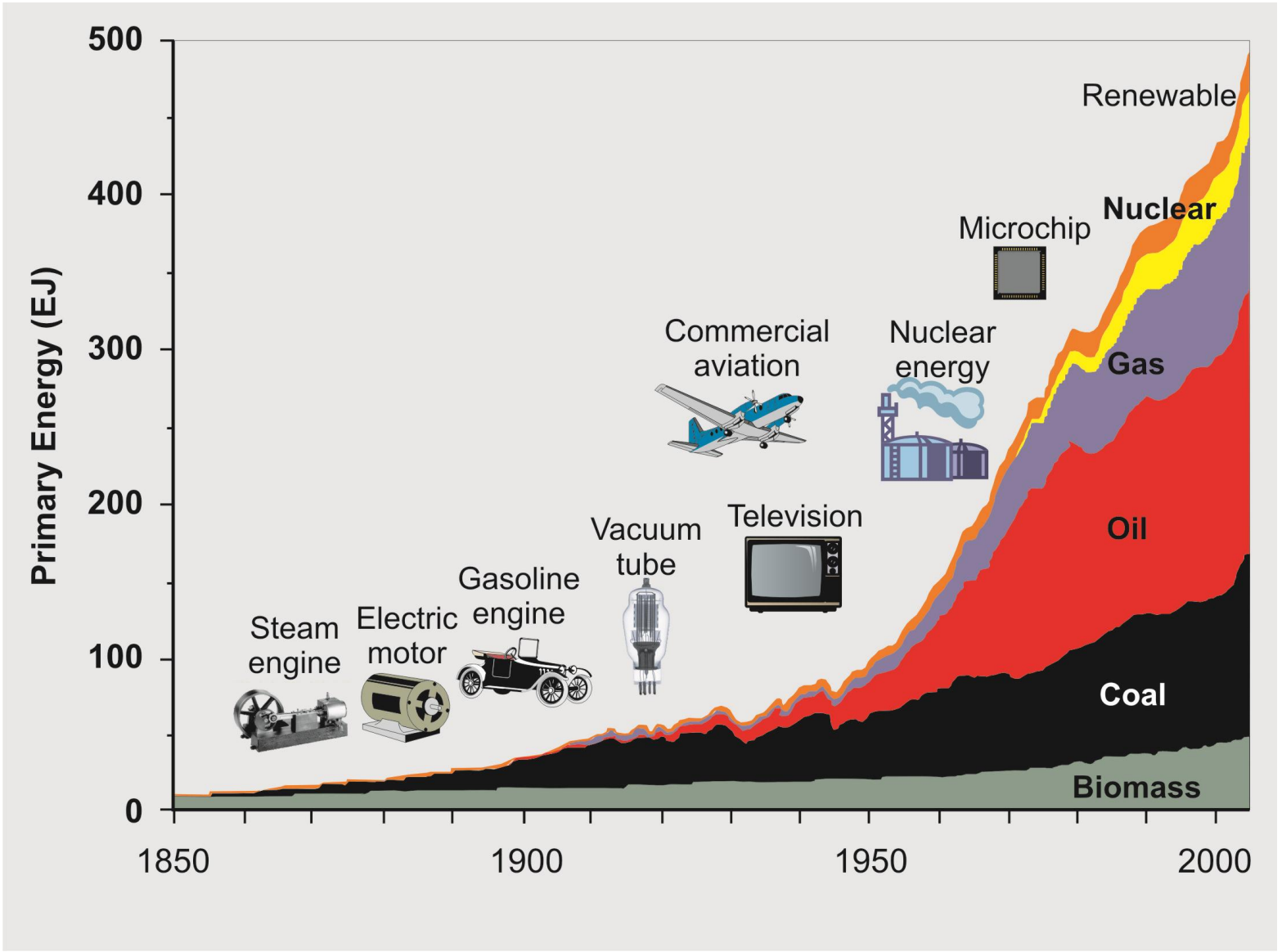
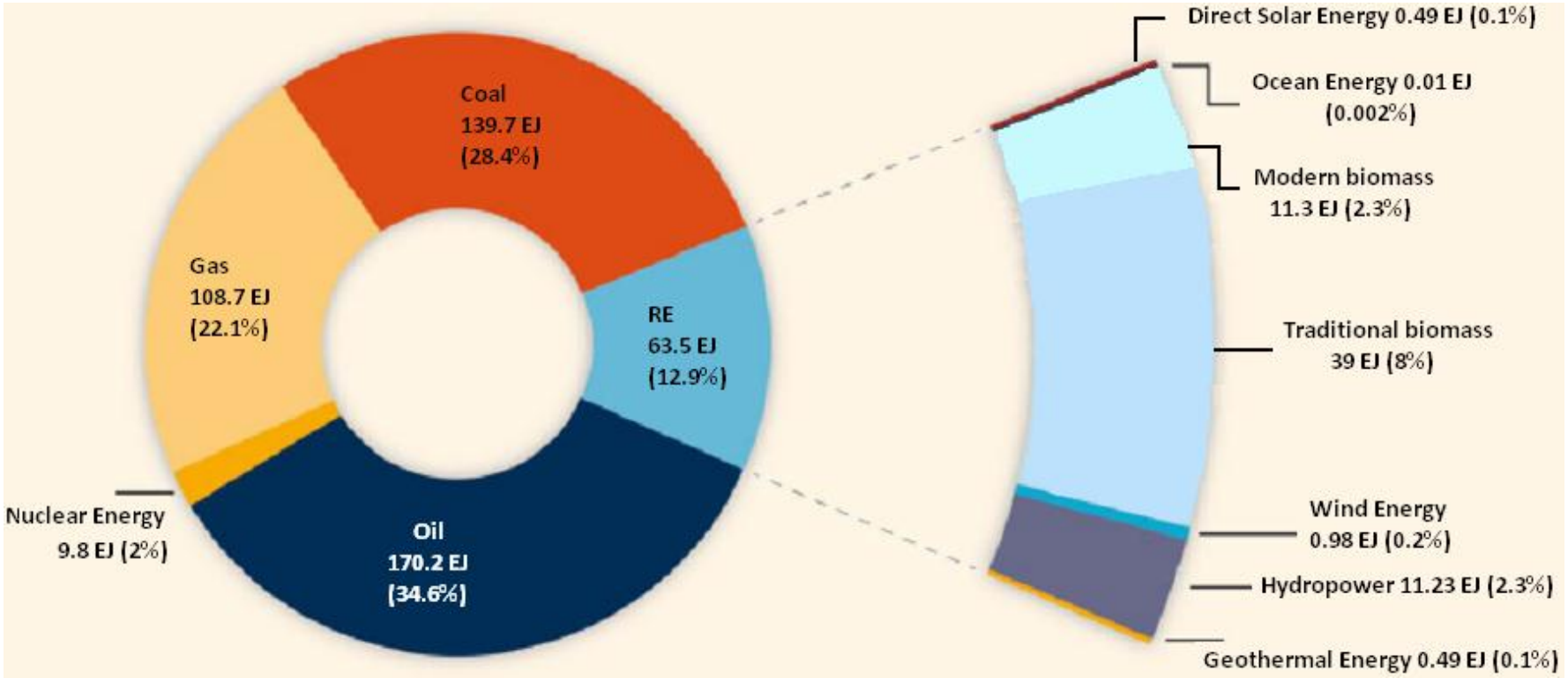
# BIOEN-BIOTA PFP SCOPE
# Joint Workshop on Biofuels & Sustainability

