



SRI International Research: Energy from Microorganisms

Carbon Recycling Forum
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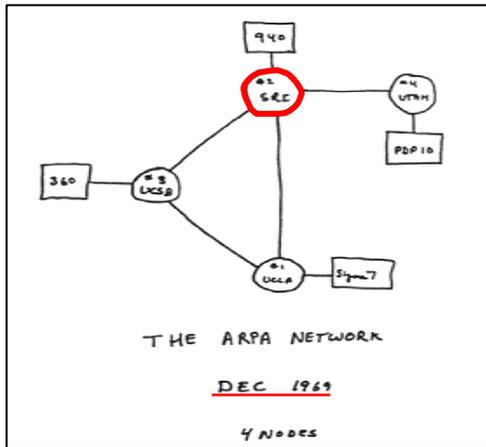


SRI is a world-leading independent R&D organization



SRI headquarters, Menlo Park, CA

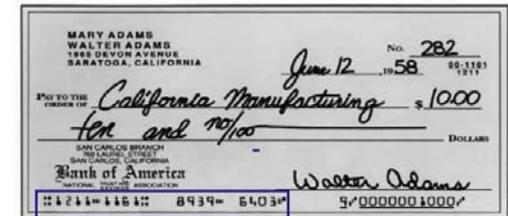
- Founded by Stanford University in 1946
 - A nonprofit corporation
 - Committed to discovery and to the application of science and technology for knowledge, commerce, prosperity, and peace
 - Independent in 1970; changed name from Stanford Research Institute in 1977
- 2,000 staff members
 - 800 with advanced degrees
 - More than 20 offices worldwide
- Consolidated 2007 revenue: \$435 million



First Internet message



Computer mouse, windows, hypertext, ...



