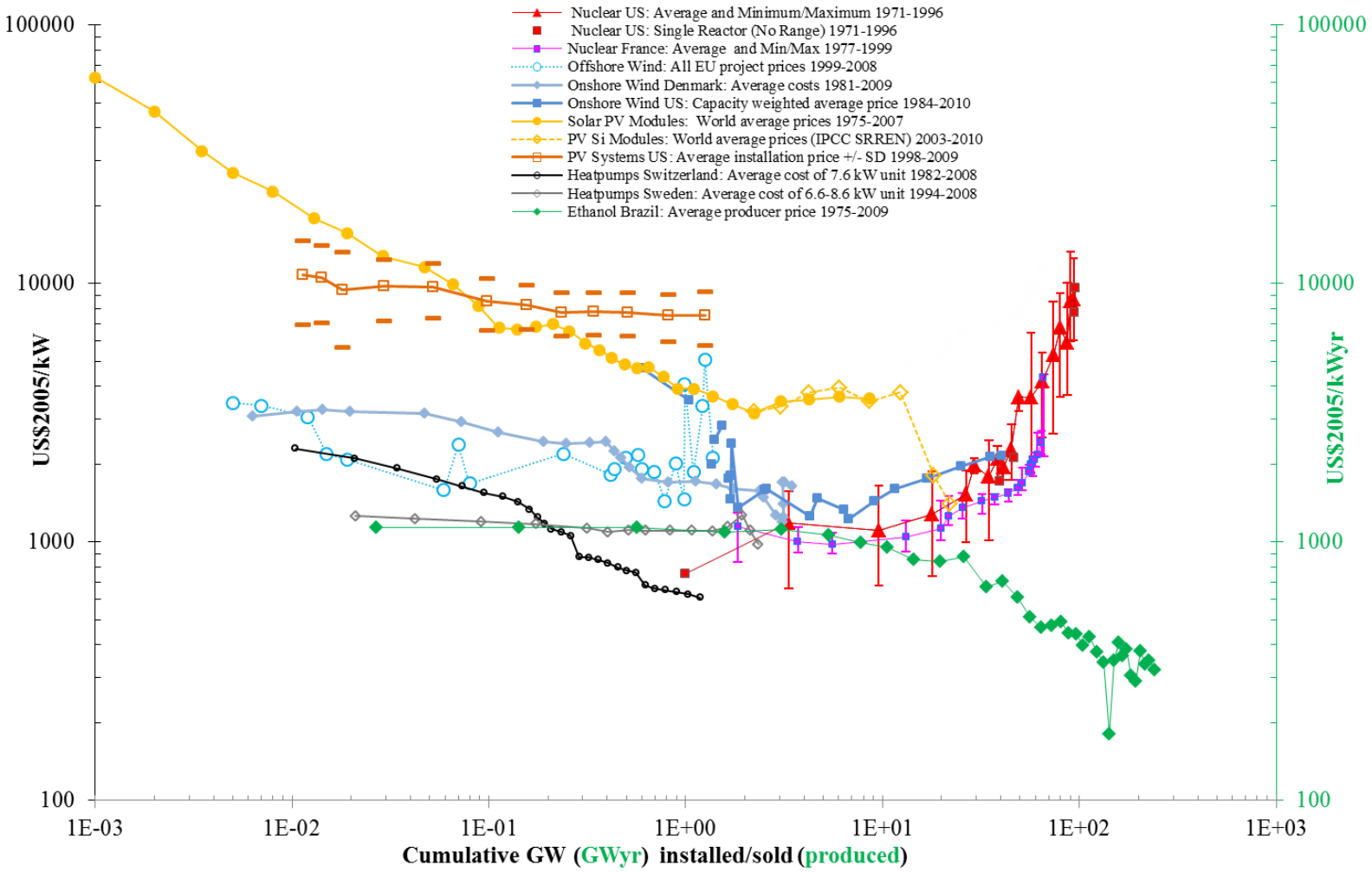


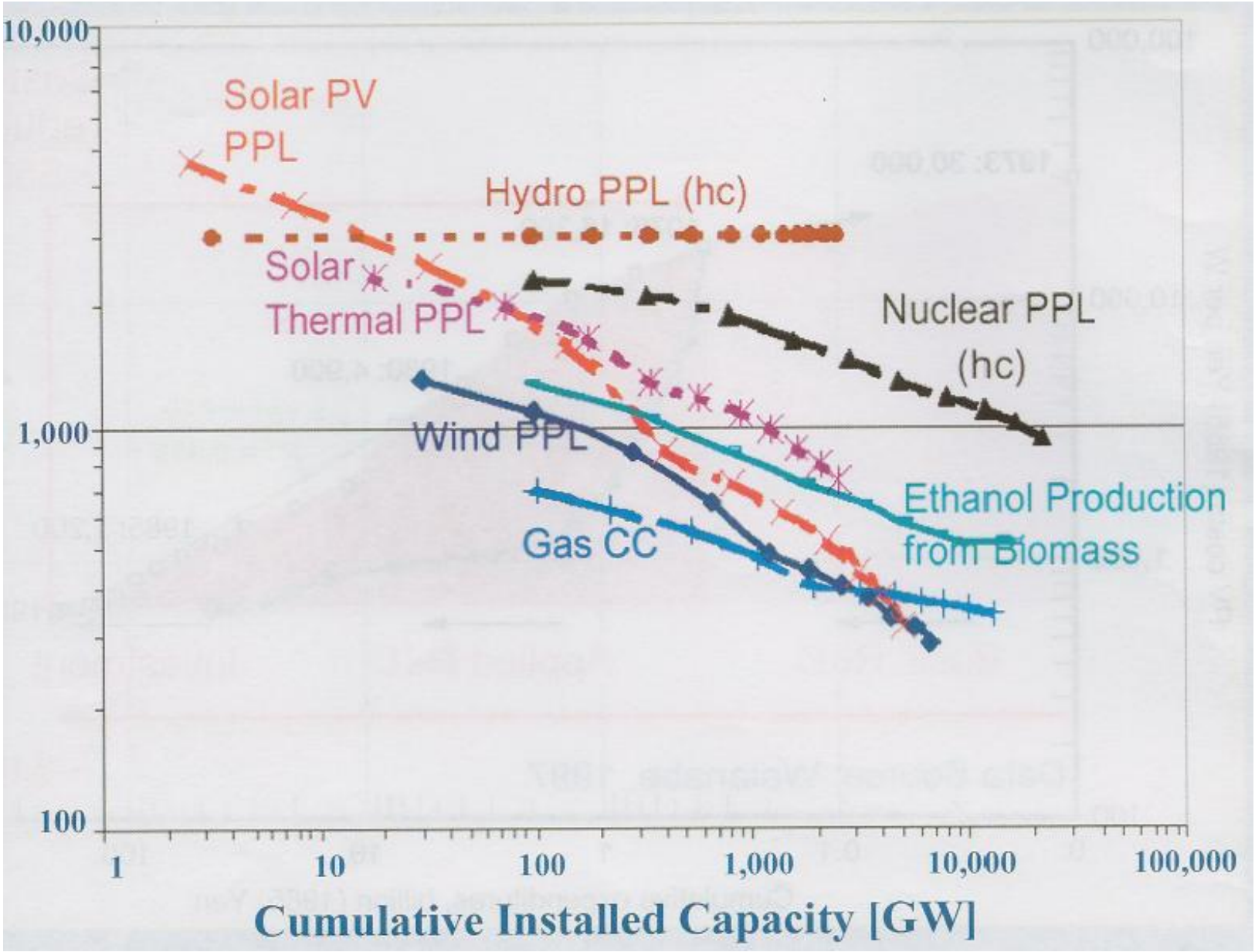
SOURCE: Organisation for Economic Co-operation and Development (OECD)/International Energy Agency (IEA), *Oil Crises and Climate Challenges: 30 Years of Energy Use in IEA Countries* (Paris: OECD/IEA, 2004), http://www.iea.org/textbase/nppdf/free/2004/30years.pdf.

