Solar High: Making It Happen

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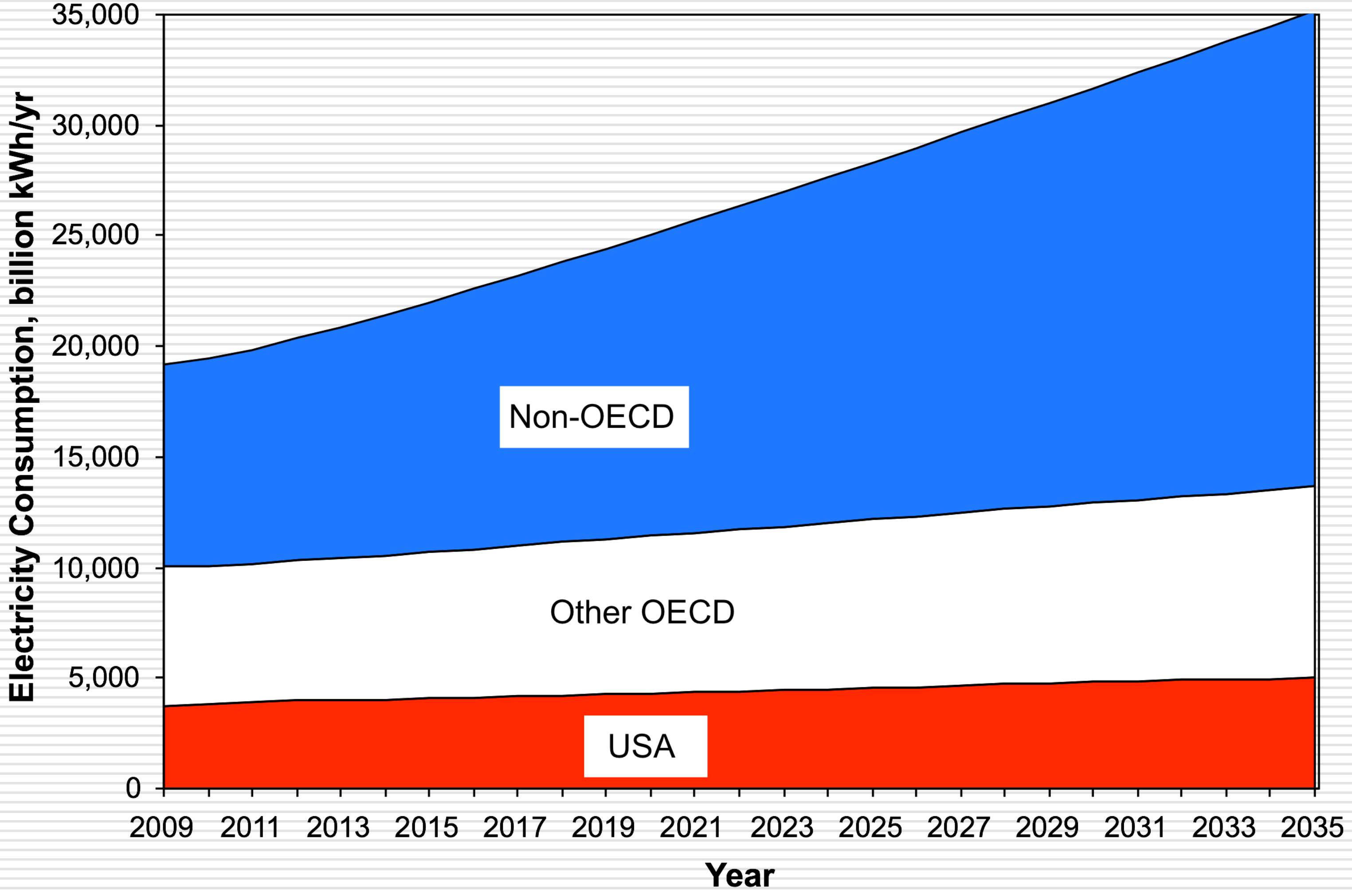
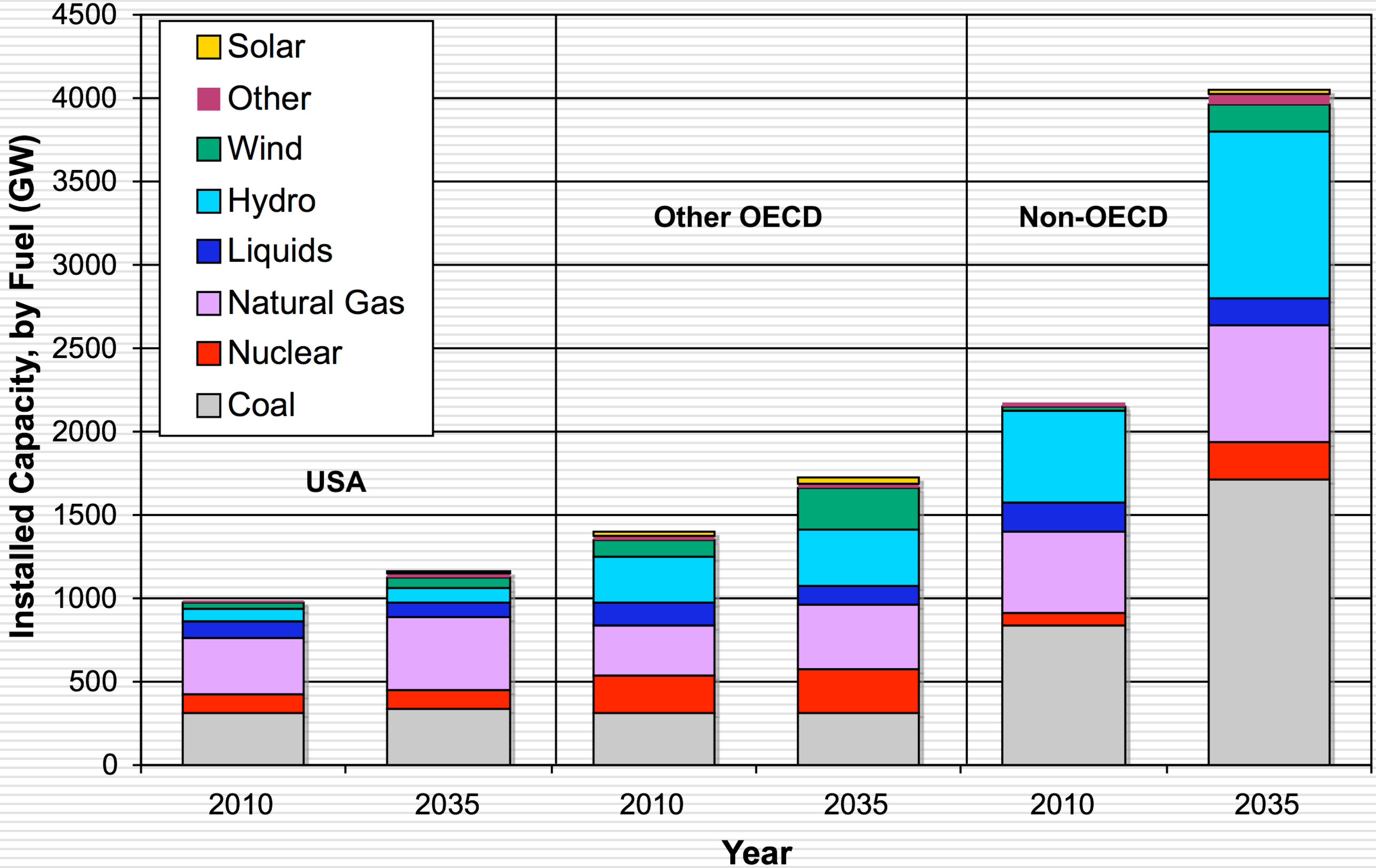
Image Source: APOD/NASA

Electricity Consumption, 2009-2035



Source: DOE EIA

Generating Capacity, 2010 & 2035



Source: DOE EIA

The Electric Problem

- There are only four available technologies that can conceivably supply electric power on a sufficient scale:
  - Nuclear (probably Gen IV fast neutron reactor)
  - Coal (perhaps “Clean Coal”)
  - Natural gas (shale gas, methane from hydrates, etc.)
  - Solar
- The first three face public resistance (whether or not justified) on environmental or NIMBY grounds.

