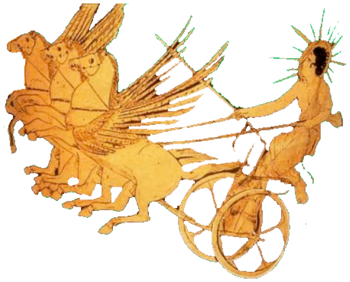


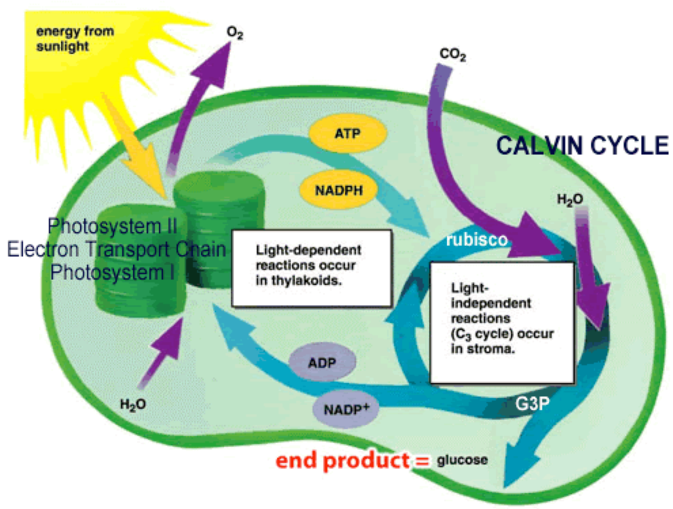
Berkeley Lab

Helios Project

Helios

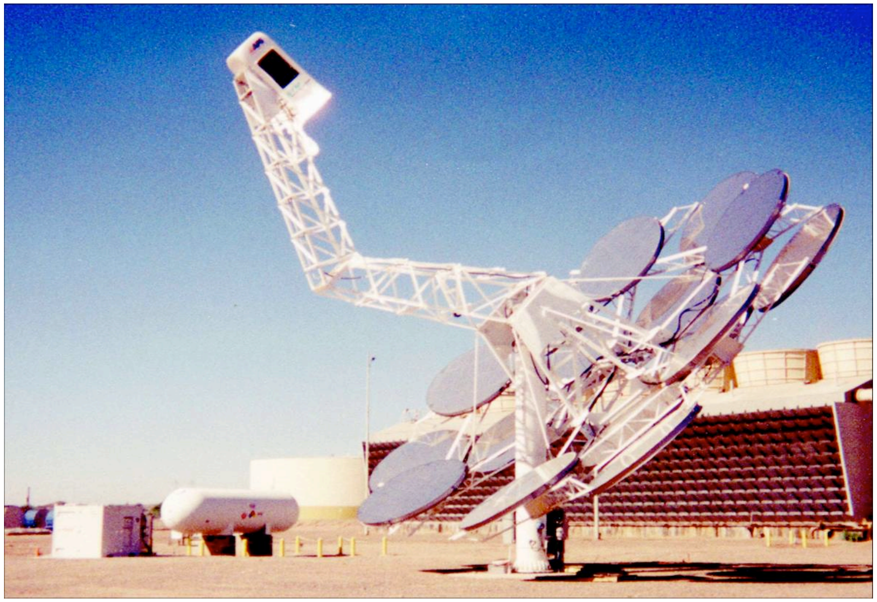
Solve the challenge of efficiently generating chemical fuel at low cost using solar energy