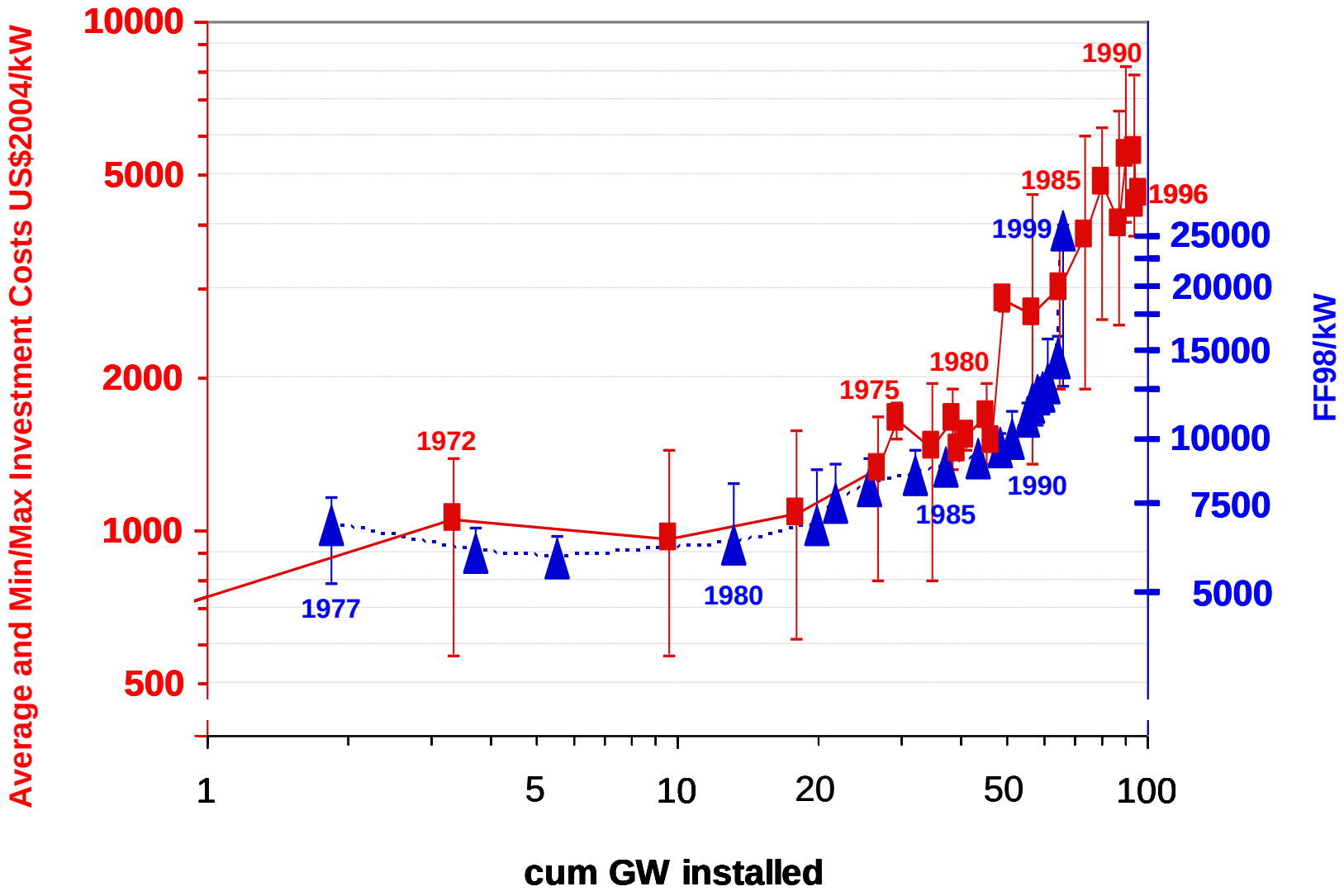

Curva de aprendizado de uma tecnologia avançada
Área sob a curva: subsídios e subvenções necessários à tecnologia avançada para esta se tornar competitiva
custo por unidade
Tecnologia convencional
Custo incremental de uma tecnologia avançada
número acumulado de unidades produzidas

