Trade offs in large scale and small scale renewable energy solutions

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CenSEPS Workshop: The Road to a 100% Renewable Energy System
Milpitas, CA; 1 August 2011

World Marketed Energy Use by Fuel Type 1990-2035

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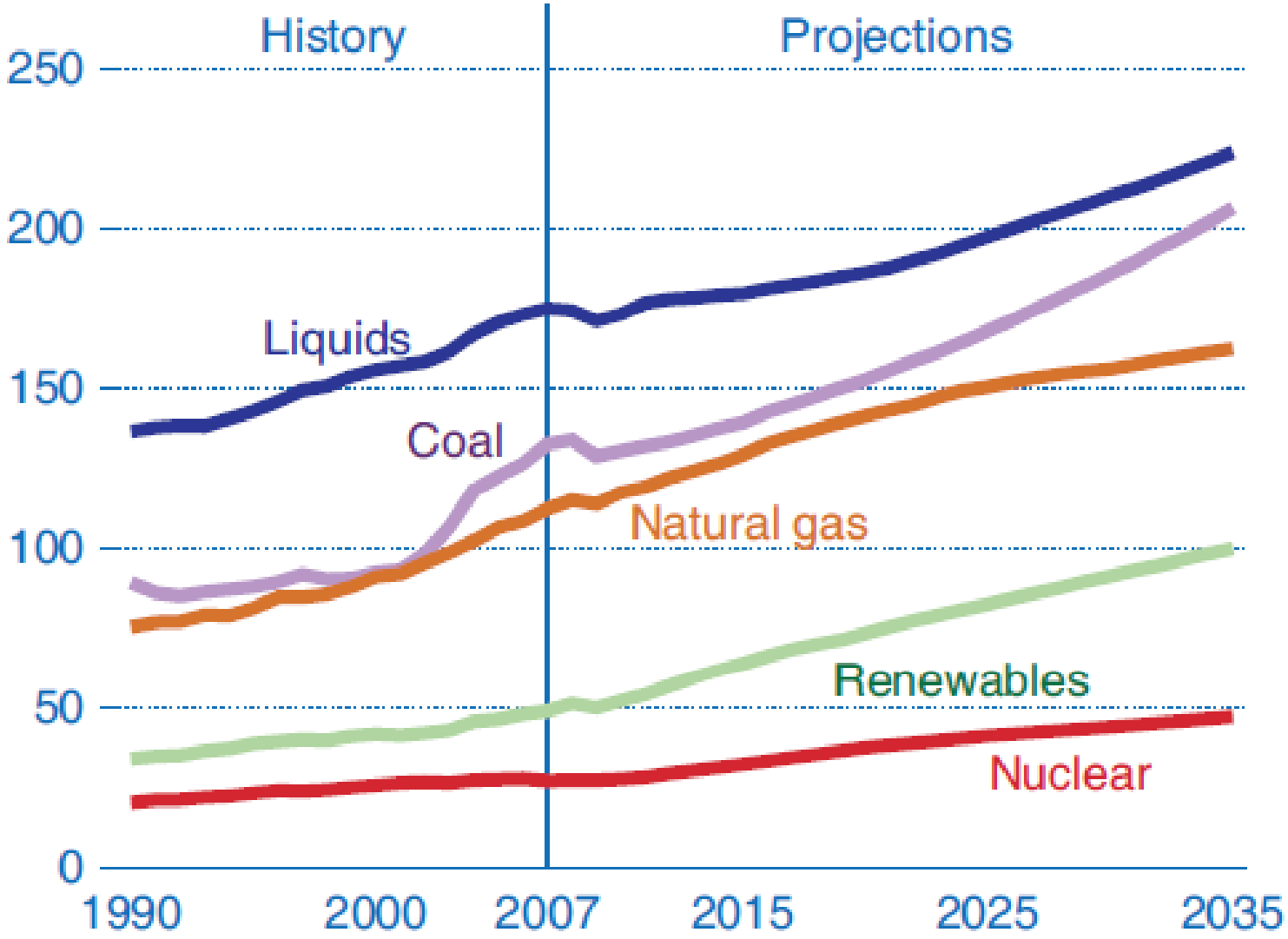
13TW **2050: 25-30TW**



1 Quad = 1.055×10^{18}J

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US Department of Energy; Energy Information Administration (2010)

100% Renewable Energies by 2050

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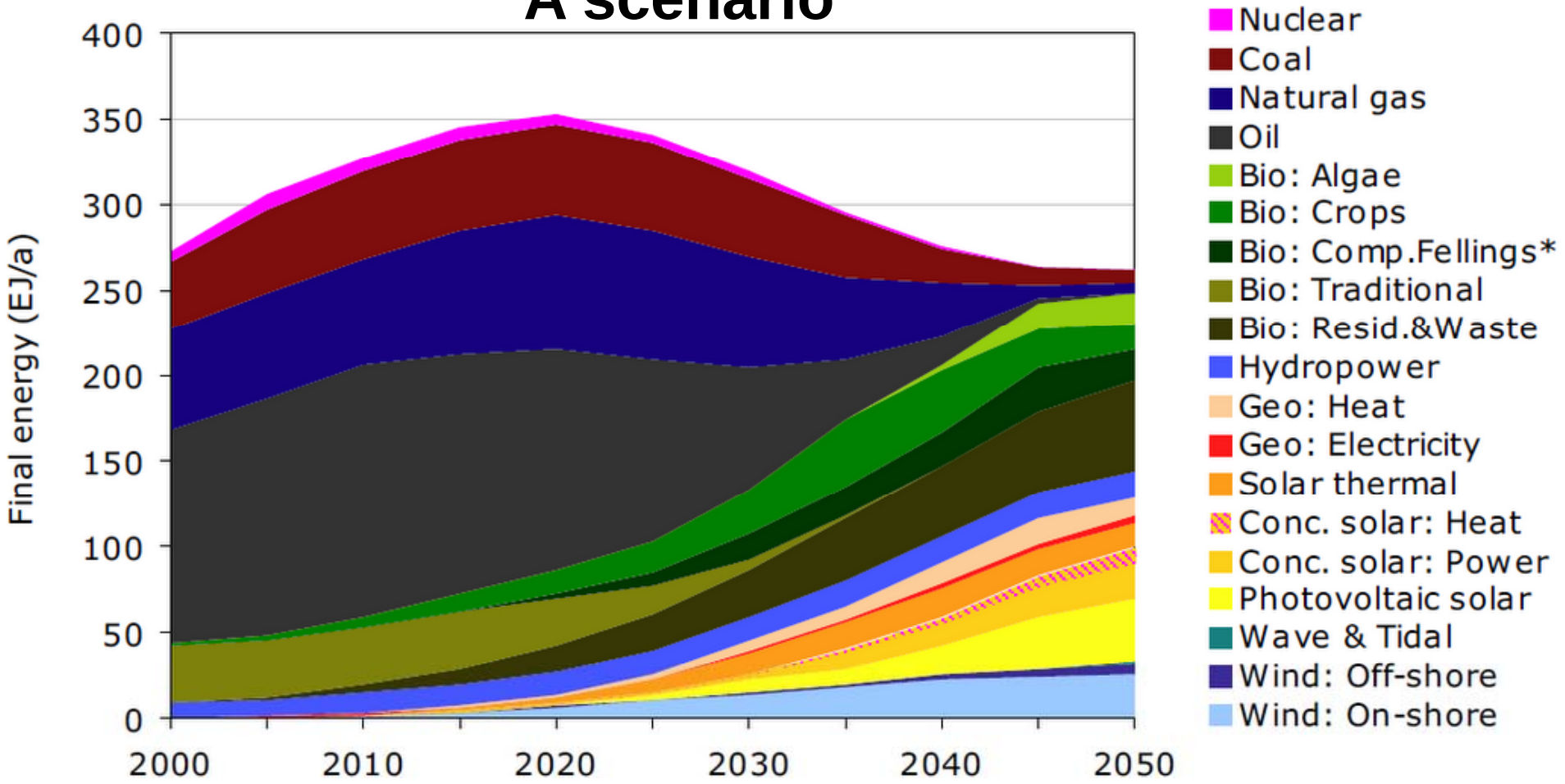
A scenario



WWF International, Ecofys, & Office for Metropolitan Architecture (2011)

