State Energy Advisory Board
22 February 2011

Challenges in Alternative Energy Production

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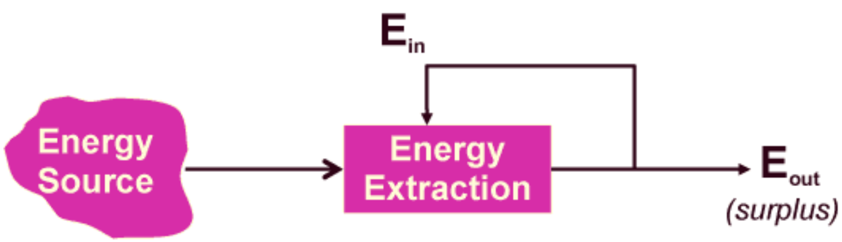
The feasibility of alternatives is not just a matter of price: other considerations also impact viability

1. Energy Return on Investment
2. Scalability and Timing
3. Substitutability
4. Commercialization
5. Input Requirements
6. Intermittency
7. Land and Water
8. Stock vs. Flow
9. "The Law of Receding Horizons"

1. Energy Return on Investment

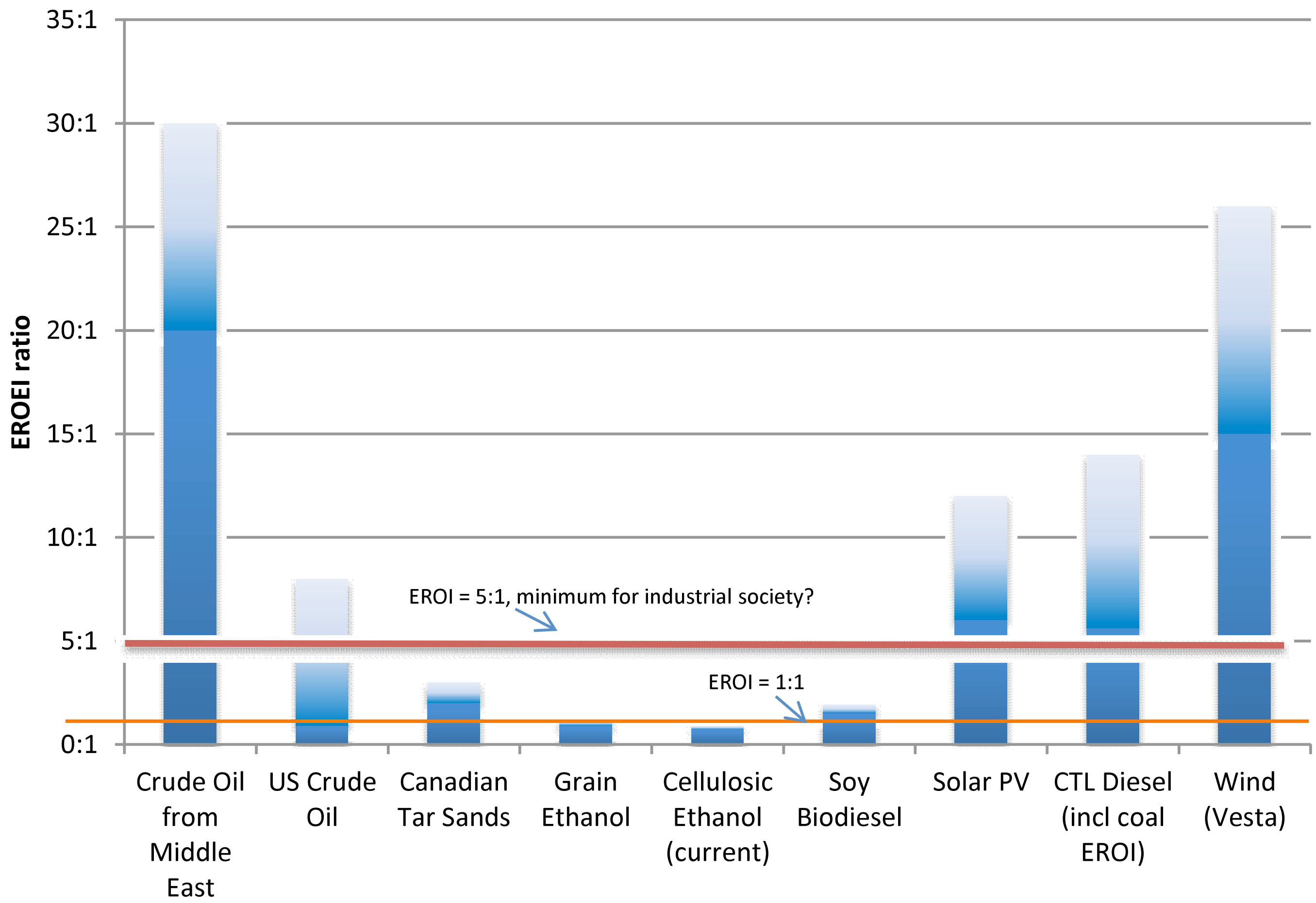
- It takes energy to make energy; what society requires is the "net" energy left over.
- Energy Return on Investment is a ratio of the energy available to be used by society compared to the energy used to produce that energy, i.e. the "profit" from energy production