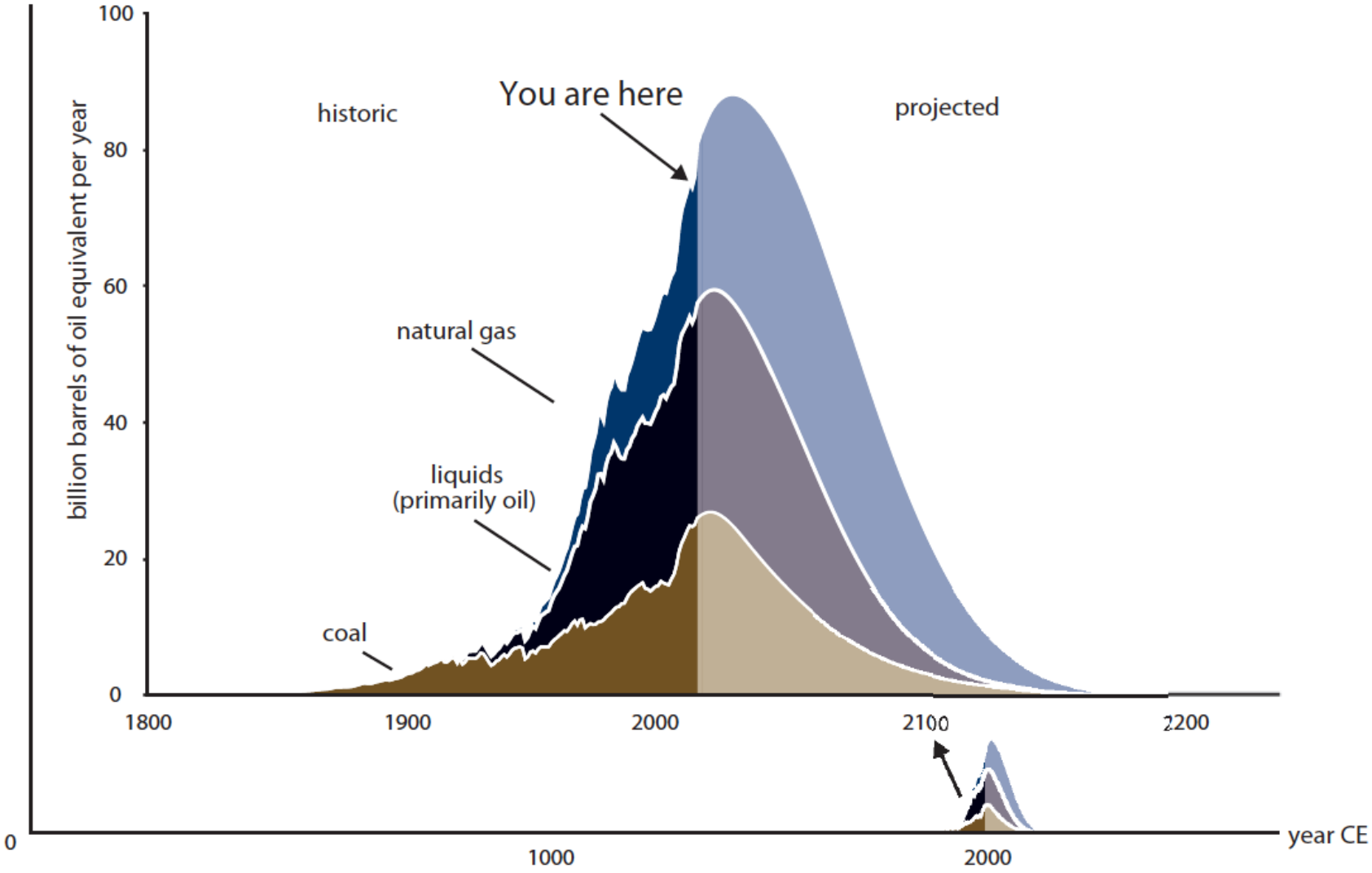
Professor José Goldemberg

26/02/2013


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


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%)

# Fossil fuels: global production, 1800–2200



# HYDROCARBONS*

BELLOW GROUND
(fossil fuels)

