Energy Options for Defense

Presented to:

Naval Postgraduate School
Defense Energy Seminar

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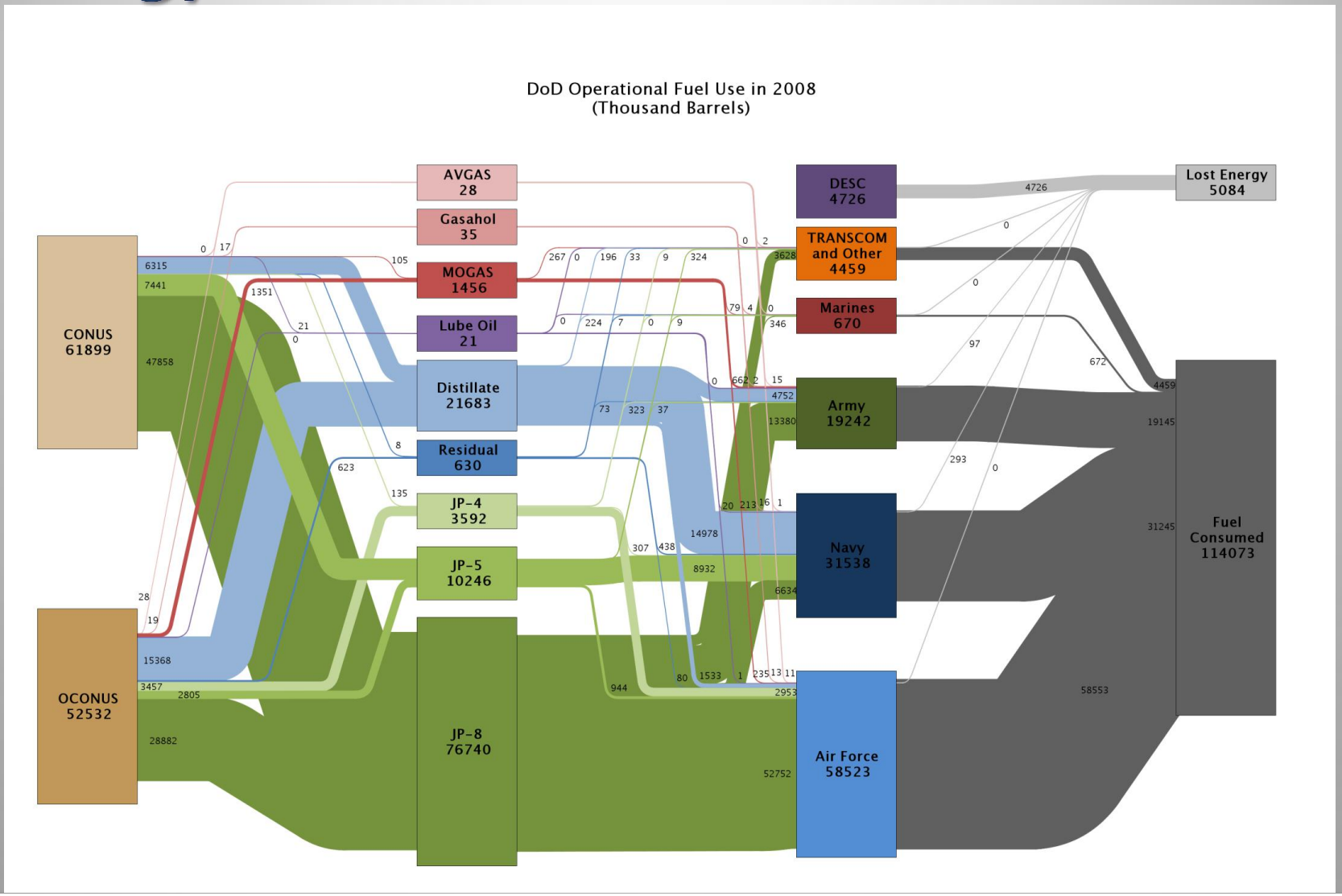
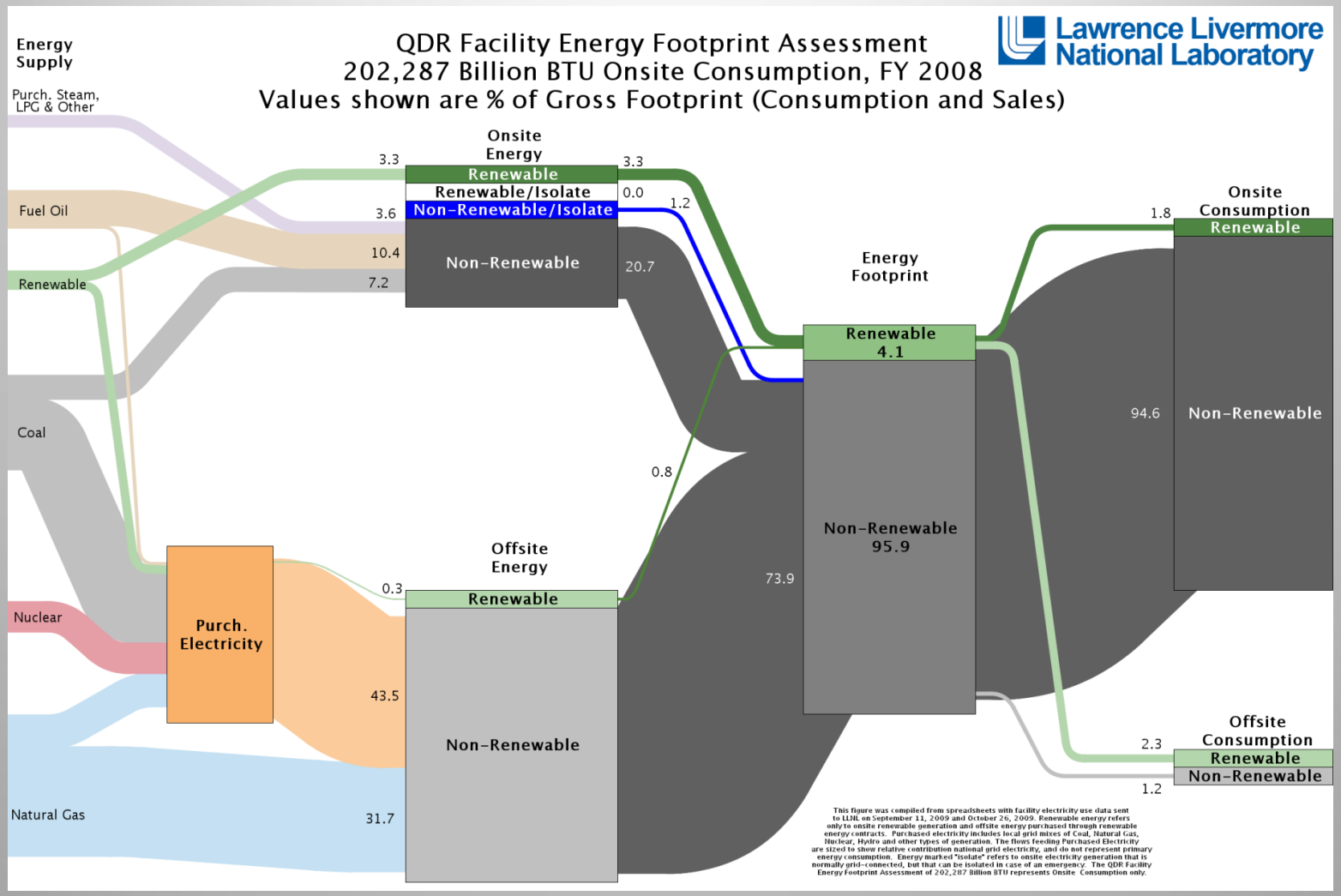
LLNL-PRES-XXXXX

Energy for Defense: DoD Fuel Use



Energy for Defense: DoD Electricity Use



Agenda

- … Across the Planet
- … Across Borders
- …Through Engineered Systems
- … For U.S. Defense
- Mini Study on Electricity

Putting "Energy" In Its Place

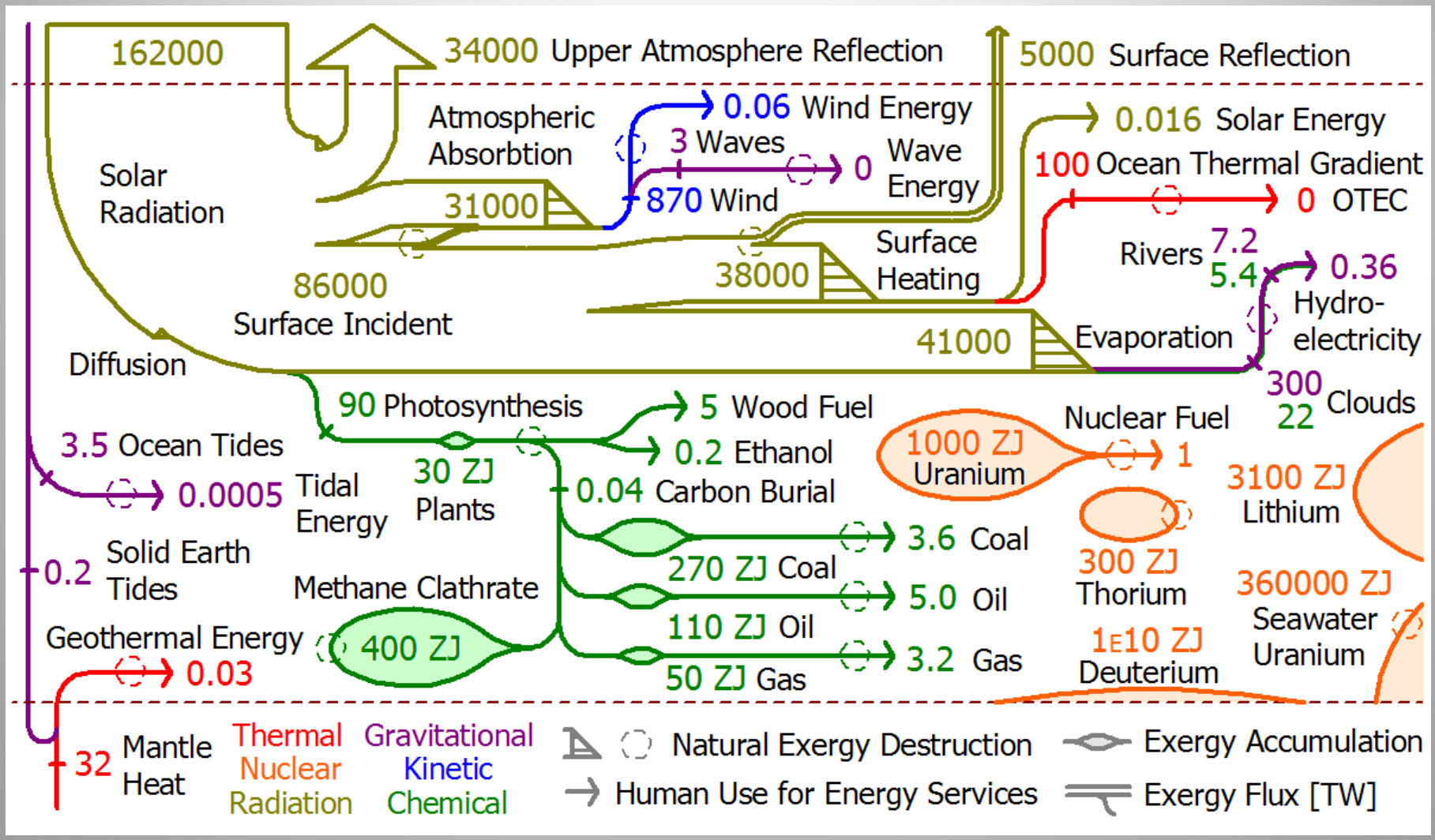
- *No* energy sources: only transfers and reservoirs