Why Wind Will Remain a Minor Source

4,400 wind turbines like this are needed to match one 2 GW power satellite

Truck

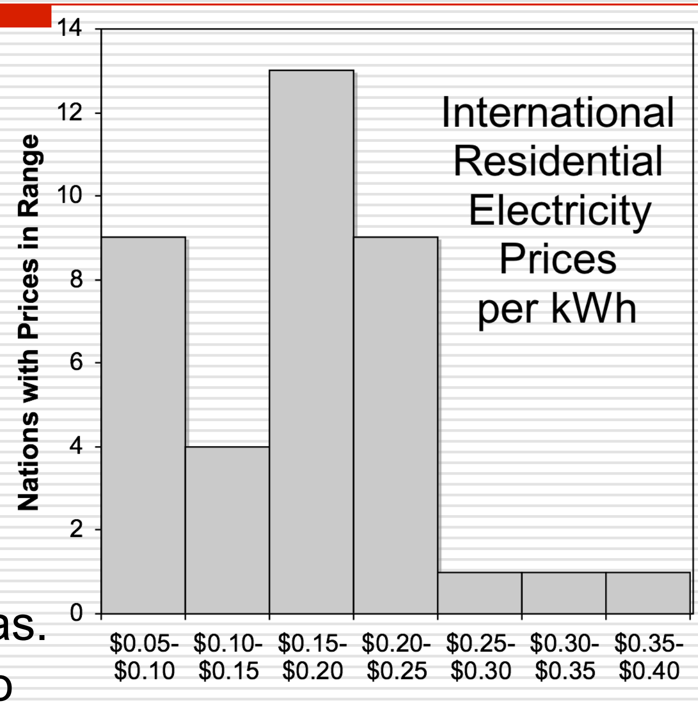
1.5 MW wind turbine
Annual output: 4 million kWh

Natural gas well annual output:
44 million cubic feet (typical),
which gives 13 million kWh heat
or 4.5 million kWh electricity

Sources: Danish Technical University & DOE EIA

The Need for Cheap Energy

- The present average US residential price of electricity is 11.45 ¢/kWh; the average wholesale price is 5.72 ¢/kWh.
- Accepting significantly higher US prices will
  - Lower the US standard of living.
  - Impose a regressive tax on people with low income.
  - Drive US industry and jobs overseas.
  - Encourage Third World countries to maximize their advantage by keeping energy cheap (i.e, .burning coal), thus *increasing* global CO_2 emissions.

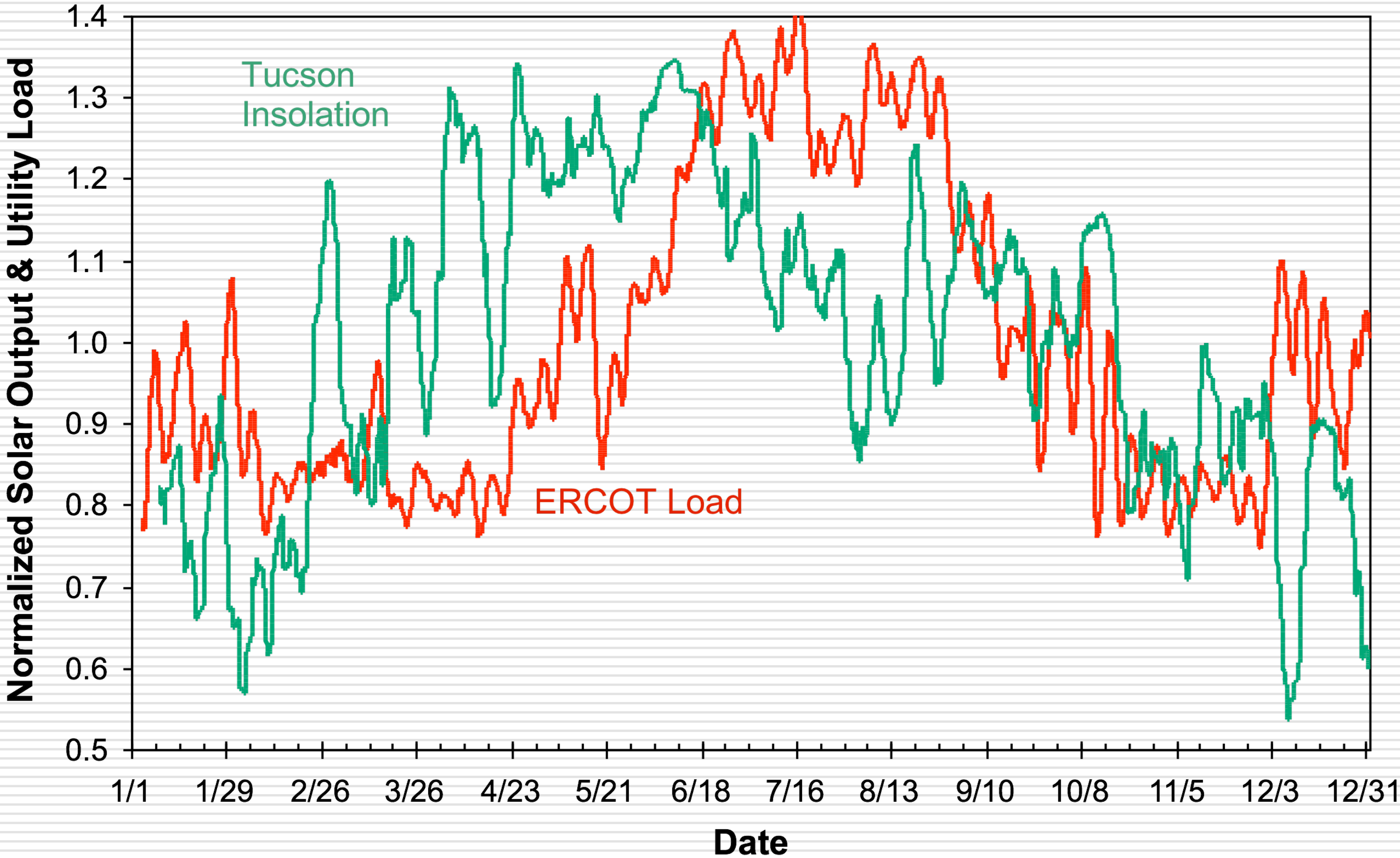


- Some overseas markets may accept higher prices, at least initially. Ireland, Italy and Denmark are among the most expensive, but they are not large markets (probably < 8 GW total new capacity by 2035).

