PRIMARY ENERGY SOURCES
Alternatives to Oil

TOO LITTLE
• Conservation / Efficiency  -- not enough
• Hydroelectric    -- not enough
• Biomass          -- not enough
• Wind             -- not enough
• Wave & Tide      -- not enough

CHEMICAL
• Natural Gas   -- sequestration?, cost?
• Clean Coal    -- sequestration?, cost?

NUCLEAR
• Nuclear Fission -- radioactive waste?, terrorism?, cost?
• Nuclear Fusion -- too difficult?, cost?
• Geothermal HDR -- cost ?, enough?
• Solar terrestrial -- cost ?
• Solar power satellites -- cost ?
• Lunar Solar Power  -- cost ?
165,000 TW of sunlight hit the earth every day
6 Boxes at 3.3 TW Each = 20 TWe
One World Energy Scheme for 30-60TW in 2050: The Distributed Store-Gen Grid

• Energy transported as electrical energy over wire, rather than by transport of mass (coal, oil, gas)
• Vast electrical power grid on continental scale interconnecting ~ 100 million asynchronous “local” storage and generation sites, entire system continually innovated by free enterprise
• “Local” = house, block, community, business, town, …
• Local storage = batteries, flywheels, hydrogen, etc.
• Local generation = reverse of local storage + local solar and geo
• Local “buy low, sell high” to electrical power grid
• Local optimization of days of storage capacity, quality of local power
• Electrical grid does not need to be very reliable
• Mass Primary Power input to grid via HV DC transmission lines from existing plants plus remote (up to 2000 mile) sources on TW scale, including vast solar farms in deserts, wind, NIMBY nuclear, clean coal, stranded gas, wave, hydro, space-based solar…”EVERYBODY PLAYS”
• Hydrogen is transportation fuel
Enabling Nanotech Revolutions

1. Photovoltaics -- drop cost by 100 fold.
2. Photocatalytic reduction of CO$_2$ to methanol.
3. Direct photoconversion of light + water to produce H$_2$.

4. Fuel cells -- drop the cost by 10-100x + low temp start + reversible

5. H$_2$ storage -- light weight materials for pressure tanks and LH2 vessels, and/or a new light weight, easily reversible hydrogen chemisorption system (material X).

6. Batteries, supercapacitors, flywheels -- improve by 10-100x for automotive and distributed generation applications.

7. Power cables (superconductors, or quantum conductors) with which to rewire the electrical transmission grid, and enable continental, and even worldwide electrical energy transport; and also to replace aluminum and copper wires essentially everywhere -- particularly in the windings of electric motors and generators (especially good if we can eliminate eddy current losses).
An interesting feature of this junction is the sensitive dependence of conductance on the contact length, $l$. Figure 2 shows the conductance values for armchair-armchair and

![Diagram showing two-terminal nanotube junction](image)

FIG. 1. (a) A two-terminal nanotube junction can be formed by bringing two tubes’ ends together in parallel and pointing opposite directions ($l$ is the contact length). (b) The transmission coefficient $T$ of the two armchair tube [[(10,10)-(10,10)] junction as a function of energy $E$ for $l=64$ Å. Interference of electron waves yields resonances in transport. (c) Current-voltage characteristics of the (10,10)-(10,10) junction for $l=46$ Å.

Cloning Project
1. Cut to short lengths (< 20 nm)
2. Purify
3. Sort by end and side chemistry
4. Attach catalyst
5. Inject into reactor and grow clone
6. Cut to desired length
7. Purify
8. Season to taste

But these organic molecules conduct electricity!

Same old chemistry.
Enabling Nanotech Revolutions

8. Nanoelectronics to revolutionize computers, sensors and devices.

9. Nanoelectronics based Robotics with AI to enable construction maintenance of solar structures in space and on the moon; and to enable nuclear reactor maintenance and fuel reprocessing.

10. Super-strong, light weight materials to drop cost to LEO, GEO, and later the moon by > 100 x, to enable huge but low cost light harvesting structures in space; and to improve efficiency of cars, planes, flywheel energy storage systems, etc.

11. Thermochemical catalysts to generate H₂ from water that work efficiently at temperatures lower than 900 C.

12. Nanotech lighting to replace incandescent and fluorescent lights

13. NanoMaterials/ coatings that will enable vastly lower the cost of deep drilling, to enable HDR (hot dry rock) geothermal heat mining.

14. CO₂ mineralization schemes that can work on a vast scale, hopefully starting from basalt and having no waste streams.