- Transfers or Flows ("Renewables")
  - Direct Solar (insolation)
  - Indirect Solar (wind, waves, hydro, biomass)
  - Geothermal (mantle heat)
  - Gravitic (tides)

- Reservoirs or Stocks
  - Oil, Gas, Coal (biomass pre-processed by the planet)
  - Nuclear Fuels (Uranium, Thorium, Deuterium, Lithium)
  - Methane Clathrates

…Across The Planet

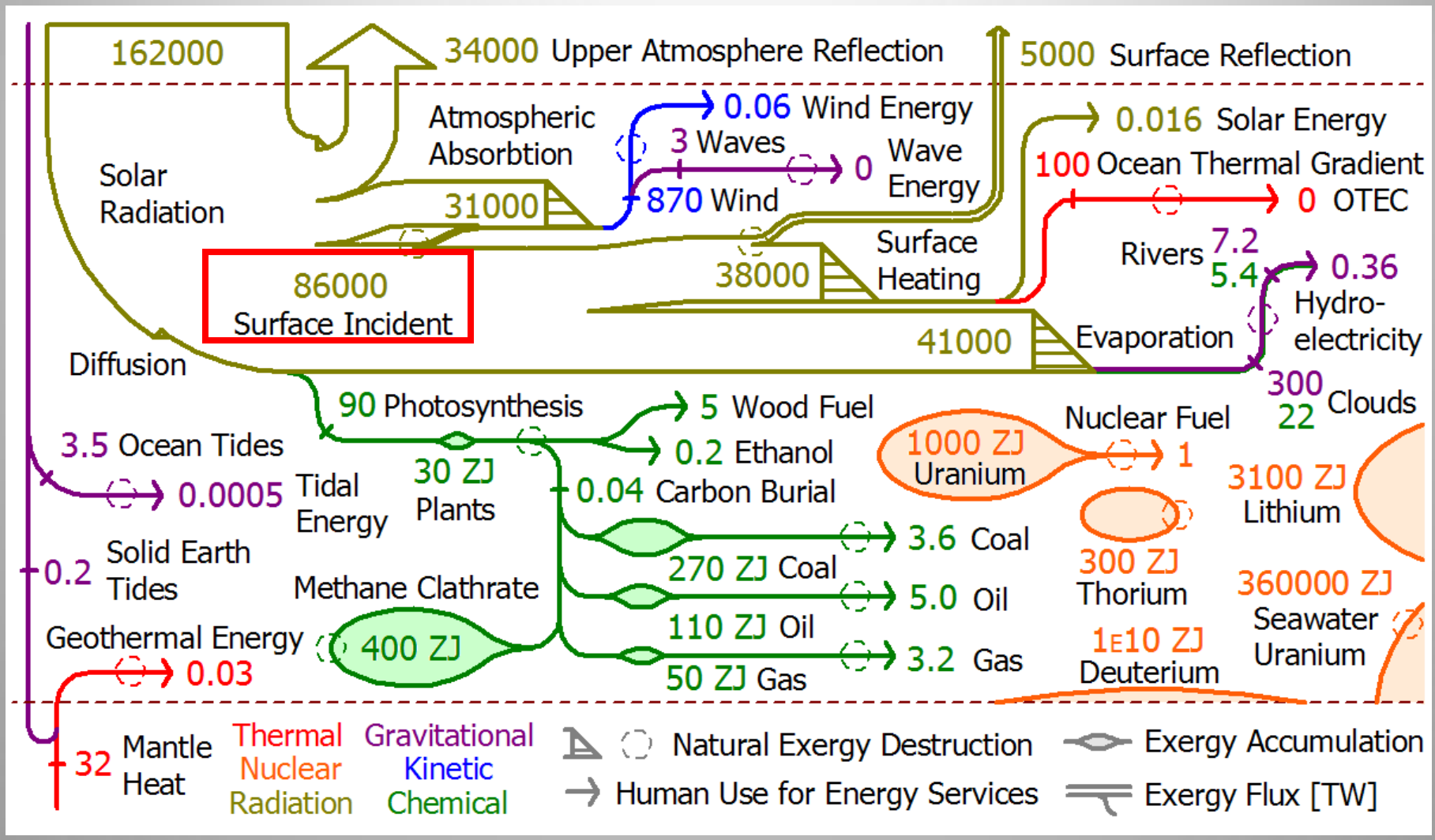
Global Exergy: Flows(TW) & Stocks (ZJ)



Source: **W. Hermann, Stanford GCEP Systems Analysis Group 2004.**

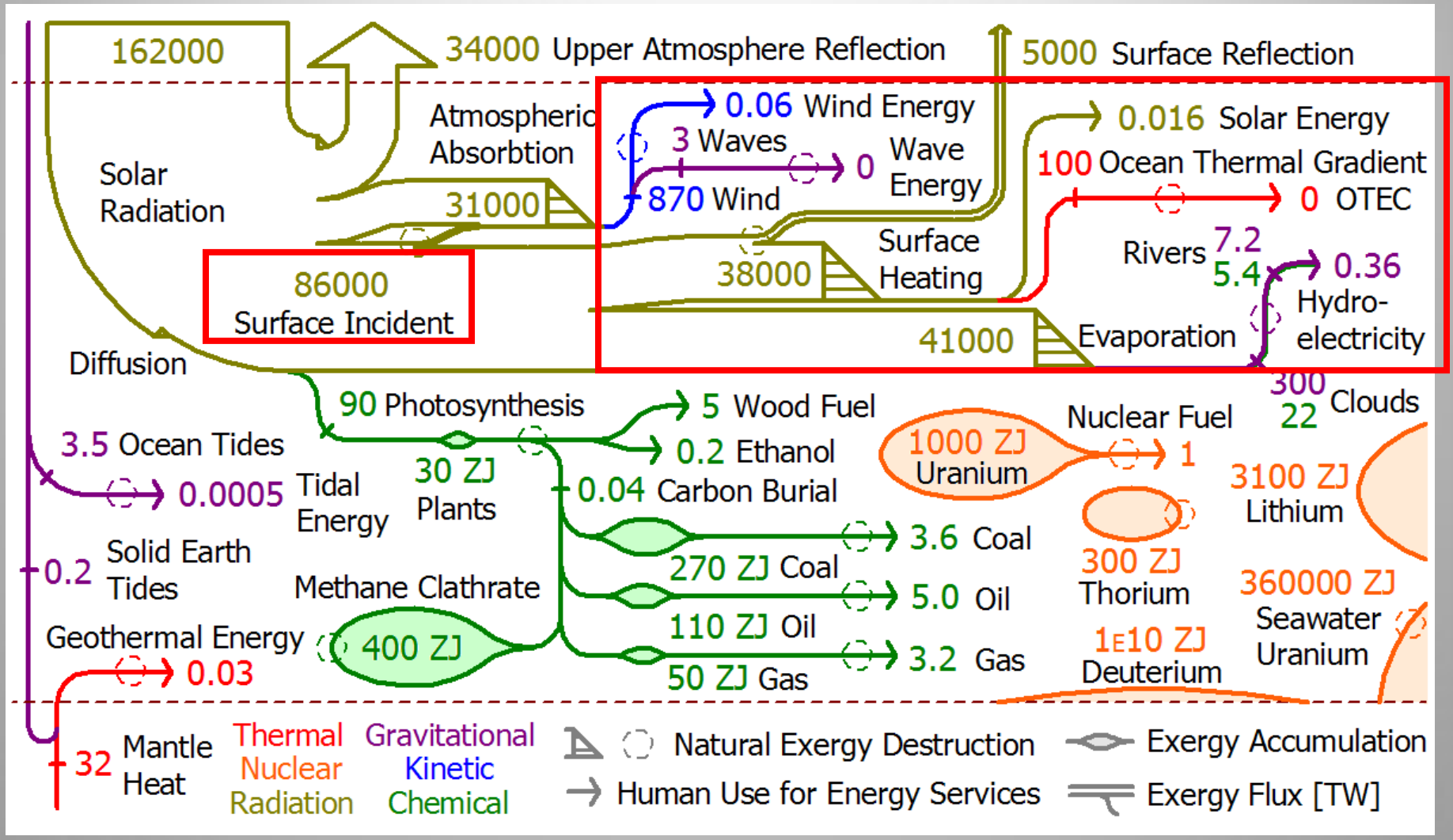
(1 ZJ = 10^{21}J)

Solar energy is vast



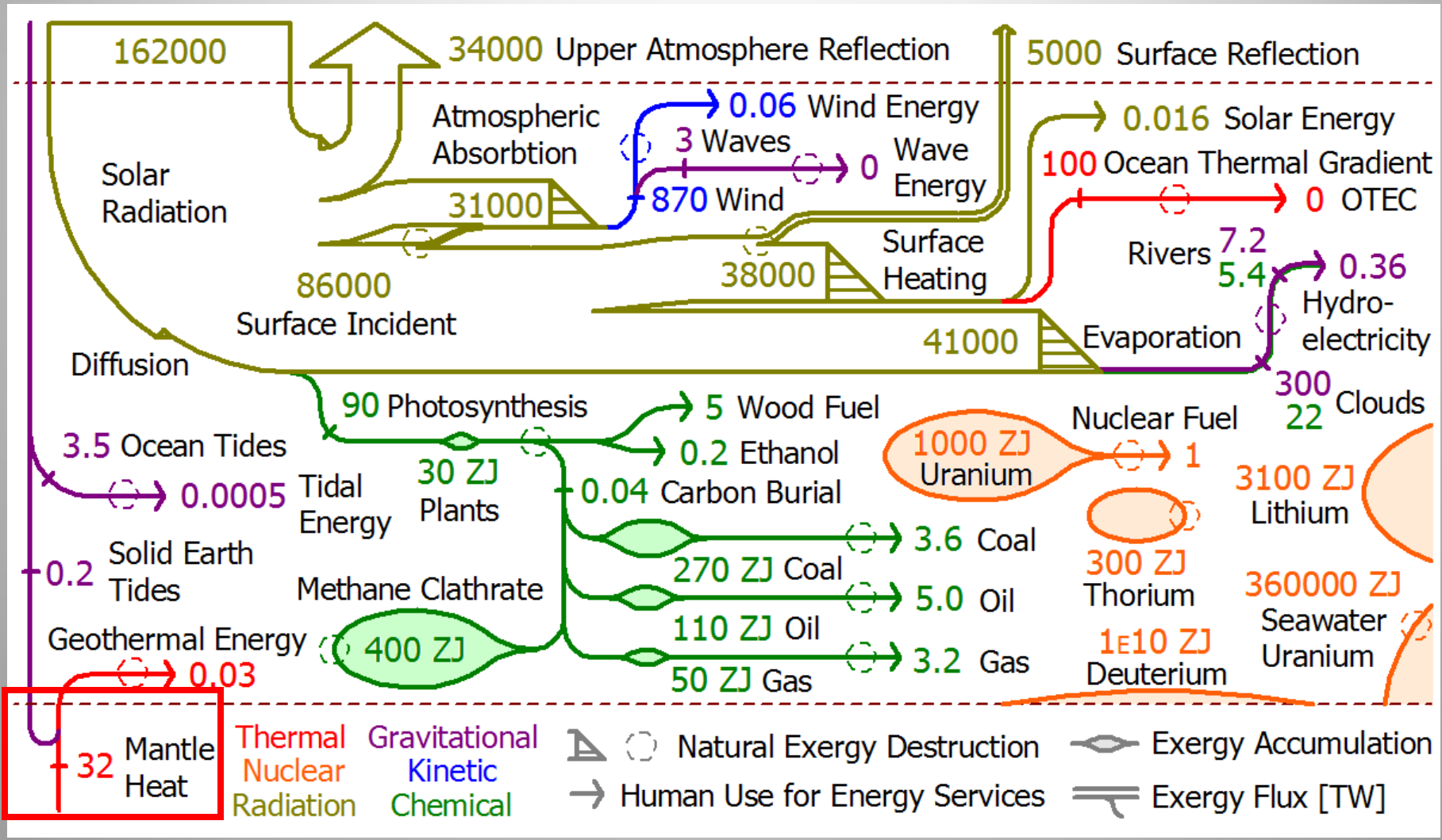
Source: **W. Hermann, Stanford GCEP Systems Analysis Group 2004.**