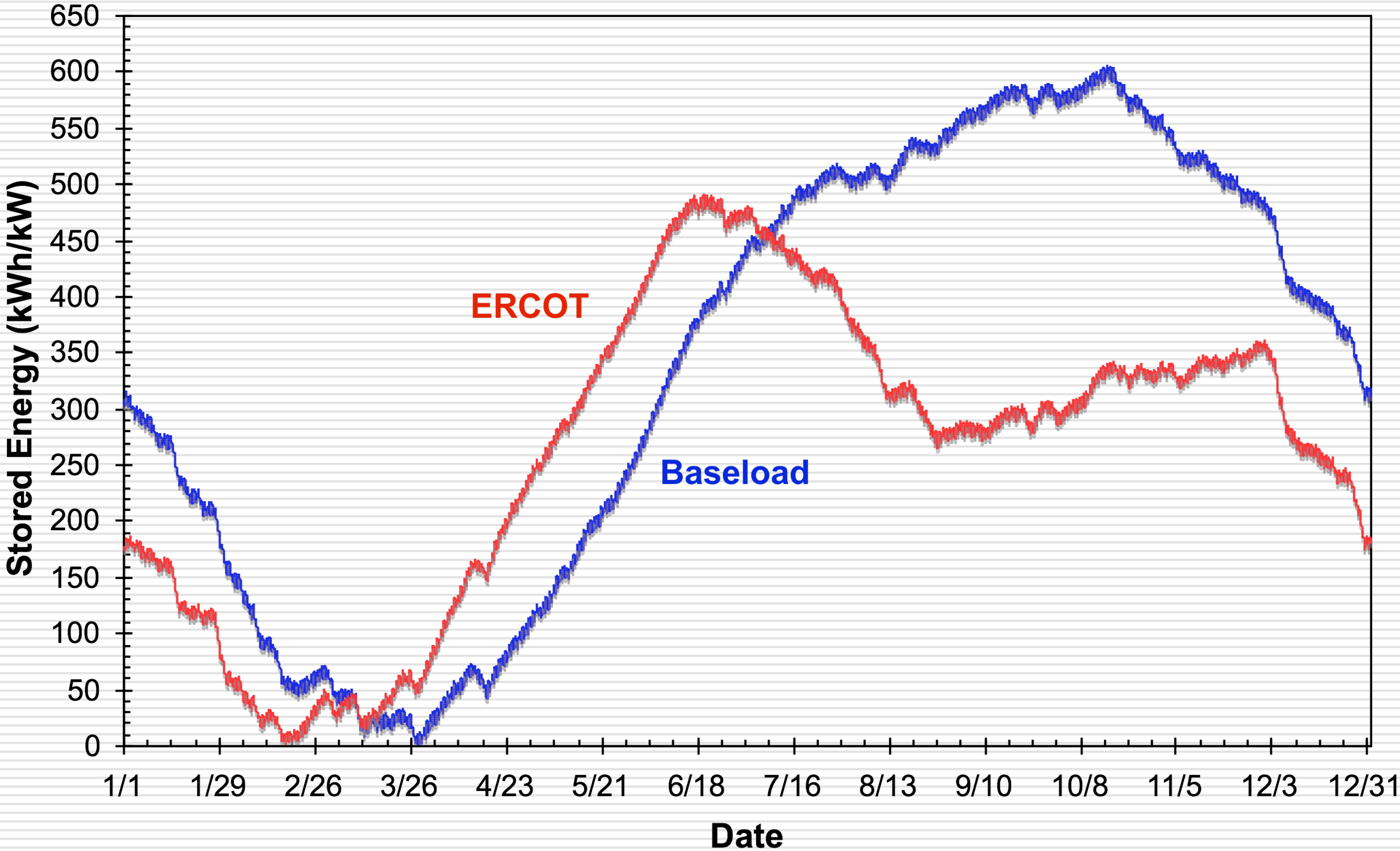
Solar Dreams

- Vision: the ultimate renewable energy source
- Reality, 2009: 0.3% of US electricity
  - EIA prospect, 2035: 0.8% of US electricity
- Goal, 2035: Grid-connected central solar plants supplying baseload, dispatchable power
- Capacity goal, 2035: 15% of new generation capacity, worldwide
  - US: 40 GW
  - Other OECD: 60 GW
  - Non-OECD: 300 GW
  - Total: 400 GW

The Solar Problem



Energy Storage Requirements



Terrestrial Solar Parameters, per kW

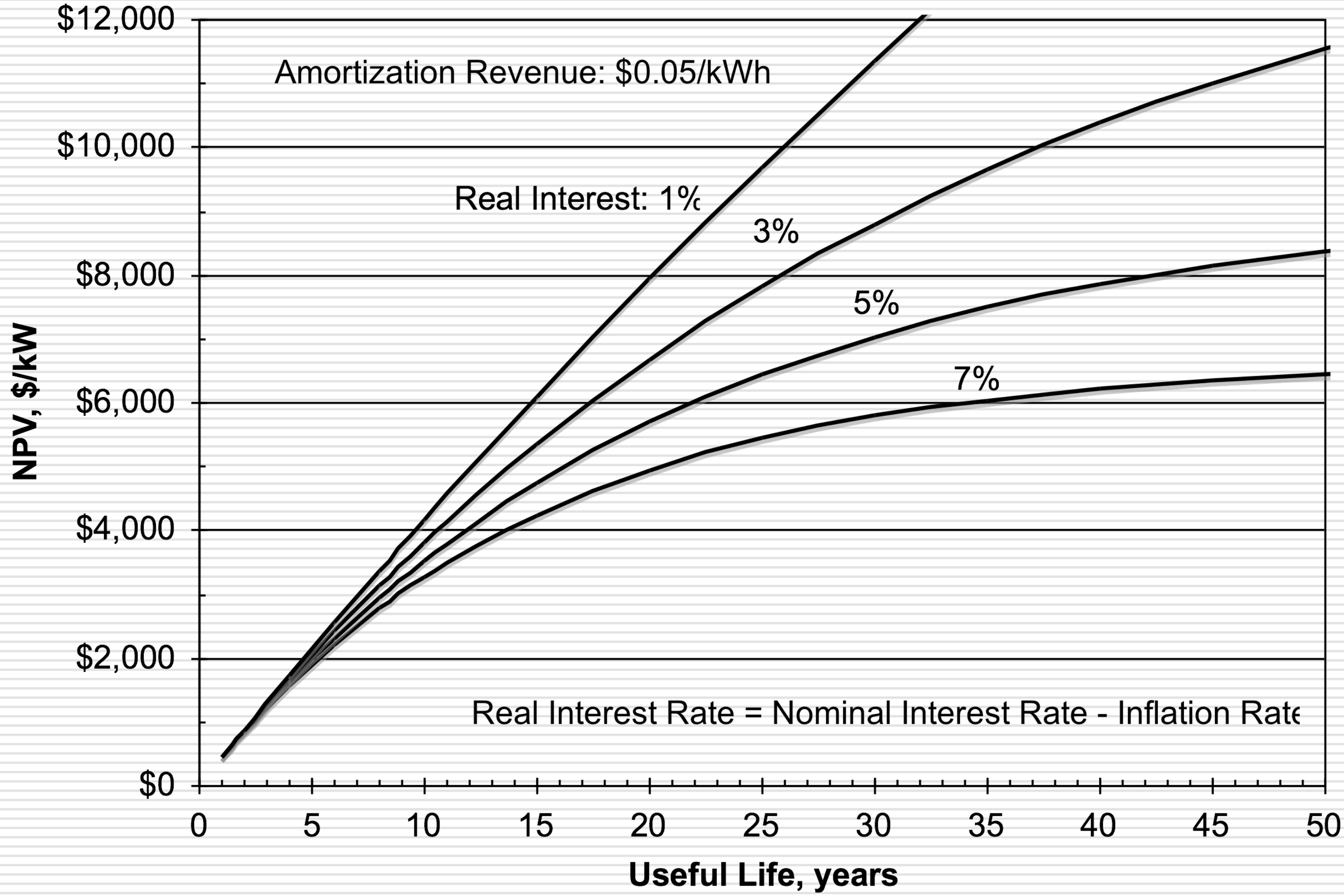
		ERCOT	Baseload
	PV array area, m^2	40.9	44.2
	Peak storage, kWh	491	606
	Max array output, kW	4.9	5.3
Costs:	Solar farm	$12,270	$13,260
	Pumped storage	$2,400	$2,400
	HVDC lines	$3,770	$4,080
	Total:	$18,440	$19,740

EIA *Annual Energy Outlook 2010:* "solar technologies are too costly for widespread use in wholesale power applications."

Terrasolar Power vs Solar High

	Tucson	GSO
Sun-track	Expensive	Easy
Concentration ratio	1	30 to 1000
Photovoltaic cells	CdTe, etc.	Multijunction
Hazards	Storm, flood, dust, birds	Radiation, micrometeors
Average insolation, W/m^2	285	1,360
Array area, m^2/kW	>40	5.5
Energy storage, kWh/kW	600	0
Transmission line, km	2,400	100?
Land area (for 2GW), km^2	400	70
Delivered energy, $/kWh	>$0.20	$0.08?