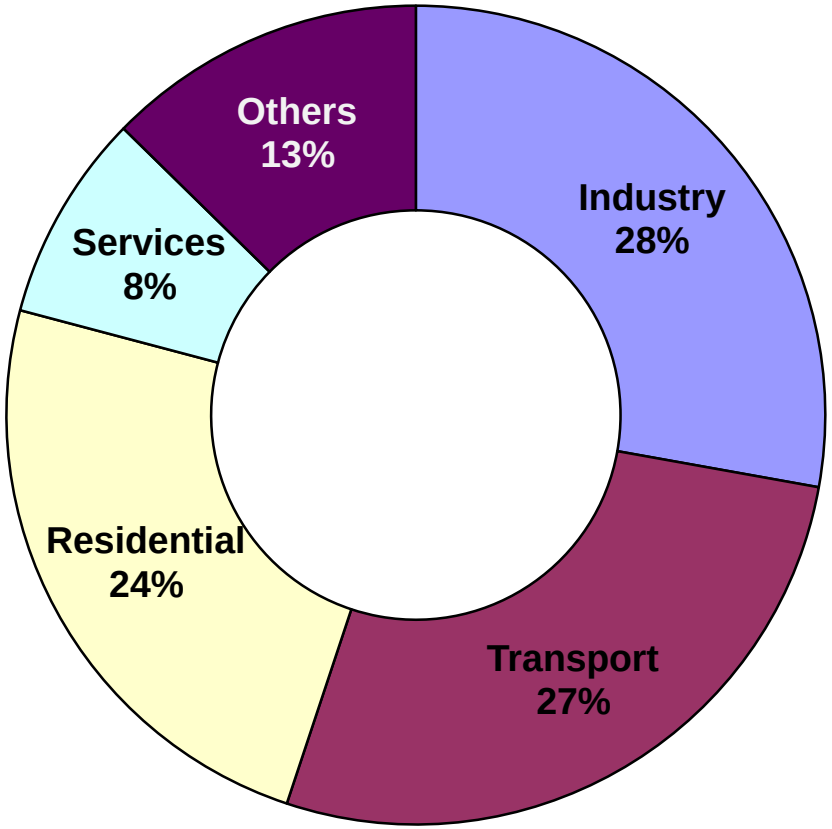
RESOURCE BASE:  0.35-2 trillions tons
Consumption: ≈ 10 billion tons/year

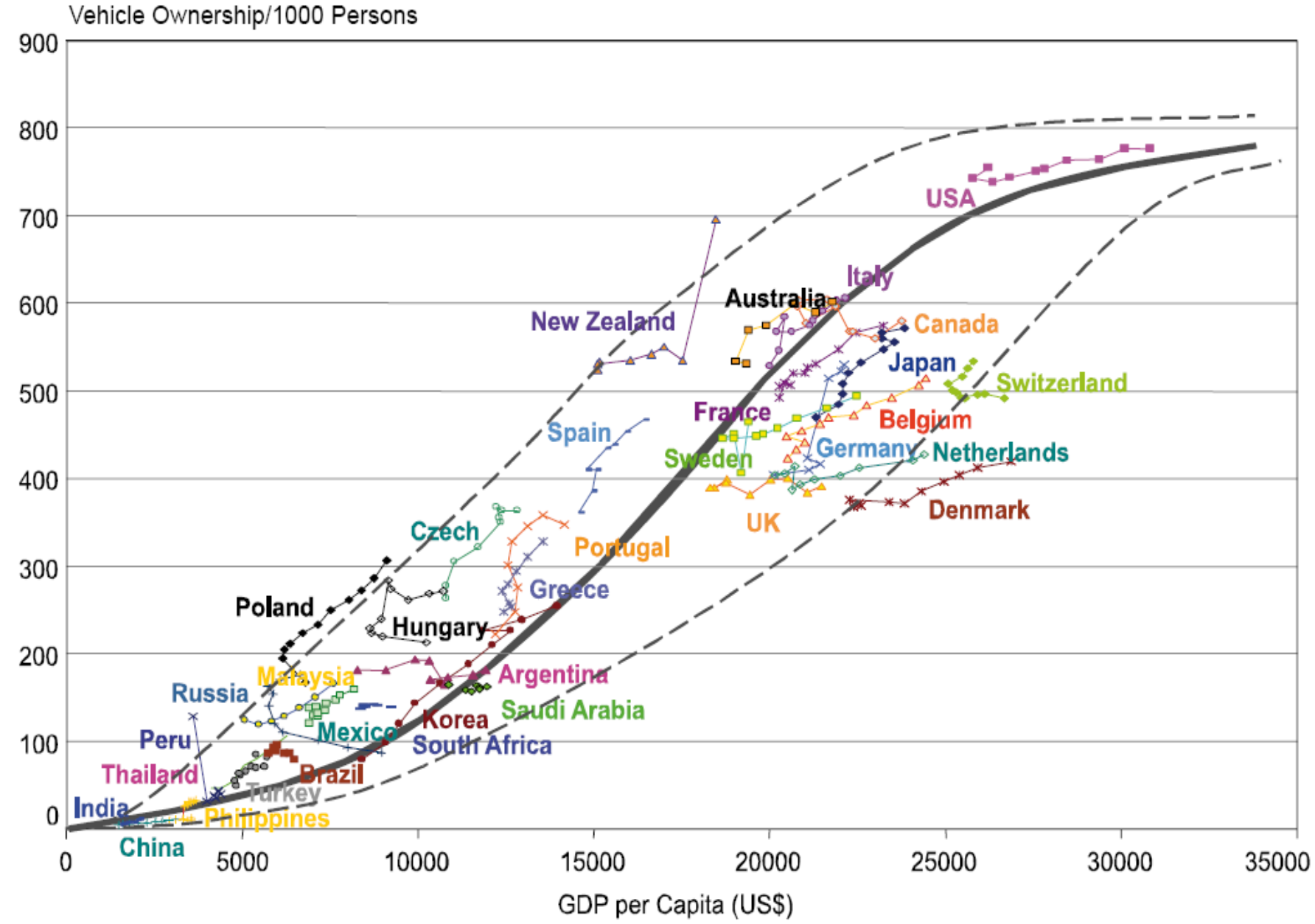
ABOVE GROUND
(forest and crops)