Solar drives other renewables



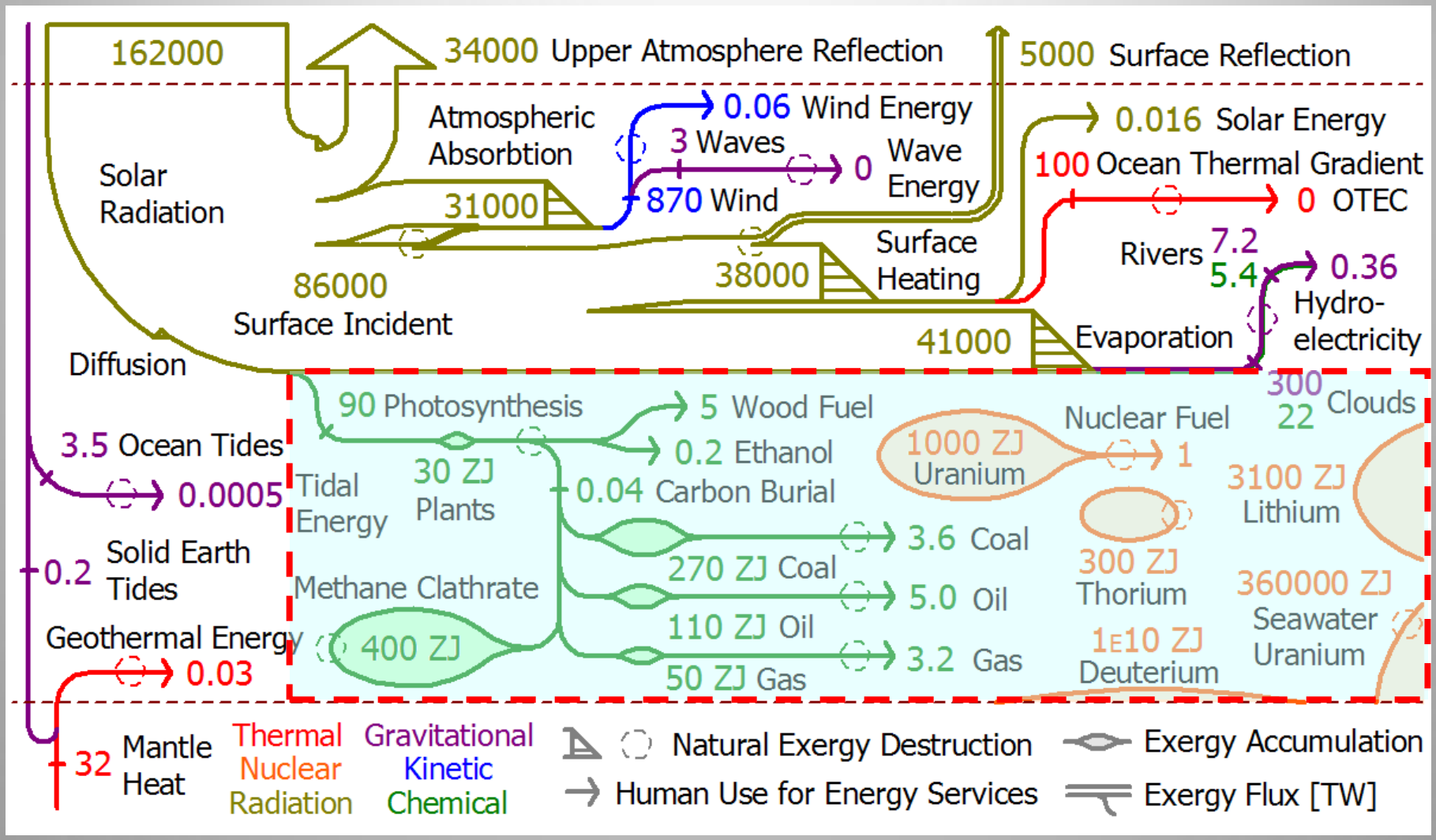
Source: **W. Hermann, Stanford GCEP Systems Analysis Group 2004.**

Geothermal as non-carbon resource



Source: **W. Hermann, Stanford GCEP Systems Analysis Group 2004.**

Global energy is mostly non-renewable



Source: **W. Hermann, Stanford GCEP Systems Analysis Group 2004.**

… Across Borders

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In the following animation:

Shows fossil major (~100EJ) reserves on an energy basis (LHV)
Magnitude of reserve shown in "altitude"

100 EJ is approximately 1 year of U.S. Energy

Red is Coal, Blue is Natural Gas, Green is Petroleum

Global Fossil Reserves

Data: BP Statistical Review, 2007

Russia is a giant

Estimate of Global Fossil Reserves (Proved)

Rank	Oil			Gas			Coal		
	Country	Pct	X (ZJ)	Country	Pct	X (ZJ)	Country	Pct	X (ZJ)
1	Saudi Arabia	22.1%	1.52	Russian Federation	26.3%	1.83	USA	27.9%	5.79
2	Iran	11.5%	0.79	Iran	15.5%	1.08	Russian Federation	16.5%	3.41
3	Iraq	9.4%	0.65	Qatar	14.0%	0.97	China	12.3%	2.55
4	Kuwait	8.5%	0.59	Saudi Arabia	3.9%	0.27	Australia	9.1%	1.88
5	United Arab Emirates	7.9%	0.54	United Arab Emirates	3.3%	0.23	India	7.6%	1.57
6	Venezuela	7.0%	0.48	USA	3.3%	0.23	South Africa	7.2%	1.48
7	Russian Federation	6.6%	0.46	Nigeria	2.9%	0.20	Kazakhstan	4.4%	0.91
8	Libya	3.3%	0.23	Algeria	2.5%	0.17	Ukraine	3.9%	0.81
9	Kazakhstan	3.3%	0.23	Venezuela	2.4%	0.17	Other Europe & Eurasia	2.1%	0.44
10	Nigeria	3.0%	0.21	Iraq	1.7%	0.12	Poland	2.1%	0.43
	11. USA	2.2%	0.16						
	13. China	1.4%	0.09	17. China	1.3%	0.09			
	22. India	0.5%	0.03	27. India	0.6%	0.04			
	Global Oil Reserves (ZJ)		6.91	Global Gas Reserves (ZJ)		6.96	Global Coal Reserves (ZJ)		20.73

Rank	Total Fossil Reserves (Proved)		
	Country	Pct	X (ZJ)
1	USA	17.8%	6.17
2	Russian Federation	16.5%	5.70
3	China	7.9%	2.74
4	Australia	5.8%	2.01
5	Iran	5.4%	1.87
6	Saudi Arabia	5.2%	1.80
7	India	4.8%	1.65
8	South Africa	4.3%	1.48
9	Kazakhstan	3.6%	1.26
10	Qatar	3.1%	1.06
	Global Fossil Reserves (ZJ)		34.6

Source: "Statistical Review of World Energy 2007", BP

Factoids:

- Only Russian Federation is in the "Top 10" for each type—*Honorable mention to U.S. (#11 in oil)*

$1\ \mathrm{ZJ} = 10^{21}\ \mathrm{J},\ 1\ \mathrm{EJ} = 10^{18}\ \mathrm{J},\ 1\ \mathrm{Quad} \sim 1\ \mathrm{EJ}$

There is more to fossil than oil

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- Only Russian Federation is in the "Top 10" for each type—*Honorable mention to U.S. (#11 in oil)*
- There are 5 reserves larger than Saudi oil (4 coal, 1 gas)

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Manifest geology?

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- There are 5 reserves larger than Saudi oil (4 coal, 1 gas)
- U.S Coal is larger than the Top 10 oil reserves combined

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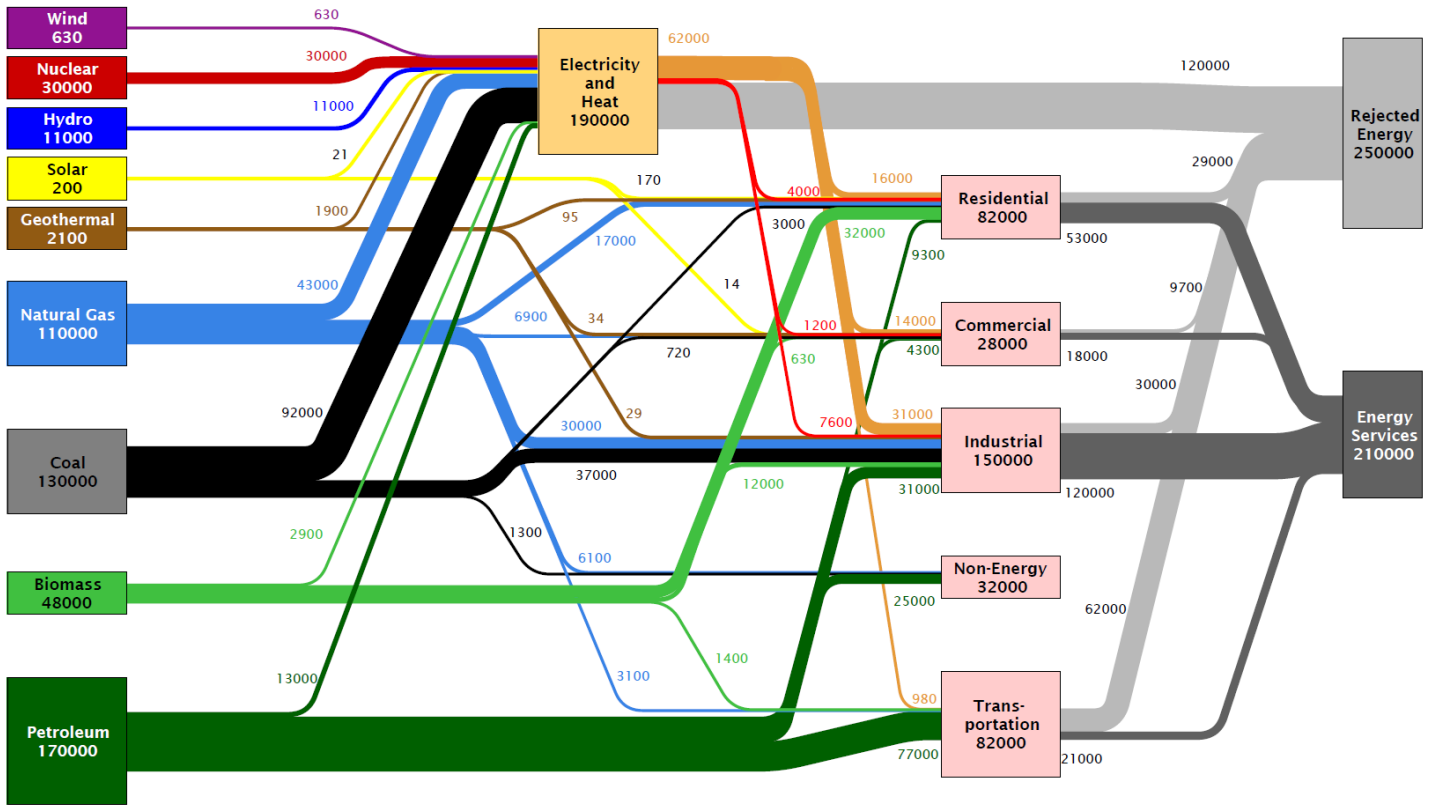
… Through Engineered Systems

