Energy for Sustainability

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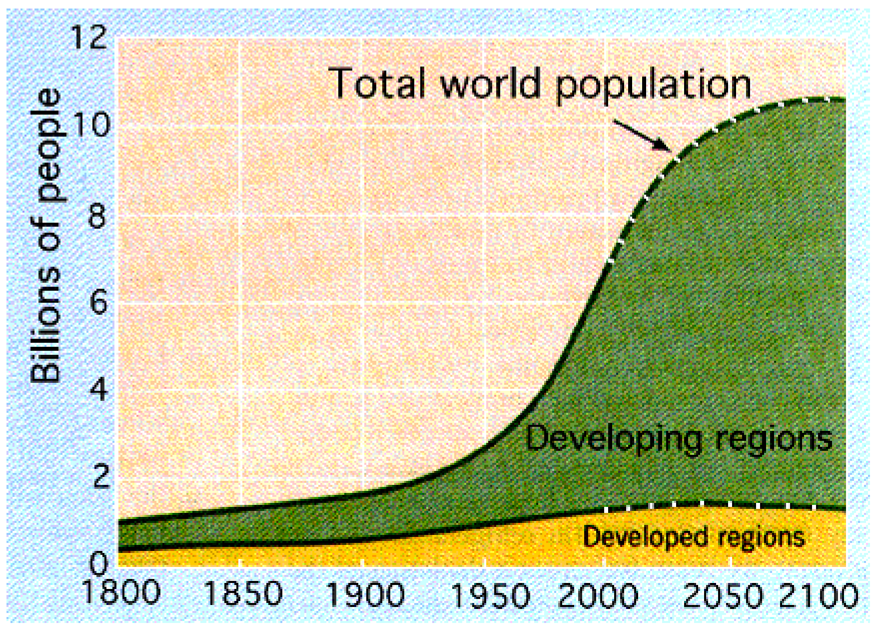
Outline

- Energy challenges

- Selected programs
  - Sustainable Energy Pathway
  - Emerging Frontiers in Research and Innovation
  - Energy for Sustainability