A Competitividade Econômica entre Etanol e Gasolina



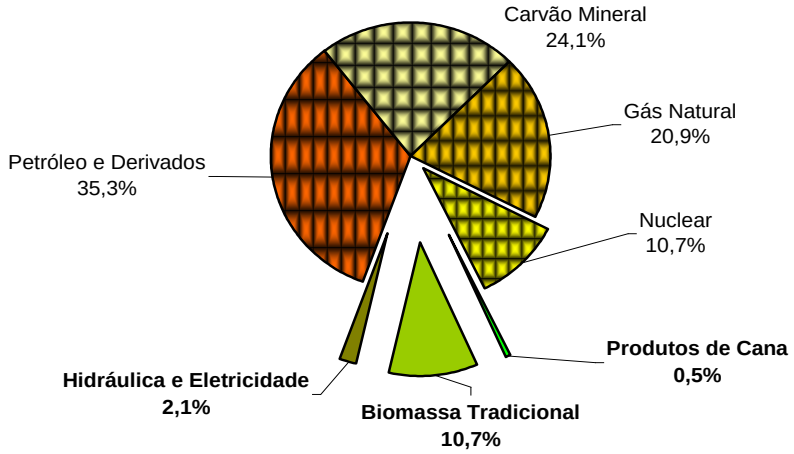

Nuclear US: Average and Minimum/Maximum 1971-1996
Nuclear US: Single Reactor (No Range) 1971-1996
Nuclear France: Average and Min/Max 1977-1999
Offshore Wind: All EU project prices 1999-2008
Onshore Wind Denmark: Average costs 1981-2009
Onshore Wind US: Capacity weighted average price 1984-2010
Solar PV Modules: World average prices 1975-2007
PV Si Modules: World average prices (IPCC SRREN) 2003-2010
PV Systems US: Average installation price +/- SD 1998-2009
Heatpumps Switzerland: Average cost of 7.6 kW unit 1982-2008
Heatpumps Sweden: Average cost of 6.6-8.6 kW unit 1994-2008
Ethanol Brazil: Average producer price 1975-2009
100000
10000
1000
100
US$2005/kW
US$2005/kWyr
1E-03
1E-02
1E-01
1E+00
1E+01
1E+02
1E+03
Cumulative GW (GWyr) installed/sold (produced)


10,000
1,000
100
Solar PV
PPL
Hydro PPL (hc)
Solar
Thermal PPL
Nuclear PPL
(hc)
Wind PPL
Ethanol Production
from Biomass
Gas CC
1
10
100
1,000
10,000
100,000
Cumulative Installed Capacity [GW]


Average and Min/Max Investment Costs US$2004/kW
10000
5000
2000
1000
500
1
5
10
20
50
100
cum GW installed
FF98/kW
25000
20000
15000
10000
7500
5000
1977
1972
1980
1975
1985
1990
1999
1996