Global Energy

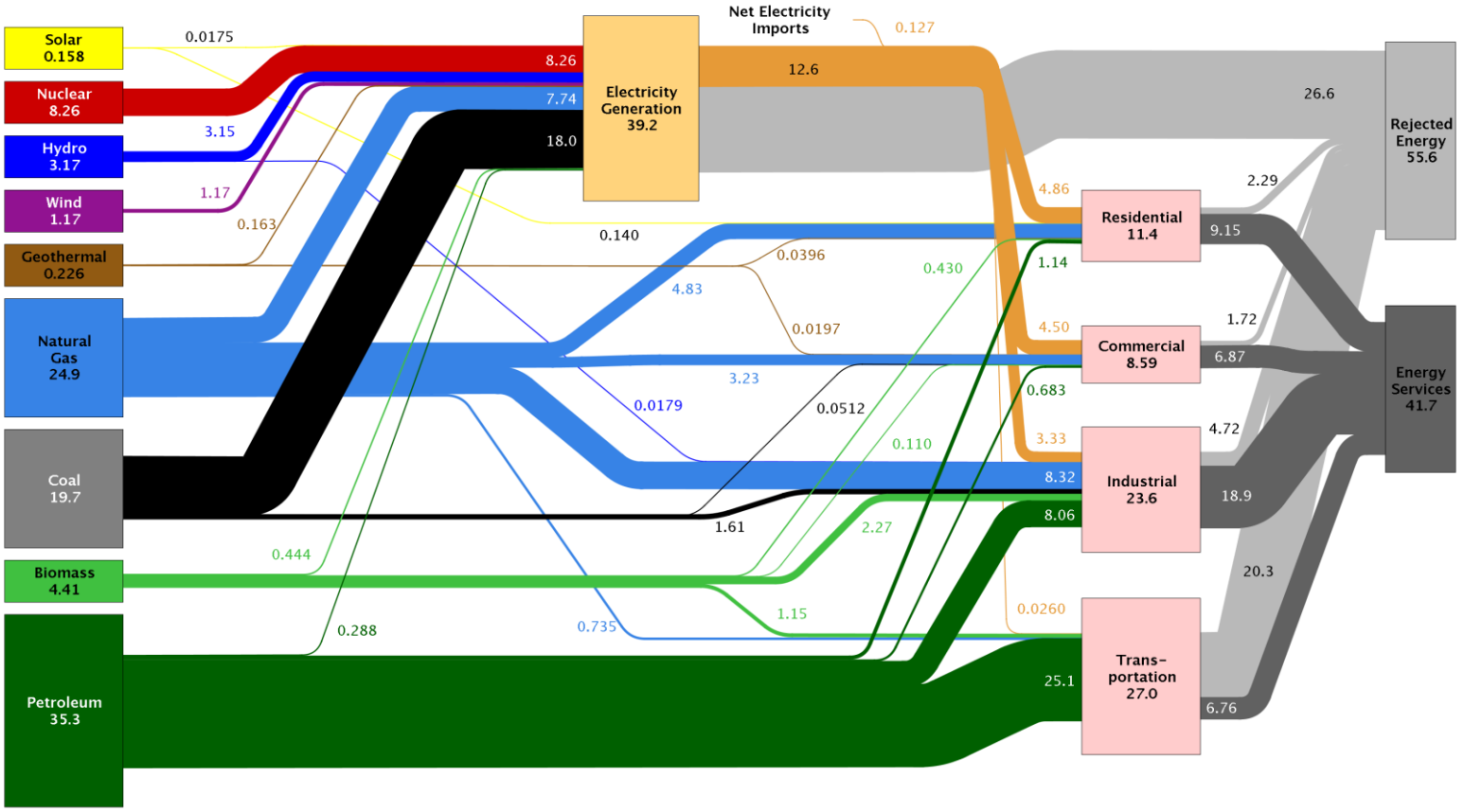
World Energy Flow
in 2007: ~490000 PJ

Lawrence Livermore National Laboratory



Source: LLNL 2011. Data is based on IEA's Extended World Energy Balances. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the U.S. Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 PJ are not included. Totals may not equal sum of flows due to statistical differences. Domestic supply includes changes in stocks. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-473098.

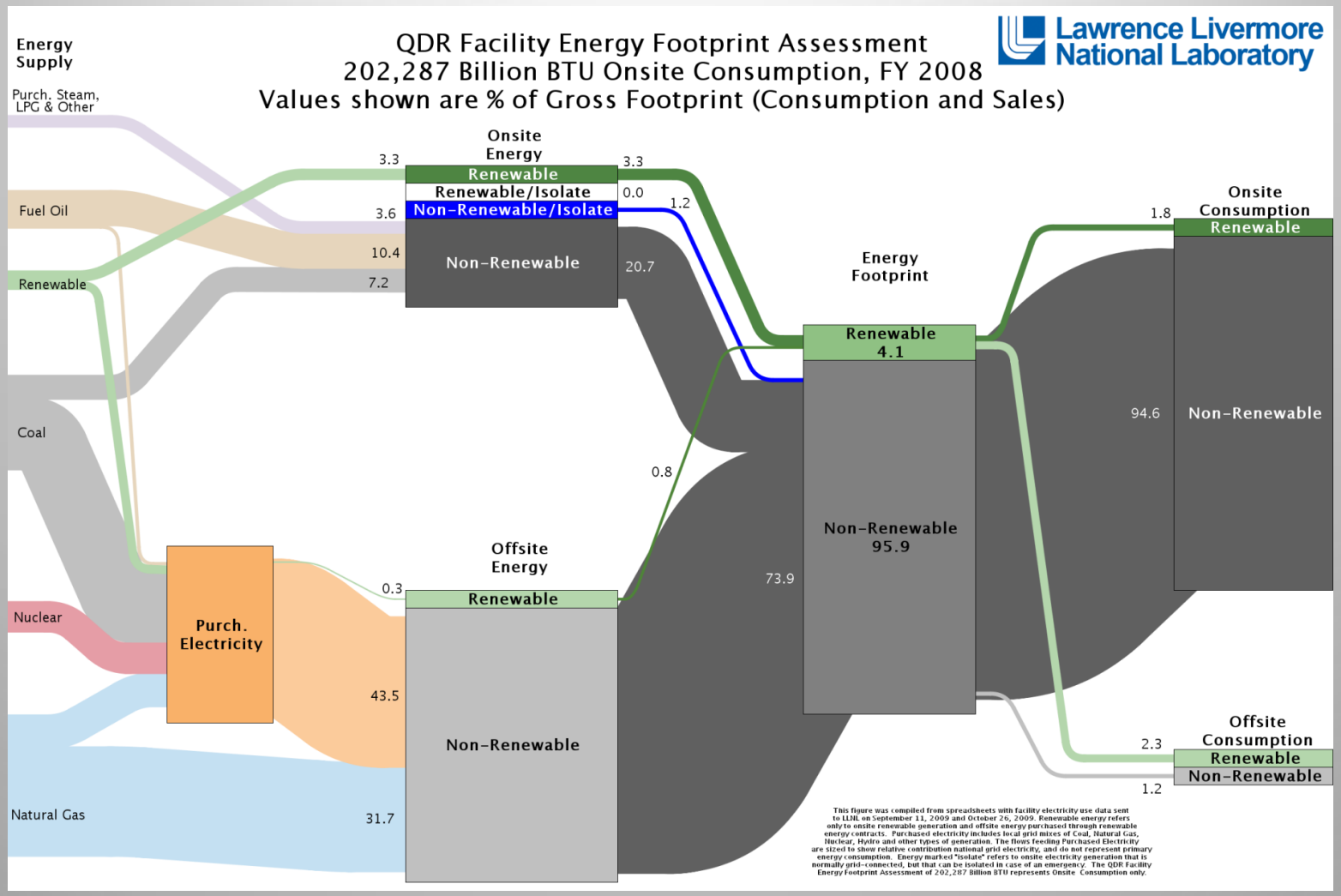
U.S. Energy



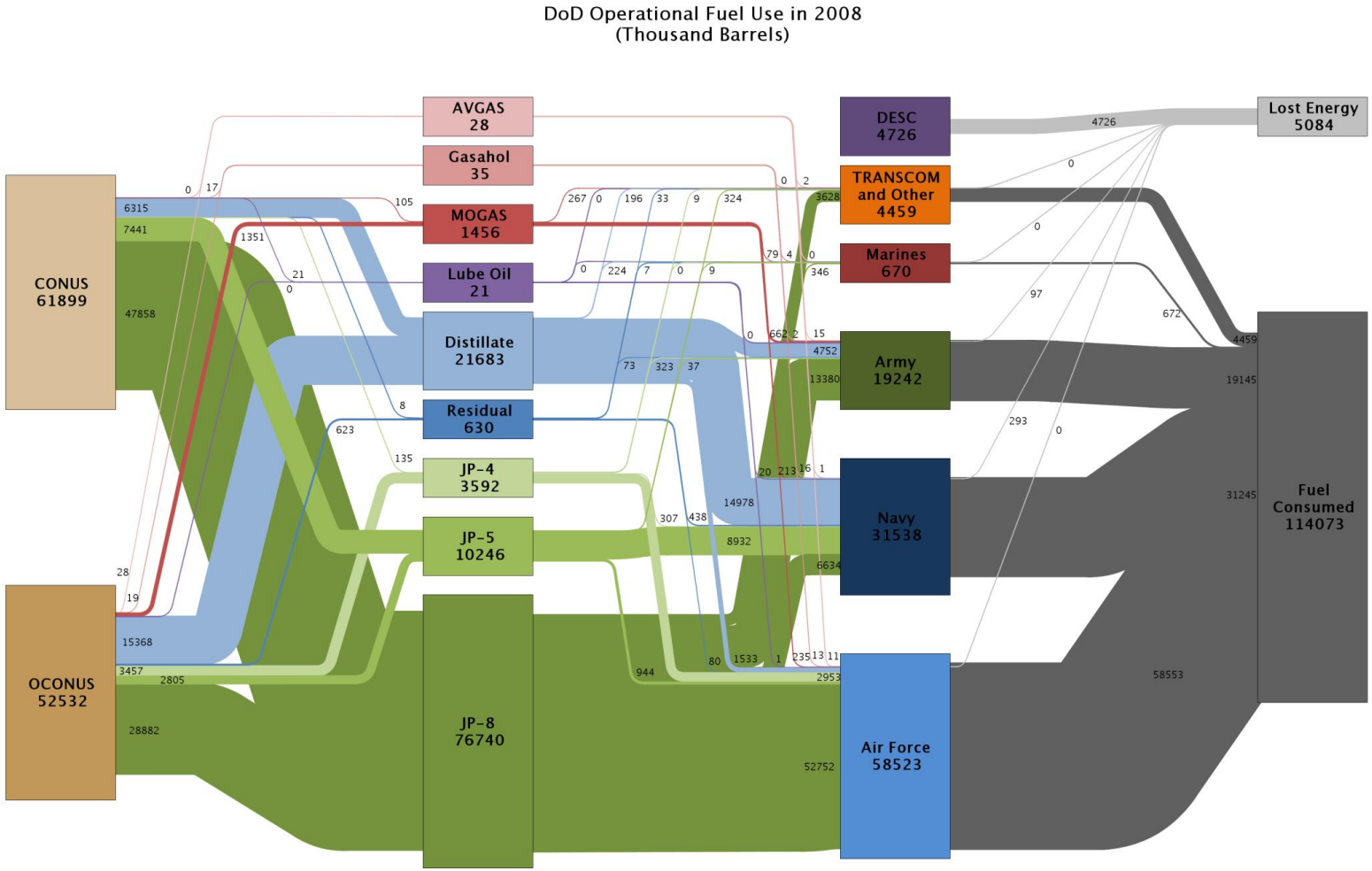
Source: LLNL 2012. Data is based on DOE/EIA-0384(2011), October, 2012. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports flows for non-thermal resources (i.e., hydro, wind and solar) in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 80% for the residential, commercial and industrial sectors, and as 25% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