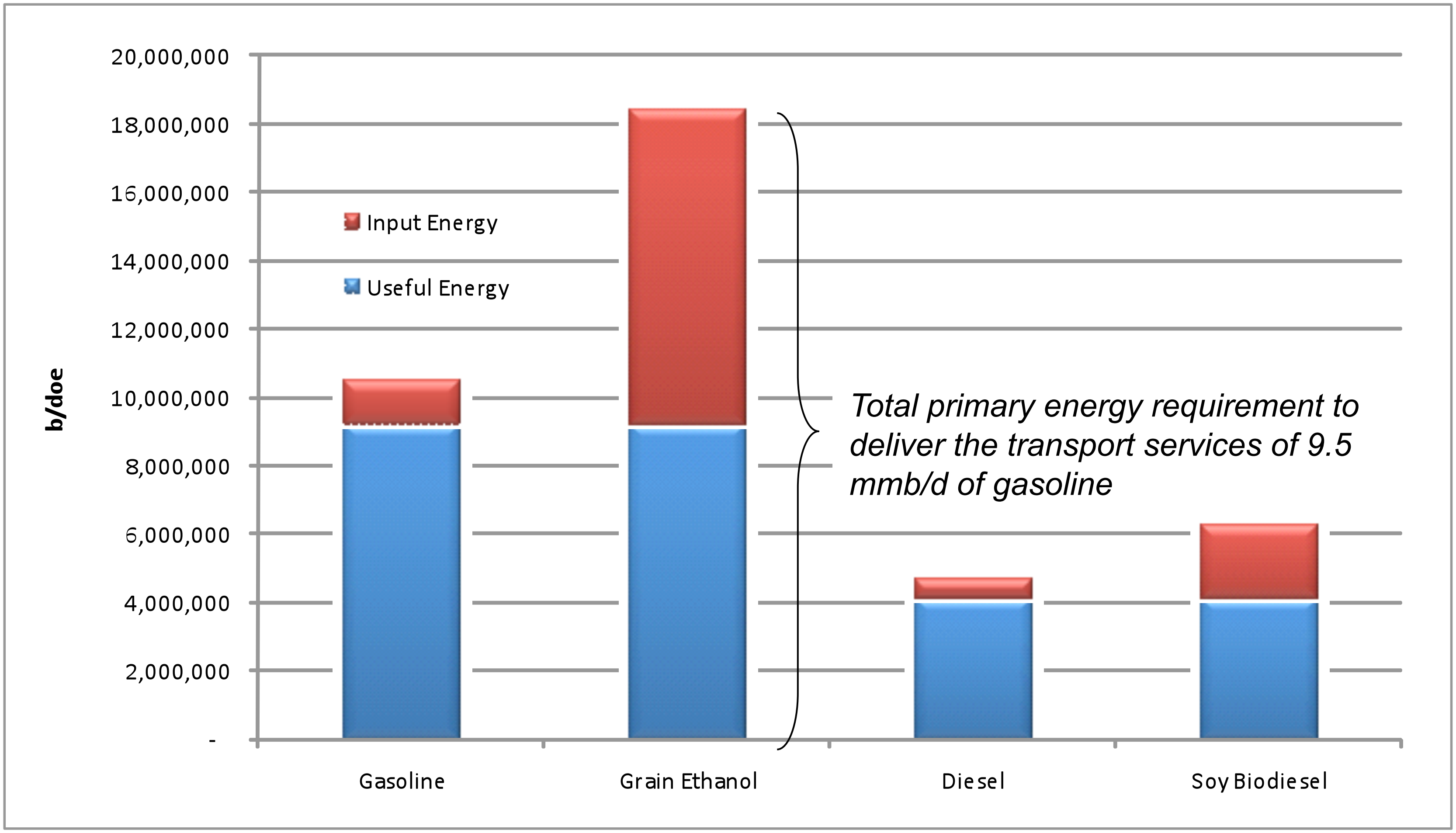
$$\text{Energy Return on Investment (EROI)} = \frac{E_{out}}{E_{in}}$$