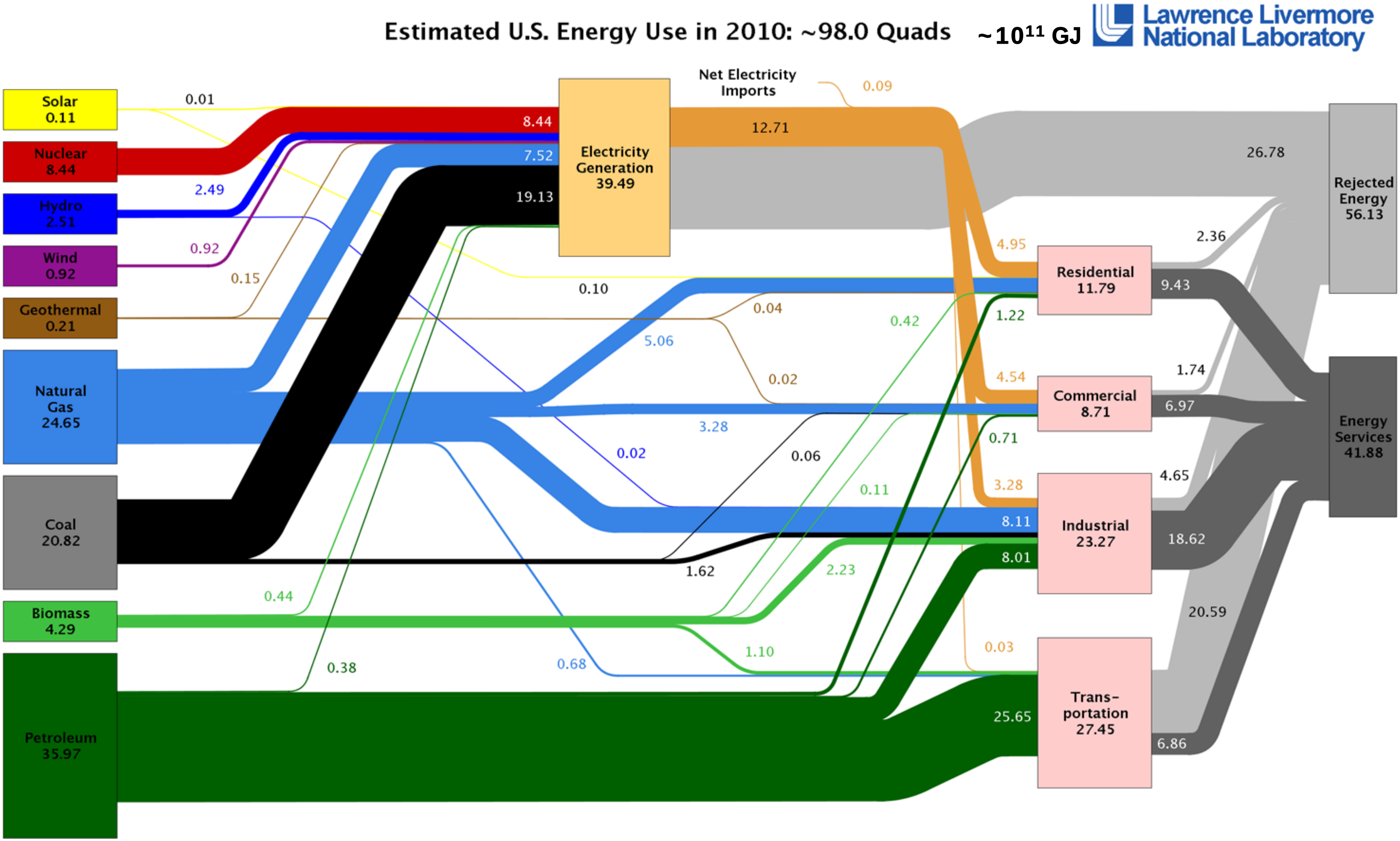
World Population

- Currently we need to design Food + Fuel supply for **7 10^9 people**
- Over next 50 years, increase the supply to support **10.5 10^9 people**



(World Populations: Fundamentals of Growth, 1990, gumption.org)

Energy Use in the United States



Source: LLNL 2011. Data is based on DOE/EIA-0384(2010), October 2011. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports flows for hydro, wind, solar and geothermal in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." (see EIA report for explanation of change to geothermal in 2010). The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 80% for the residential, commercial and industrial sectors, and as 25% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

Energy Use in the United States

1. Electricity → Too much CO_2 emission

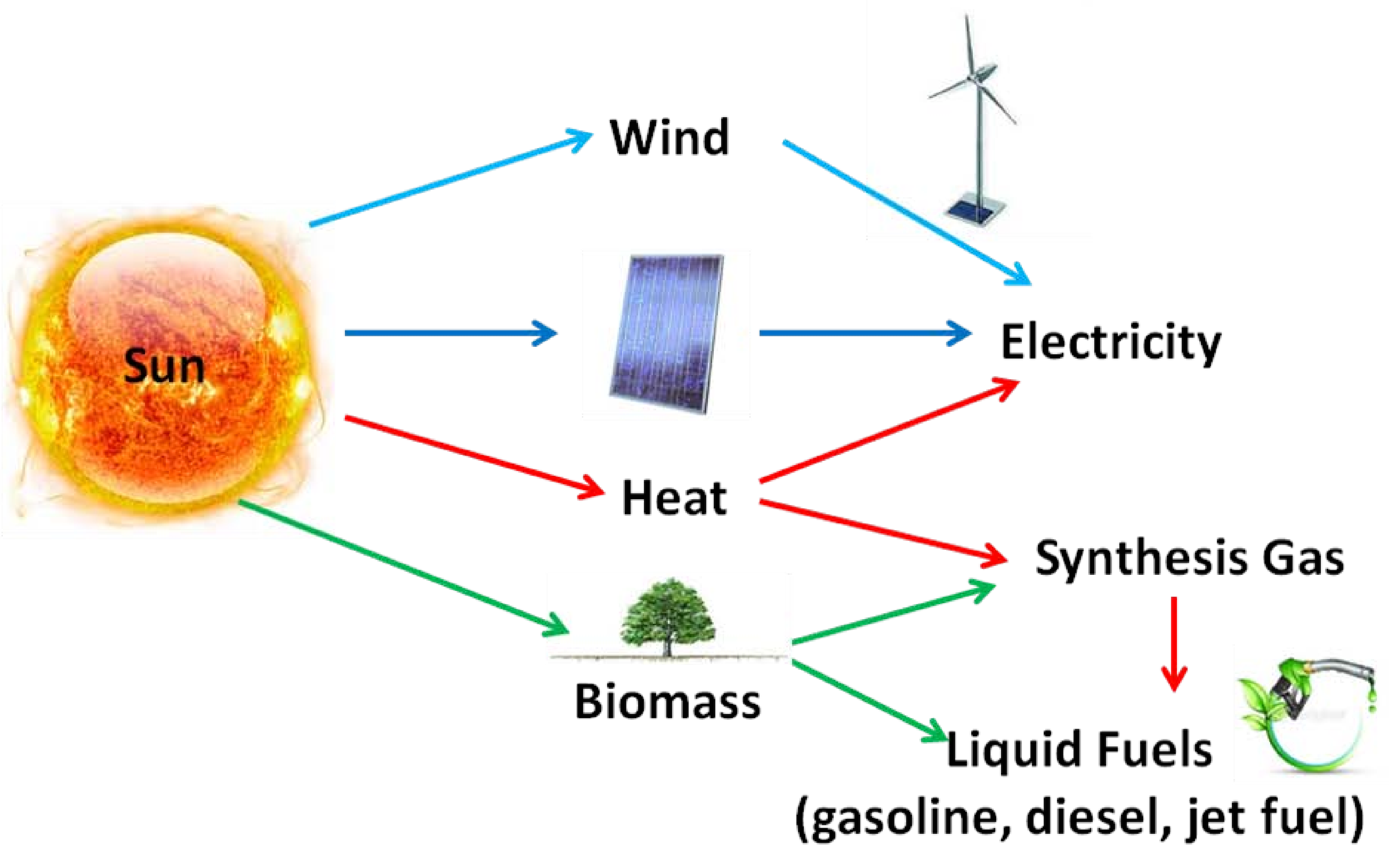
2. Natural Gas → Plenty from Gas Shales (Some environmental concerns)