RESOURCE BASE : 1 trillion tons

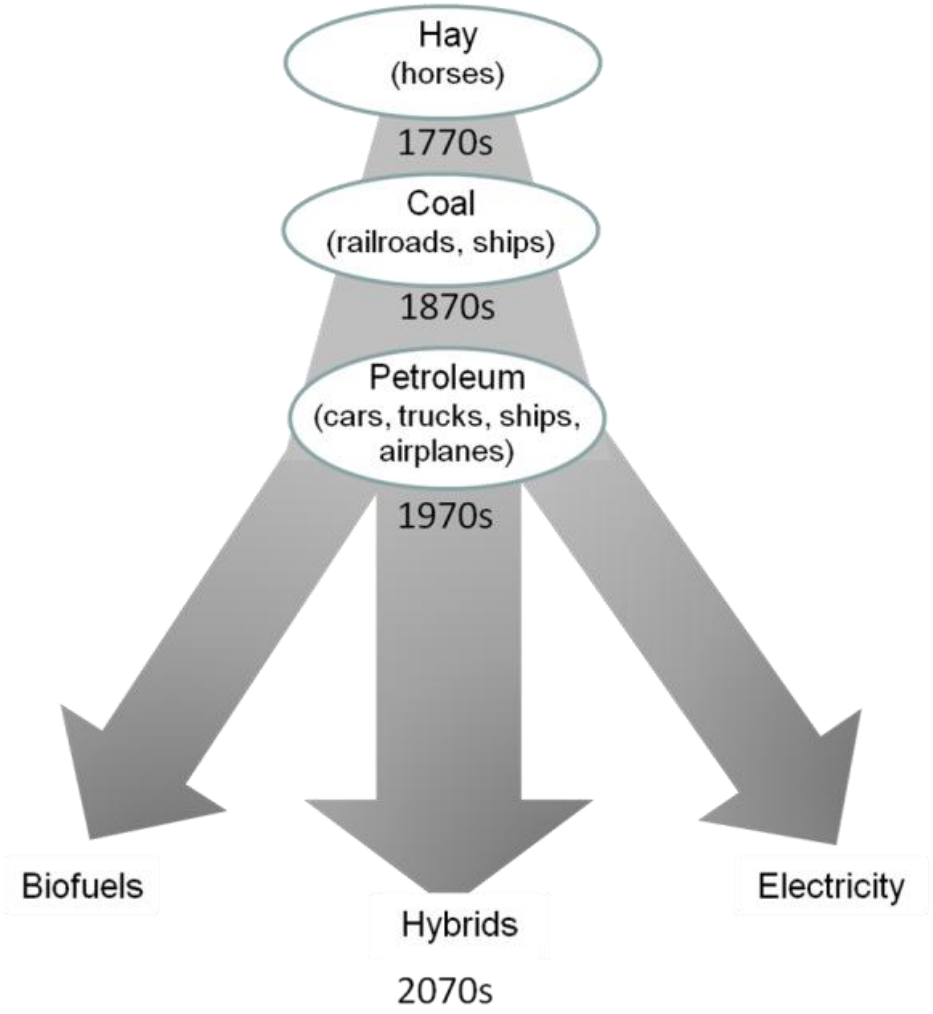
* Hydrocarbons are organic compounds consisting entirely of hydrogen and carbon