Source: Charles Hall, Pradeep Tharakan, John Hallock, Wei Wu and Jae-Young Ko, Advances in Energy Studies Conference, Porto Venere, Italy, September 2002, cited on eroei.com

Most alternative energies have low EROIs compared to oil



The lower the EROI, the more energy society must devote to producing energy, and the less left for society



2. Scalability and Timing

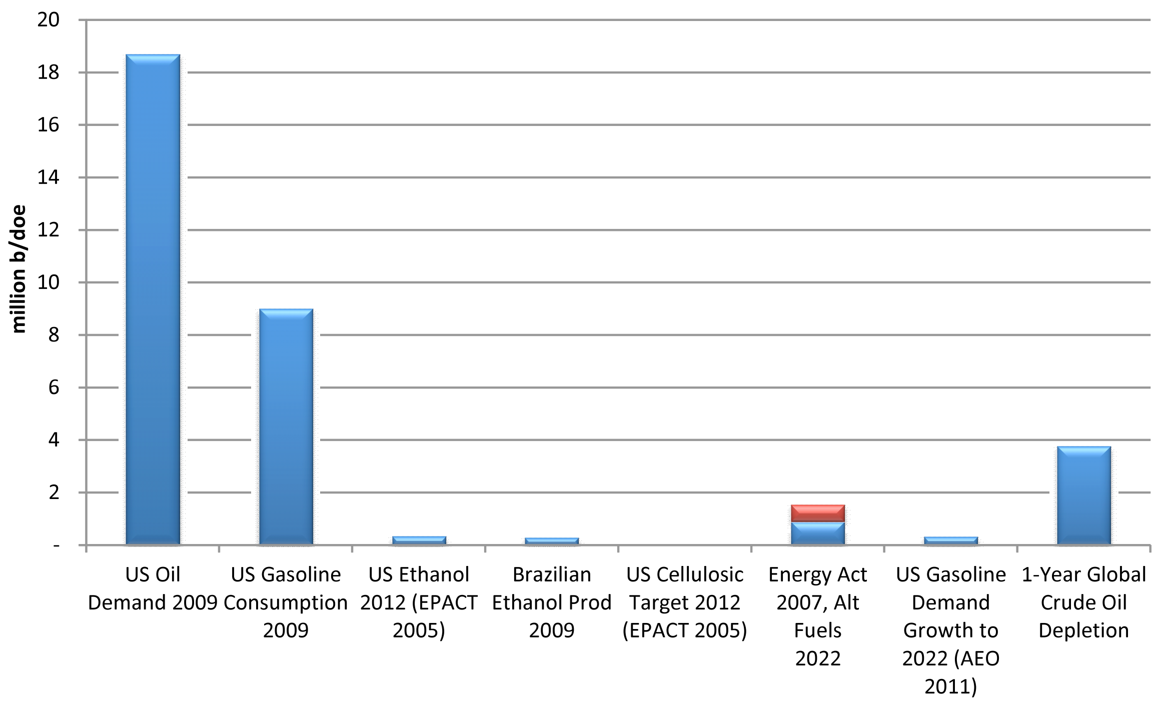
- For the promise of an alternative to be achieved, it must be supplied in the time frame needed, in the volume needed, at a reasonable cost