3. Petroleum → Most painful import!

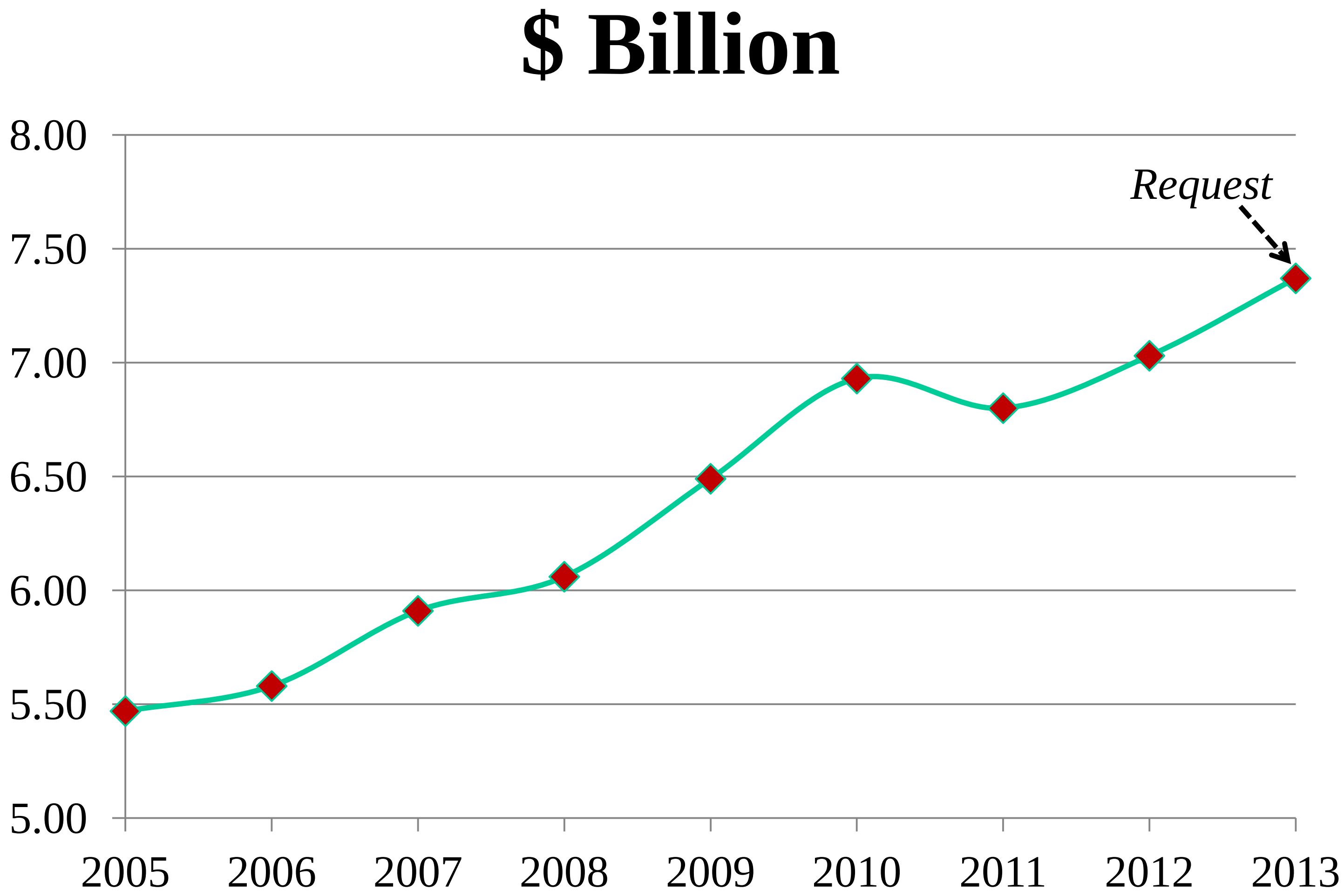
4.7 10^9 barrels/year

= **$460 billion/year**

One Sustainable Source of Energy



National Science Foundation Budget



Merit Review Process

- Proposal Preparation and Submission
- 3 Months

Steps 4-7

- Proposal Review and Processing
- 6 Months

Steps 8-9

- Award Processing
- 1 Month

1 Opportunity Announced

2 Proposal Submitted

3 Proposal Received

4 Reviewers Selected

5 Peer Review

6 Program Officer Recommend-ation

7 Division Director Review

8 Business Review

9 Award Finalized

Merit Review Criteria

- **Intellectual Merit:** potential to advance knowledge
- **Broader Impacts:** potential to benefit society

Five Review Elements

1. What is the potential for the proposed activity to:

   a. advance knowledge and understanding within its own field or across different fields (Intellectual Merit); and

   b. benefit society or advance desired societal outcomes (Broader Impacts)?

2. To what extent do the proposed activities suggest and explore creative, original, or potentially transformative concepts?

3. Is the plan for carrying out the proposed activities well-reasoned, well-organized, and based on a sound rationale? Does the plan incorporate a mechanism to assess success?

4. How well qualified is the individual, team, or institution to conduct the proposed activities?

5. Are there adequate resources available to the PI (either at the home institution or through collaborations) to carry out the proposed activities?

Selected Programs Related to Energy Research:

1. Sustainable Energy Pathways (NSF 11-590)
2. Emerging Frontiers in Research and Innovation: Photosynthetic Biorefineries (NSF 12-583)