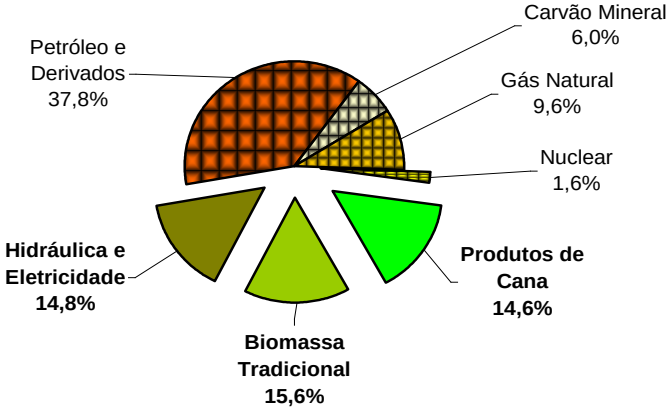
Oferta de energia - Mundo

Energia Renovável: 13,3%



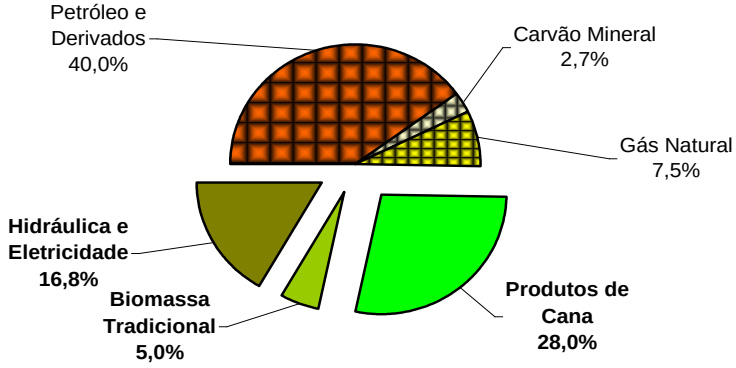
Oferta de Energia - Brasil

Energia Renovável: 45,0%



Oferta de Energia - São Paulo

Energia Renovável: 49,8%



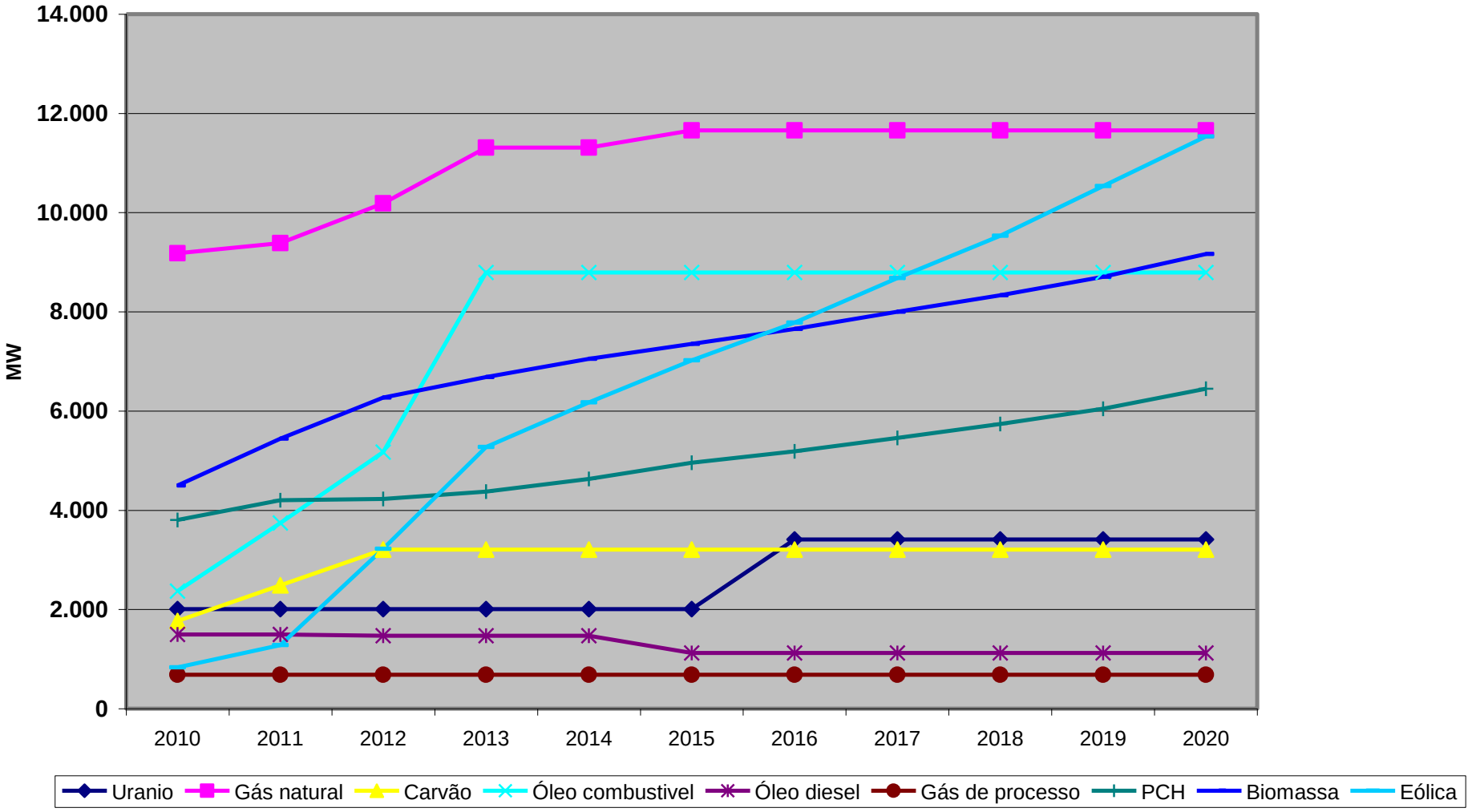
Ano: 2006

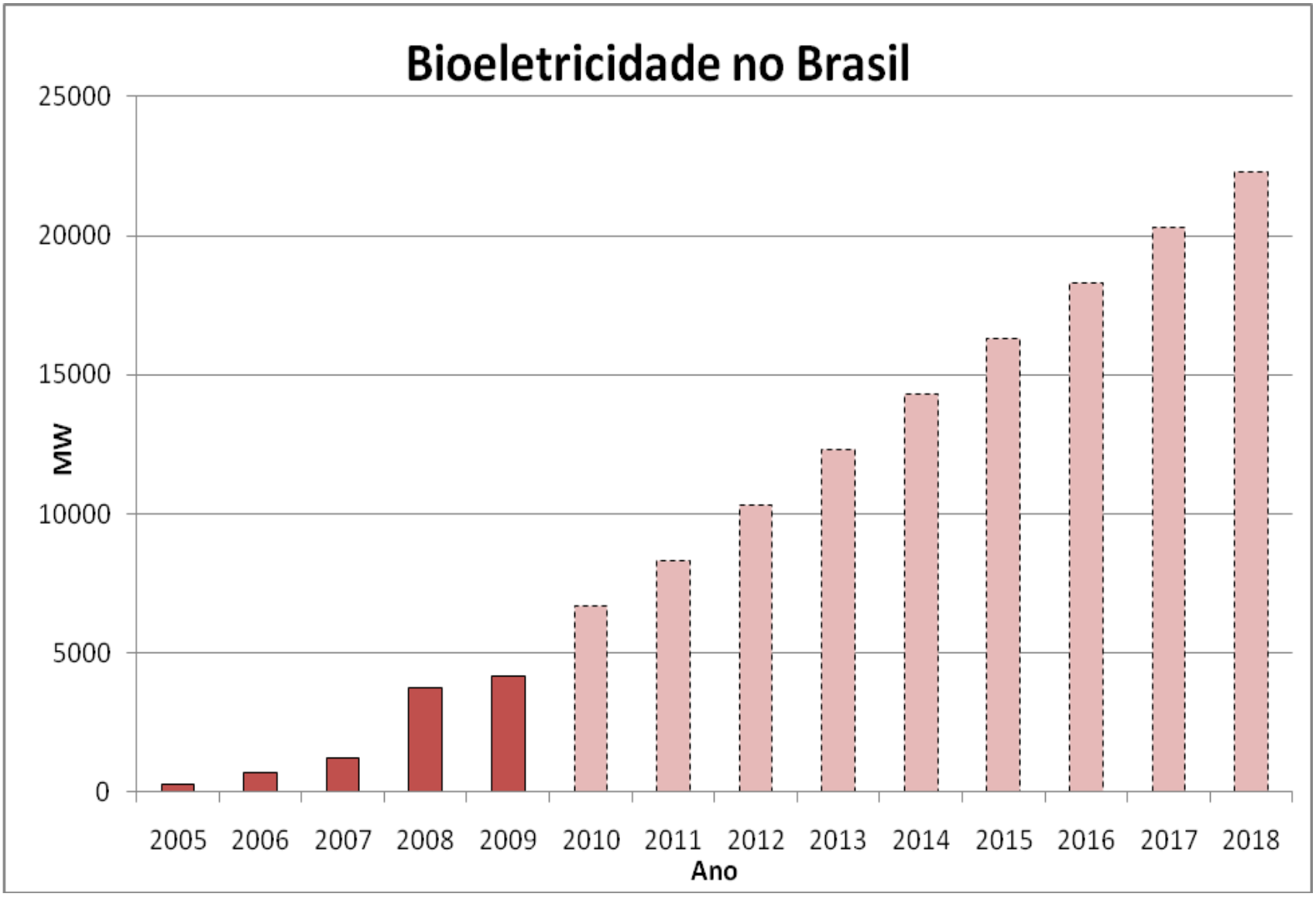
A evolução da matriz energética brasileira (2010 – 2030)