Photosynthesis



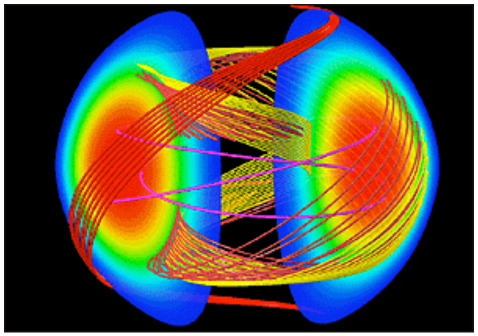
cheap but inefficient

Solar Driven Electrolysis

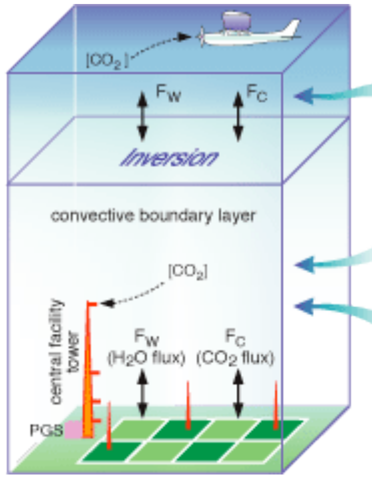


efficient but expensive

Berkeley Lab
Broad-based Energy Strategy

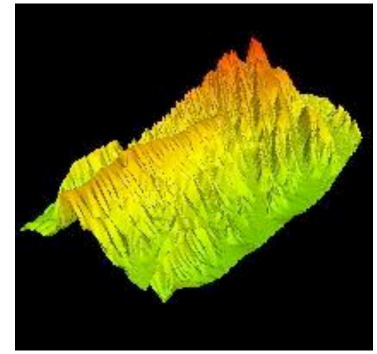


Fusion



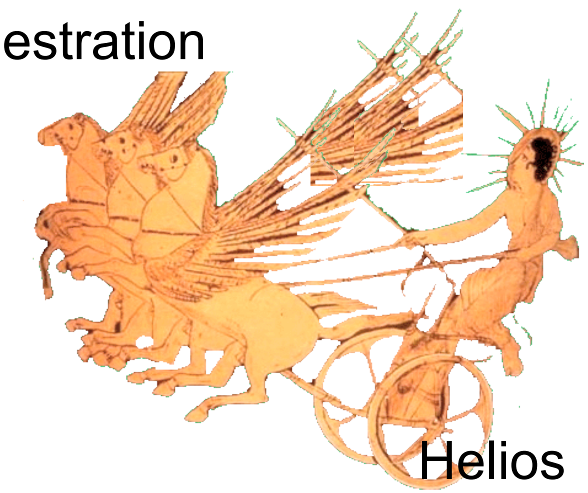
Carbon sequestration

geothermal

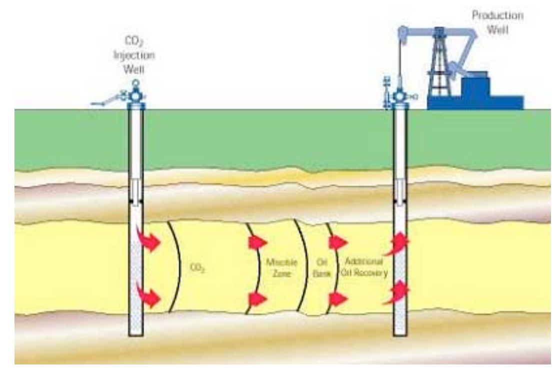


Computation and Modeling

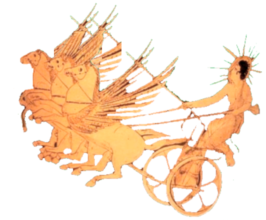
Energy Efficiency