3. Energy for Sustainability (NSF 13-7644)

Sustainable Energy Pathways

NSF 11-590

Amount

$36M for 20 awards

Awards

Up to $500K/year

Up to 4 years

Requirements

At least 3 PIs (one lead, 2 co-PIs)

Represents 2 or more disciplines

Restrictions

Max 3 proposals per organization

Max 1 proposal per PI, Co-PI, Senior personnel

To develop efficient pathways towards sustainable energy, from starting points to ending points, via a systems approach in the priority areas of

- Sustainable Energy Harvesting, Conversion, and Storage
  - Energy harvesting and conversion
  - Energy storage solutions
  - Critical elements and materials
  - Nature inspired processes
  - Reducing carbon intensity
- Energy Transmission, Distribution, Efficiency, and Use
  - Transmission and distribution
  - Energy efficiency and management

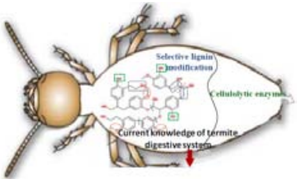
Biofuels

SEP Projects, Sept. 2012, about $2 million/each

(1) **Alkaliphilic microalgae-based sustainable & scalable processes for renewable fuels and products** — University of Toledo; Montana State University; University of North Carolina at Chapel Hill

(2) **Sustainable Housing through Holistic Waste Stream Management and Algal Cultivation** — Ohio University

(3) **Consortium for Nature-Inspired Lignocellulosic Biomass Processing** — Washington State University



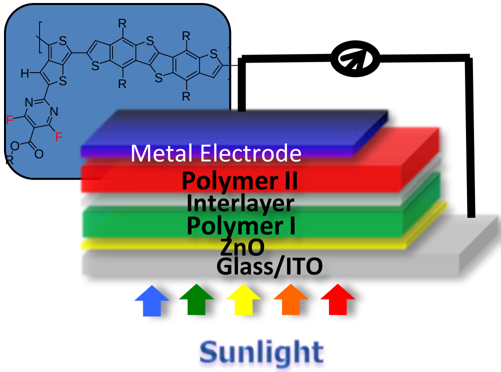
(4) **Sustainable Forest-Based Biofuel Pathways to Hydrocarbon Transportation Fuels: Biomass Production, Torrefaction, Pyrolysis, Catalytic Upgrading, and Combustion** — Michigan Technological University

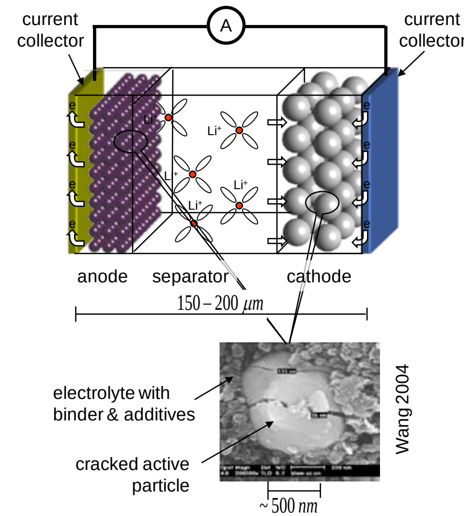
(5) **Integrated National Framework for Cellulosic Drop-in Fuels** — University of Maine