The Solar High Challenge



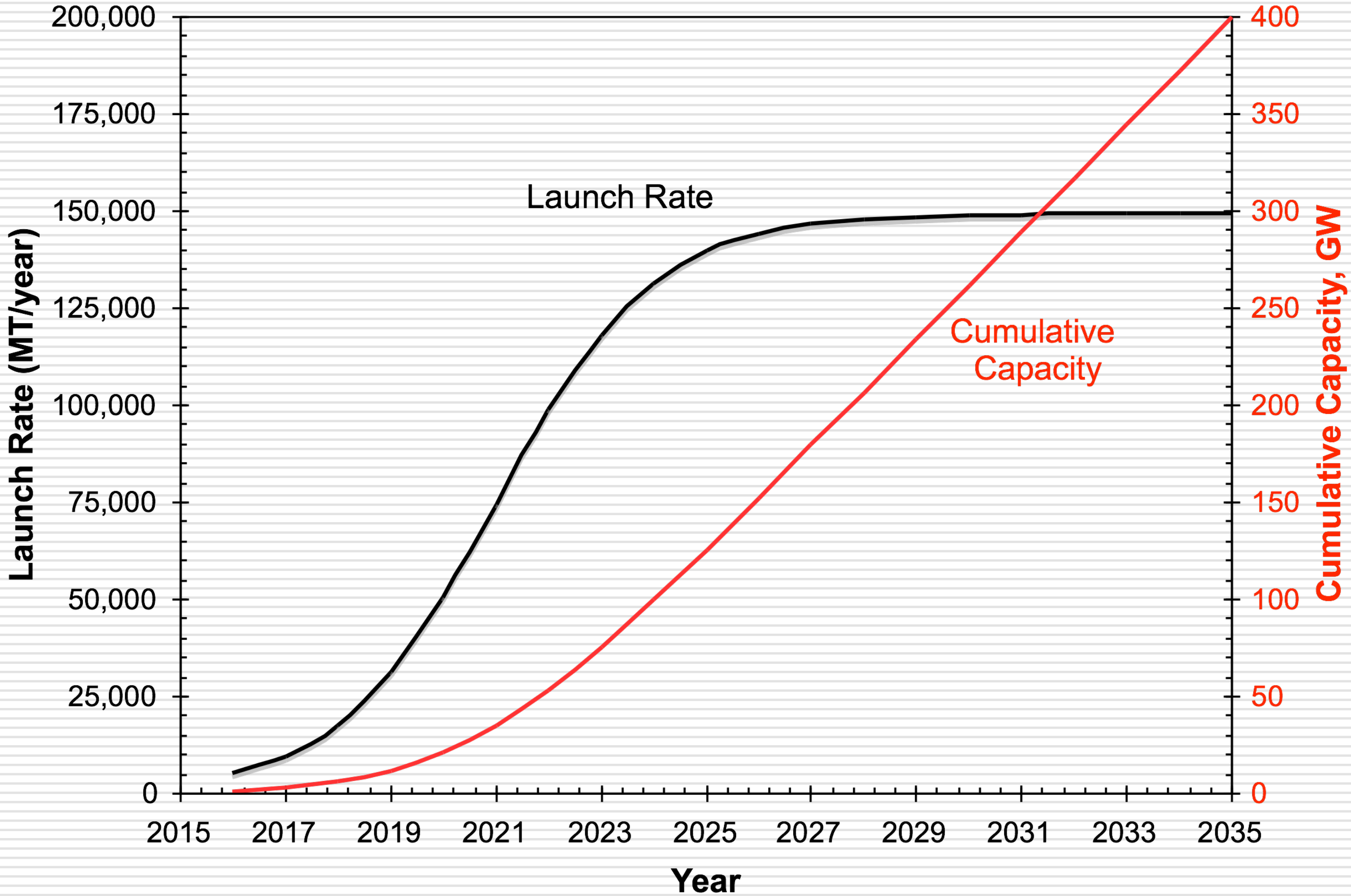
Meeting the Challenge

We need

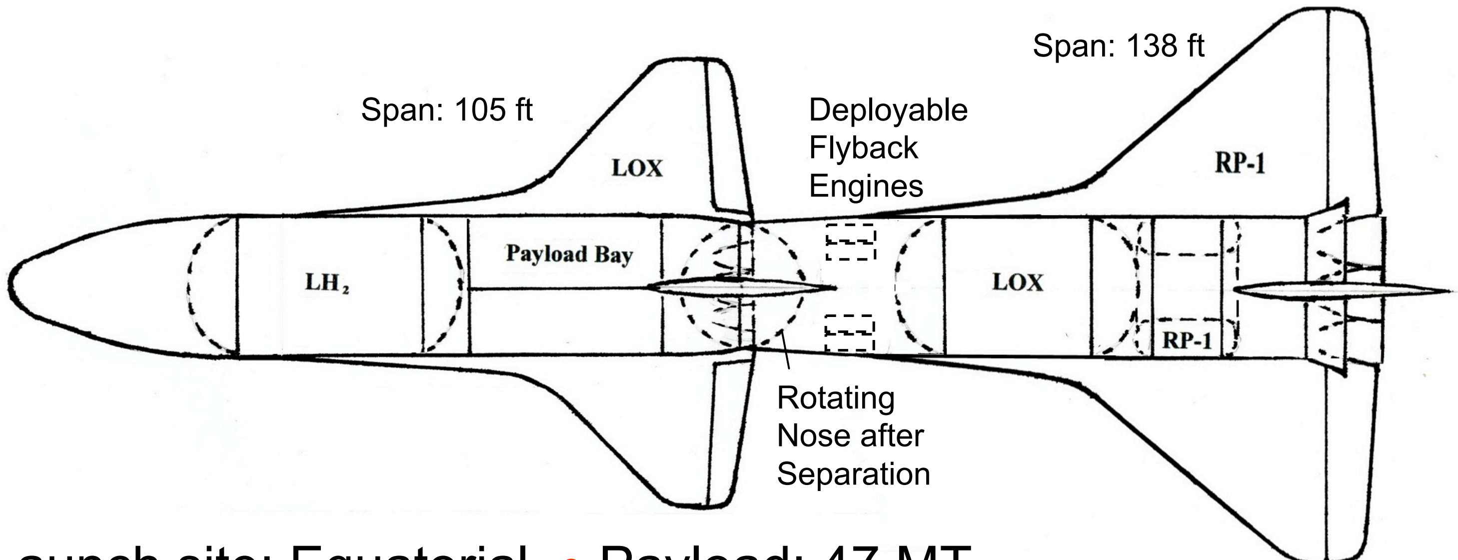
- Cheap mass production of rectennas.
- High overall efficiency, from sun to utility grid.
- Very light solar conversion devices, microwave transmitters and gossamer space structures.
- High specific impulse electric propulsion from LEO to GSO, through the radiation belts.
- Efficient (robotic?) assembly of large structures in space.
- Cheap launch to LEO

Launch to LEO is the most controversial, but all it really needs are fully reusable vehicles.