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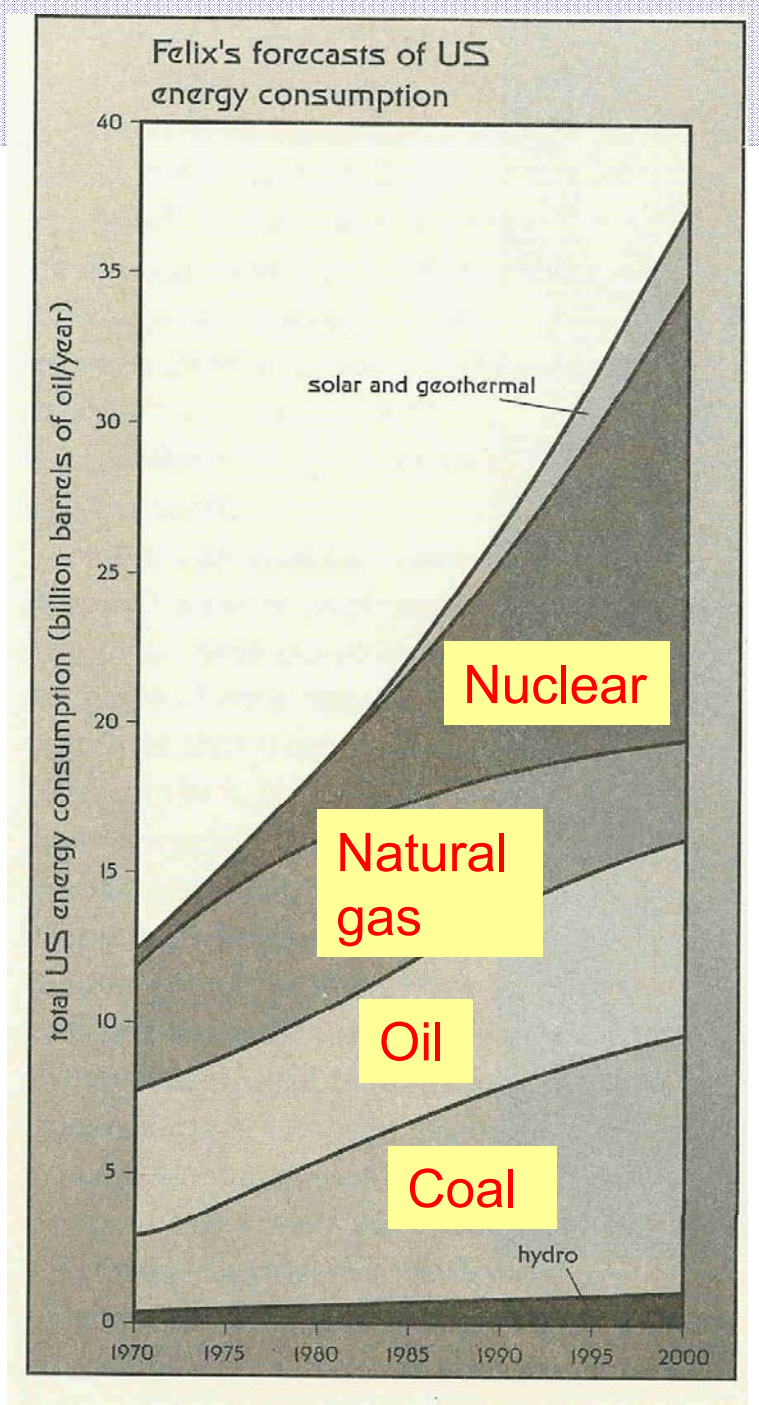
Felix's forecasts of US energy consumption in year 2000 (early 1970's)



Vaclav Smil, Energy at the Crossroads, 2005

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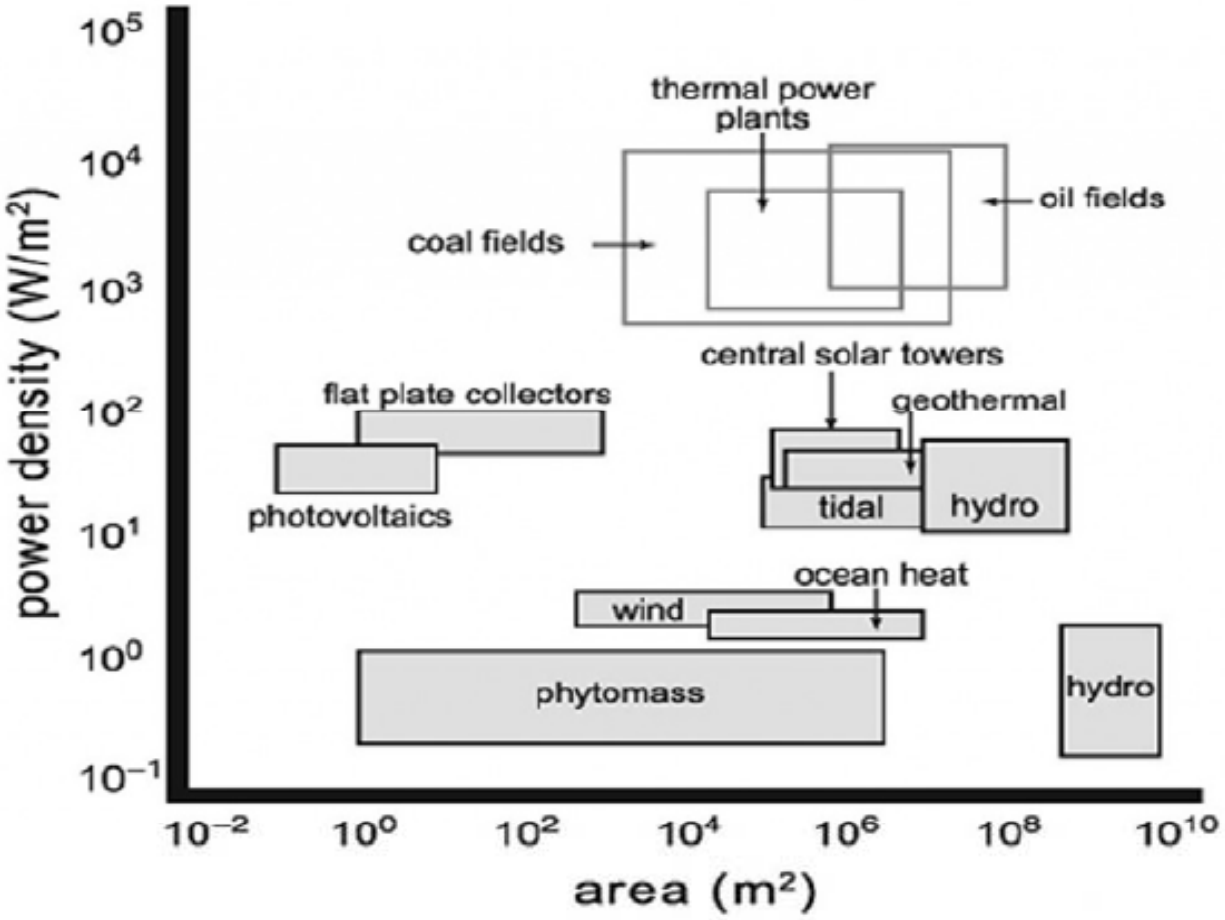
All Renewables Are Diffuse



Power densities of fossil fuel extraction, thermal electricity generation and renewable modes of electricity production. Reproduced from: V.Smil *Energy Transitions: History, Requirements, Prospects* (Praeger: 2010).