## WORLD'S SETORIAL SHARES OF TOTAL FINAL CONSUMPTION
## 2008

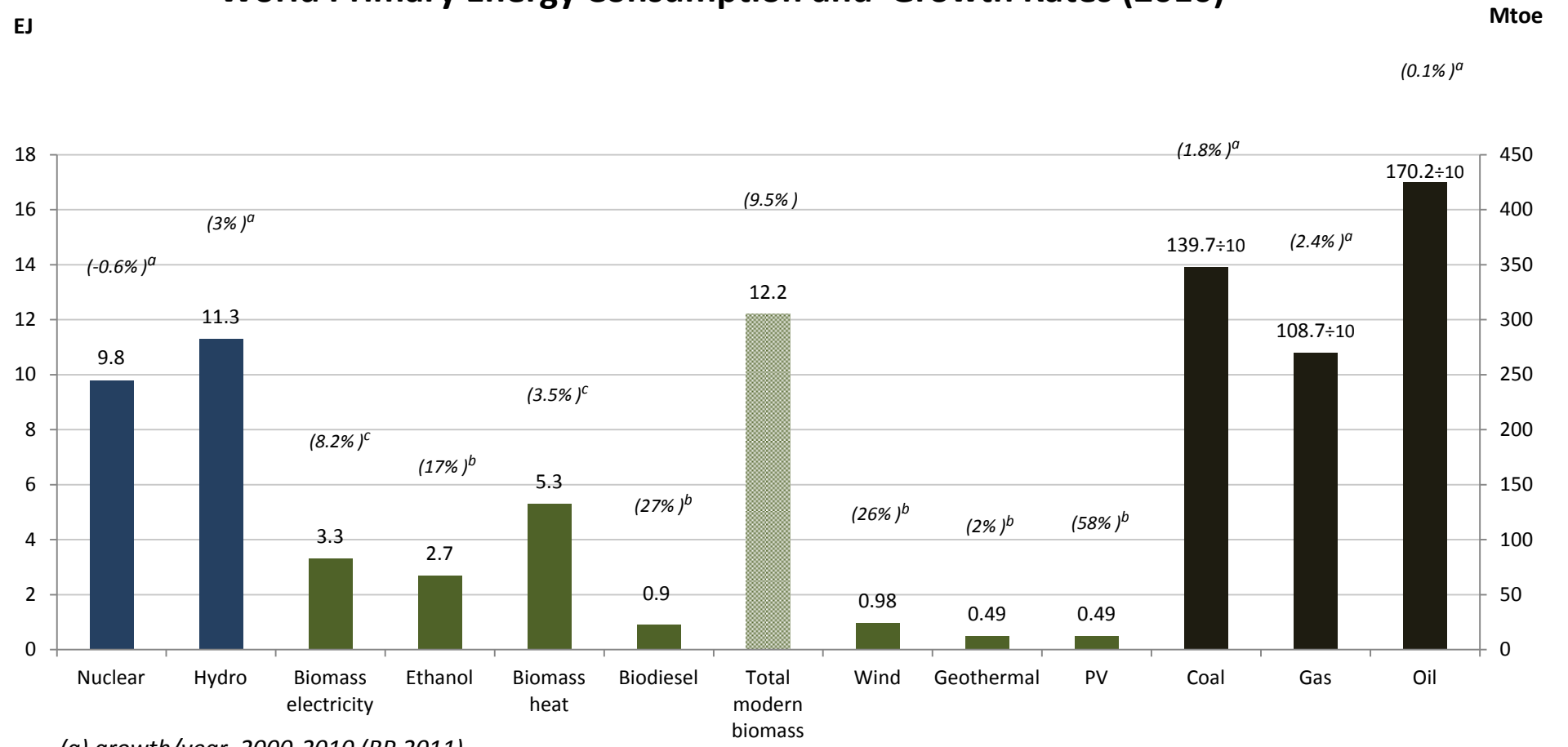



Vehicle Ownership/1000 Persons
900
800
700
600
500
400
300
200
100
0
0
5000
10000
15000
20000
25000
30000
35000
GDP per Capita (US$)
USA
Italy
Australia
New Zealand
Canada
Japan
Switzerland
France
Belgium
Spain
Germany
Netherlands
Sweden
Denmark
UK
Czech
Portugal
Greece
Poland
Hungary
Malaysia
Argentina
Russia
Saudi Arabia
Korea
Mexico
Peru
South Africa
Thailand
Brazil
Turkey
India
Philippines
China

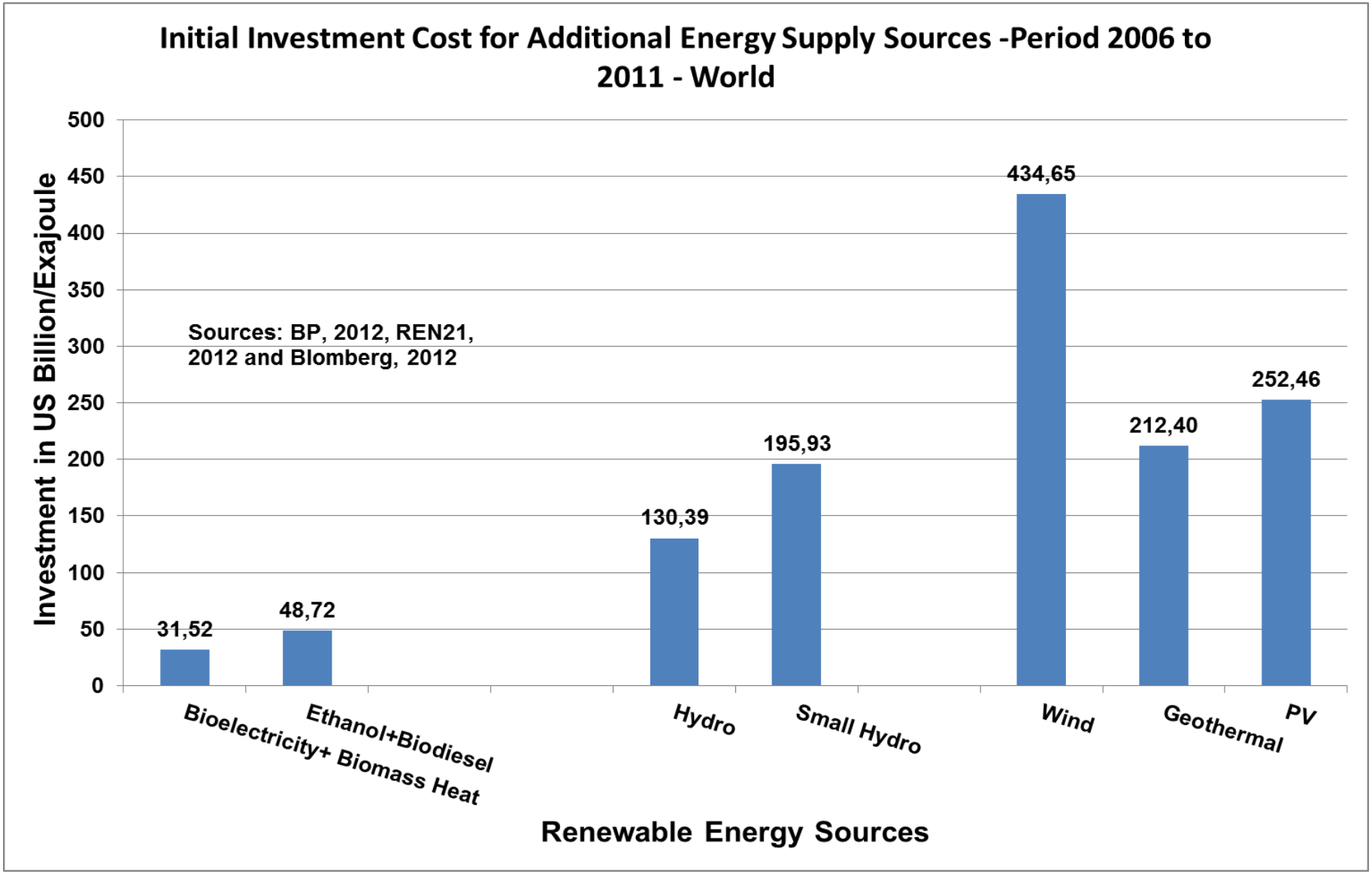
# The Evolution of Transportation



# World Primary Energy Consumption and Growth Rates (2010)




*(a) growth/year 2000-2010 (BP,2011)*
*(b) growth/year 2006-2011 (REN21, 2012)*
*(c) growth/year 2010-2011 (REN21, 2012)*