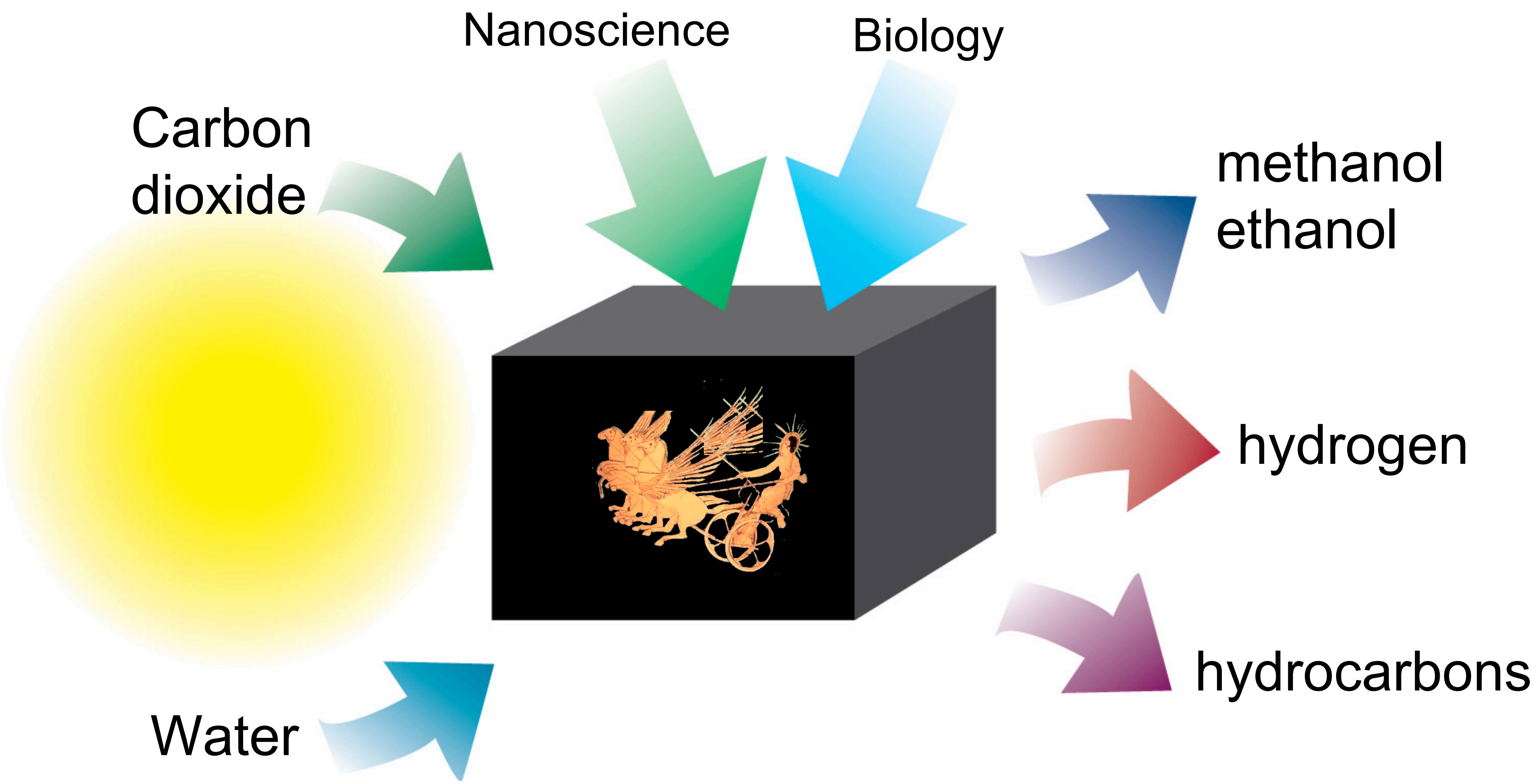
Helios



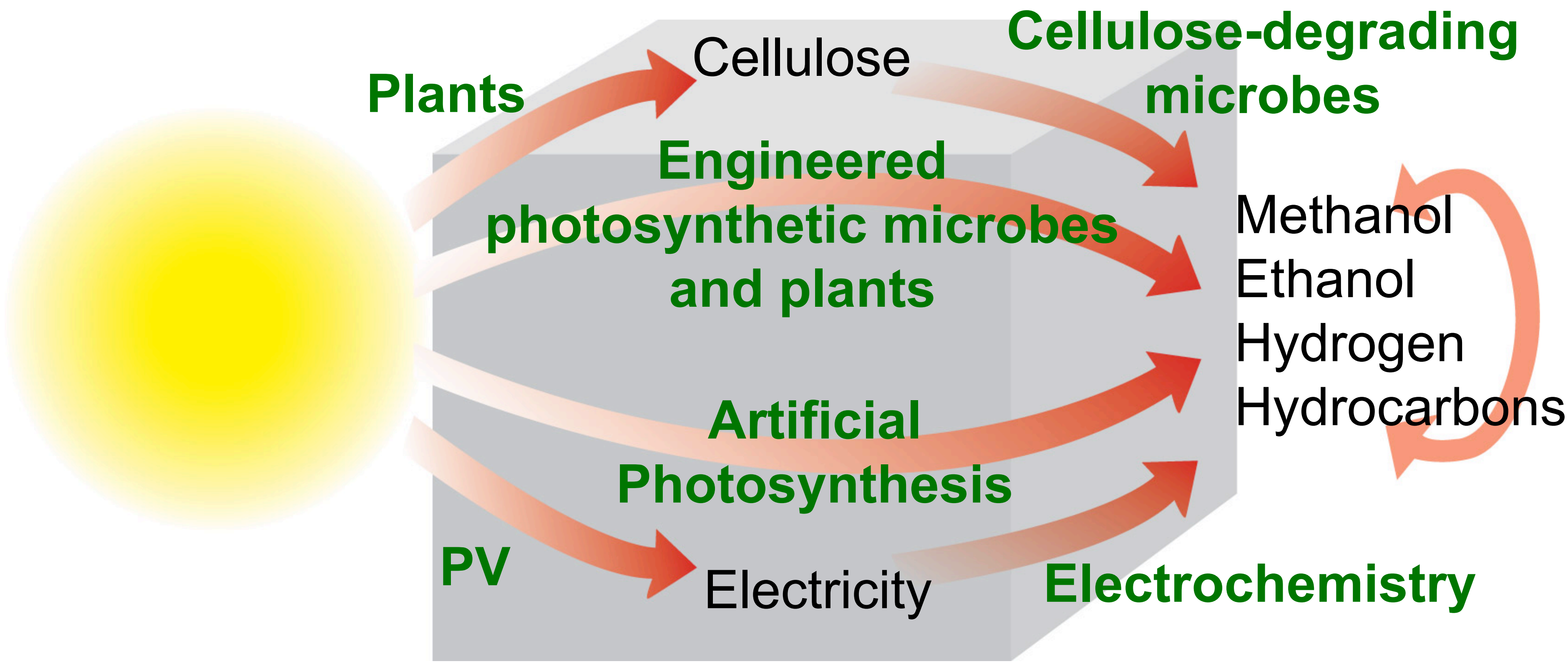
Fossil recovery



Helios


Nanoscience
Biology
Carbon dioxide
methanol
ethanol
hydrogen
hydrocarbons
Water

Helios



Plants
Cellulose
Cellulose-degrading microbes
Engineered photosynthetic microbes and plants
Methanol
Ethanol
Hydrogen
Hydrocarbons
Artificial Photosynthesis
PV
Electricity
Electrochemistry

The Target

- Light-to-Fuel at 10% Power Efficiency
- $ 3/GJ (= Gasoline at $0.4/ Gallon)