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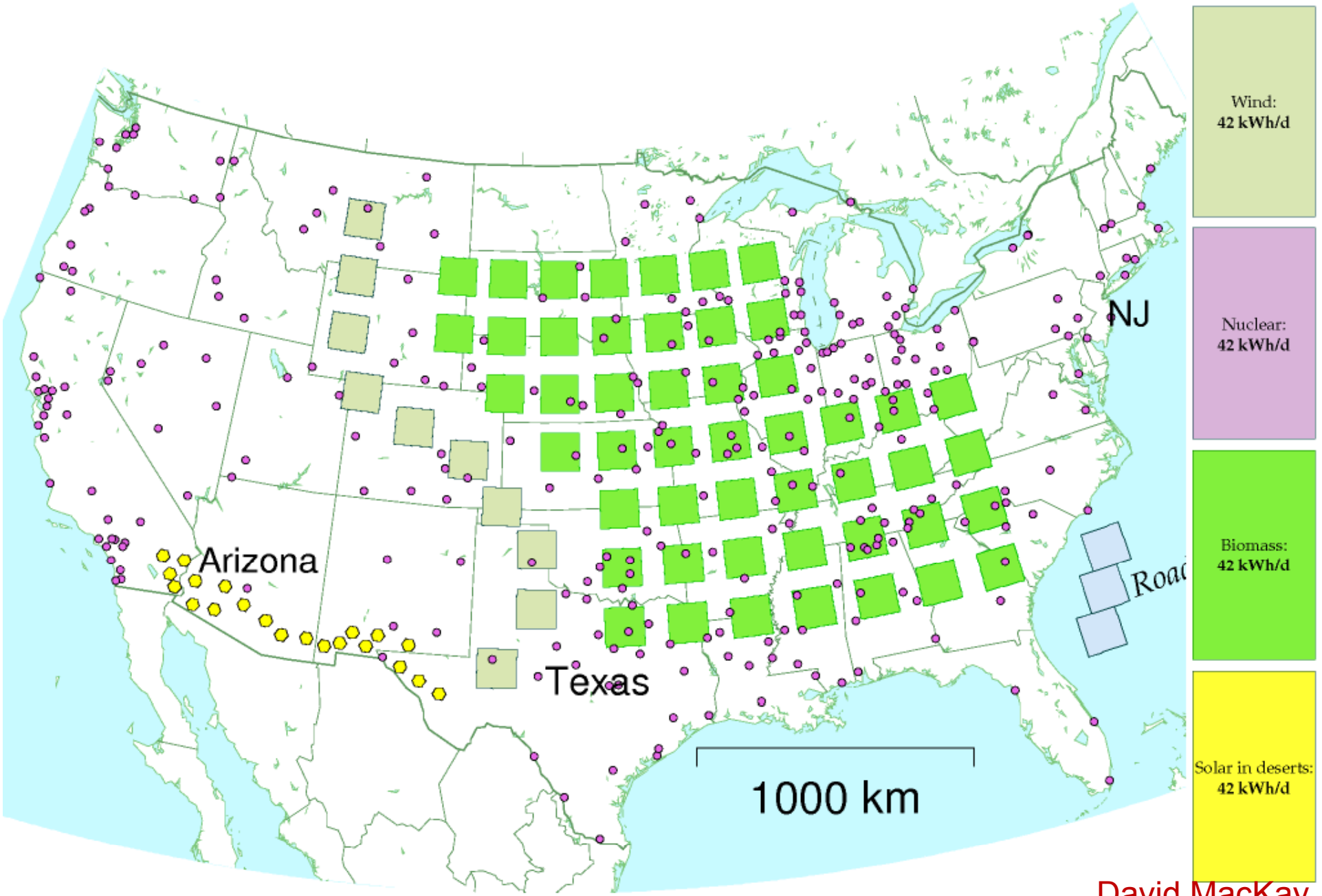

2100 GW of wind (60-fold increase)

525 one-gigawatt nuclear power stations (five-fold increase)

David MacKay

Sustainable Energy without the Hot Air

Efficiency vs. Size (Conventional Engines)

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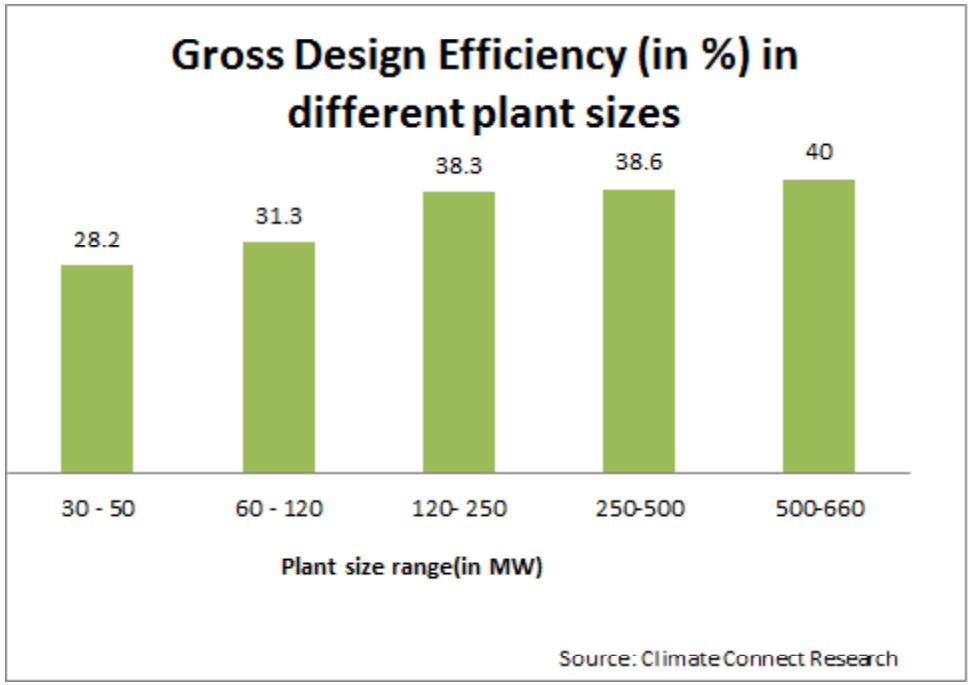

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Contradiction Chains, Darrell Mann, Univ. of Bath, UK

Wind Turbine Evolution

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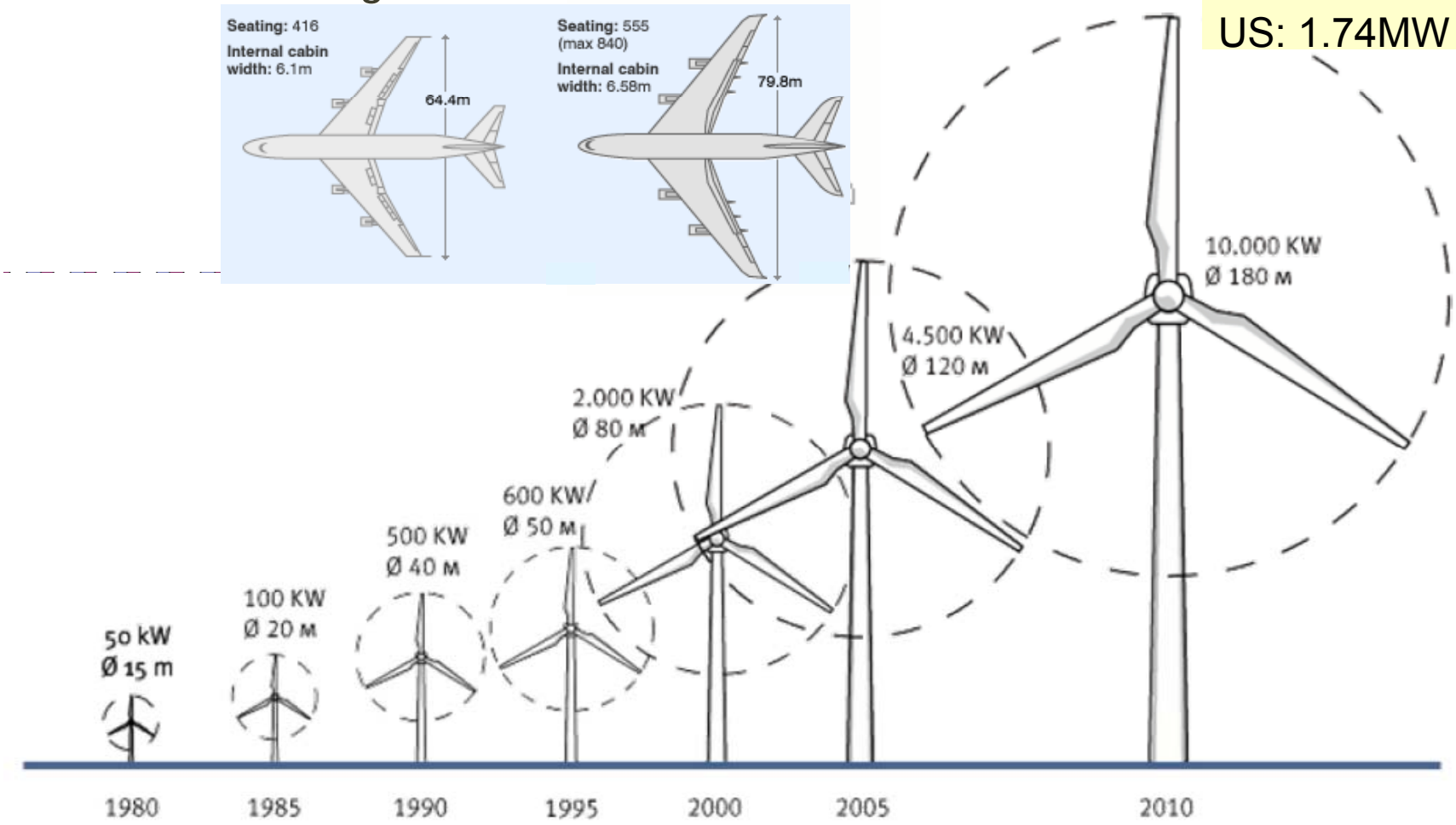
2009 average turbine size in US: 1.74MW