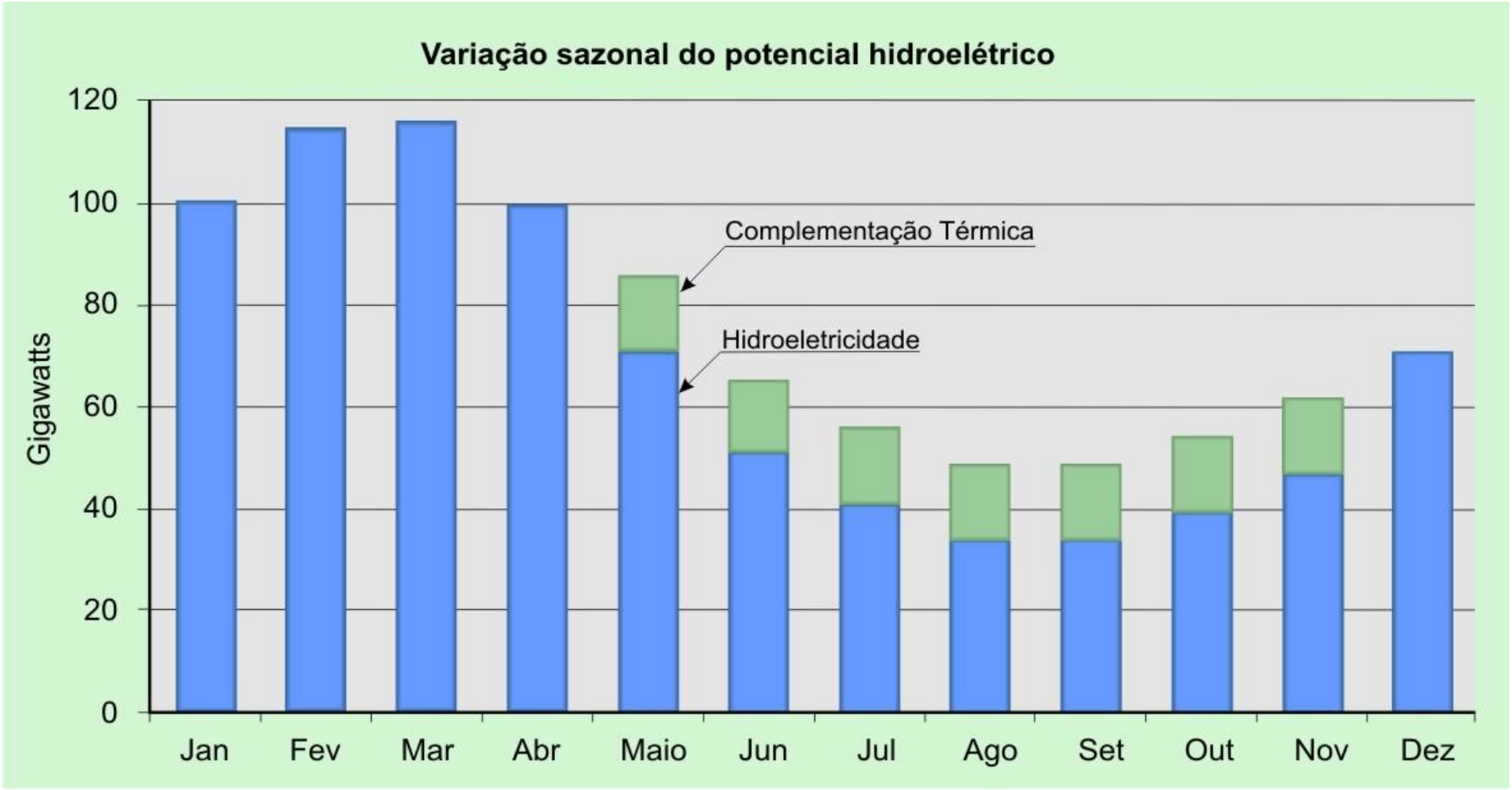
Fontes	2010	2020	2030
Hidroelétricas (incluindo Itaipu)	82.90	115.1	148.6
Térmicas	17.5	28.9	42.6
Gás Natural	9.2	11.7	17.5
Nuclear	2.0	3.4	7.4
Carvão	1.8	3.2	4.9
Outras	4.5	10.6	12.88
Alternativas	9.1	27.0	40.8
PCHs (Pequenas Centrais Hidroelétricas)	3.8	6.4	9.0
Eólica	0.8	11.5	13.5
Biomassa	4.5	9.1	22.3
Total	109,6	171.1	232.0