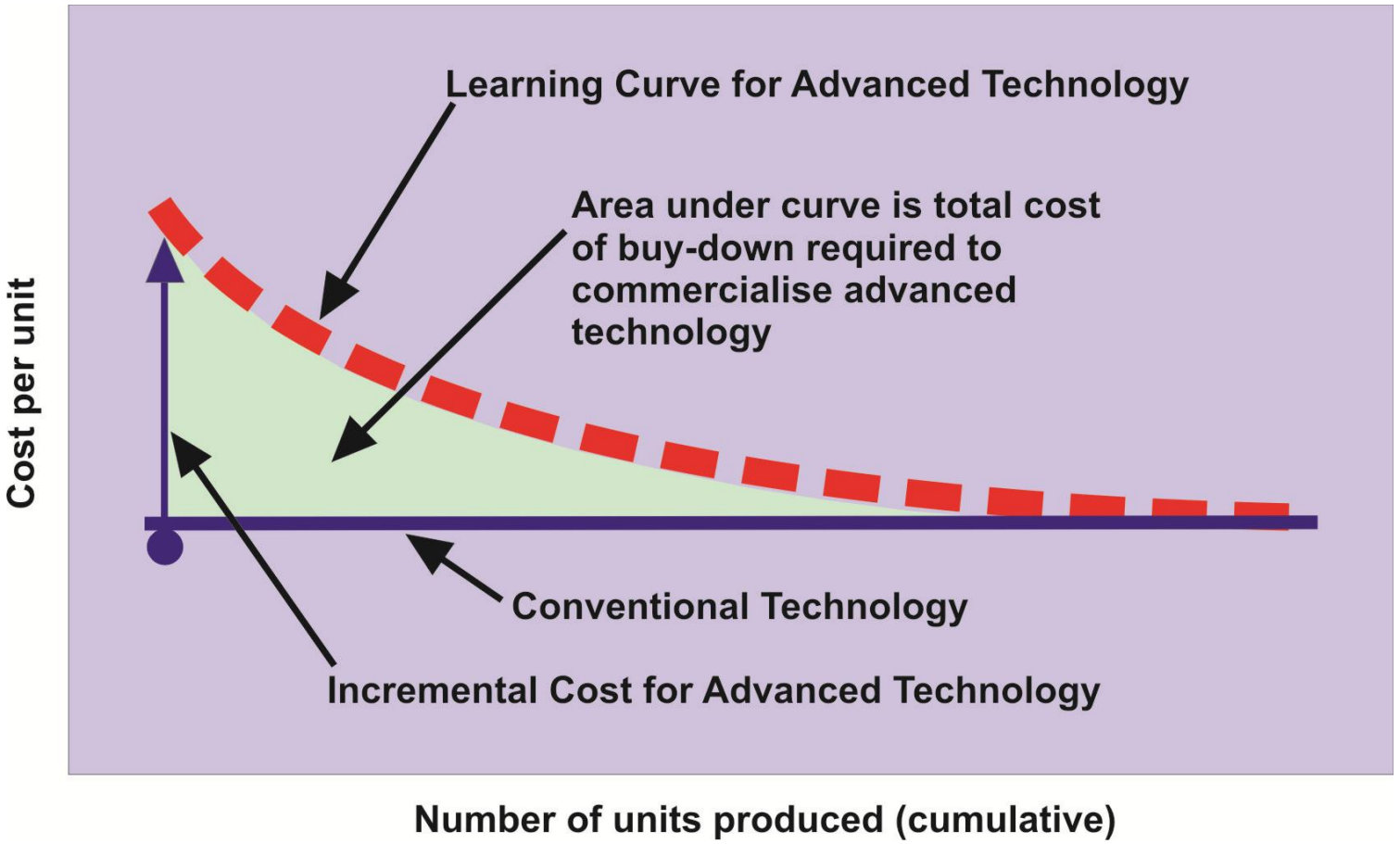

Initial Investment Cost for Additional Energy Supply Sources -Period 2006 to 2011 - World
Investment in US Billion/Exajoule
500
450
400
350
300
250
200
150
100
50
0
Sources: BP, 2012, REN21, 2012 and Blomberg, 2012
31,52
48,72
130,39
195,93
434,65
212,40
252,46
Bioelectricity+ Biomass Heat
Ethanol+Biodiesel
Hydro
Small Hydro
Wind
Geothermal
PV
Renewable Energy Sources

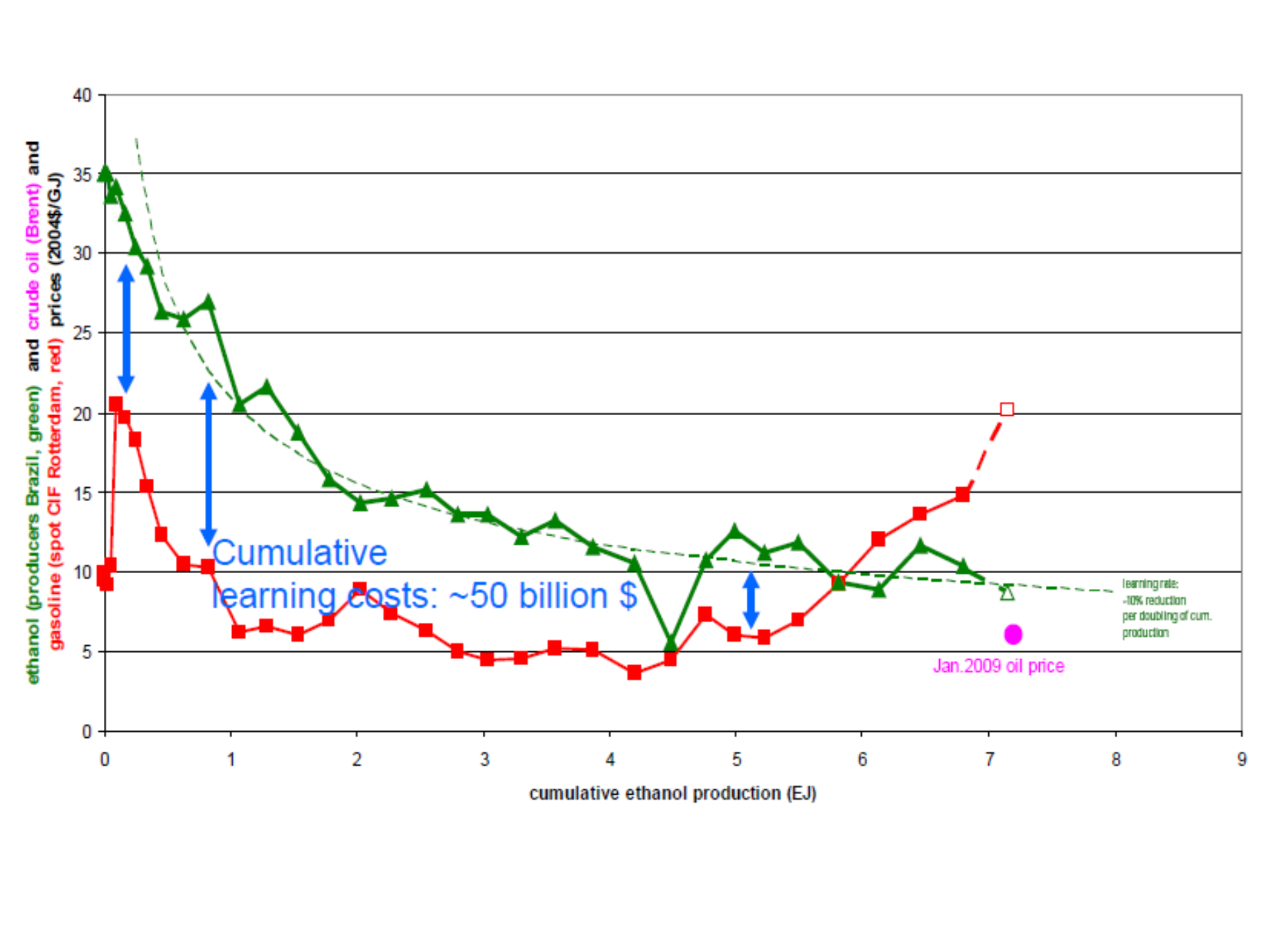
# Renewable energy growth and amount of financing in the period 2011-2006