Trend toward bigger turbine sizes

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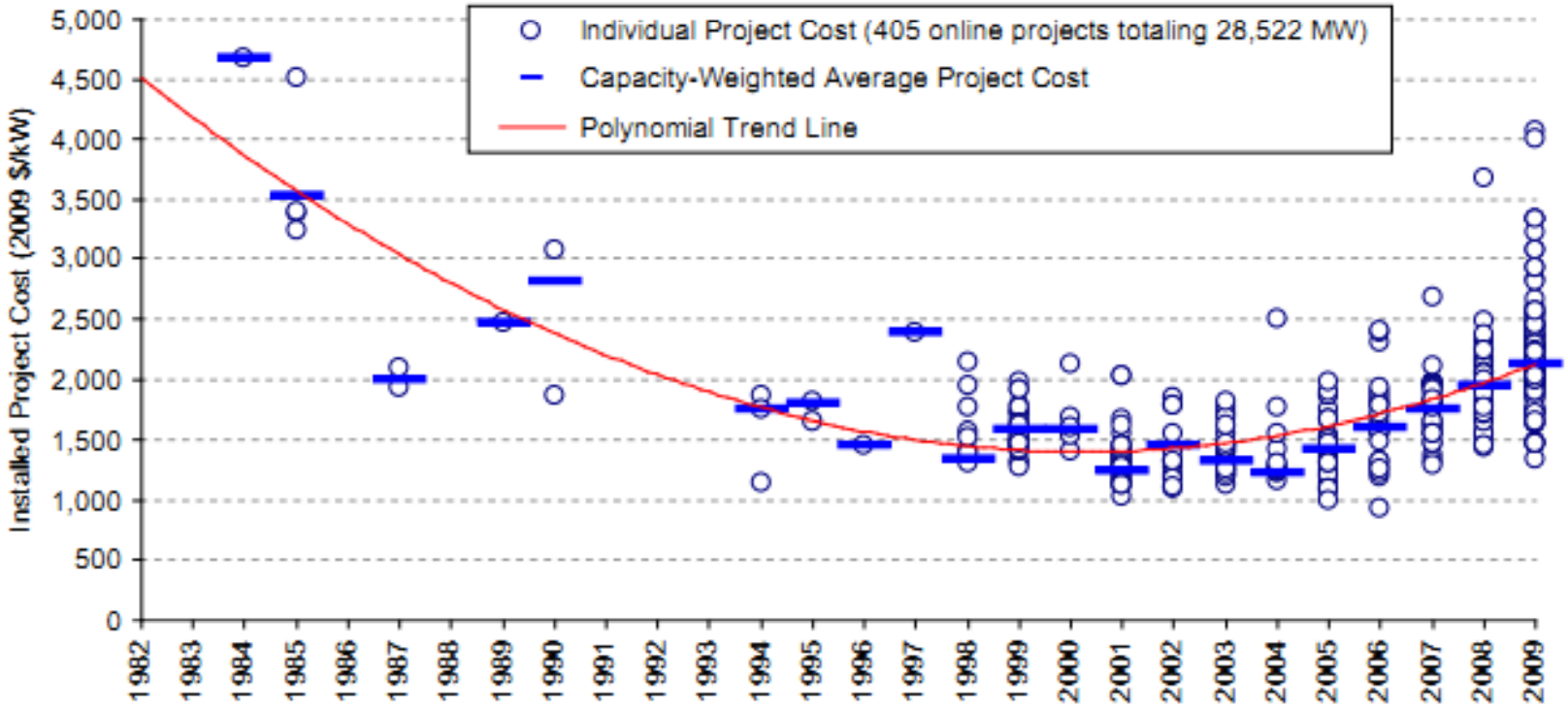
Installed project costs are on the rise after a long period of decline.



Source: Berkeley Lab (some data points suppressed to protect confidentiality)

Figure 27. Installed Wind Power Project Costs Over Time

2009 Wind Technologies Market Report, US Department of Energy

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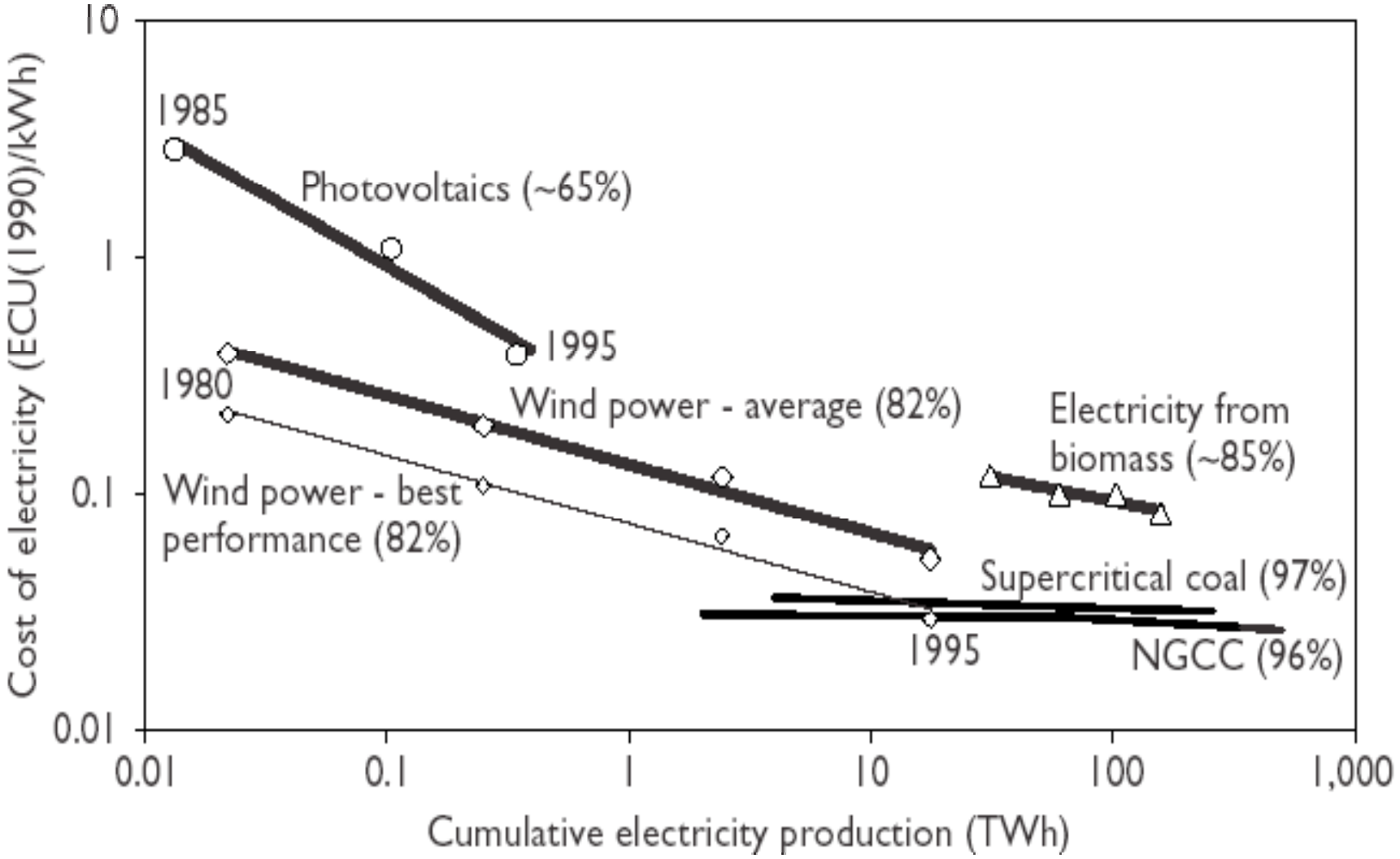
Learning Curves