… For U.S. Defense

Energy for Defense: DoD Electricity Use



Energy for Defense: DoD Fuel Use



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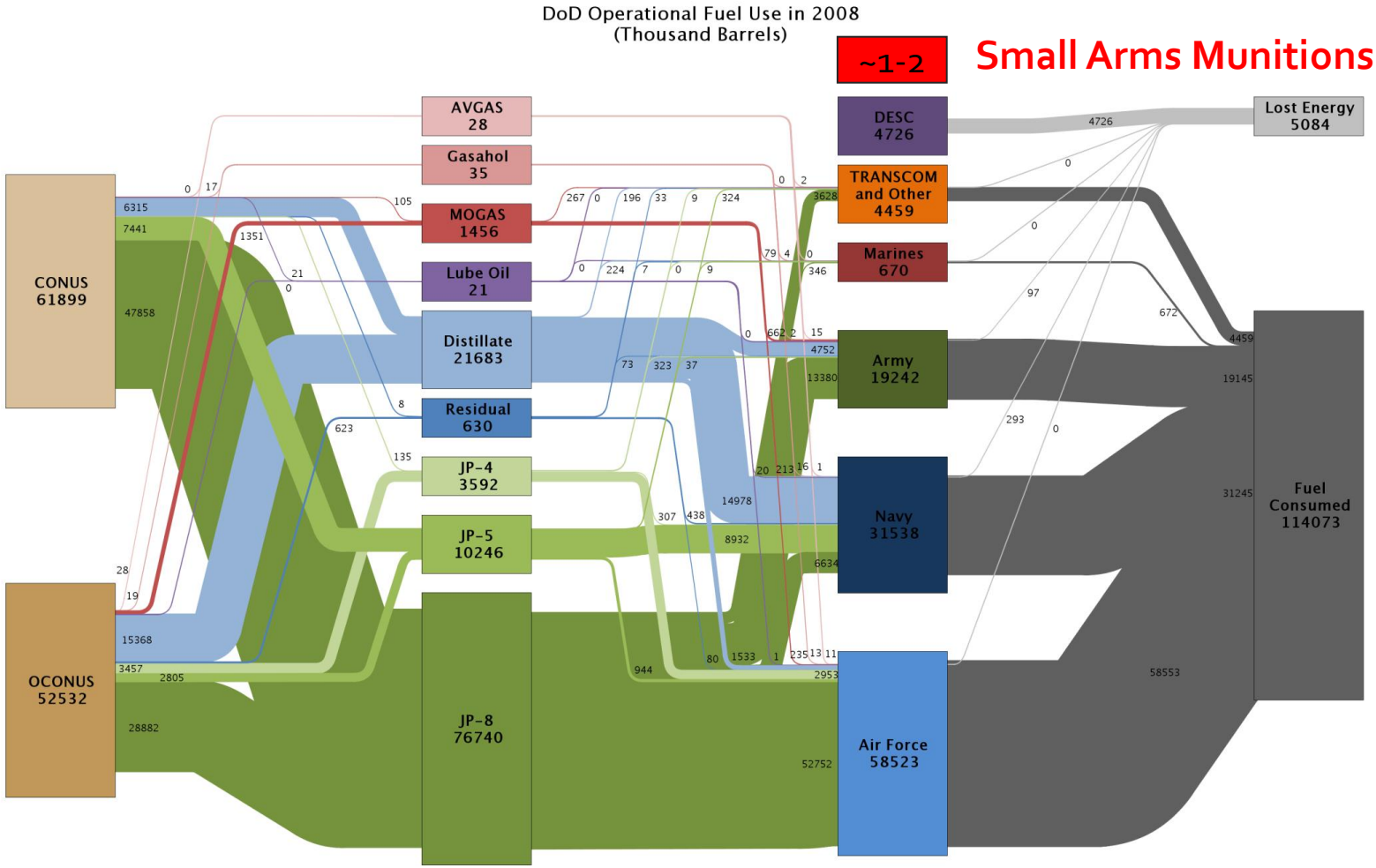


"Energy" for Defense

Munitions

25hp @ 700RPM
30 rds = 140 kJ

Electricity

~100W

Supplies

Food ~ 120W
Water ~ 5L/day

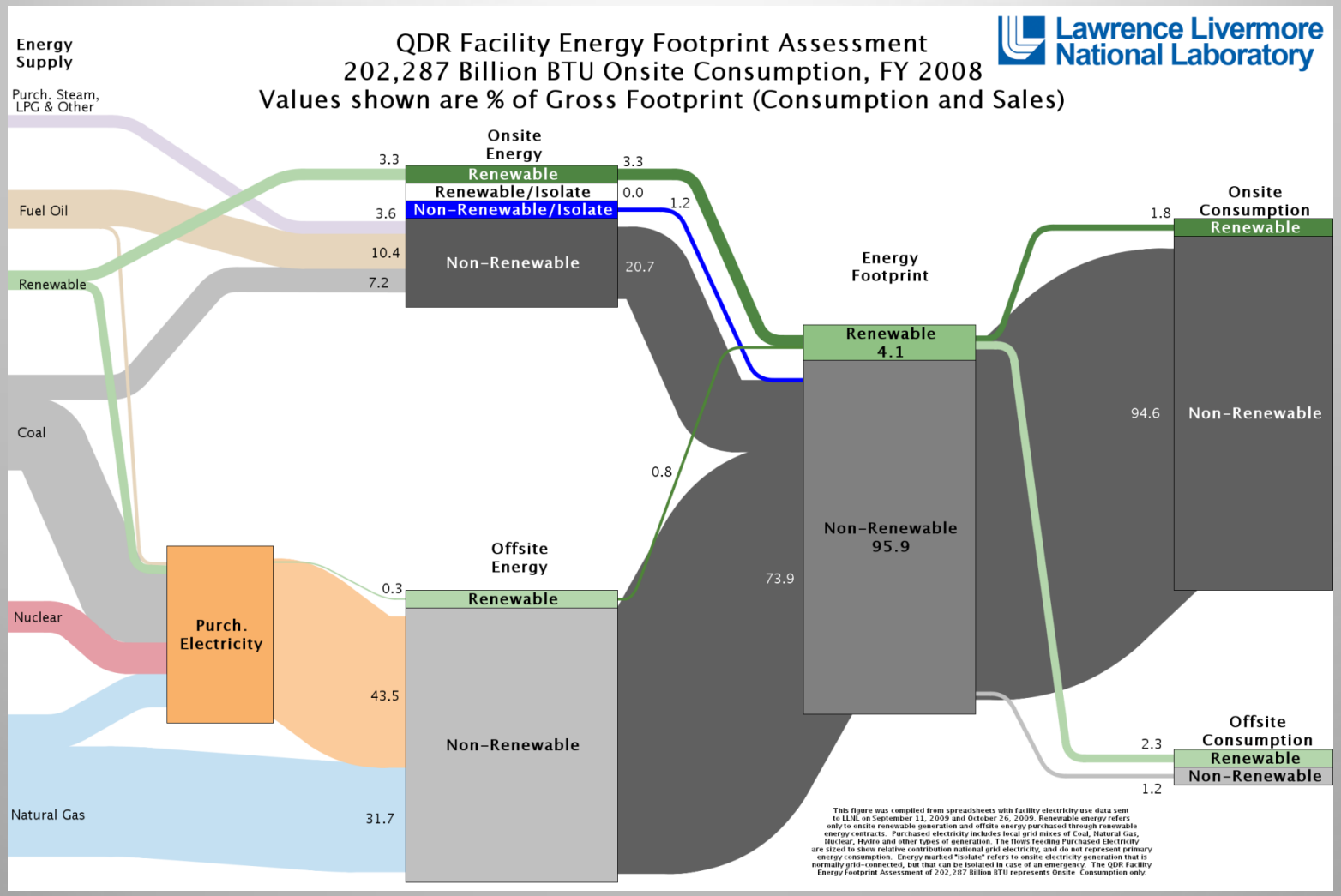
MH-60S
2x GE700-401
10MW shaft (peak)

F/A-18E
2x GE F414-400
35MW thermal (CAP nominal)