Fontes PDE 2020
PNE 2030

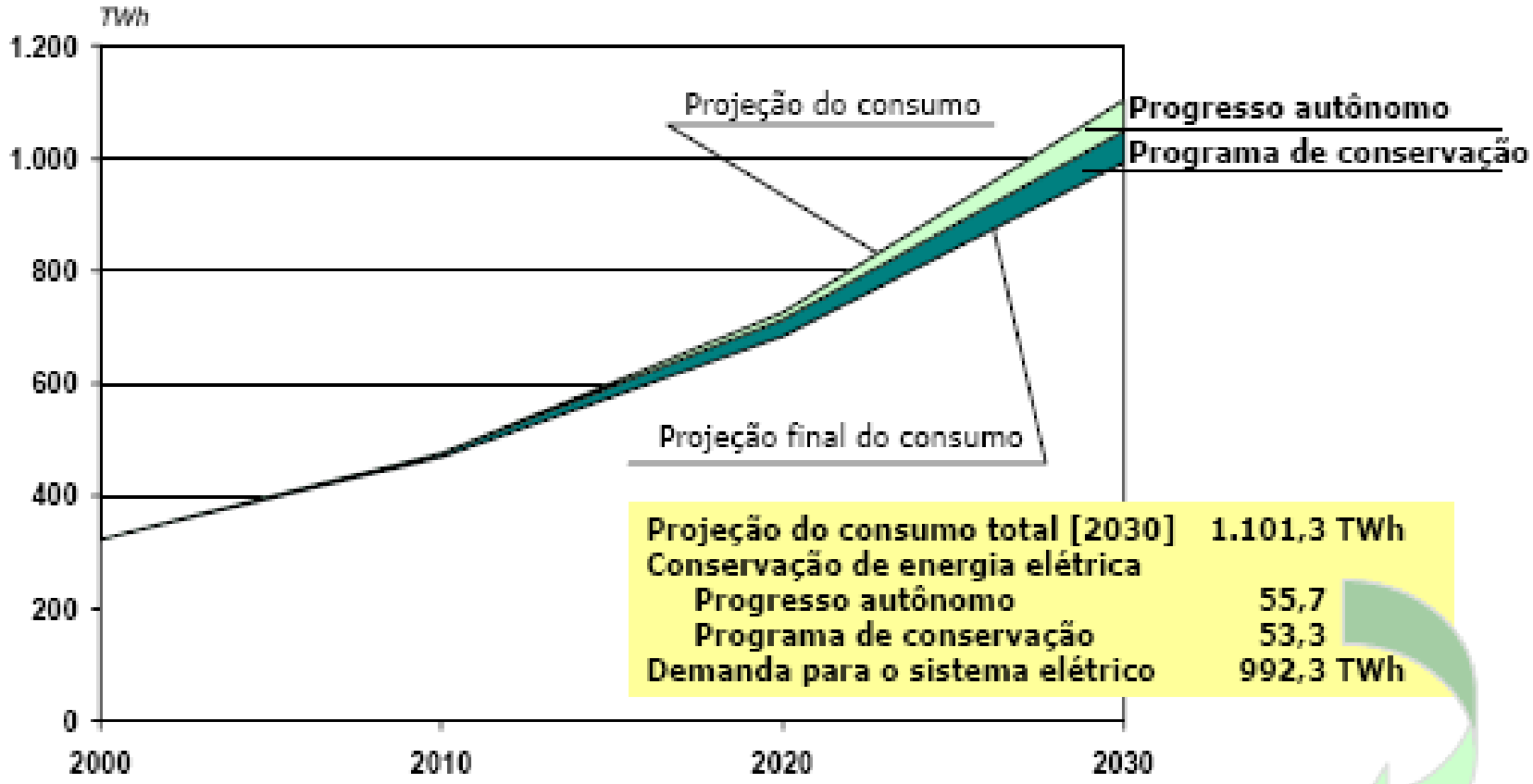
EVOLUÇÃO DA CAPACIDADE INSTALADA EXCLUINDO HIDRO (MW)




Bioeletricidade no Brasil
25000
20000
15000
10000
5000
0
MW
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
Ano


Variação sazonal do potencial hidroelétrico
Gigawatts
120
100
80
60
40
20
0
Complementação Térmica
Hidroeletricidade
Jan
Fev
Mar
Abr
Maio
Jun
Jul
Ago
Set
Out
Nov
Dez

Consumo final de eletricidade: conservação



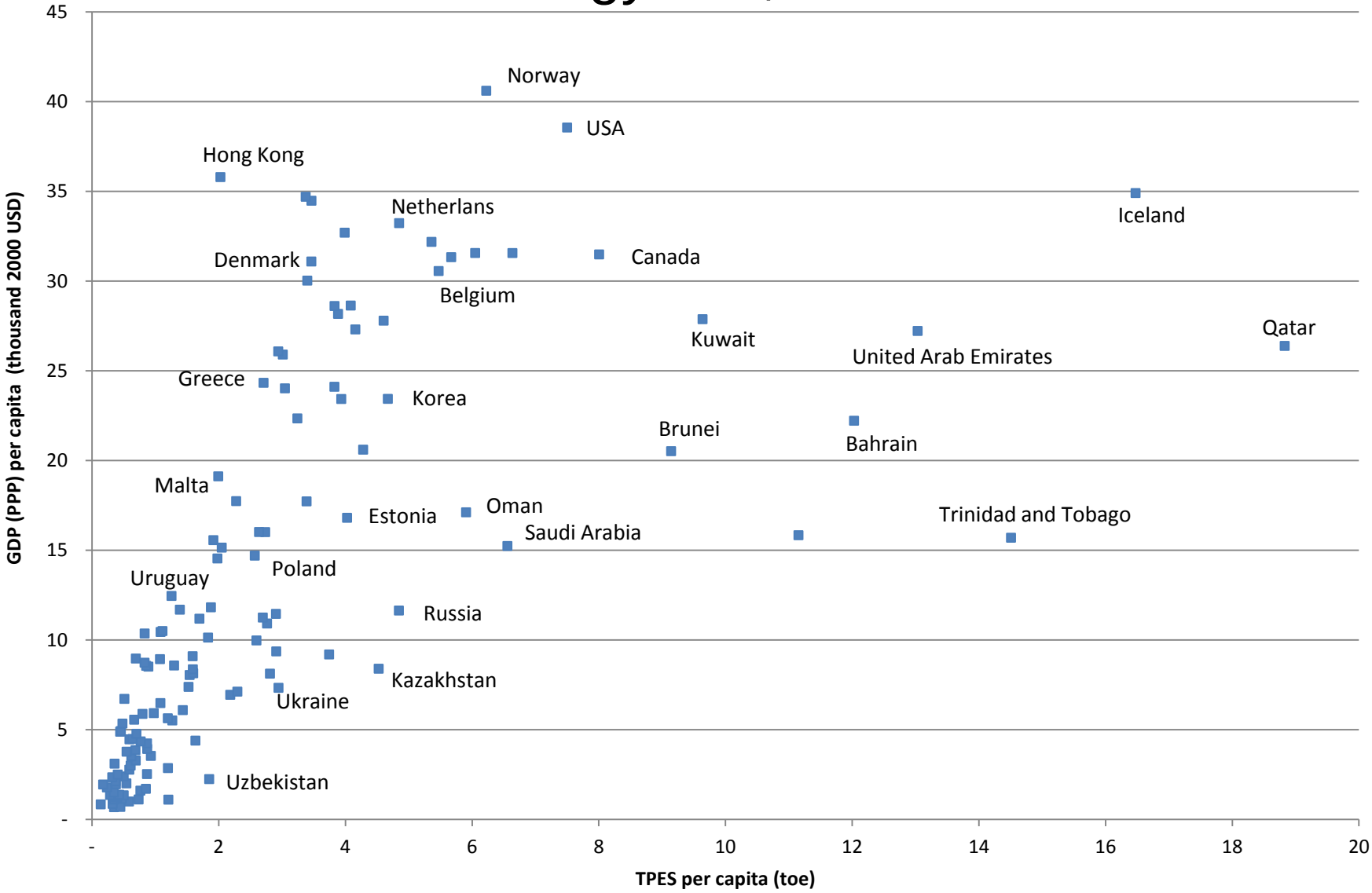
Projeção do consumo total [2030]	1.101,3 TWh
Conservação de energia elétrica	
Progresso autônomo	55,7
Programa de conservação	53,3
Demanda para o sistema elétrico	992,3 TWh