Deployment Scenario

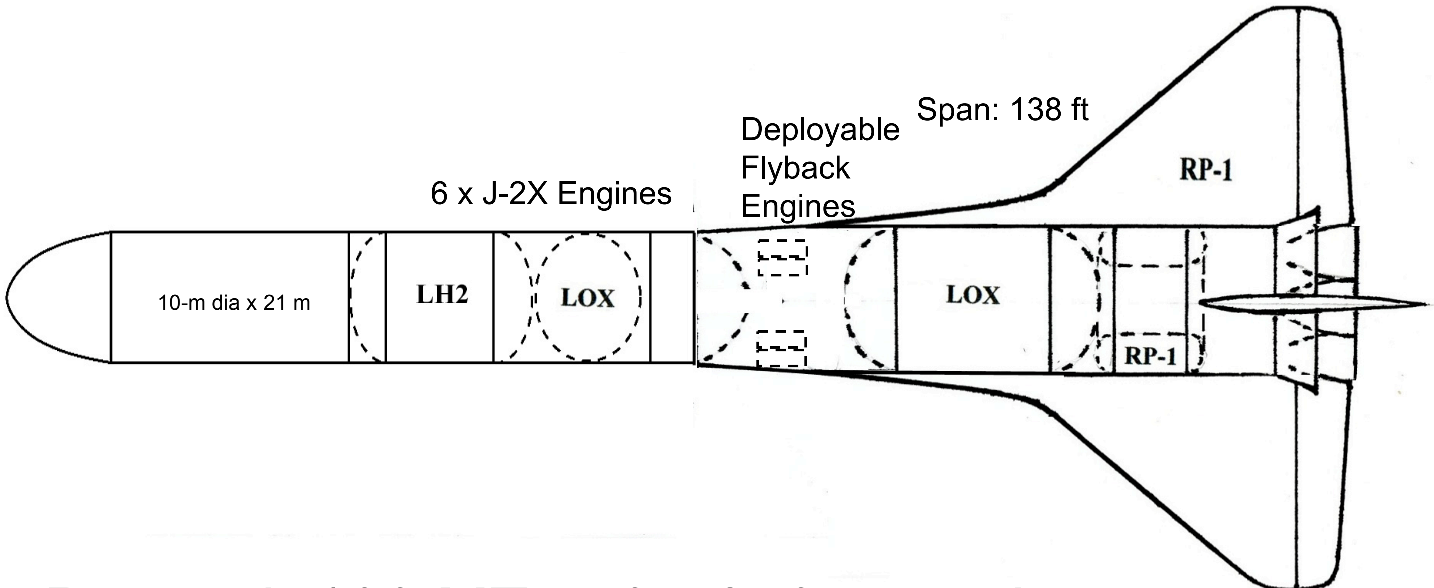


Nansen/Talay TSTO Full RLV



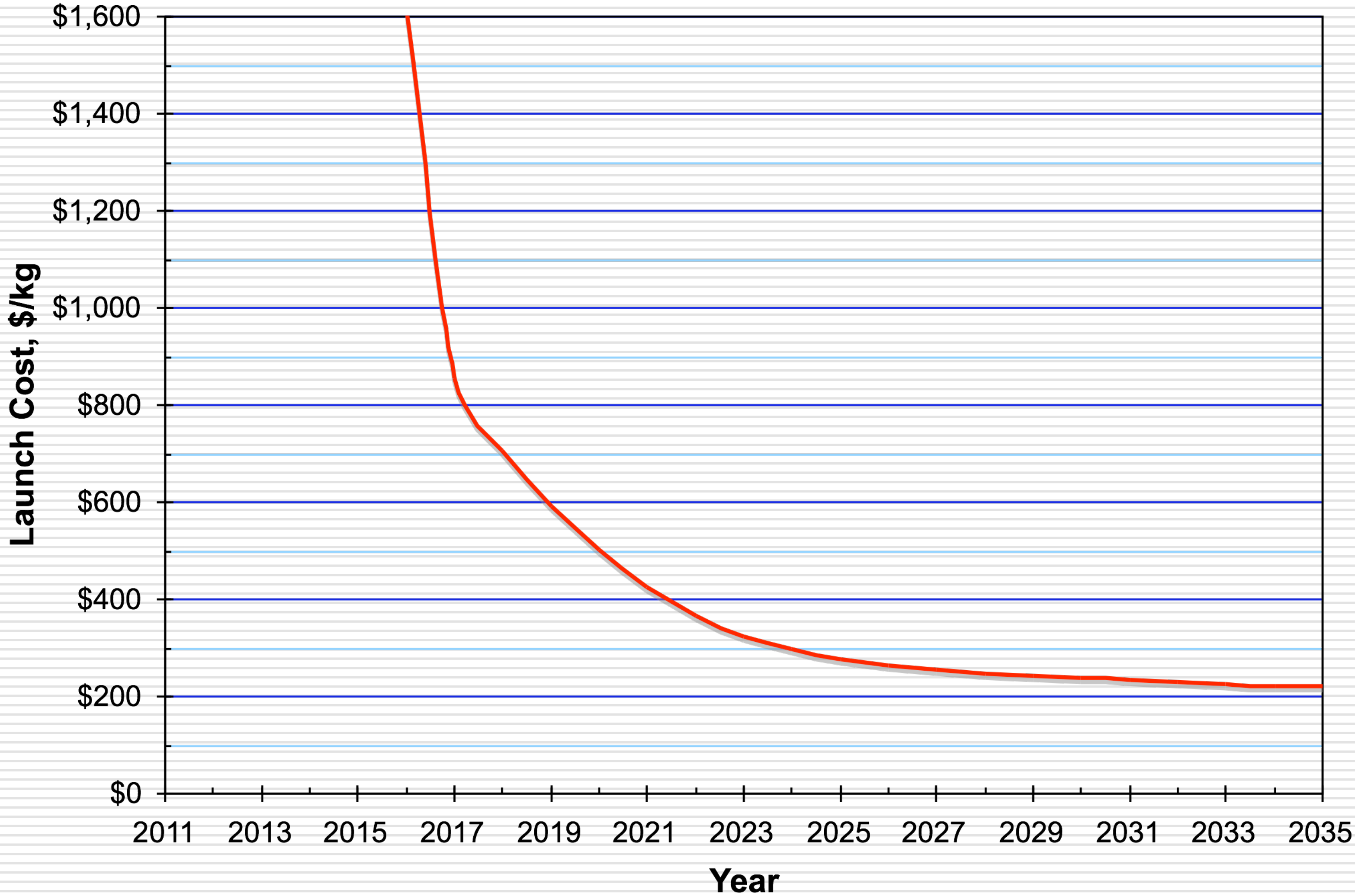
- Launch site: Equatorial • Payload: 47 MT
- Horizontal mating; vertical fueling and launch
- Final orbit: 0^{o} inclination; 250 nmi circular
- Booster flyback with deployable jet engines
- Payload bay = 10 m dia x 13.5 m • Mated length: 103 m (339 ft)
- Based on Saturn technology • Wet wings
- Booster: 5 x RD-171 engines; Orbiter: 6 x J-2X engines
- Orbiter OMS: 2 x RL-10A4 engines