| Energy source | Annual energy growth rate 2011/2006 | Incremental Energy (EJ) 2011-2006 | | 2011-2006 | Investment 2011/2006 (US$) | Investment value (USB$/EJ) |
|---|---|---|---|---|---|---|
| Total Renewables | | 6.17 | | 6.17 | 1105.65 | 1306.07 |
| Modern biomass | | 4.20 | | 4.20 | 165.70 | 0.00 |
| Bioelectricity | 9.10% | 1.271 | Bioelectricity + Biomass Heat | 2.253 | 71.00 | 31.52 |
| Ethanol | 17.00% | 1.246 | Ethanol+Bio diesel | 1.944 | 94.70 | 48.72 |
| Biomass heat | 4.00% | 0.982 | | | | |
| Biodiesel | 27.00% | 0.698 | | | | |
| Hydro | | **2.175*** | | **2.175*** | **283.65*** | 130.39 |
| Small Hydro | 5.00% | 0.161 | | 0.161 | 31.60 | 195.93 |
| Nuclear | | | | | | |
| Wind | 26.00% | 0.931 | | 0.931 | 404.70 | 434.65 |
| Geothermal | 2.00% | 0.060 | | 0.060 | 12.70 | 212.40 |
| PV | 58.00% | 0.821 | | 0.821 | 207.30 | 252.46 |
| Coal | | | | | | |
| Gas | | | | | | |
| Oil | | | | | | |