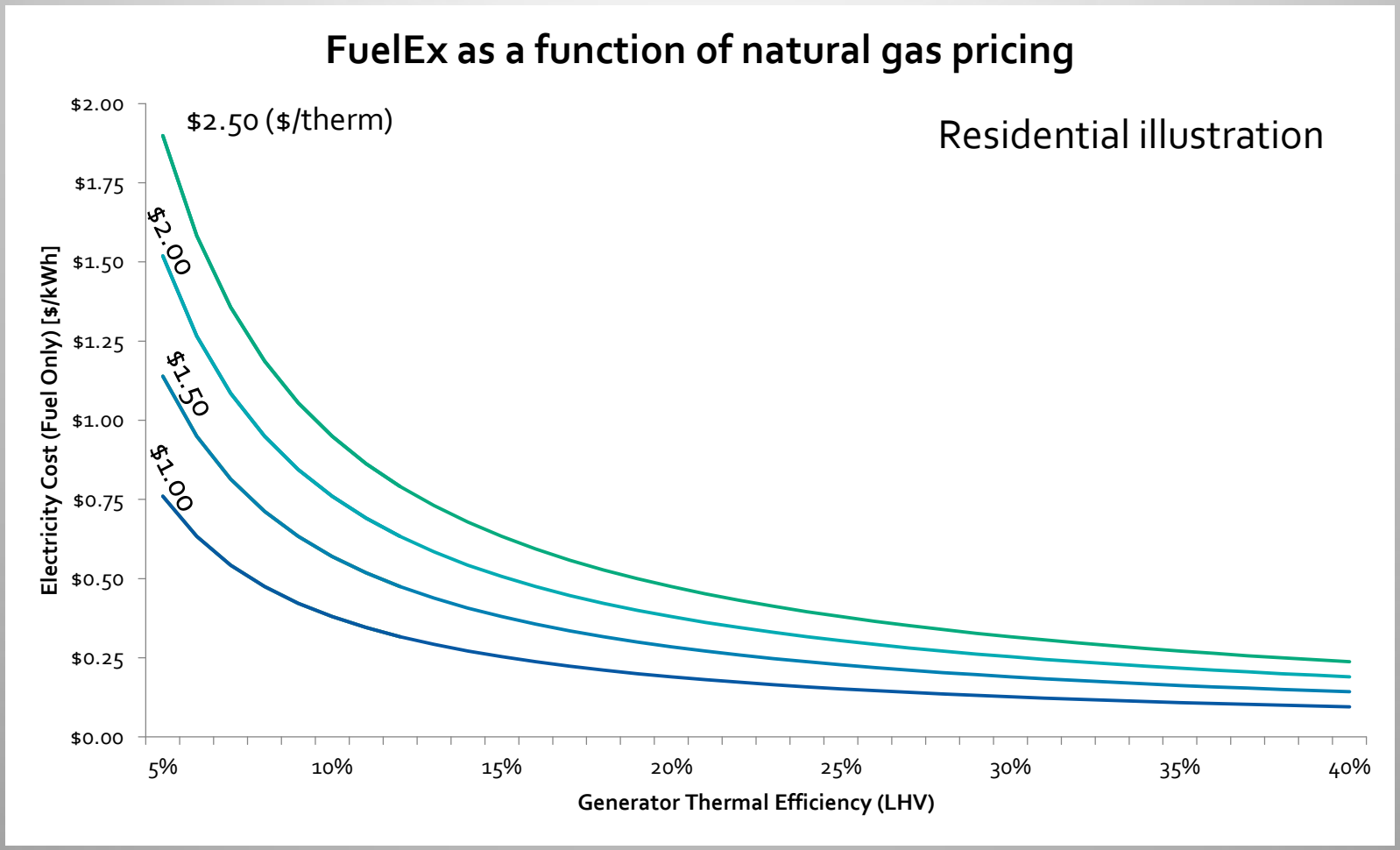
Ticonderoga Class
4x LM2500
64MW shaft (peak)

Where to innovate?
A Mini-Study In Electricity

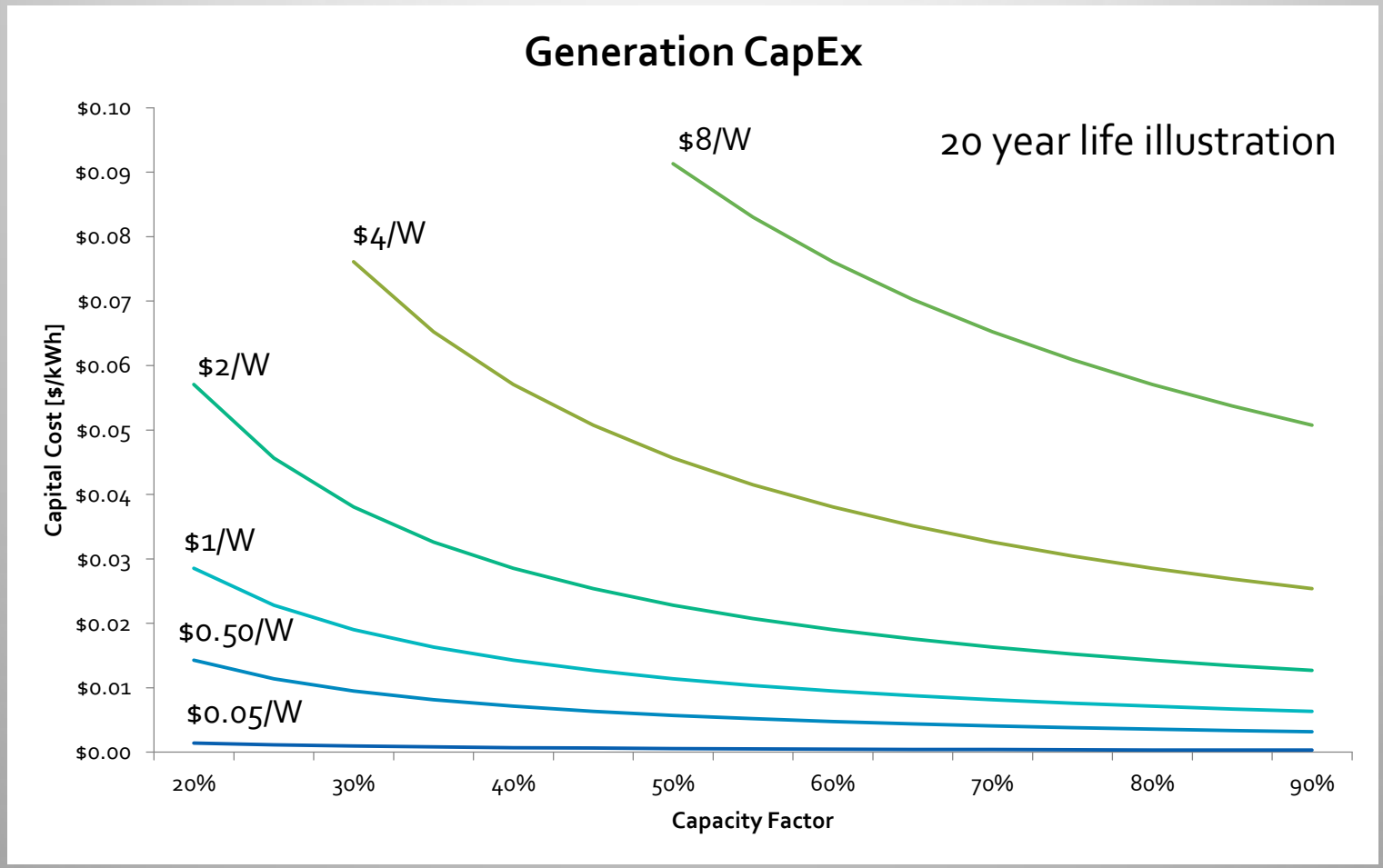
Energy for Defense: DoD Electricity Use



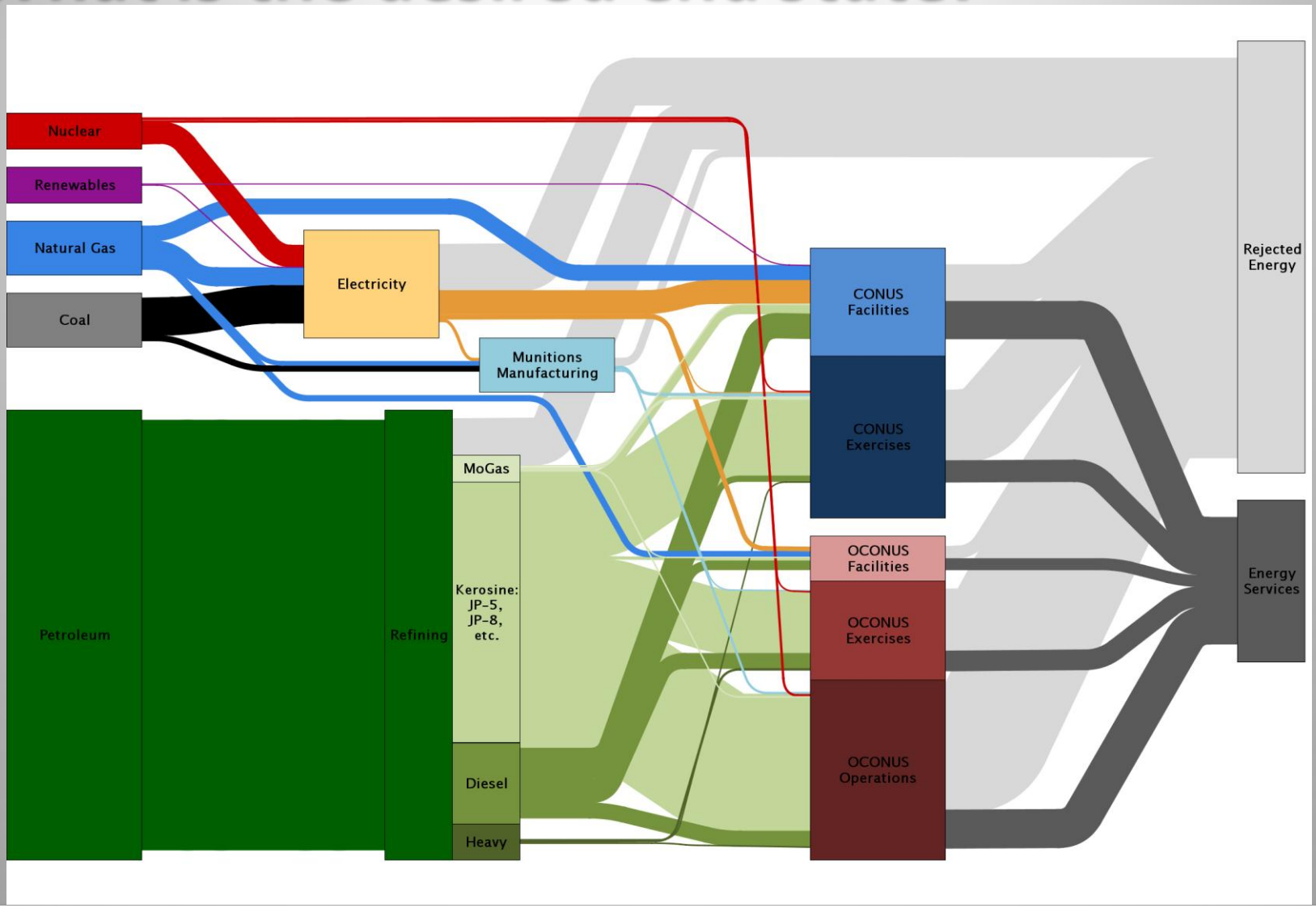
Natural Gas "FuelEx" – Technology Neutral



Capital Cost of Generation – Technology Neutral



What is the desired end state?