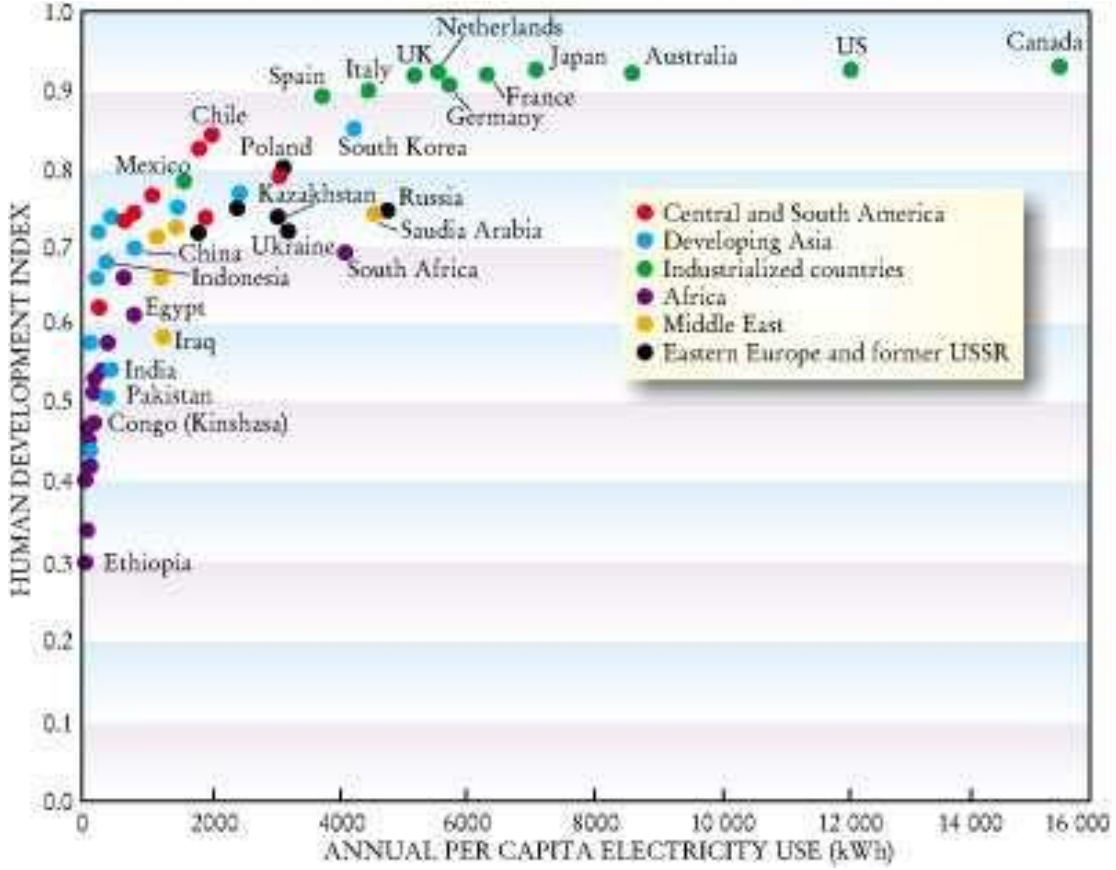
Em 2030, cerca de 10% da demanda será atendida por meio da conservação de energia

Fonte: EPE

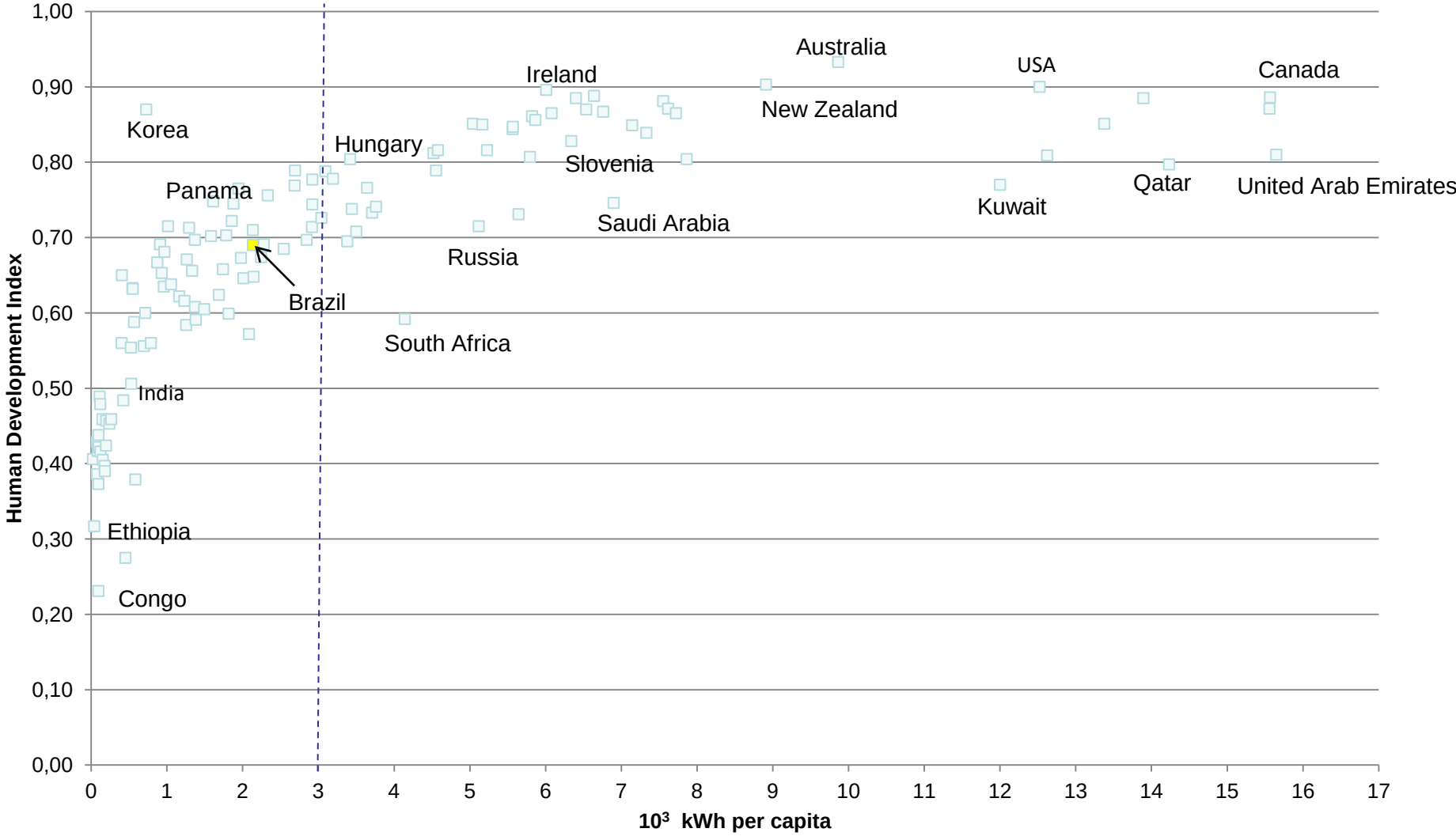
Obs.: consumo final de energia exclusive consumo não energético e consumo do setor energético