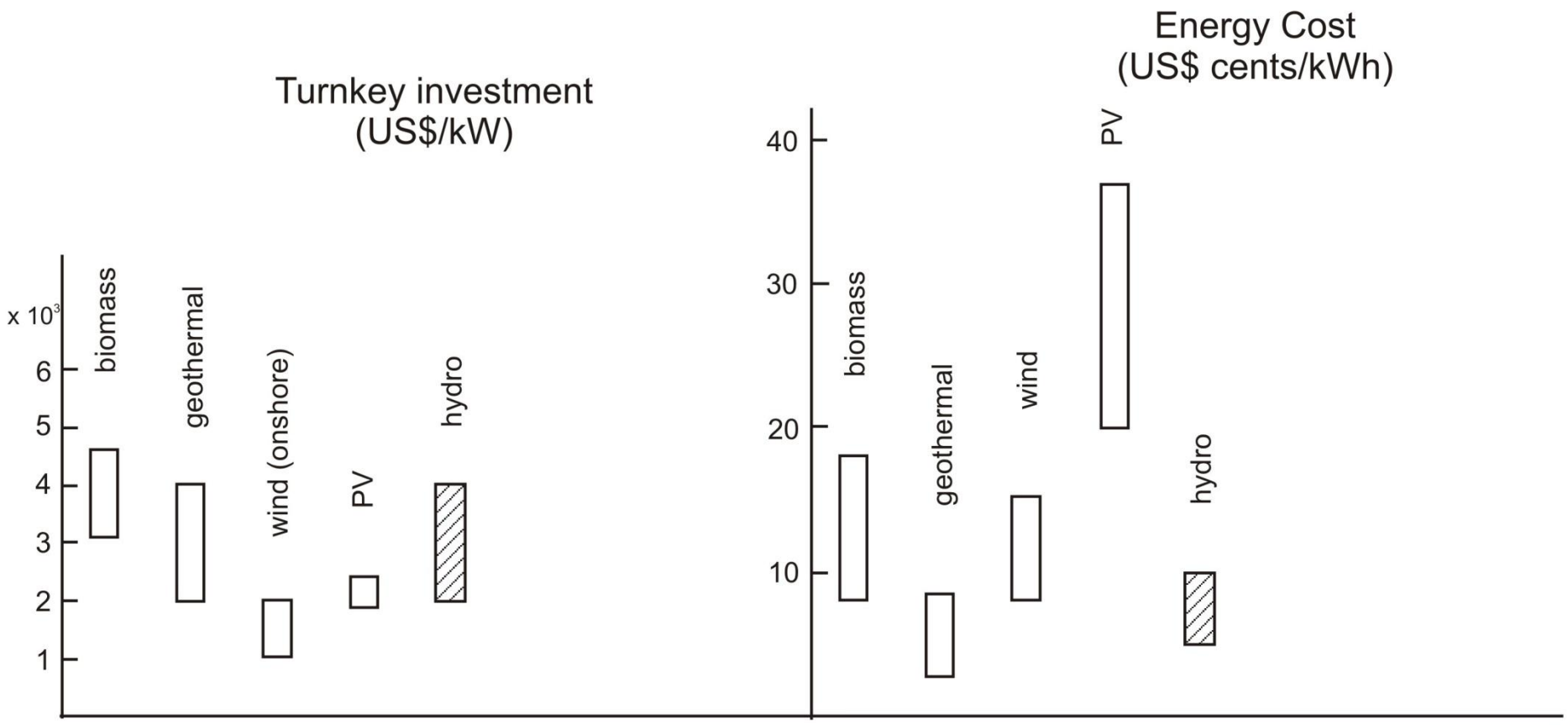
*** Period 2011/2004**

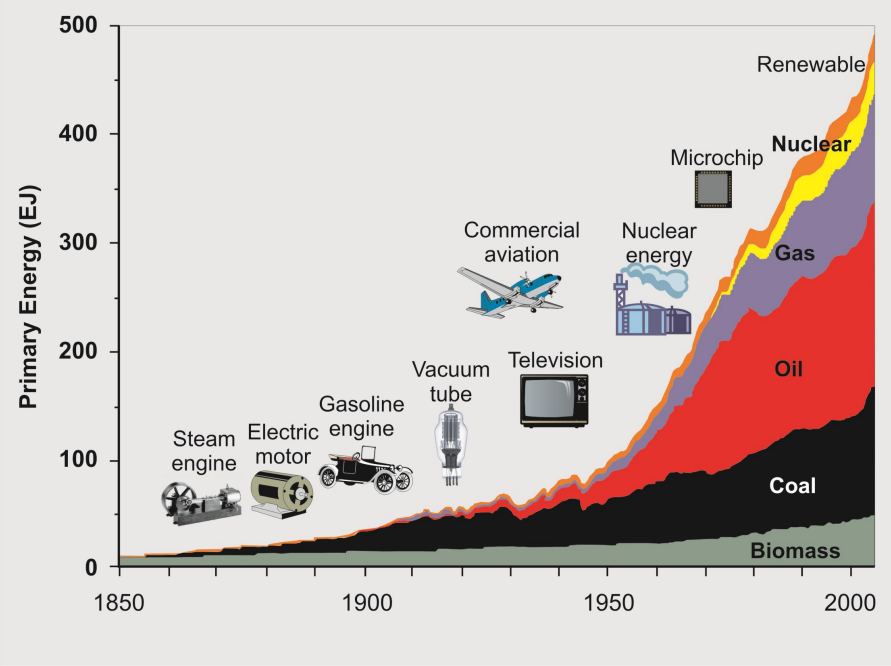
**Sources**: BP, 2012, REN21, 2012 and Blomberg, 2012


Learning Curve for Advanced Technology
Area under curve is total cost of buy-down required to commercialise advanced technology
Conventional Technology
Incremental Cost for Advanced Technology
Cost per unit
Number of units produced (cumulative)


ethanol (producers Brazil, green) and crude oil (Brent) and gasoline (spot CIF Rotterdam, red) prices (2004$/GJ)
cumulative ethanol production (EJ)
Cumulative learning costs: ~50 billion $
learning rate: ~10% reduction per doubling of cum. production
Jan.2009 oil price
0
5
10
15
20
25
30
35
40
0
1
2
3
4
5
6
7
8
9

# Renewables


Turnkey investment
(US$/kW)
x 10³
6
5
4
3
2
1
biomass
geothermal
wind (onshore)
PV
hydro
Energy Cost
(US$ cents/kWh)
40
30
20
10
biomass
geothermal
wind
PV
hydro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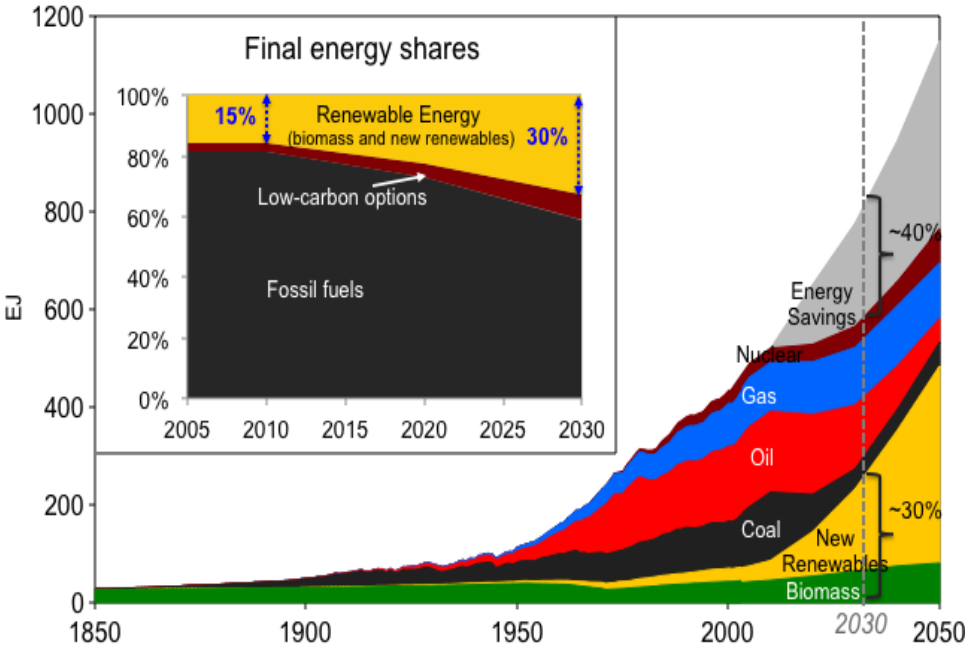
EJ
1200
1000
800
600
400
200
0
1850
1900
1950
2000
2030
2050
Final energy shares
100%
80%
60%
40%
20%
0%
2005
2010
2015
2020
2025
2030
15%
Renewable Energy
(biomass and new renewables)
30%
Low-carbon options
Fossil fuels
Energy Savings
~40%
Nuclear
Gas
Oil
Coal
New Renewables
~30%
Biomass