Thank You

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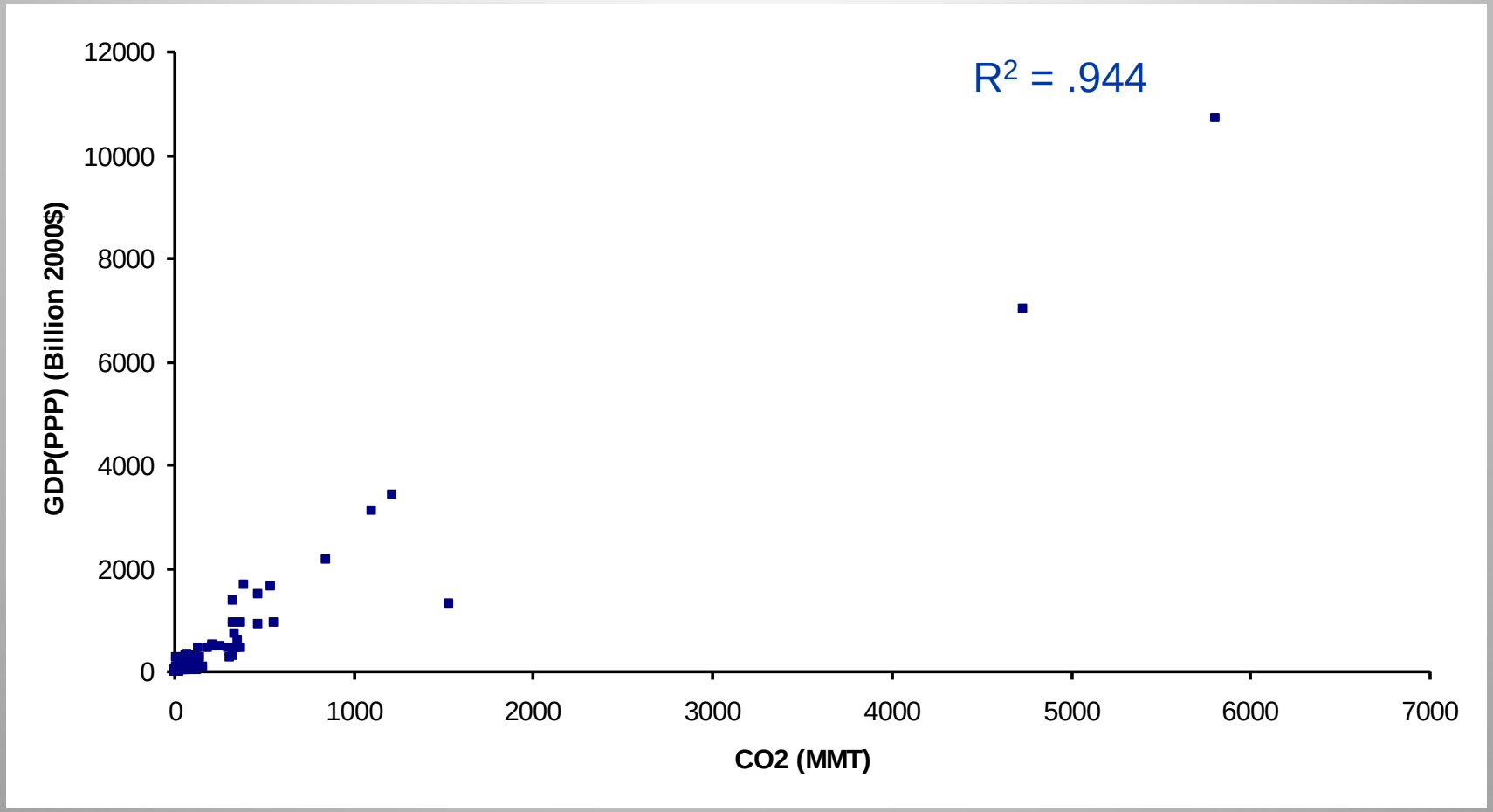
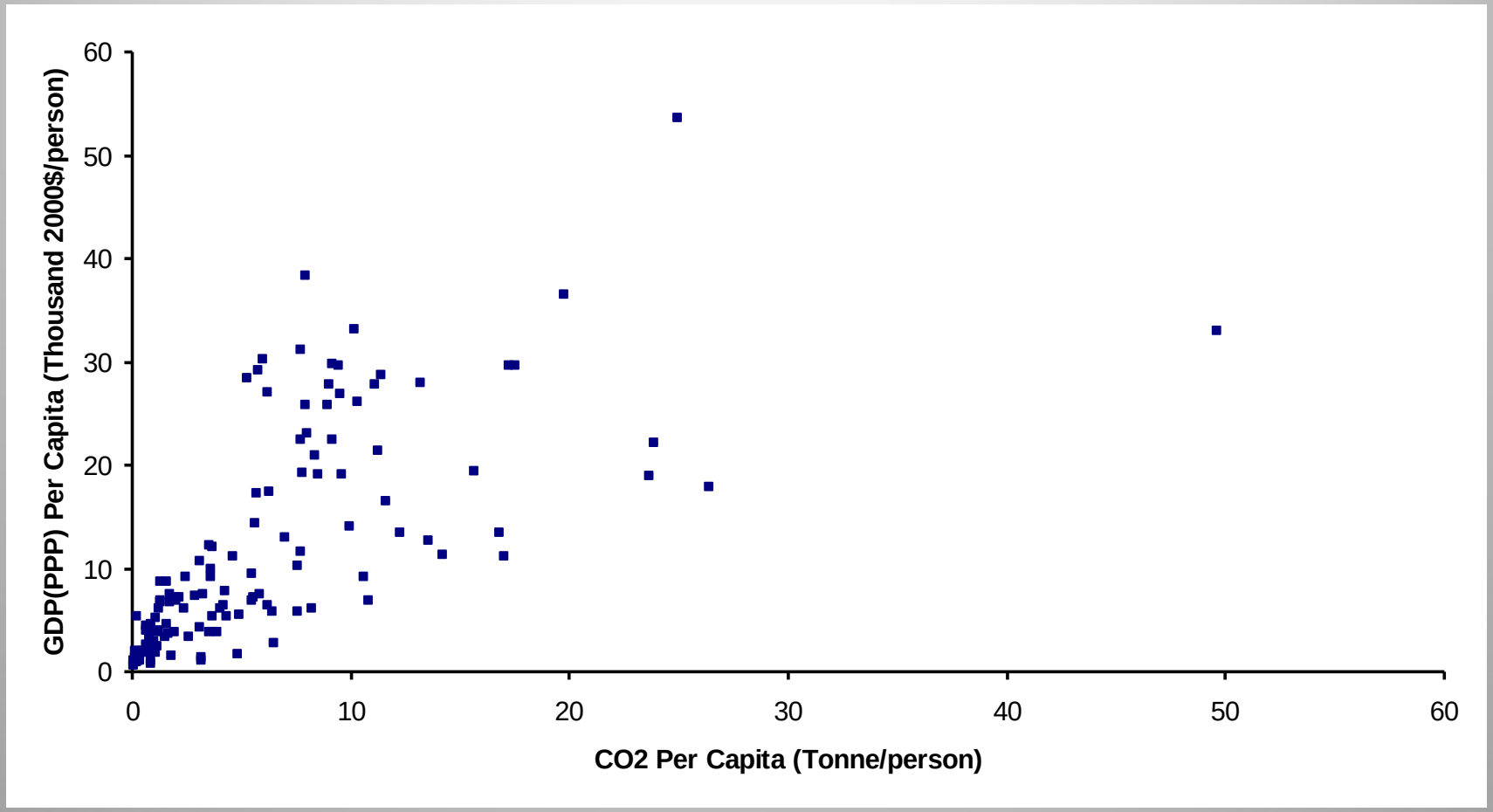
Geopolitics and Economics

Aggregate National GDP vs CO_2



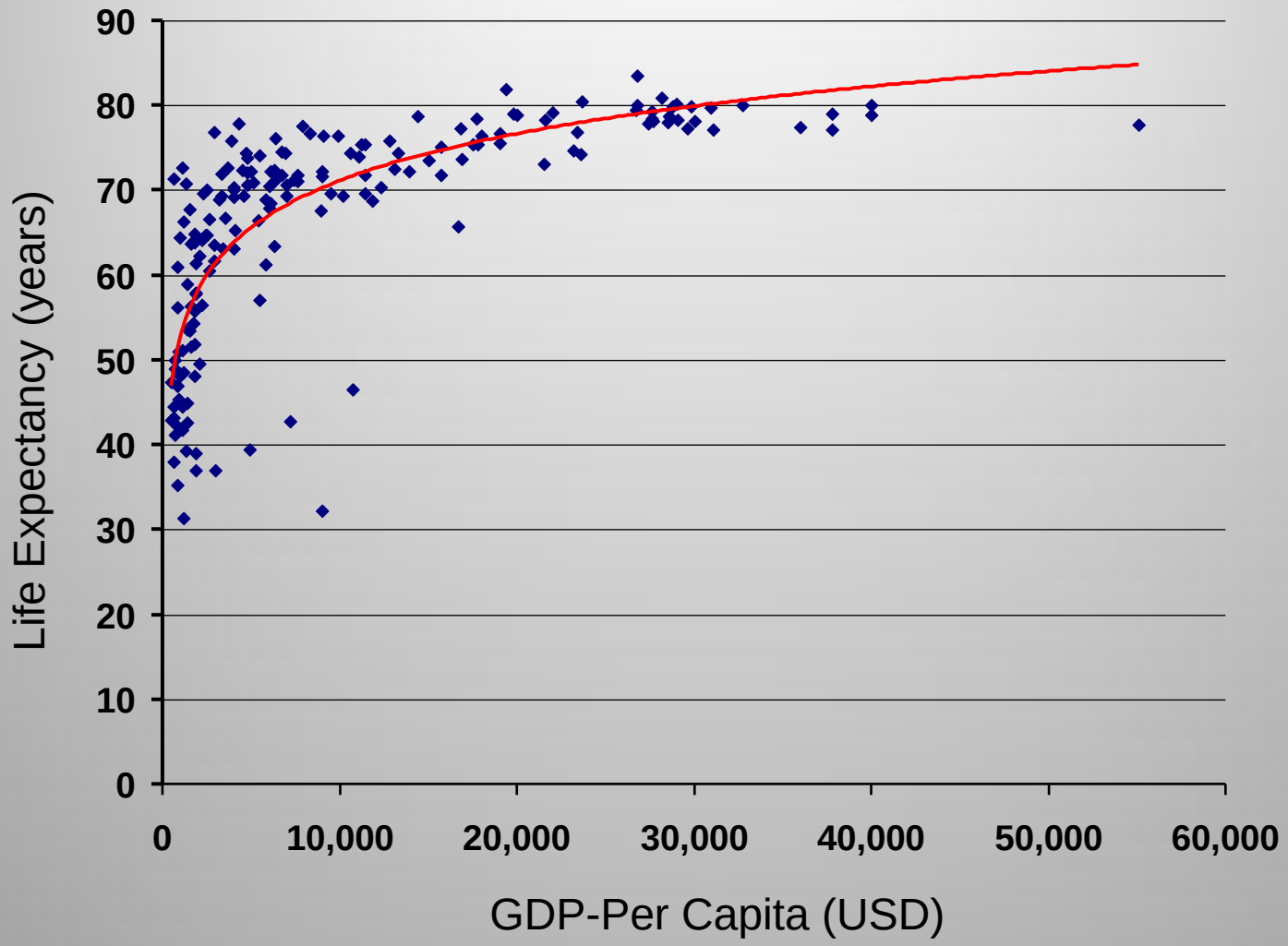
Source: "Key World Energy Statistics 2006", IEA