Solar and Batteries

SEP Projects, Sept. 2012, about $2 million/each

(6) **Development of Economically Viable, Highly Efficient Organic Photovoltaic Solar Cells**	University of Chicago; Northwestern University; University of California-Los Angeles
(7) **Routes to Earth Abundant Kesterite-based Thin Film Photovoltaic Materials**	Pennsylvania State Univ University Park; University of Florida; University of Illionois at Urbana-Champaign
(8) **A Sustainable Pathway to Terawatt-Scale Solution-Processed Solar Cells from Earth Abundant Elements**	University of Washington
(9) **Earth-abundant thin-film solar cells as a sustainable solar energy pathway**	University of Toledo
(10) **Non-Aqueous Redox Flow Battery Chemistries for Sustainable Energy Storage**	University of Michigan Ann Arbor
(11) **A Lab-to-Market Paradigm for the Optimal Design of Sustainable Energy Storage Materials**	University of Colorado at Boulder

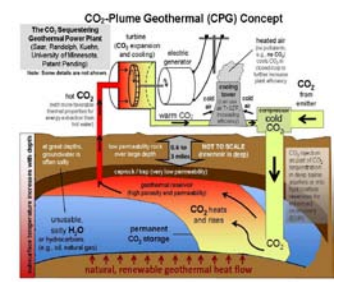


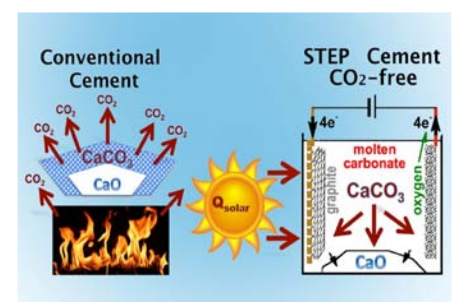


Wind, Tidal, Thermal, CO_2

SEP Projects, Sept. 2012, about $2 million/each

(12)	**Sustainability of Tidal Energy**	University of Washington
(13)	**Collaborative: Achieving a Sustainable Energy Pathway for Wind Turbine Blade Manufacturing**	University of Massachusetts Lowell; Wichita State University
(14)	**Pathways to Scalable, Efficient and Sustainable Soil Borehole Thermal Energy Storage Systems**	University of Colorado at Boulder; Colorado School of Mines
(15)	**A Novel Method Using CO2 and Geothermal Resources for Sustainable Energy Production and Storage**	University of Minnesota-Twin Cities
(16)	**Sustainable co-synthesis of cement and fuels**	George Washington University





Buildings and Integration

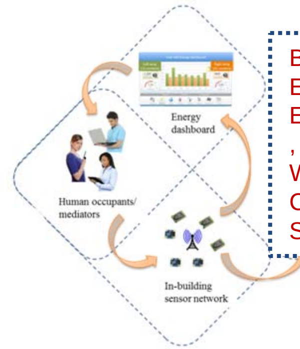
SEP Projects, Sept. 2012, about $2 million/each

(17) **A Unified Framework for Sustainability in Buildings through Human Mediation** — Rensselaer Polytechnic Institute; University of Wisconsin-Madison

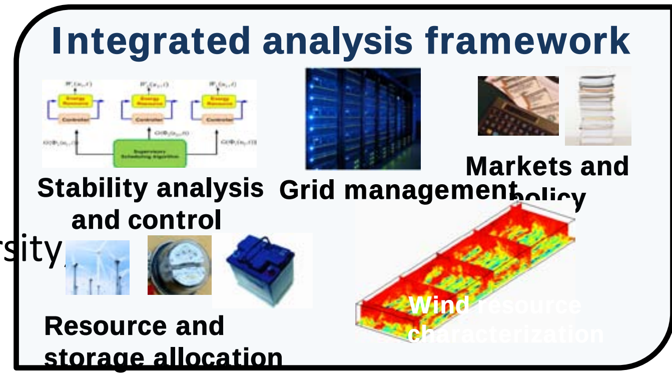
(18) **Creating An Energy Literate Society Of Humans, Buildings, And Agents For Sustainable Energy Management** — University of Southern California

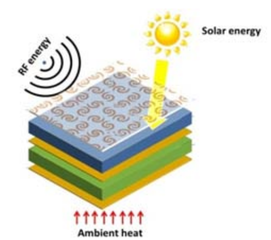
(19) **Integrating Heterogeneous Energy Resources for Sustainable Power Networks - A Systems Approach** — Johns Hopkins University; North Carolina State University, Smith College