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"Learning by Doing" cost reductions versus installed capacity for various electricity generating technologies (IEA, 2000)

Wind Turbine Installation

Intermittency of Renewables

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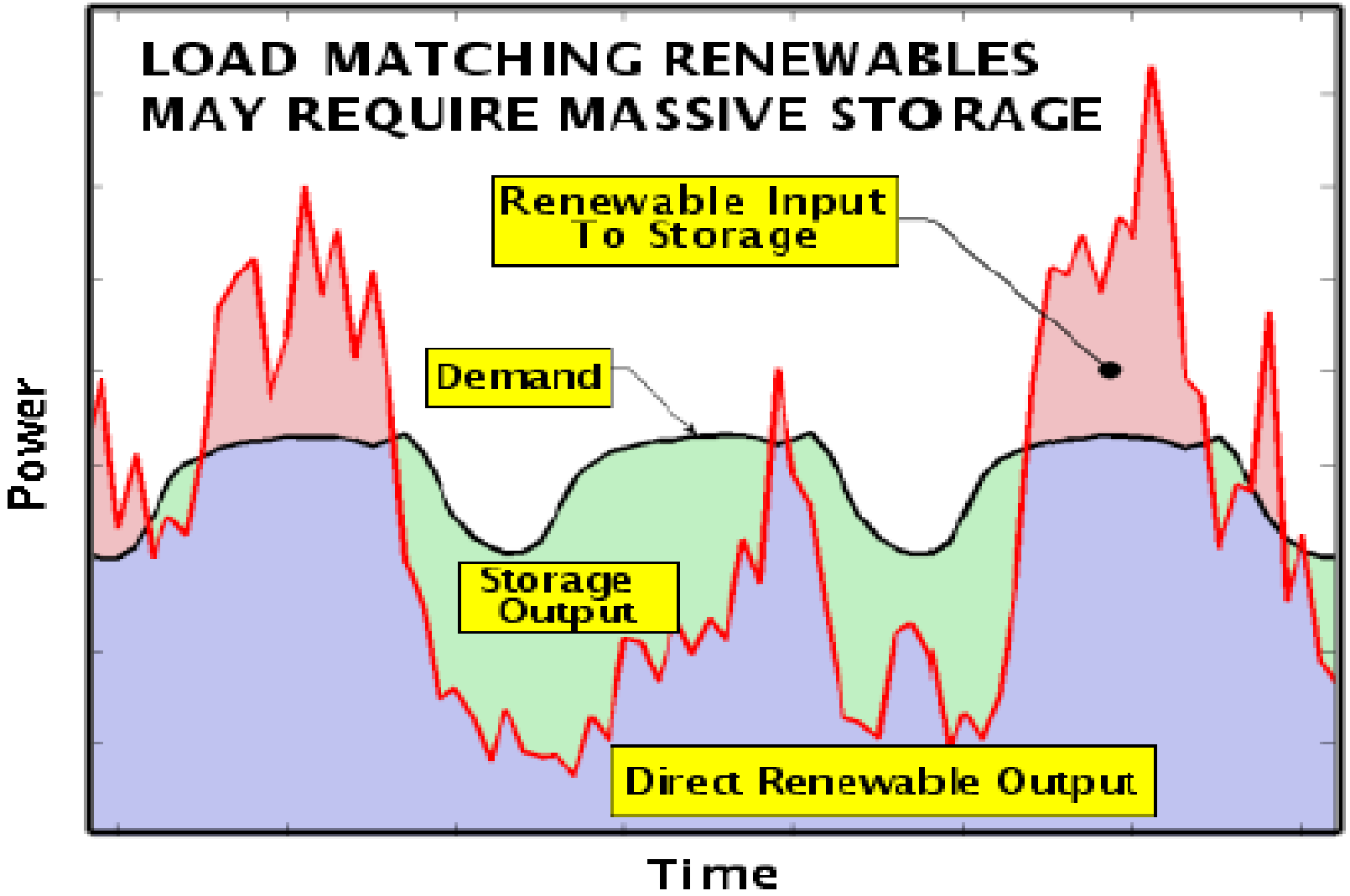
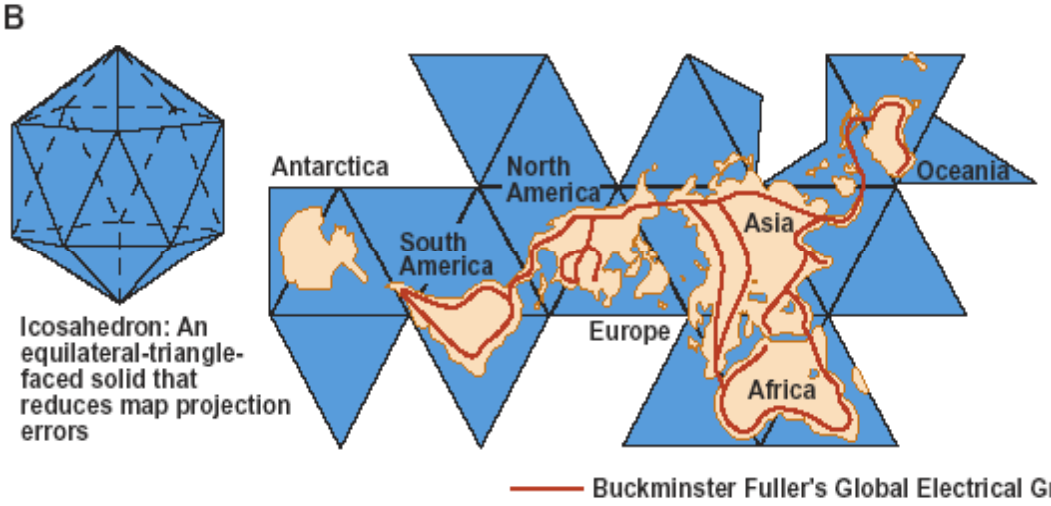


Capturing
Solar Energy in space
(Peter Glaser et al., 1970s)



Global Superconducting
Transmission Grid
(Buckminster Fuller,1970s)

Visionary Technology Systems that could Enable a Global Economy Powered by Renewable Energy.