- Carbon Neutral
- Manufacturable and Sustainable
- Storable and Transportable Fuel
(energy density Spec.)

Energy Density Spec.

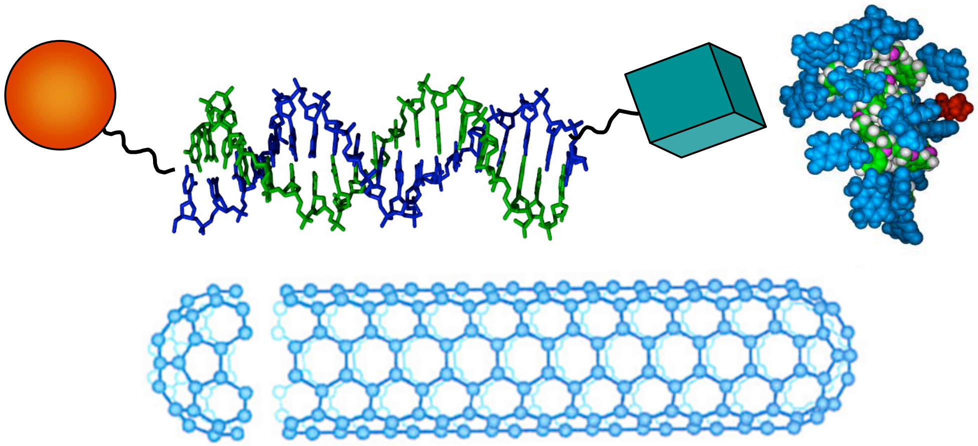
Energy Density sorted by Wh/l

Material	**Volumetric**	**Gravimetric**
Diesel	10,942Wh/l	13762Wh/kg
Gasoline	9,700 Wh/l	12,200 Wh/kg
LNG	7,216 Wh/l	12,100 Wh/kg
Propane	6,600 Wh/l	13,900 Wh/kg
Ethanol	6,100 Wh/l	7,850 Wh/kg
Methanol	4,600 Wh/l	6,400 Wh/kg
Liquid H2	2,600 Wh/l	39,000* Wh/kg