(20) **Sustainable Energy Pathways Through Education and Technology** — University of New Mexico



Building Energy, Environment, Lighting, Water Control Systems





Selected Programs Related to Energy Research:

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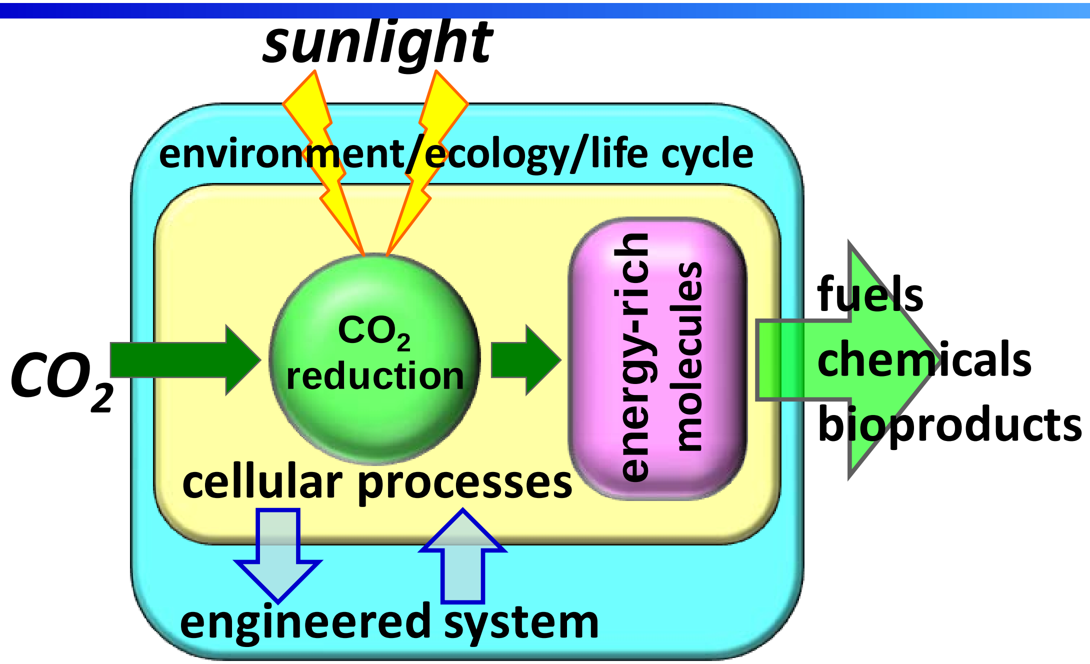
Upscaling Photobiological Processes: the Sustainable Photosynthetic Biorefinery



Objective: Establish the fundamental principles which efficiently deliver light and CO_2 to photosynthetic micro-organisms in scalable platforms for the sustainable & flexible production of fuels, chemicals, and bio-products

Expected Transformative Impact

- New paradigms for the rational/sustainable design and upscaling of photosynthesis-based, bio-manufacturing platforms that use sunlight and atmospheric CO_2 as inputs
- Advances in the basic science of flexibly transforming atmospheric CO_2 to complex and/or energy-rich molecules through metabolic processes
- Novel engineered systems for the emerging bio-economy

EFRI-PSBR Grants in FY12

Sept. 2012, $2 million/each

(1) **Cyanobacterial Biorefineries**	University of Wisconsin-Madison
(2) **Microalgae Lab-on-Chip Photobioreactor Platform for Genetic Screening and Metabolic Analysis Leading to Scalable Biofuel Production**	Texas A&M University Main Campus
(3) **The Diatom-based Photosynthetic Biorefinery**	Oregon State University