Expendable Upper Stage Version

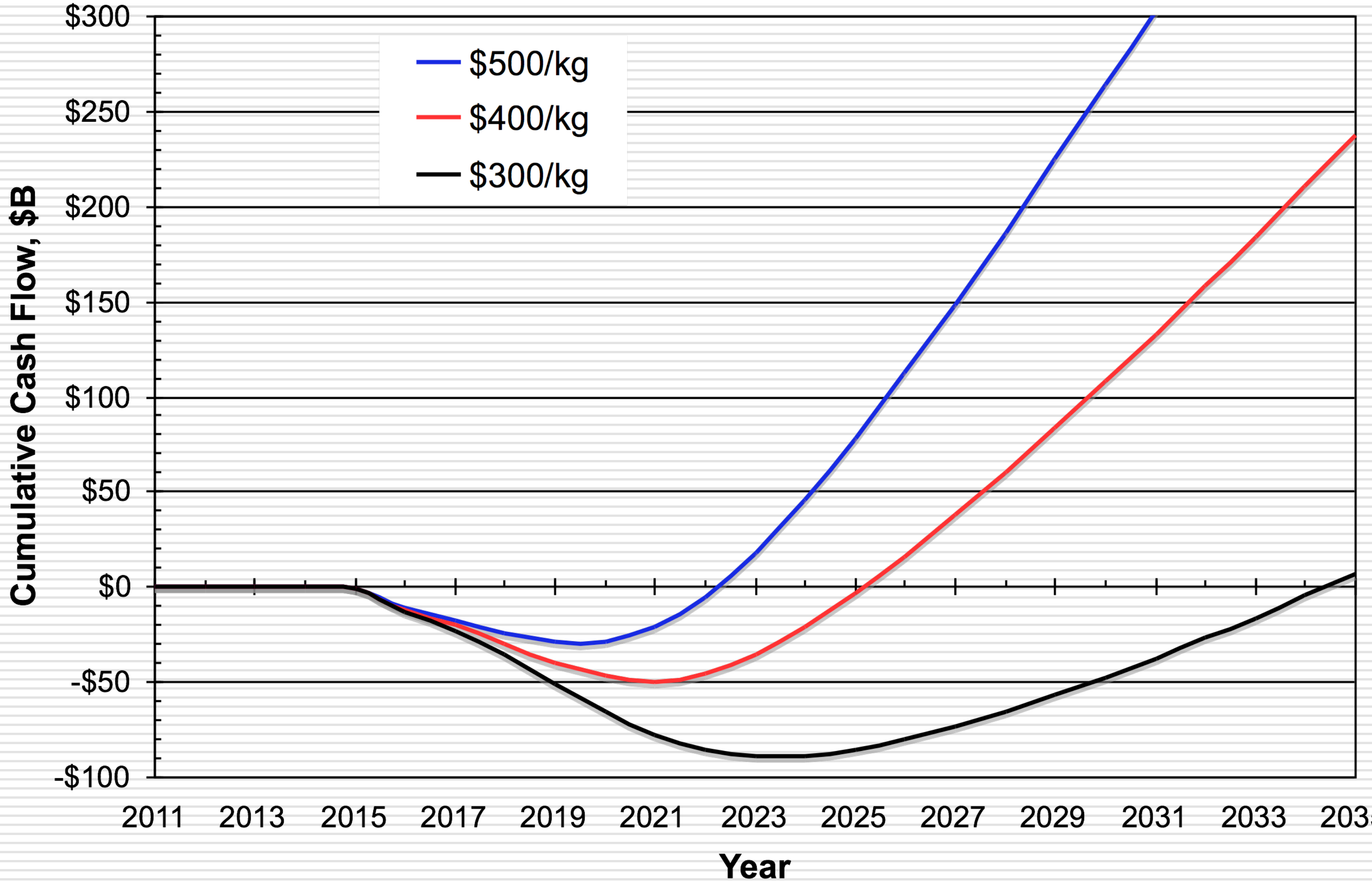


- Payload: 100 MT to 0^o, 250 n.m. circular
- Same Booster
- Payload: bay: 10 m X 21 m
- Orbiter: same 6 J-2X engines
- Needs gantry for vertical mating, fueling and launch

The Magical Economies of Scale



Launch Enterprise Cash Flow



Recommendations

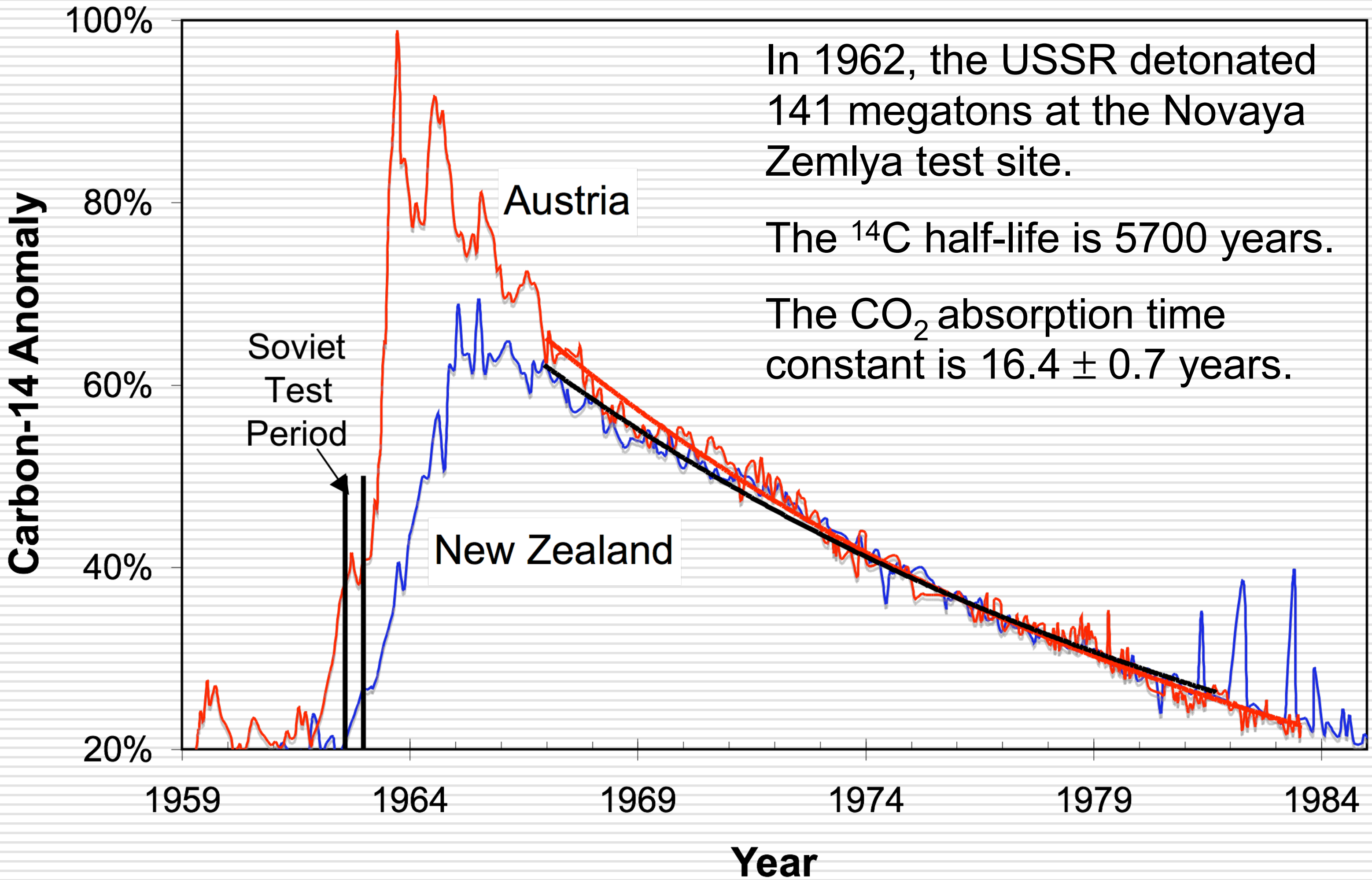
- Present space-based solar power (SBSP) as a natural extension to terrestrial solar -- and a great opportunity for the solar energy industry.
- Do not claim that we need SBSP to avoid anthropogenic global warming (AGW). Instead, point out that SBSP is a "no regrets" approach to that problem, more effective than regulation, with no penalty if AGW proves unimportant.
- We can and we must make SBSP cost-competitive with nuclear power, natural gas and coal, without subsidies or artificial incentives.