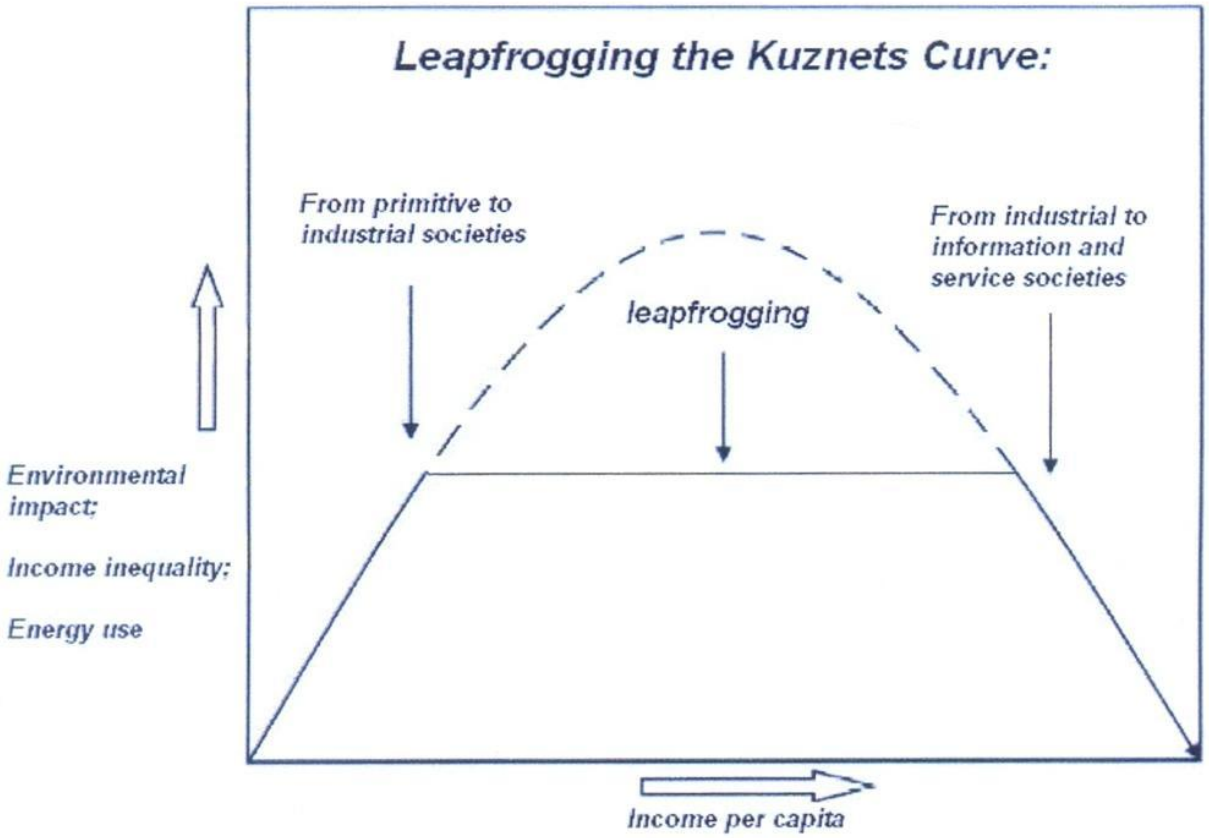
Relation between GDP per capita and per capita energy use, 2008




HUMAN DEVELOPMENT INDEX
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
2000
4000
6000
8000
10 000
12 000
14 000
16 000
ANNUAL PER CAPITA ELECTRICITY USE (kWh)
Netherlands
UK
Japan
Australia
US
Canada
Spain
Italy
France
Germany
Chile
Poland
South Korea
Mexico
Kazakhstan
Russia
Saudia Arabia
China
Ukraine
South Africa
Indonesia
Egypt
Iraq
India
Pakistan
Congo (Kinshasa)
Ethiopia
Central and South America
Developing Asia
Industrialized countries
Africa
Middle East
Eastern Europe and former USSR

HDI *vs* kWh/capita (2008)




Leapfrogging the Kuznets Curve:
From primitive to industrial societies
leapfrogging
From industrial to information and service societies
Environmental impact:
Income inequality:
Energy use
Income per capita