FY13 proposals are currently being reviewed

Energy for Sustainability Program

within

Chemical, Bioengineering, Environmental, and Thermal Systems (CBET) Division

Full Proposal Window: January 15, 2013 - February 19, 2013

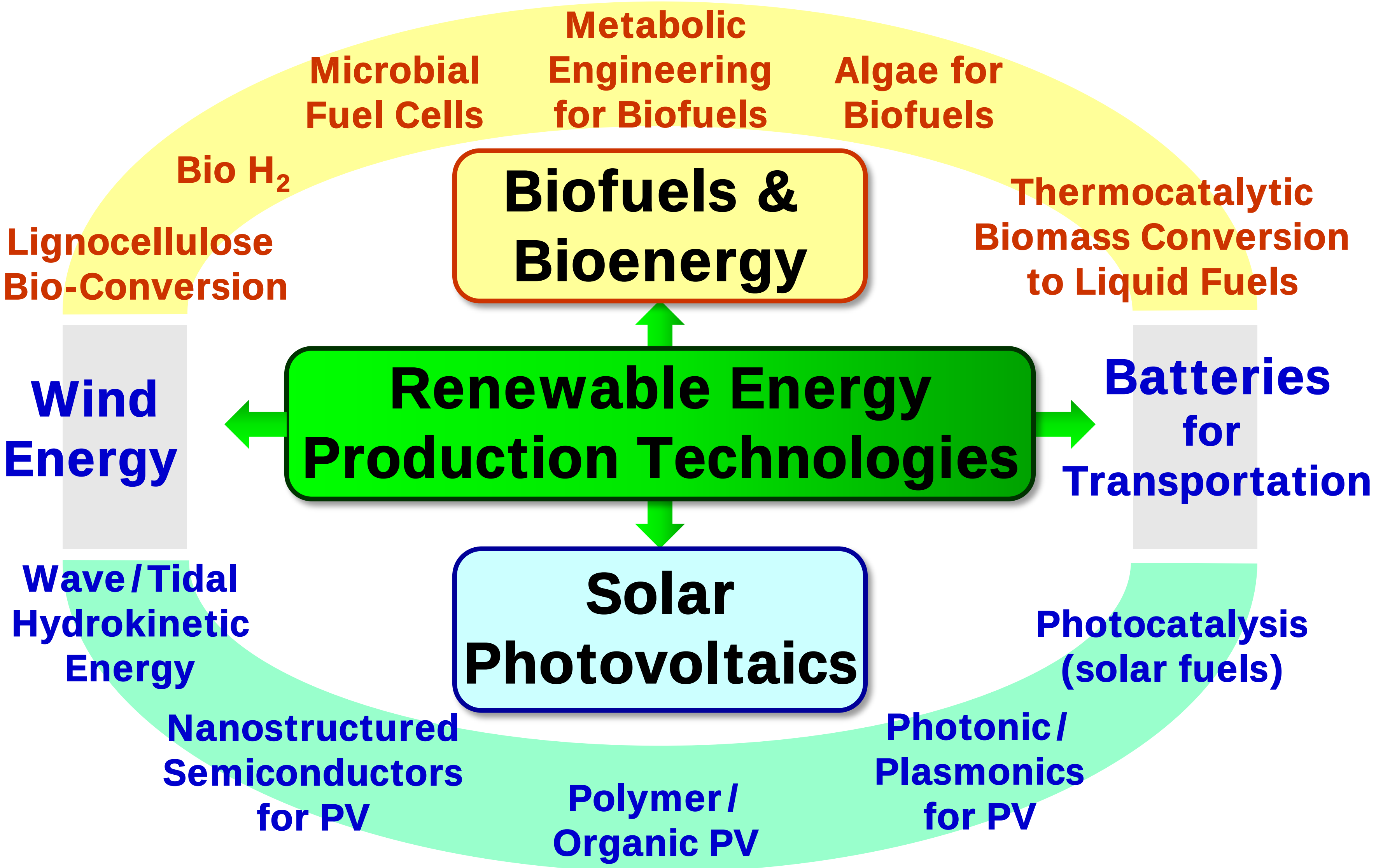
January 15, 2014 - February 18, 2014

(Ongoing program NSF 13-7644)

CBET Energy for Sustainability Program support:

- Fundamental engineering research and education that will enable **innovative processes** for the **sustainable** production of **electricity** and **transportation fuels**. The processes must be environmentally **benign**, reduce **greenhouse gas** emission, and utilize **renewable** resources.

ENG/CBET Energy for Sustainability Program: Current Emphasis Areas: ~160 active grants