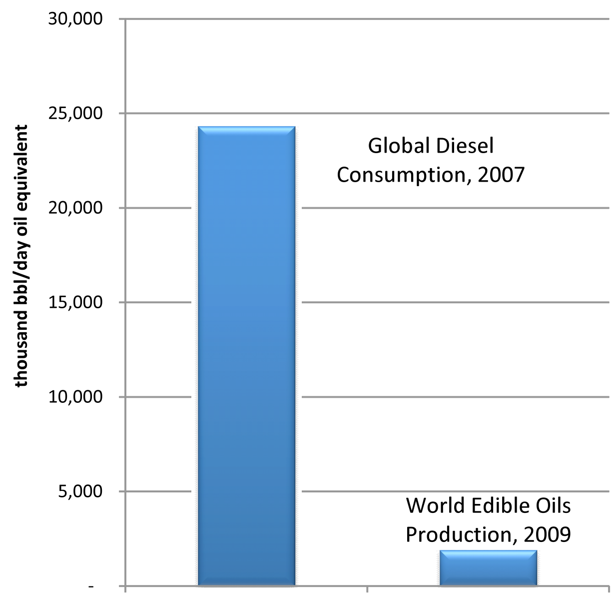
The current rate of global oil depletion is about 3.5-4 million b/d per year. By 2020, we would need **42-48 million b/d** of new production, or 5 Saudi Arabias, just to stay flat

Canadian tar sands now produce about 1 million b/d. By 2020, production is forecast to rise to 3.5 million b/d, or an additional **2.5 million b/d** over 10 years

Tar sands provide neither the scale nor timing to offset oil depletion

The problem of scale





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3. Substitutability

- Is an alternative a direct substitute, or does it require infrastructure changes to use it?

Electrification of transportation, such as with electric vehicles
- Retooling of factories to produce the vehicles
- Development of a large scale battery industry
- Development of recharging facilities
- "Smart grid" solutions and deployment
- Design and production of instruments for the maintenance and repair of vehicles
- Spare parts industry
- More generation and transmission facilities

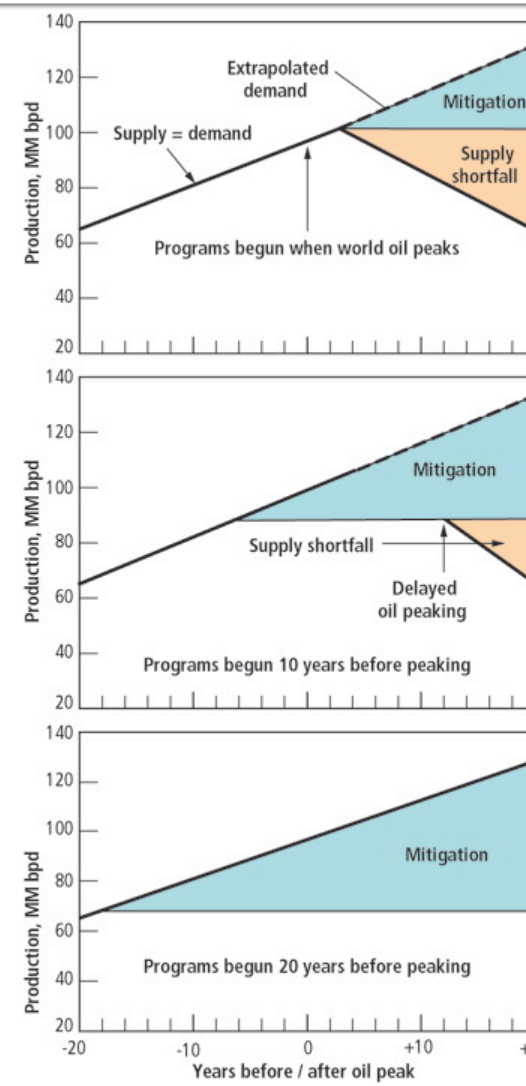
Ethanol
- Cannot be transported in existing pipeline infrastructure
- Requires more energy-intensive truck and train transport