Marty Hoffert

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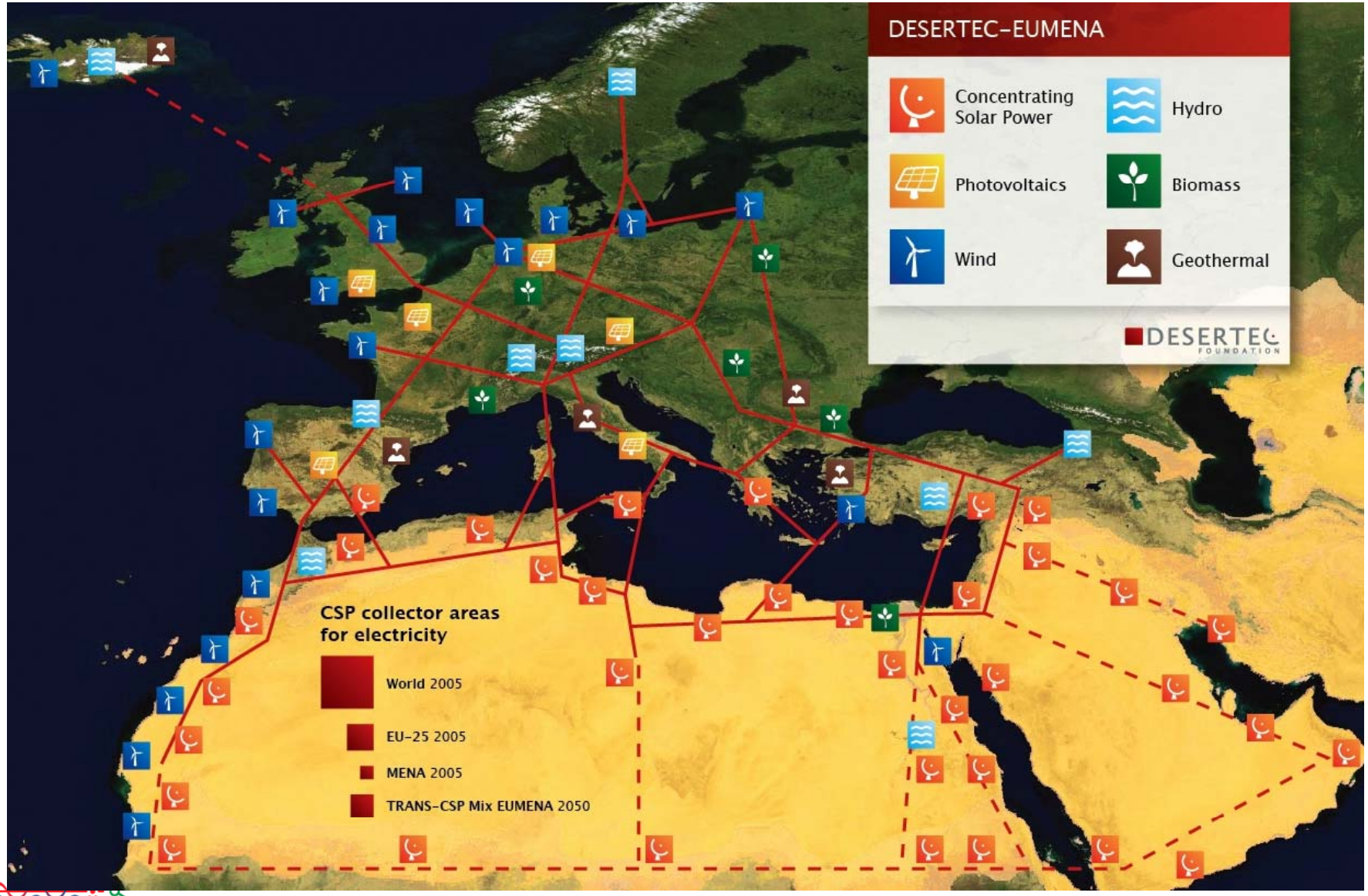
Desertec



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US Energy Flow 2008

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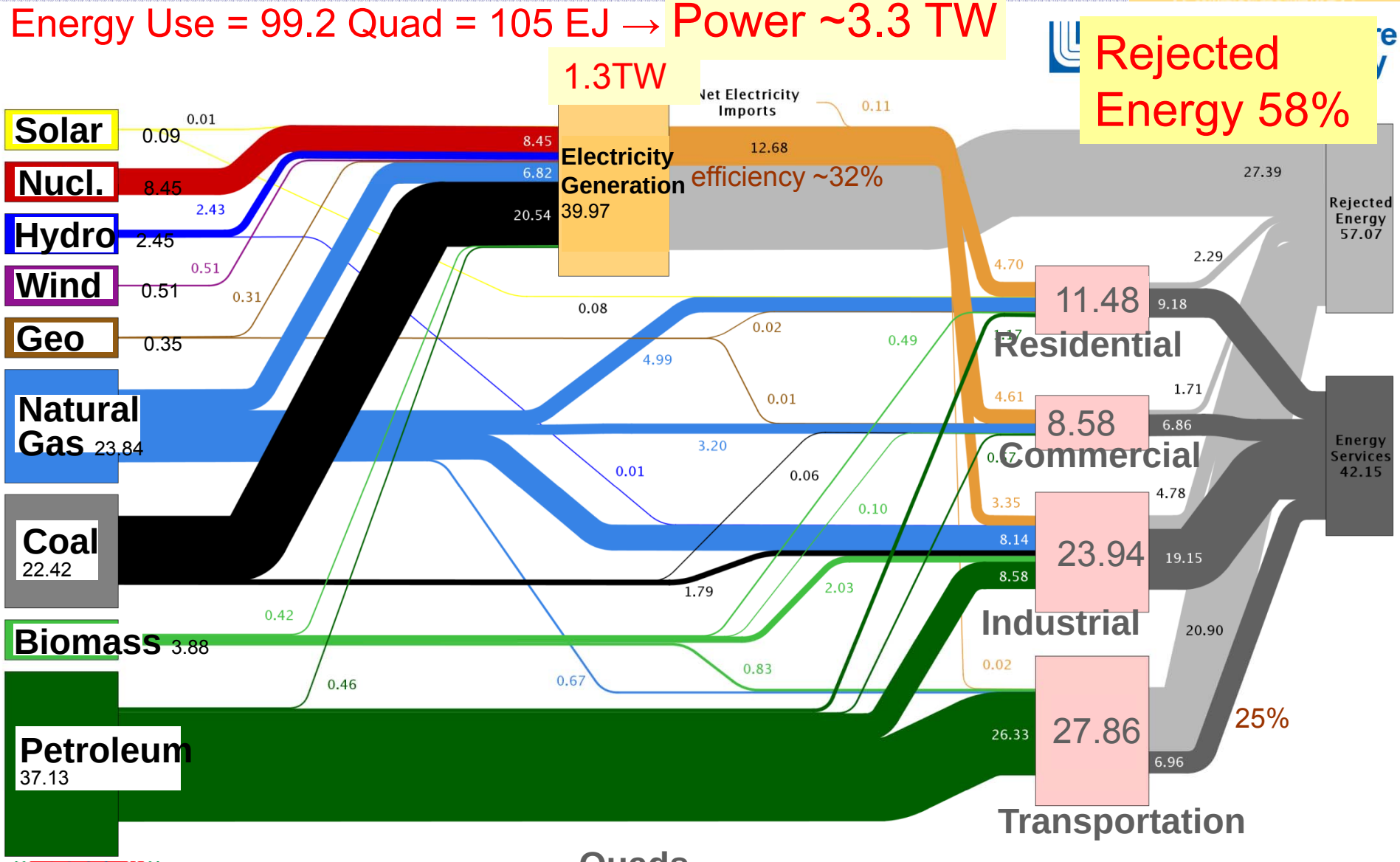
Energy Use = 99.2 Quad = 105 EJ → Power ~3.3 TW



http://eed.llnl.gov/flow

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US Energy Flow 1950

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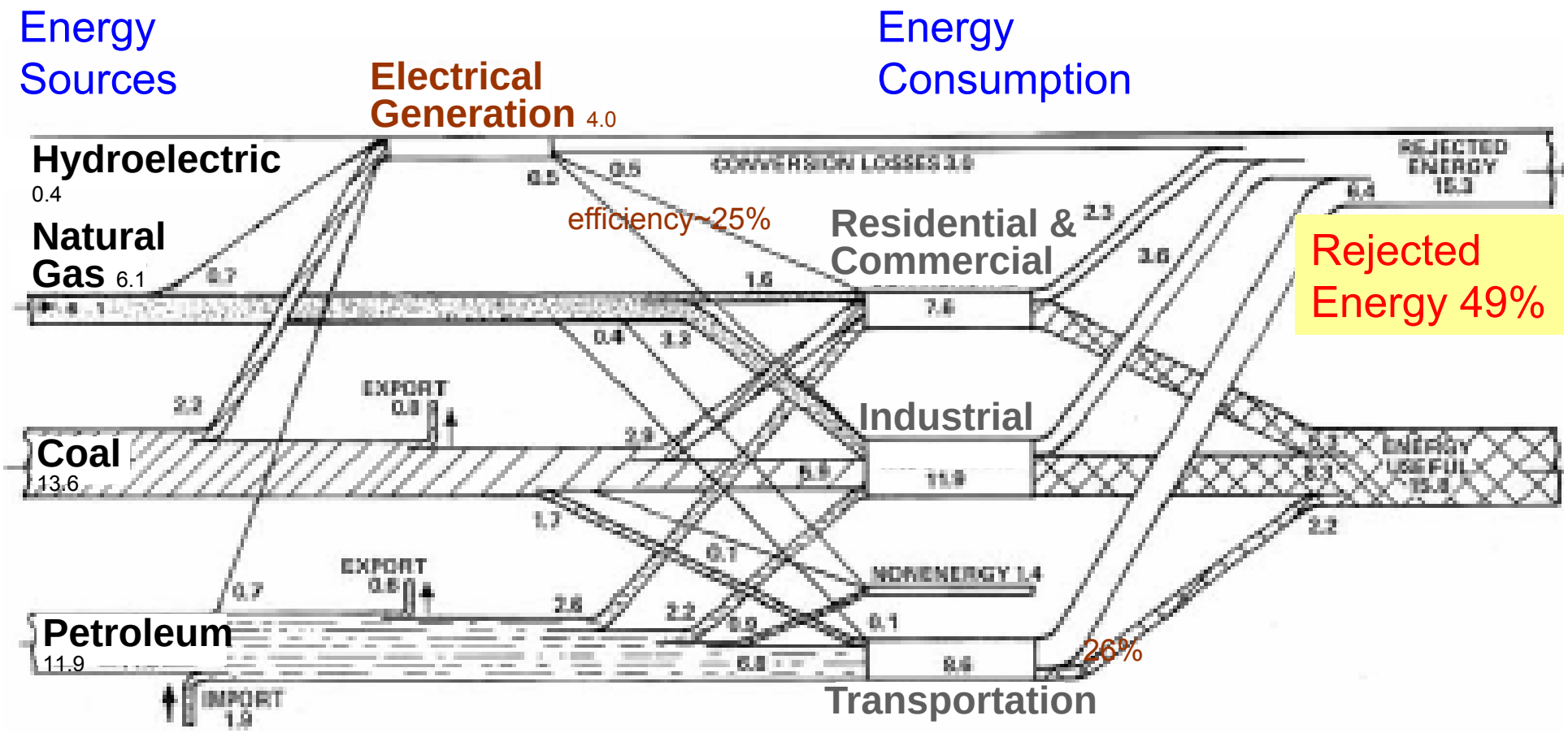