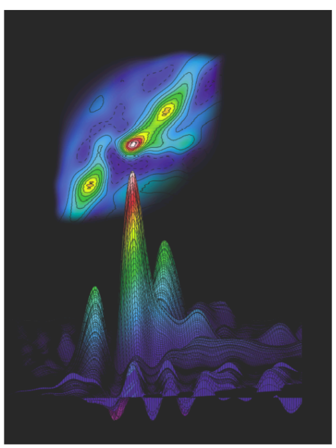
Some benchmarks to consider

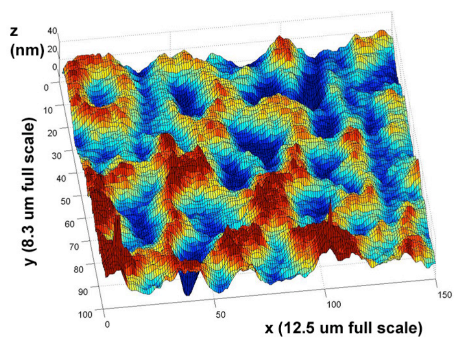
- Biomass-to-fuel: From ~0.35% to 3.6%
  - At 3.6% efficiency, 100M acres of arable land (25% of total currently farmed land) will supply all fuel for transportation based on current fuel efficiency.
- Light-to-electricity: 20% efficiency at mass production, $0.02/KWh
- Electricity-to-chemical storage:
  - Presently at most 50% energy efficient; over-voltage to drive rates
  - Water to hydrogen 4 electrons; CO_2 to methanol six electrons
- Direct solar-to-fuel
  - Sunlight oxidizing water: 1.23 volts
  - Overall Power Efficiency Requirement: 10%
- Fuel interconversion:
  - 95% selective
  - Greater than10,000 turnovers/sec/site

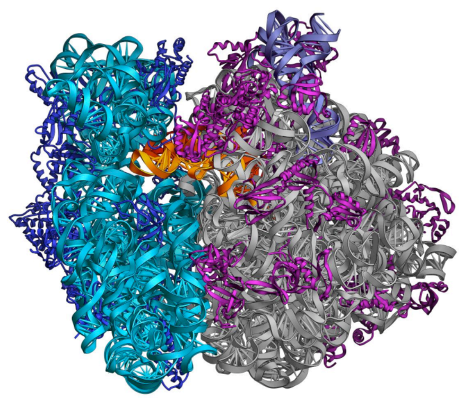
Combine Nanoscience and Biological Research at LBNL