4. Commercialization

- Is the alternative commercial today?

The average time between laboratory benchtop demonstration and full-scale commercialization is 20 years

Mitigation efforts require long lead-times



Source: Hirsch Report 2006

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5. Input Requirements

- The inputs to alternative energy development are material resources, not money. Are there supply constraints on inputs?

A key input to thin-film solar is indium. Known world reserves would last 13 years at current consumption rates

Global Demand on Raw Materials from Emerging Technologies

Raw Material	Fraction of Today's Total World Production		Emerging Technologies (selected)
	2006	2030	
Gallium	0.28	6.09	Thin-layer photovoltaics, integrated circuits, white LEDs
Neodymium	0.55	3.82	Permanent magnets, laser technology
Indium	0.40	3.29	Displays, thin-layer photovoltaics
Germanium	0.31	2.44	Fiber-optic cable, infrared optical technologies
Scandium	Low	2.28	Solid oxide fuel cells, aluminum alloying element
Platinum	Low	1.56	Fuel cells, catalysts
Tantalum	0.39	1.01	Microcapacitors, medical technology
Silver	0.26	0.78	Radio-frequency ID tags, lead-free soft solder
Tin	0.62	0.77	Lead-free soft solder, transparent electrodes
Cobalt	0.19	0.40	Lithium-ion batteries, synthetic fuels
Palladium	0.10	0.34	Catalysts, seawater desalination
Titanium	0.08	0.29	Seawater desalination, implants
Copper	0.09	0.24	Efficient electric motors, radio-frequency ID tags
Selenium	Low	0.11	Thin-layer photovoltaics, alloying element
Niobium	0.01	0.03	Microcapacitors, ferroallys
Ruthenium	0.00	0.03	Dye-sensitized solar cells, Ti-alloying element
Yttrium	Low	0.01	Superconduction, laser technology
Antimony	Low	Low	Antimony-tin-oxides, microcapacitors
Chromium	Low	Low	Seawater desalination, marine technologies

Source: Gerhard Angerer et al, "Raw Materials for Emerging Technologies," (Karlsruhe: Fraunhofer Institute for Systems and Innovation Research; Berlin: Institute for Futures Studies and Technology Assessment, 2009).

6. Intermittency

- Our energy system operates 24/7/365 and our system has been built on this expectation. Large scale deployment of renewables requires storage solutions

Wind turbines generate electricity on average 25-30% of a year
Solar PV produces peak generation about 4.5 hours per day, or about 15% of nominal capacity