Electronic banking

You probably use or benefit from an SRI invention every day



SRI is developing a diverse energy portfolio

Core Capabilities

Catalysis

Combustion, pyrolysis, gasification

Condensed matter

Carbon capture

Energy harvesting, conversion

Fuel cells

Hydrogen

Materials

Safety

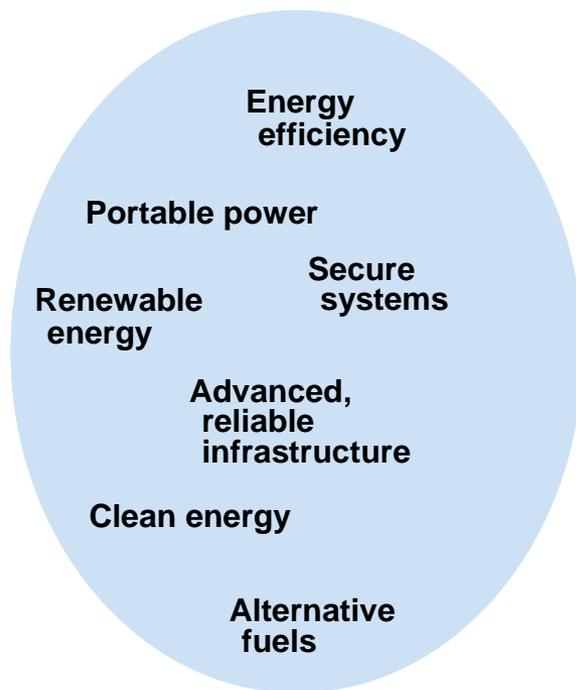
Sensing

Separations

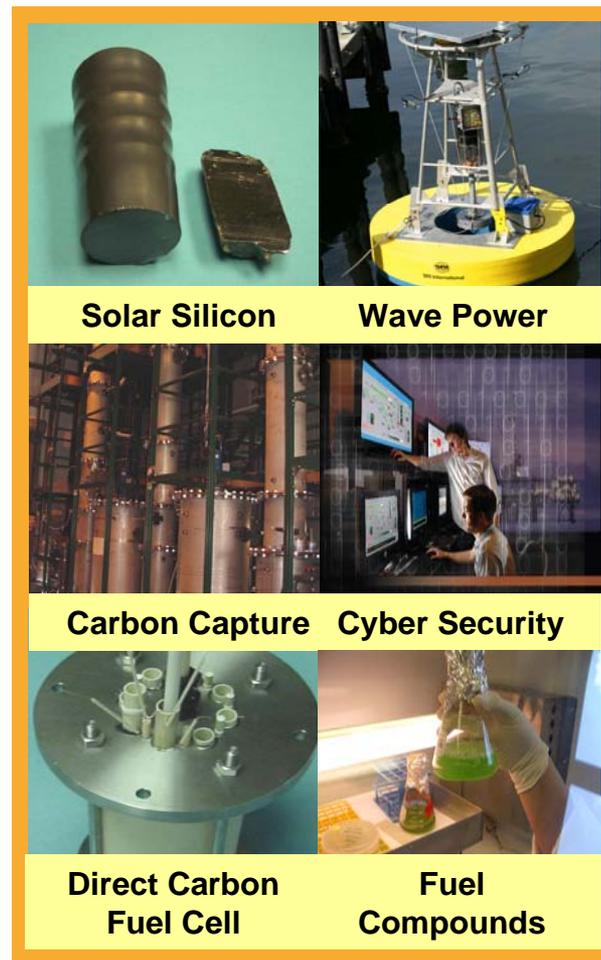
Software

Synthetic biology

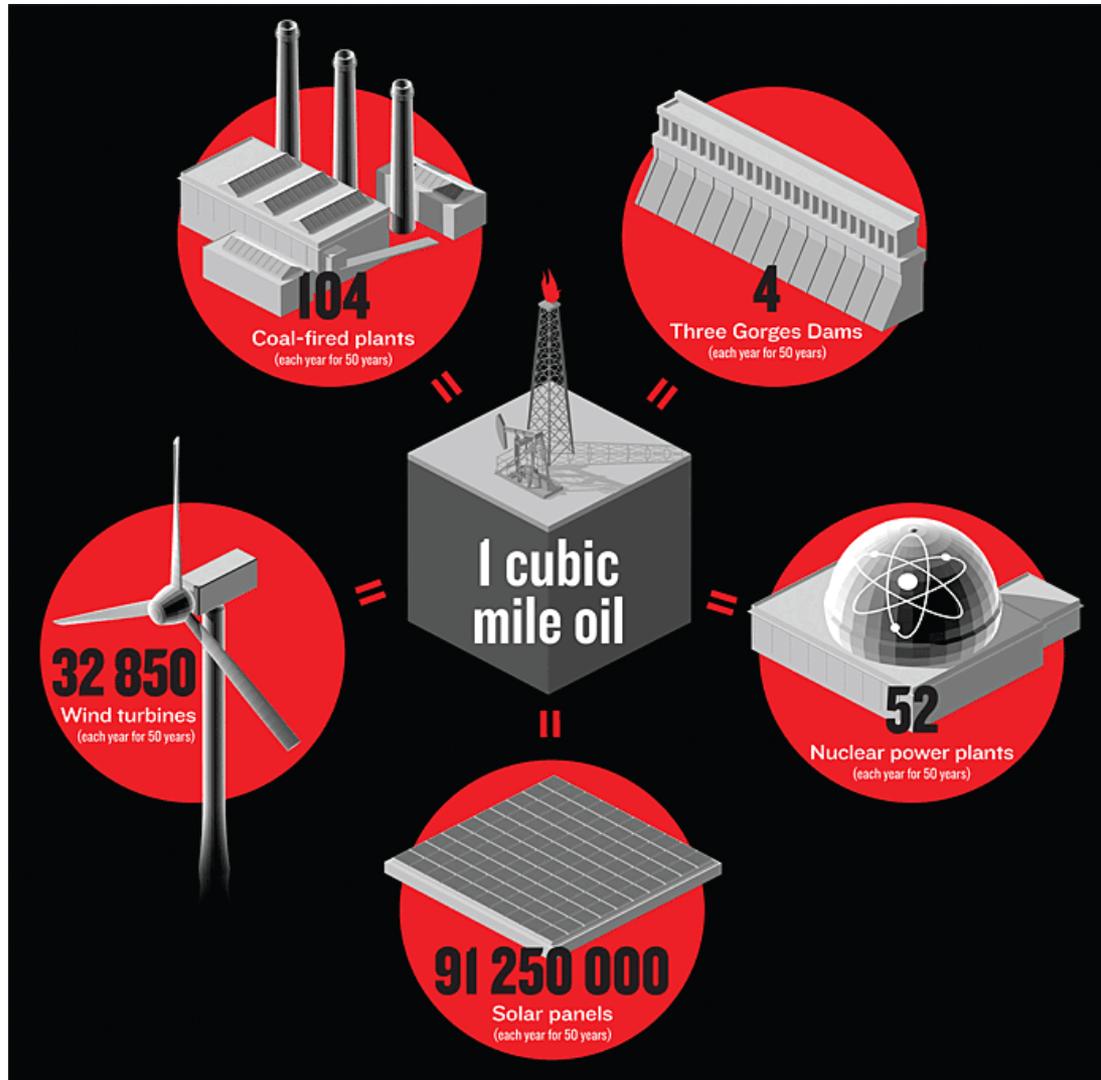
R&D Activities



Energy Technologies



We need a diverse energy portfolio to meet our enormous energy needs



***Current world energy consumption is equivalent to about 2.6 cubic miles of oil**

Source: <http://www.spectrum.ieee.org/print/4820>

We also need a diverse energy portfolio because no single energy source is perfect

Resource	Technology Readiness	Resource Availability	Renewable	Near-Term Social Costs
Coal	Green	Green	Red	carbon, air pollution, land use/habitat
Natural Gas	Green	Yellow	Red	carbon, air pollution
Oil	Green	Red	Red	carbon, air pollution, geopolitics
Nuclear	Green	Yellow	Yellow	waste disposal, geopolitics
Biomass	Yellow	Yellow	Green	carbon? air pollution? land use/habitat
Geothermal	Green	Red	Green	land use/habitat?