Total: 33.9 Quad → 1.13TW
Population: 161M

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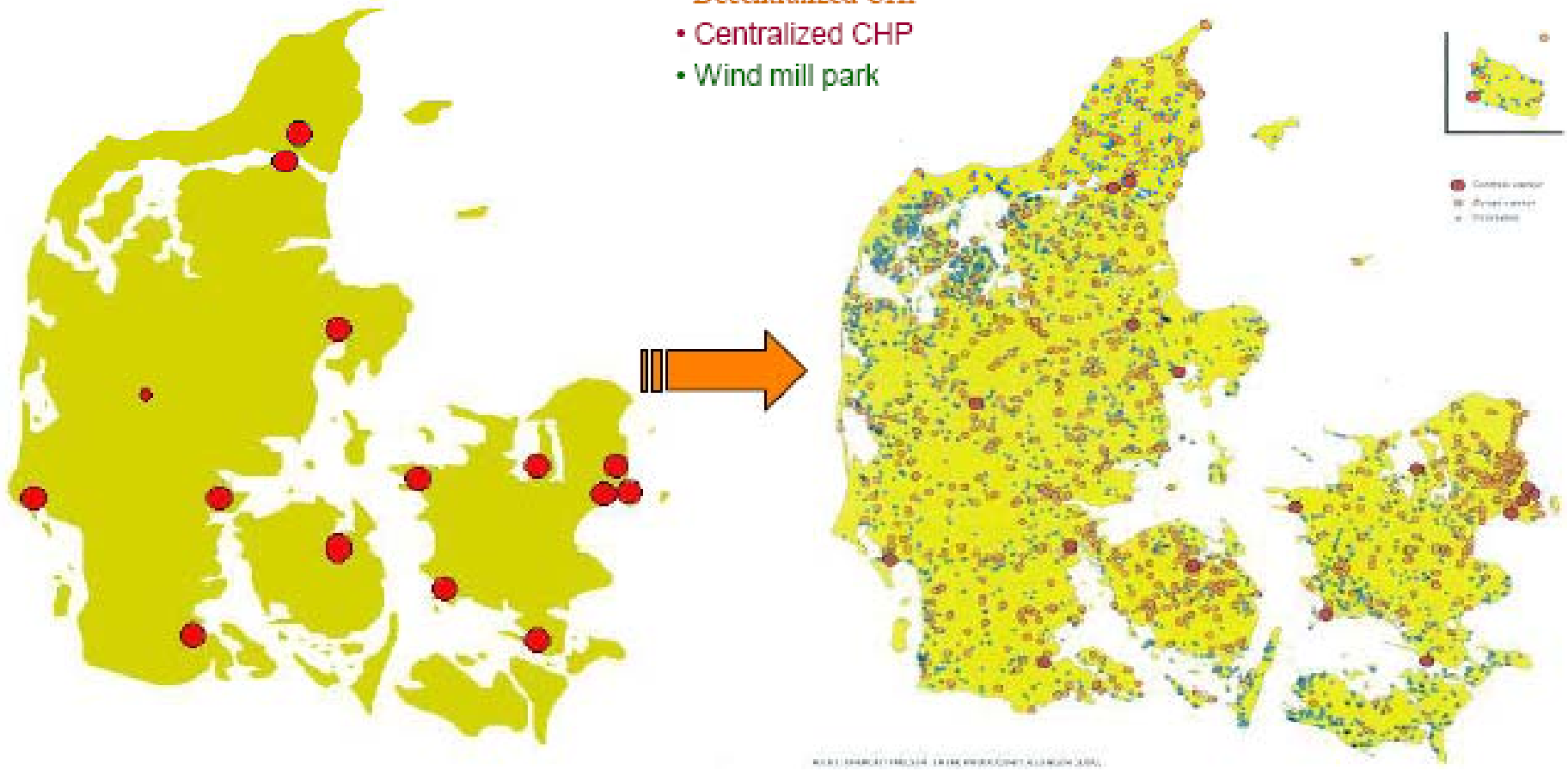
Lawrence Livermore National Lab., http://eed.llnl.gov/flow

Denmark: From Centralized to Decentralized Power Production

Centralized production in the mid 80's

Legend:
- Decentralized CHP
- Centralized CHP
- Wind mill park

Decentralized production of today



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Electricity- Hot Water Cogeneration