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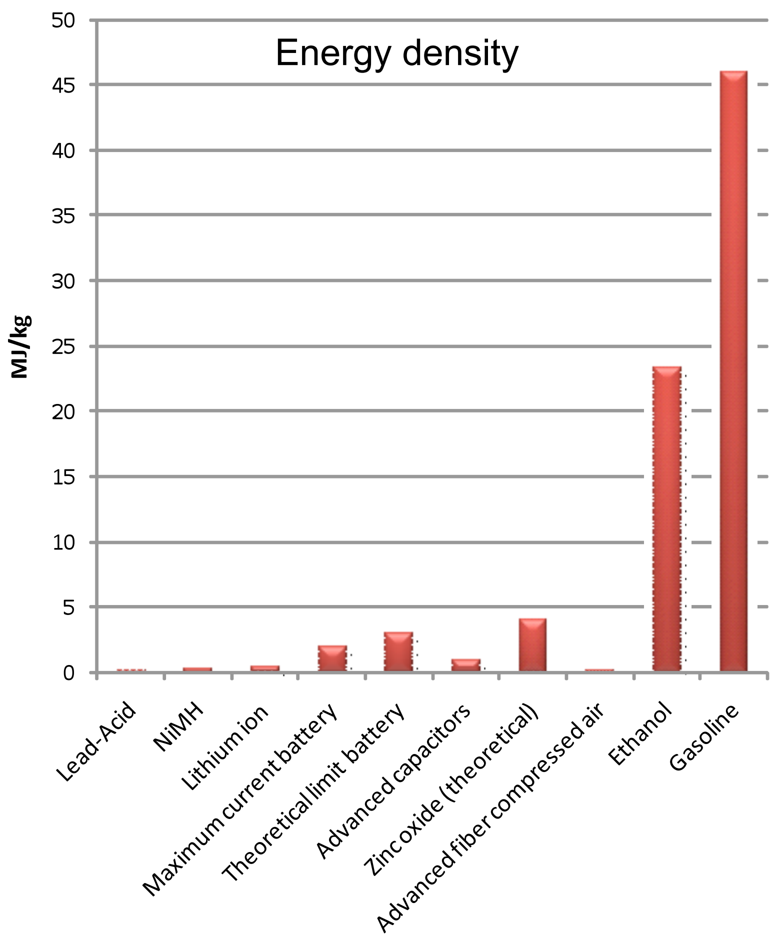
Energy density is a major challenge to energy storage



- Lower energy density results in higher consumption of material resources for any given amount of energy storage

Source: *Bulletin of the Atomic Scientists*, http://www.thebulletin.org/web-edition/columnists/kurt-zenz-house/the-limits-of-energy-storage-technology, Jan 2009

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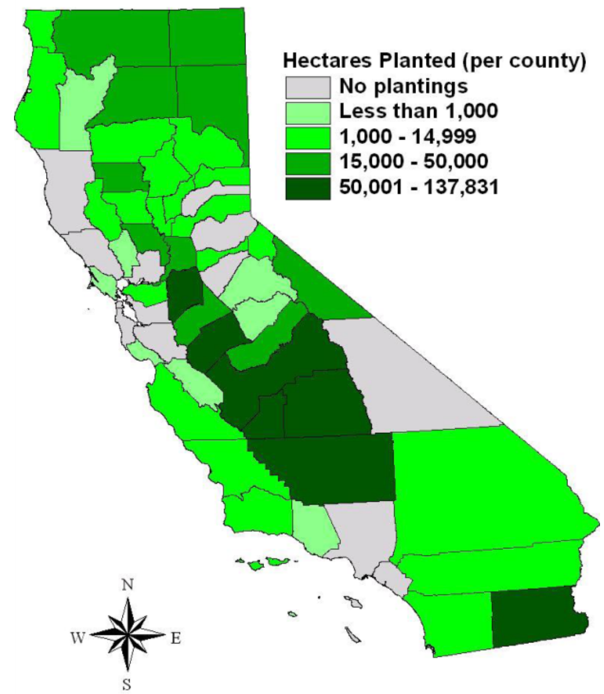
7. Land and Water

- The denser an energy form is, the less land is needed for its deployment. Large-scale deployment of alternatives will incur considerable land costs



Planting of 2.7 million acres of California's irrigated pastureland would produce switchgrass enough to supplant only 1.5-4% of California's gasoline consumption with cellulosic ethanol

Source: Coughlin, Katie, David Fridley (Lawrence Berkeley National Laboratory). 2008. *Physical Energy Accounting for California: A Case Study of Cellulosic Ethanol Production. California Energy Commission, PIER-Energy-Related Environmental Research Program. CEC-500-2008-xxx*