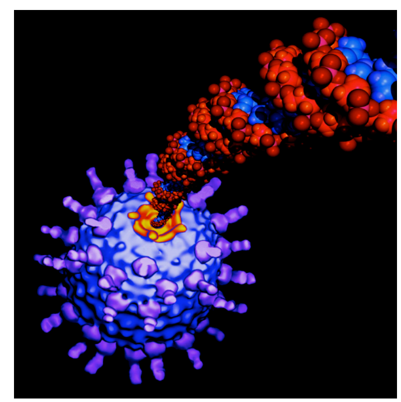


10 nm

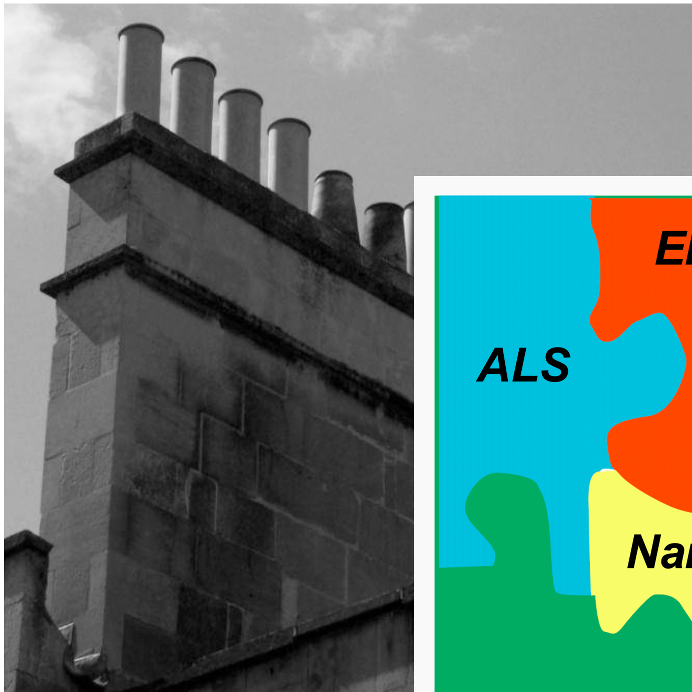


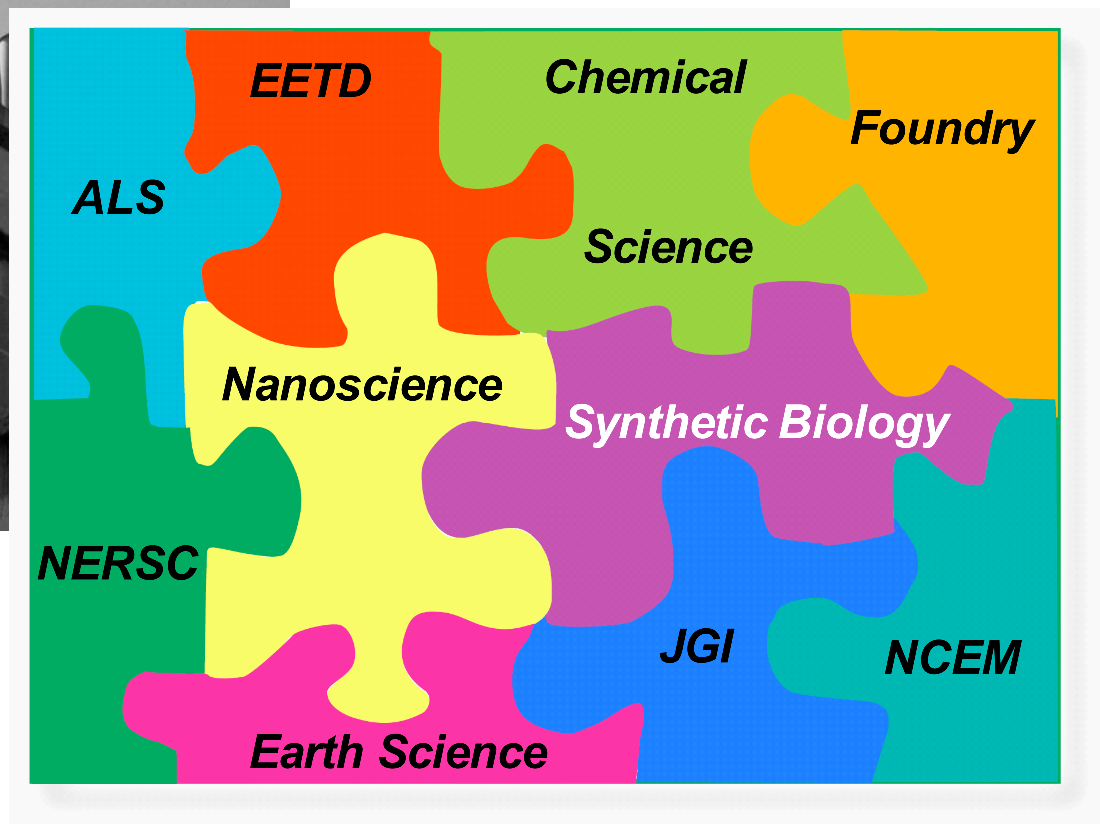






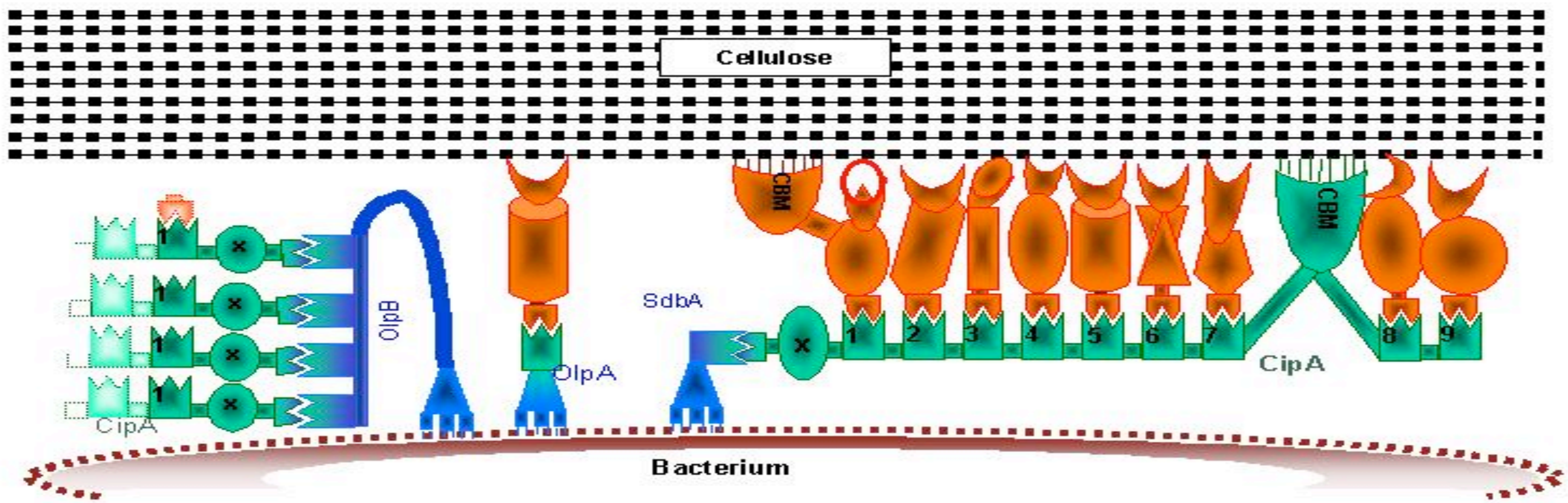
Scale of the Helios problem requires breaking down the stovepipes