Hydroelectric	Green	Red	Green	land use/habitat
Wave/tide	Red	Red	Green	land use/habitat?
Wind	Yellow	Yellow	Green	land use/habitat
Solar	Yellow	Yellow	Green	land use/habitat
Thermal Gradients	Red	Yellow	Green	land use/habitat?

Technology advances and shifting societal concerns can change valuations



SRI is applying its expertise in microbiology to explore how energy can be derived from biological systems

- SRI's microbiology program addresses needs in health, defense, and industry
 - Large scale screening of bioactive compounds to discover and develop antimicrobial drugs against:
 - Biodefense organisms (*B. anthracis*, *Y. pestis*, *F. tularensis*)
 - Antibiotic resistant bacteria (methicillin resistant *S. aureus*)
 - *Mycobacterium tuberculosis* (causative agent of tuberculosis)
 - Degradation of high energy compounds (explosives such as DNT, TNT and RDX).
 - Mitigation of microbiologically induced corrosion of metal.
- Energy projects
 - Fuel from microorganisms
 - Alkane production by *Vibrio furnissii*
 - Ethanol from biomass
 - Microbial fuel cells



Sediment-anode microbial fuel cells

Can bioinformatics and synthetic biology help?

Consider bacteria as chemical factories, and a metabolic network as a black box:



Input Compounds

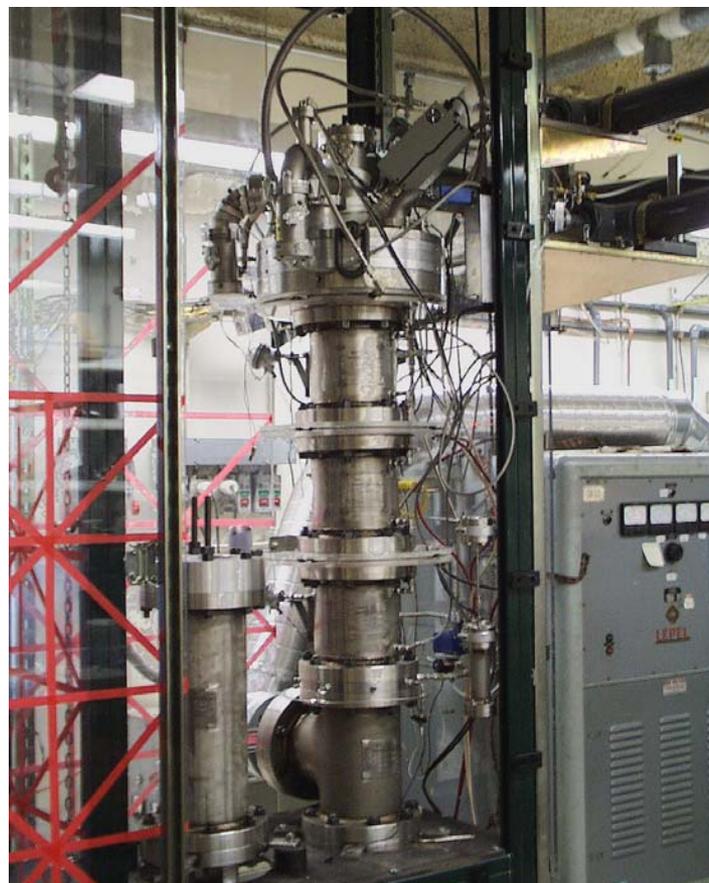


**Output Compounds
+
More Bacteria**

- What inputs?
- What outputs?
- How do we modify the network to have the desired behavior?

Experience with conventional fuels provides unique insight on ways to use emerging fuels

- Options for algal biomass utilization:
 - Thermochemical
 - Pyrolysis to oils and char
 - Gasification to syn-gas to fuels
 - Bioprocessing
 - Anaerobic digestion
 - Separation
 - ♦ Carbohydrates to fuels via fermentation
 - ♦ Lipids to biodiesel
 - ♦ Proteins to animal feed, plastics or other compounds
- SRI interests:
 - Catalyst development
 - Separations
 - Novel chemical processing to produce oils compatible with current fuel systems and vehicles



Entrained flow reactor for combustion, gasification, and pyrolysis

Marine environments: a key component in carbon cycles

- Marine Technology Program established in 2007
 - Created through collaboration between SRI, the state of Florida, the city of St. Petersburg, Pinellas County, and the University of South Florida's Center for Ocean Technology
- Studies surface and subsurface marine environments
 - Research, development, deployment, and operation of advanced sensors and their systems.
 - Research and engineering in optics, acoustics, MEMS, mass spectrometry, and related marine sciences.
- Unique capabilities to examine ocean acidification



Portable Underwater Mass Spectrometry

Membrane Introduction Mass Spectrometry (MIMS)

In Situ Analysis

Simultaneous detection of multiple chemical species, including dissolved gases and volatile organics

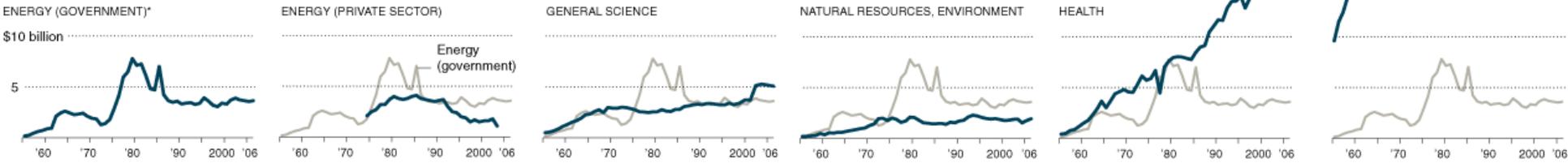


Energy research needs sustained investment

Declining Investment in Energy R.&D.

Spending for energy research and development peaked during the oil crisis and has since fallen while spending in most other sectors continues to grow.

Research and development spending by function, in 2006 dollars



Sources: American Association for the Advancement of Science; Dan Kammen, University of California at Berkeley

*Data after 1998 adjusts for U.S. accounting changes.

David Constantine/The New York Times