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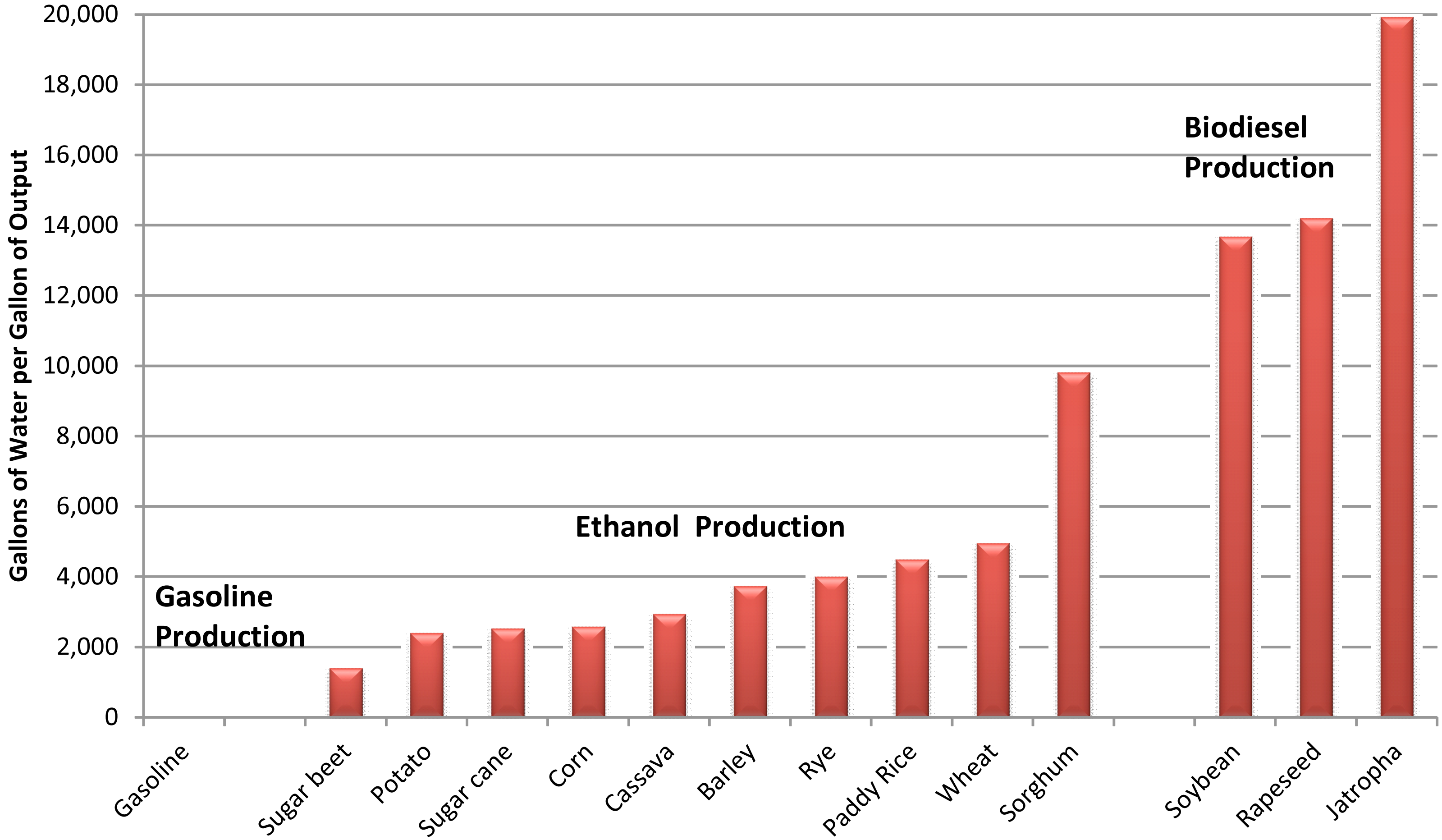
Full-cycle water requirements for biofuel production