Cellulose to Fuel

Improve upon the microbial degradation of lignocellulosic materials



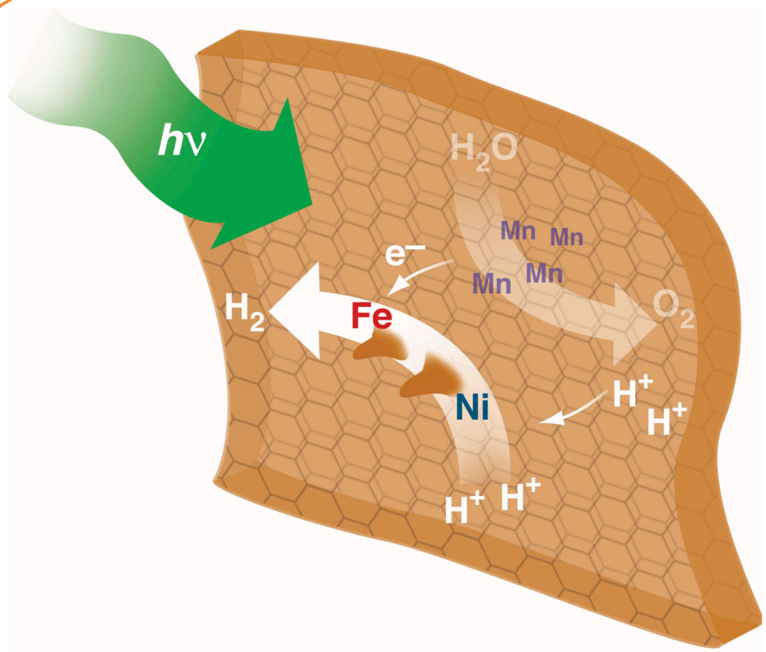
Catalysts
- robust enzymes
- artificial catalysts

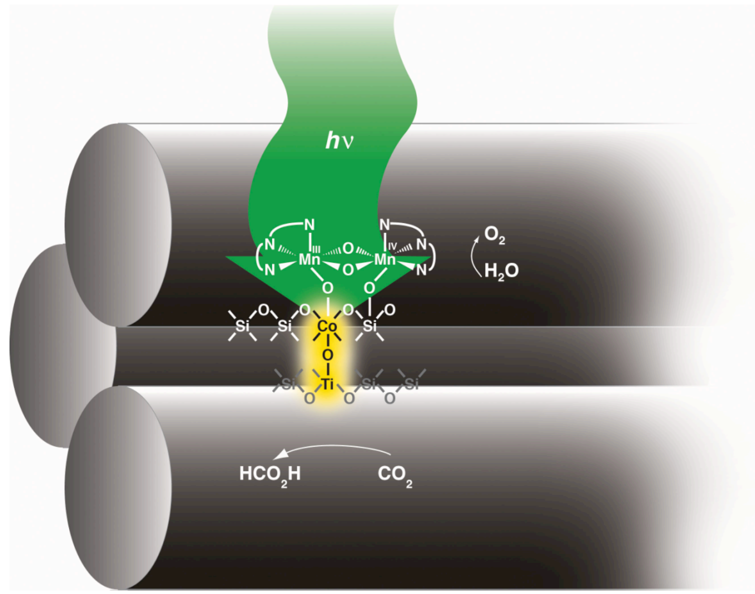
Separations
- Extract ethanol from water