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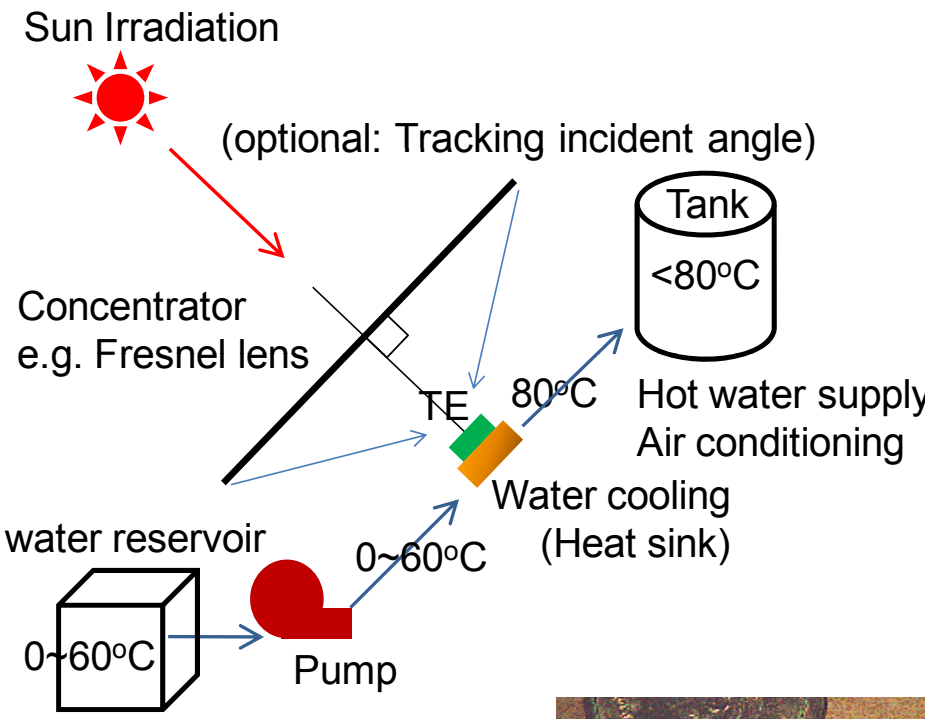
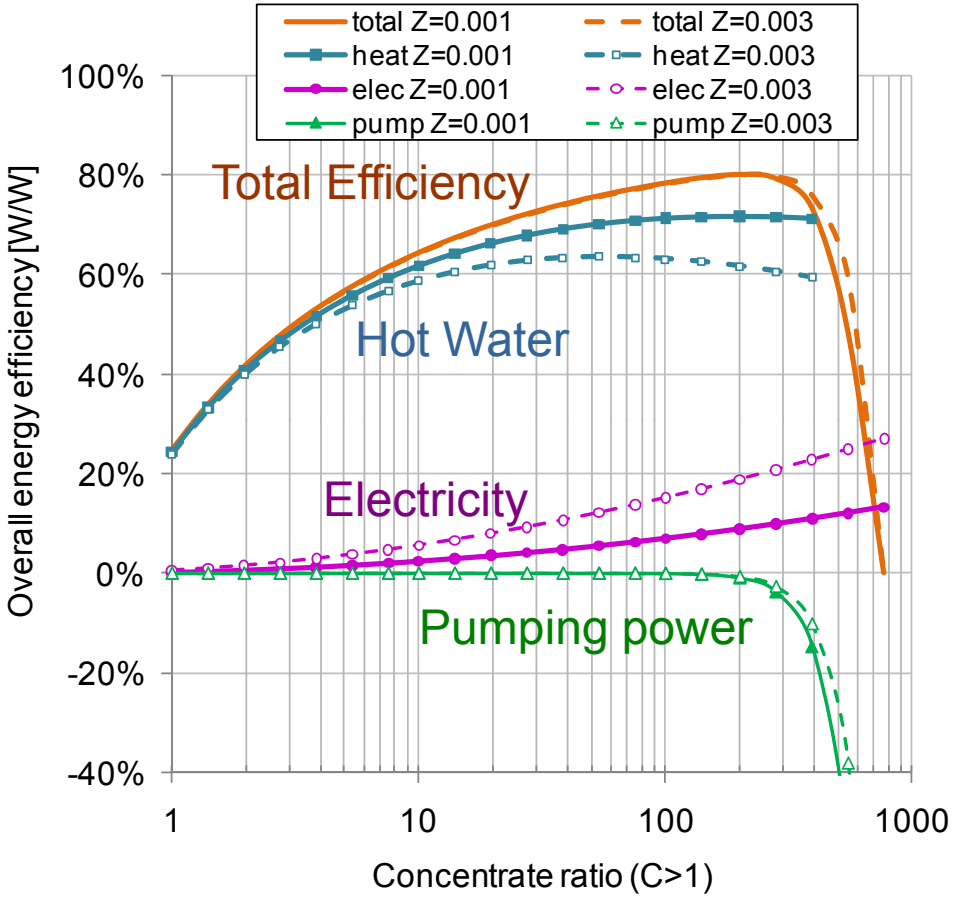
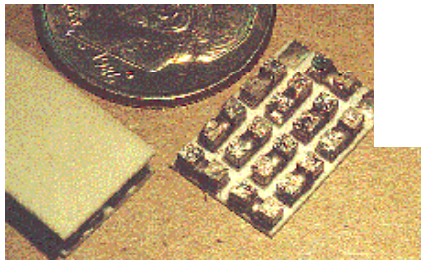




Thermoelectric Device



K. Yazawa, A. Shakouri, "System optimization of hot water concentrated solar thermoelectric generation," Proc. Thermal Issues in Emerging Technologies (ThETA 3), Dec 19-22, Cairo, Egypt, pp. 283-290, 2010.

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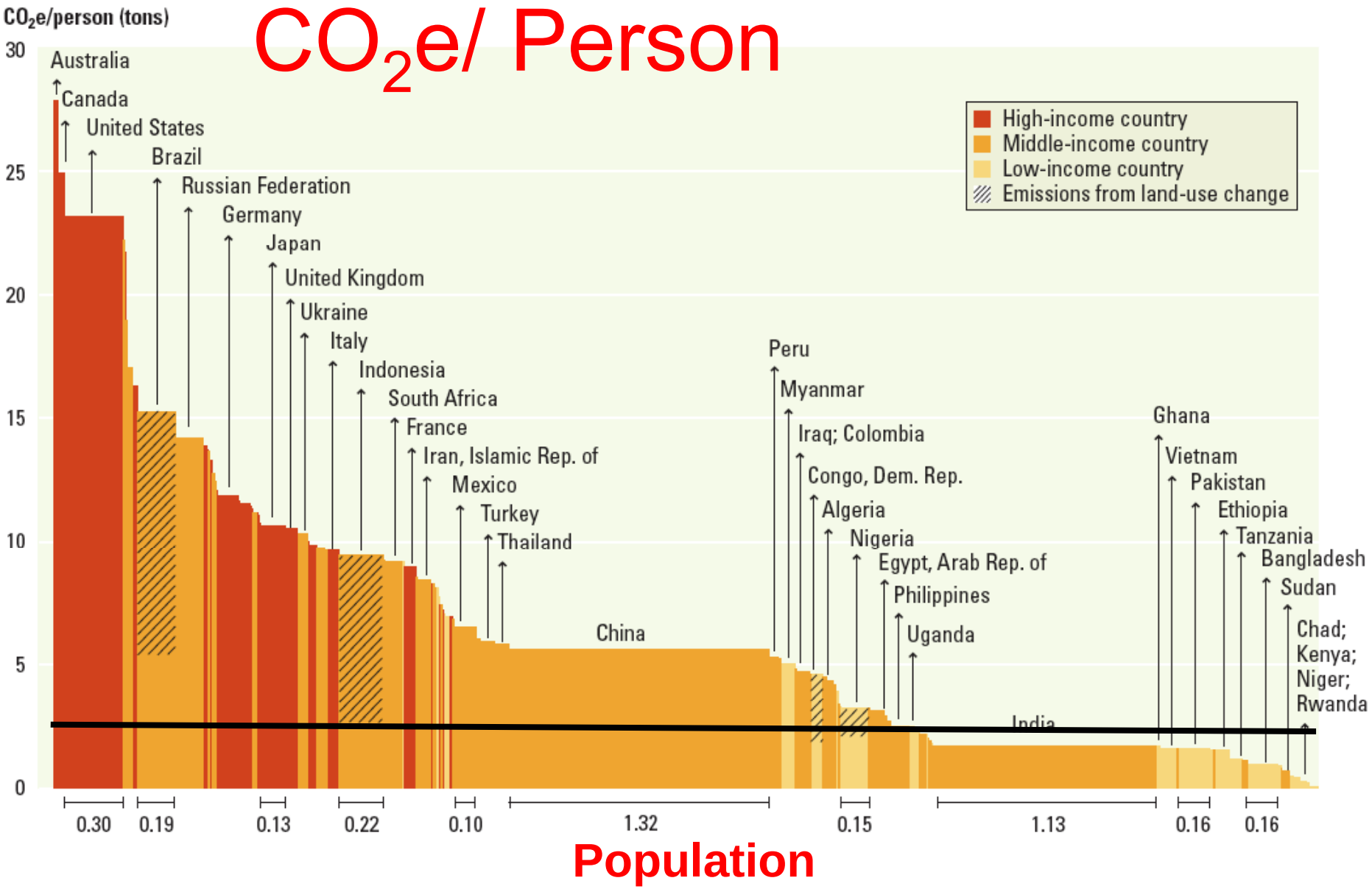
Figure 1.1 Individuals' emissions in high-income countries overwhelm those in developing countries



Sources: Emissions of greenhouse gases in 2005 from WRI 2008, augmented with land-use change emissions from Houghton 2009; population from World Bank 2009c.

Note: The width of each column depicts population and the height depicts per capita emissions, so the area represents total emissions. Per capita emissions of Qatar (55.5 tons of carbon dioxide equivalent per capita), UAE (38.8), and Bahrain (25.4)—greater than the height of the y-axis—are not shown. Among the larger countries, Brazil, Indonesia, the Democratic Republic of Congo, and Nigeria have low energy-related emissions but significant emissions from land-use change; therefore, the share from land-use change is indicated by the hatching.

Large Scale vs. Small Scale Renewable Energy Solutions?

- Renewable energies are dilute (distributed generation makes sense)
- Large scale energy storage is a key challenge
- There are opportunities for local co-generation and the optimization of the energy system
- Solutions for developed and developing countries could be different