Source: "The Water Footprint of Bioenergy," *Proceedings of the National Academy of Science*, June 2009, www.pnas.orgcgidoi10.1073pnas.0812619106;
Water Usage for Current and Future Ethanol Production, *Southwest Hydrology,* Sept-Oct 2007

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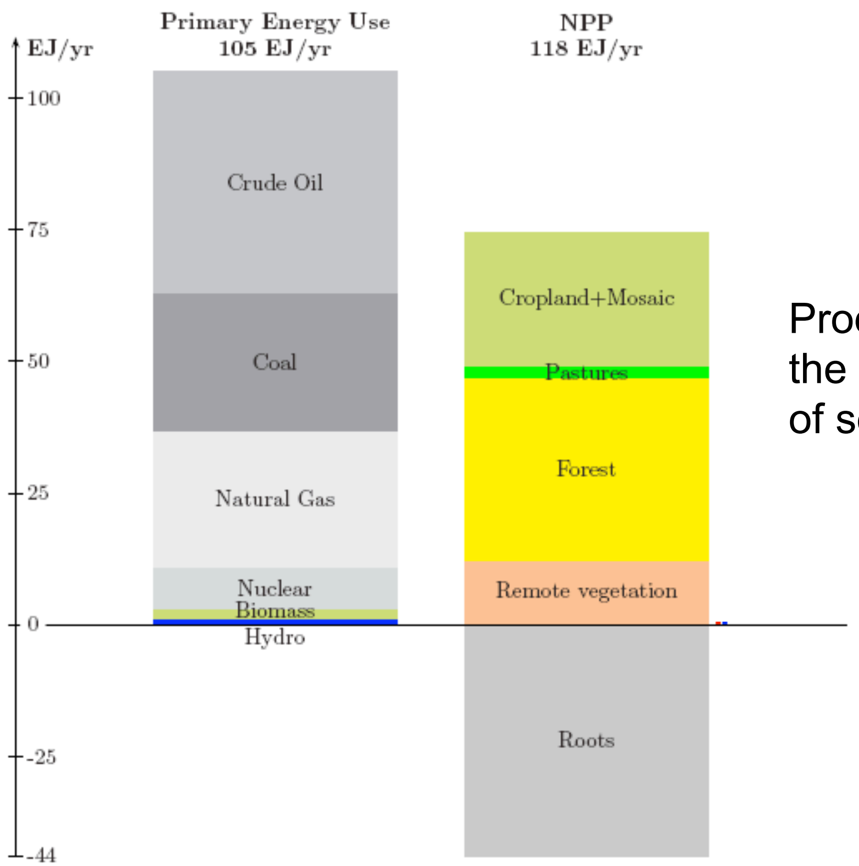
8. Stock vs. Flow

Most alternatives rely on an energy flux to replace a stock of stored energy; utilization is constrained by the flux

Consumption of ***stocks*** of stored solar energy



Production from the annual ***flow*** of solar energy

Source: Tad Patzek, *How Can We Outlive Our Way of Life?,* OECD, Paris, 11-12 September 2007

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9. "The Law of Receding Horizons"

- The breakeven costs of energy-input-intensive alternative energies will dynamically rise with the overall cost of energy

Price of Crude Oil	Breakeven Price for Shale
1970: $1.50/barrel	$2/barrel
1980: $30/barrel	$40/barrel
2007: $70/barrel	$90/barrel

When will Colorado "Shale Oil" become economic?

Can alternatives deliver on their promises?

- Alternatives are required: energy supply uncertainties and climate change are key drivers
- Alternatives today rely extensively on fossil fuel energy
- The transition from reliance on extraction of stored energy to current energy income will be challenging
- Technology alone is likely insufficient to power the transition; demand, behavior, and lifestyle changes will also be necessary