Better microbes
- selectivity
- rates
- reduced toxicity

Tractable cellulose
- decrease crystallinity
- decrease lignin

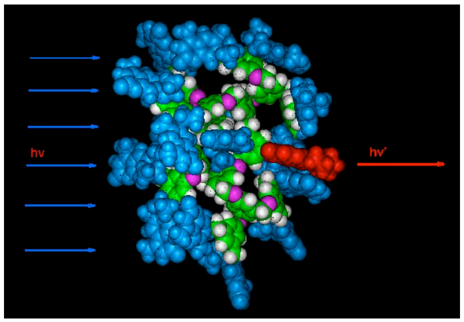
Design of catalytic active sites



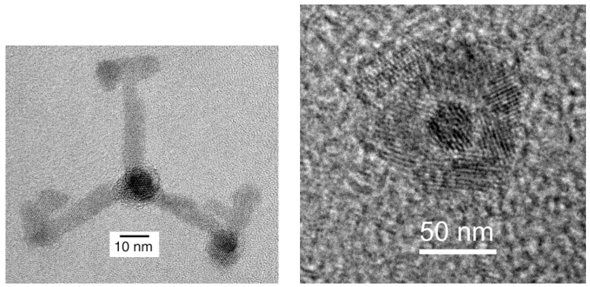


Biomimetic active site design
--embedded in 3D nanostructure for product separation on the nanoscale

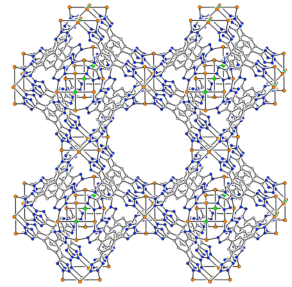
Novel Catalytic Microenvironments



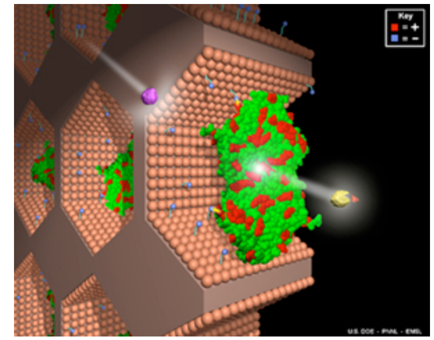
Organic dendrimers



inorganic dendrimers and micelles



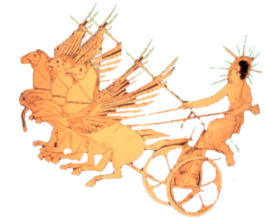
Inorganic channels



PNNL

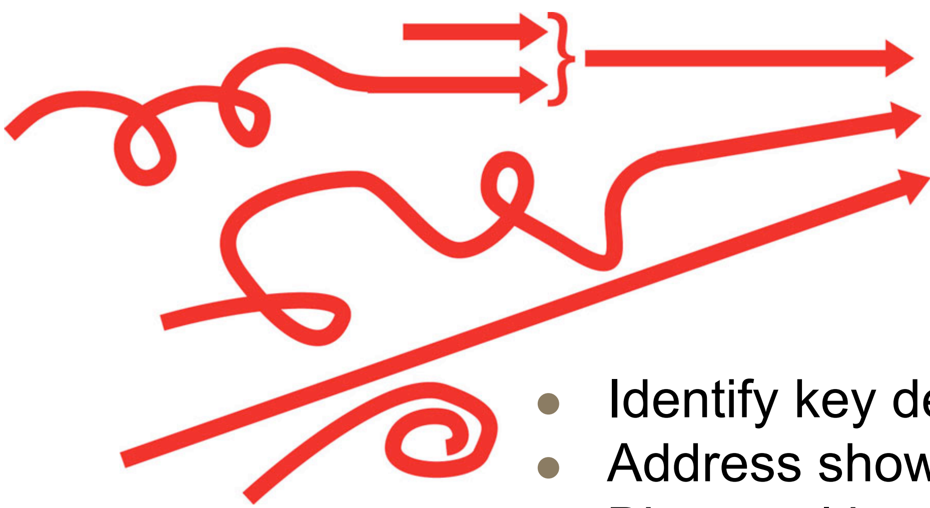
- control fluctuations
- control "flow" of reactants and products

Helios metrics for success



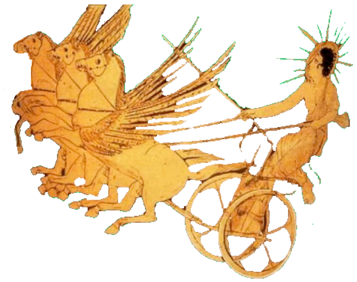
The goal of Helios is to provide a significant breakthrough within ten years

Science and technology trajectory analysis:



Fuels

- Identify key decision points
- Address showstoppers as quickly as possible
- Bi-annual international workshops to assess progress
- Annual plan
- Milestones and goals for ensuing three years
- Semi-annual reporting
- Annual Helios retreat/review with external reviewers



Berkeley Lab

Helios Project

Further Information:
Elaine Chandler, Helios@lbl.gov
510 486-6854