GDP vs CO_2



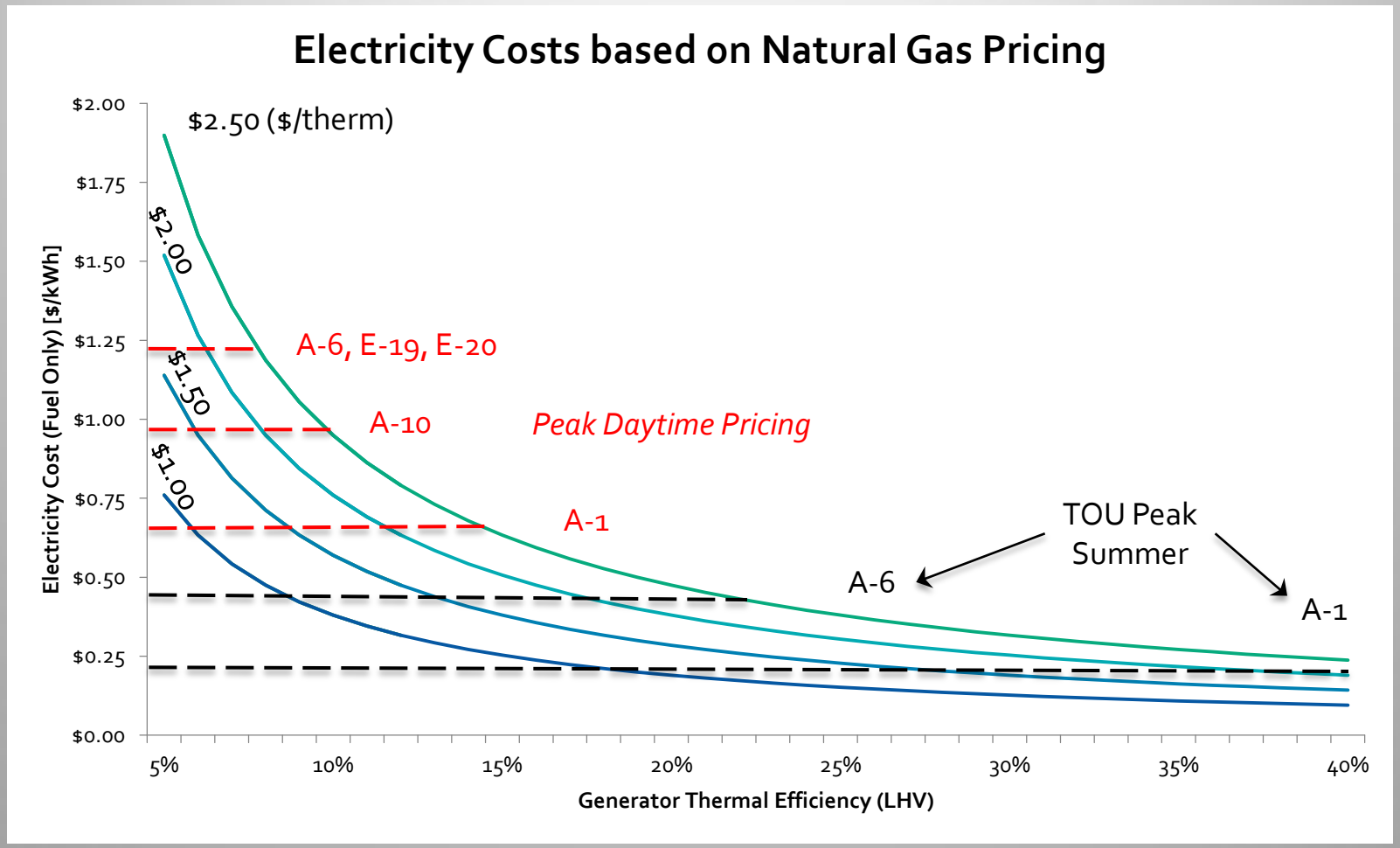
Source: "Key World Energy Statistics 2006", IEA

Wealth and Life Expectancy (2003)

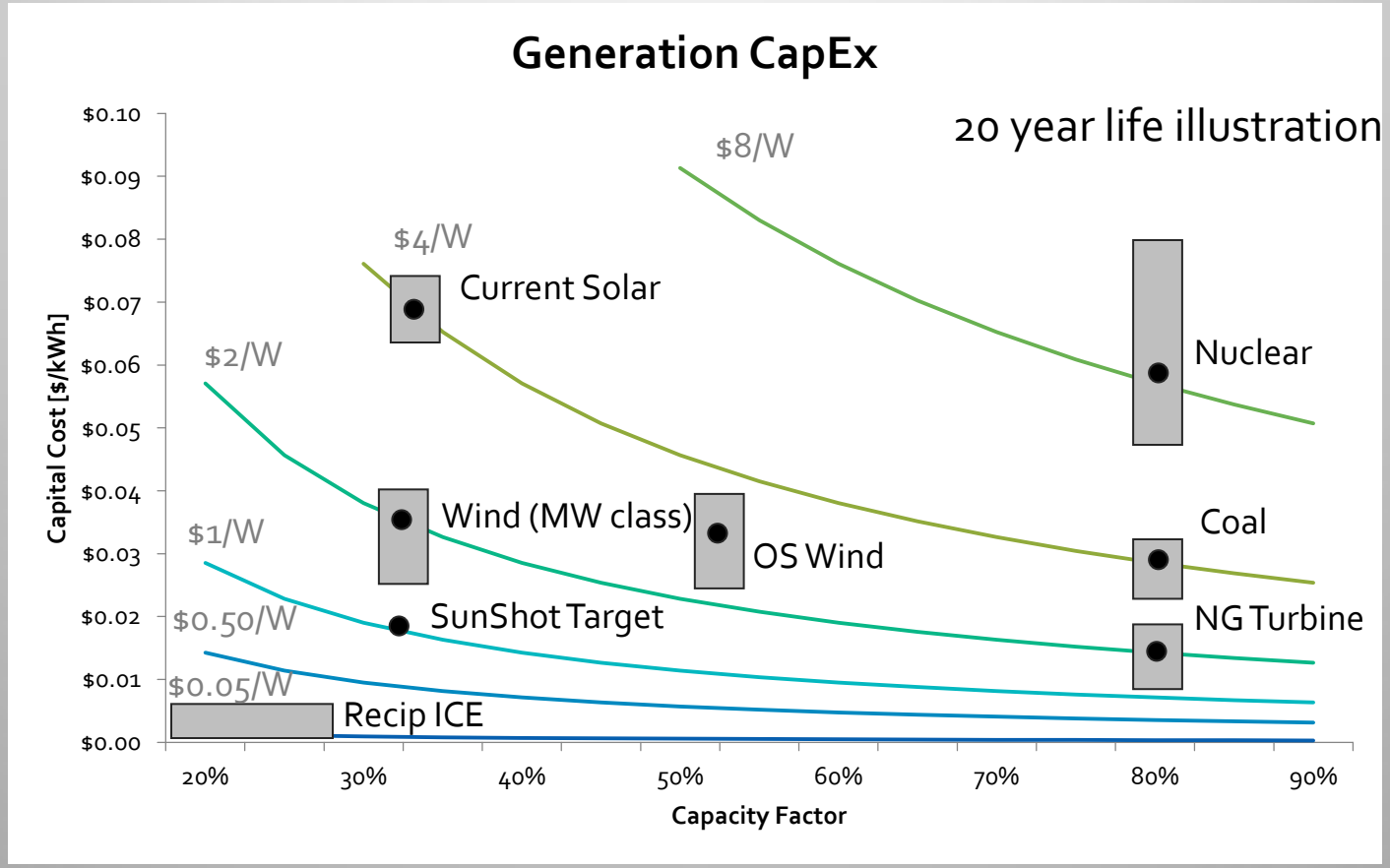


Source: CIA World Factbook

Natural Gas OpEx relative to PG&E pricing



CapEx of Sample Technologies (Context)



Energy for Individual Weapons

25hp @ 700RPM
30 rds = 140 kJ

47hp @ 650RPM
200 rds = 1800 kJ

~850 kJ

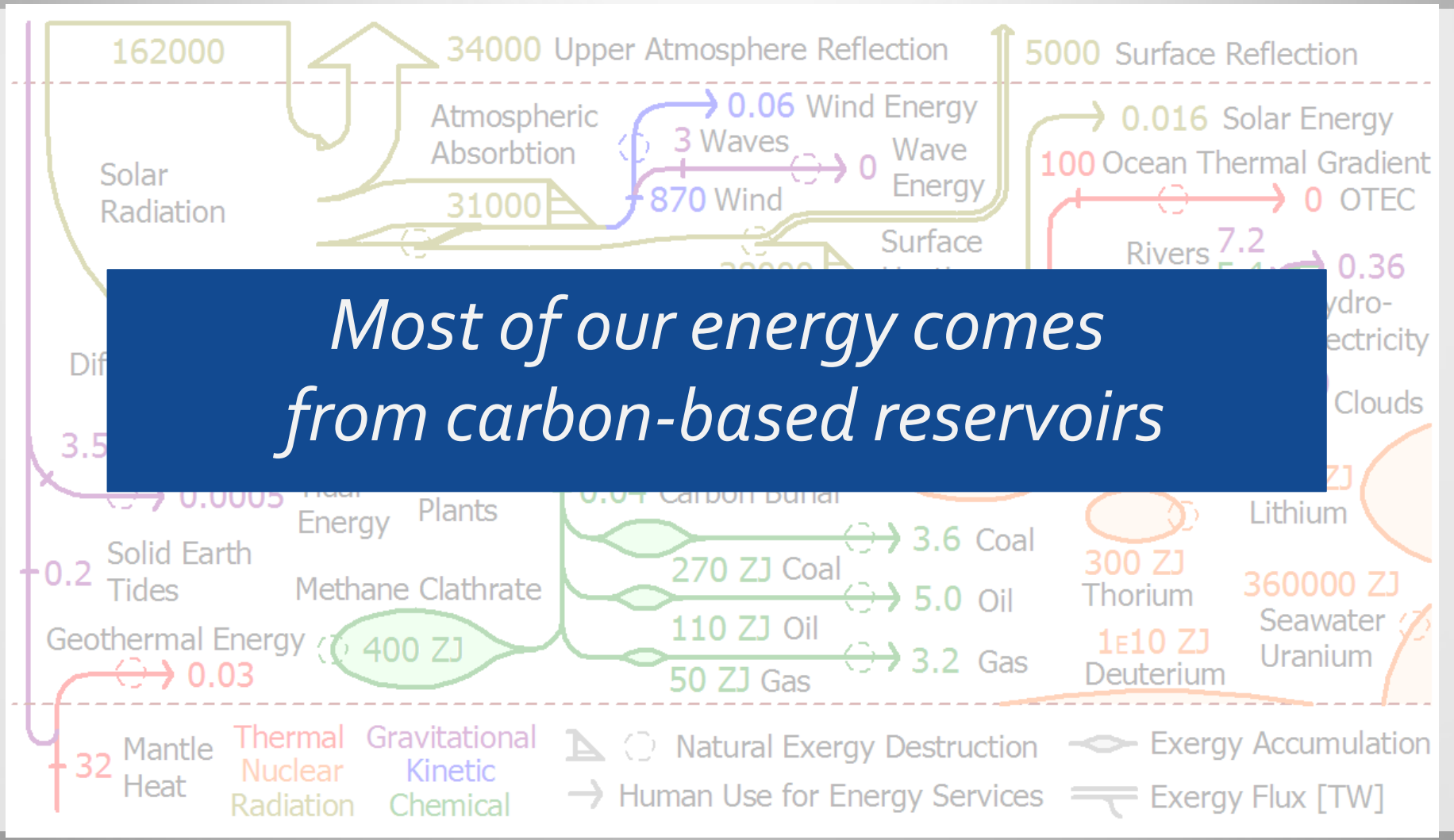
Crew-Served Weapons

~ 11,000 kJ

180hp @ 450RPM
200 rds = 9140 kJ

1900 hp @ 625 RPM
578 rds = ~250,000 kJ

Global energy is mostly non-renewable



Most of our energy comes from carbon-based reservoirs

Source: **W. Hermann, Stanford GCEP Systems Analysis Group 2004.**