Appendix: Climate Change

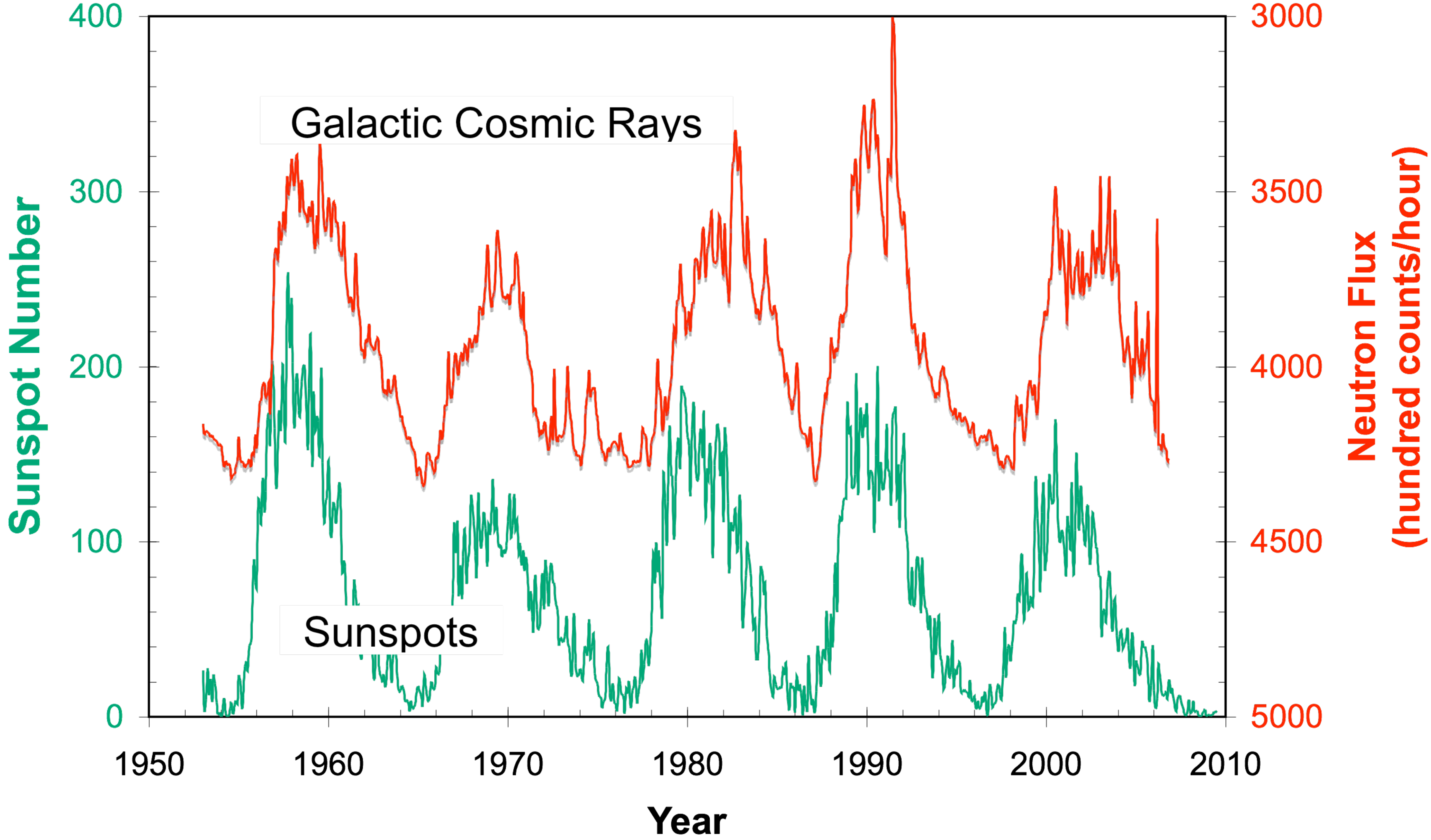
- Anthropogenic global warming (AGW) is controversial.
- Opinions don't matter: the observational evidence will eventually prevail.
- There is a growing body of evidence that the problem has been greatly exaggerated.
- Citing climate change as a principal reason for SBSP or relying on high energy prices related to it risks cancellation of the program if or when the theory of AGW is discredited.

Let's look at some actual data…

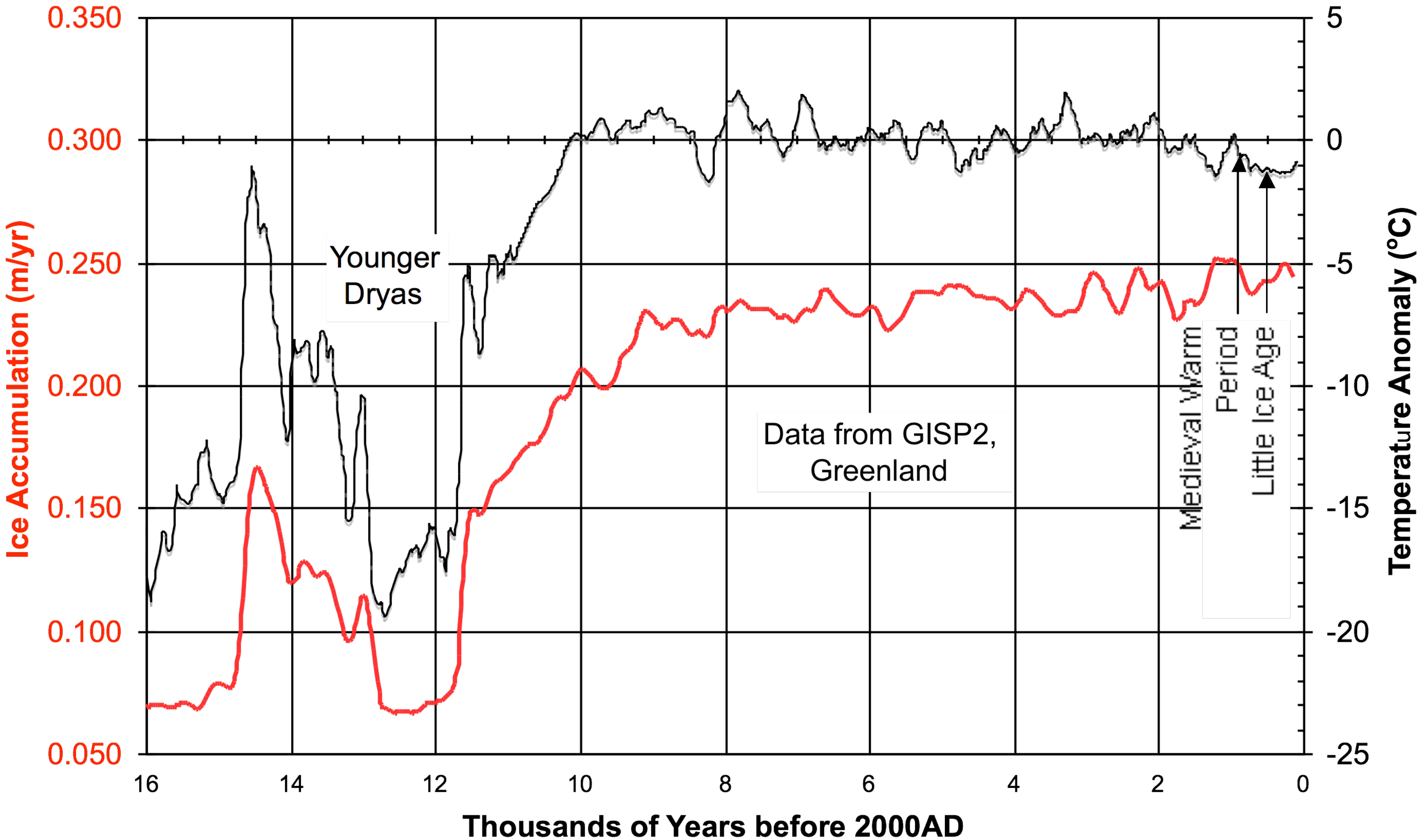
Absorption of CO_2 after Nuclear Airburst



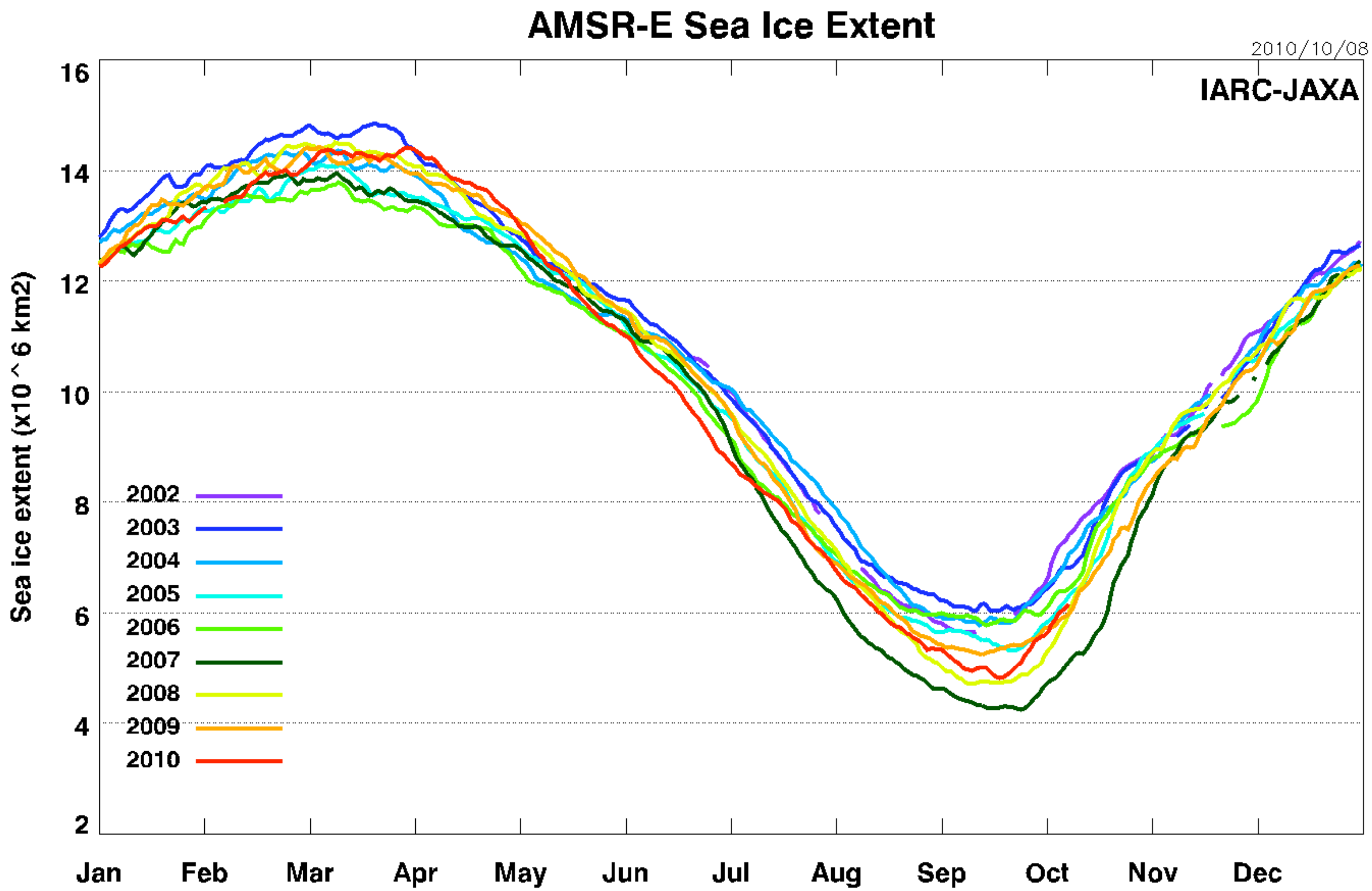
Sunspots and Galactic Cosmic Rays



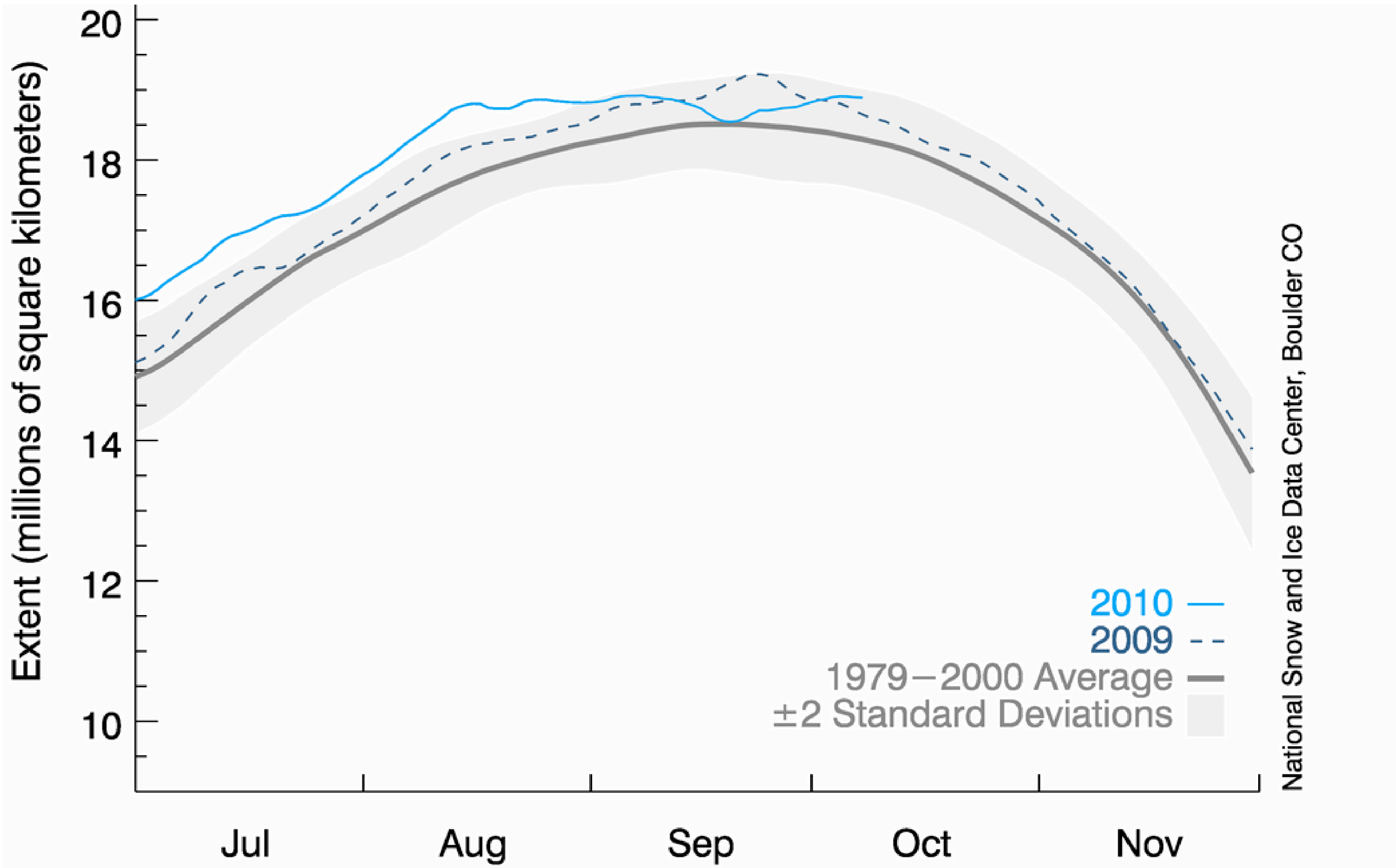
The Holocene Climate



Arctic Cooling



Antarctic Cooling



Cautionary Quotations

- *"An hypothesis is always preferable to the truth, for we tailor an hypothesis to fit our opinion of the truth, whereas the truth is only its own awkward self. Ergo, never discover the truth when an hypothesis will do."*

  -- attributed to Niccolo Machiavelli (1513)

- *"No matter if the science is all phony…Climate change [provides] the greatest chance to bring about justice and equality in the world."*

  --- Christine Stewart, Canadian Minister for the Environment, 1998.

- *"The largest threat to freedom, democracy, the market economy and prosperity is no longer socialism. It is, instead, the ambitious, arrogant, unscrupulous ideology of environmentalism."*

  -- Václav Klaus, President of the Czech Republic, 2008