CBET Energy for Sustainability Program Current Investments: Biofuels & Bioenergy

Plant biomass conversion

- Pretreatment & enzymes
- Thermal-catalytic conversion to liquid hydrocarbons

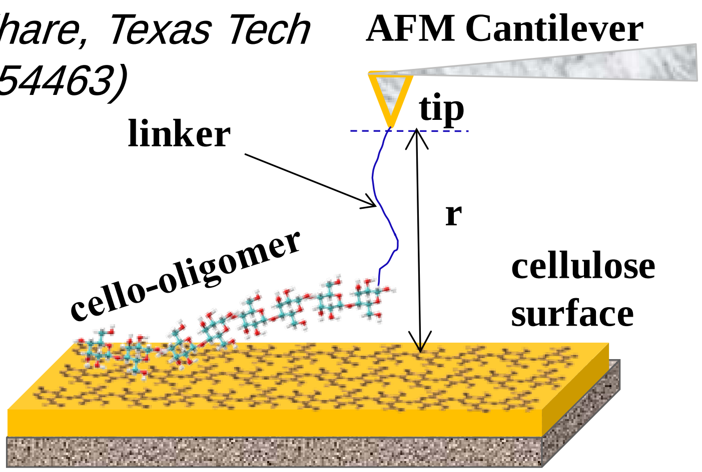
Advanced biofuels

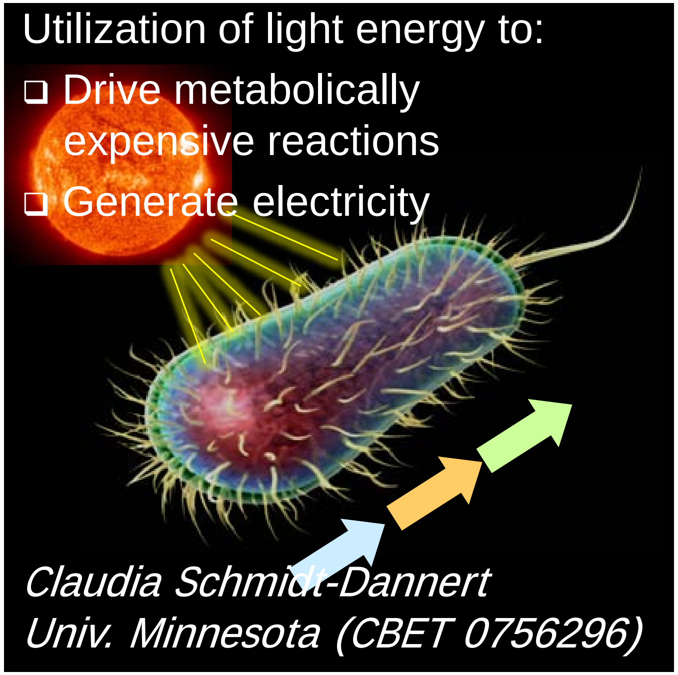
- Biofuels via metabolic engineering
- Energy-rich metabolites from algae
- Fuels from CO_2

Bioenergy

- Microbial/enzyme fuel cells
- Direct carbohydrate fuel cells
- Hydrogenase water-splitting to H_2

Rajesh Khare, Texas Tech (CBET0854463)





CBET Energy for Sustainability Program Current Investments: Wind & Wave Energy

Modeling & simulation (wind)

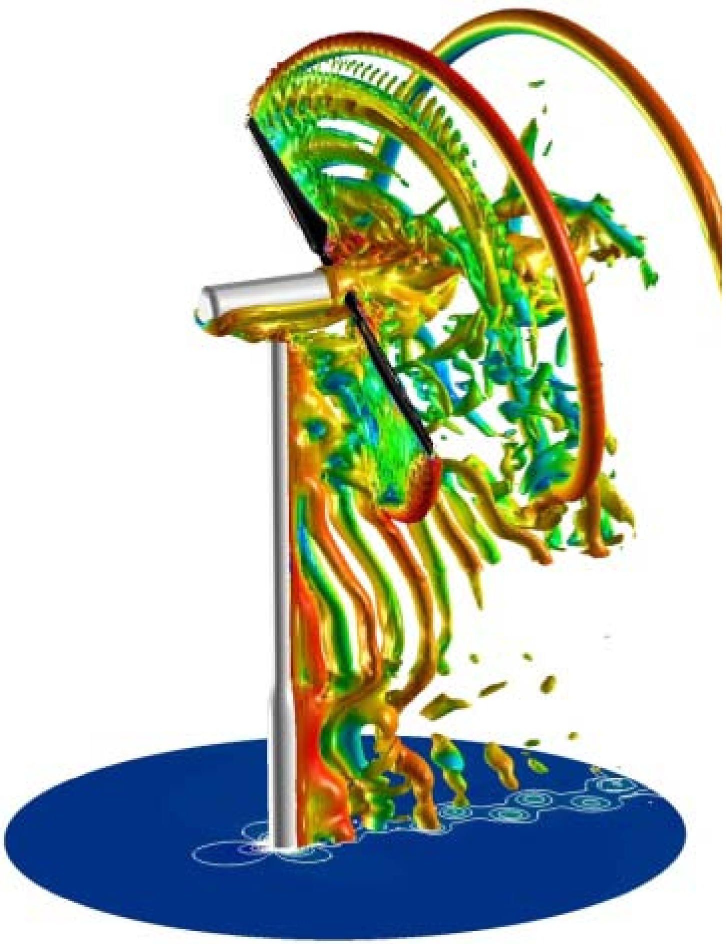
- Turbine aerodynamics & control
- Wind turbine farm interactions with atmospheric boundary layer

Advanced concepts (wind)

- Gas-expanded lubricants
- Piezoelectric systems
- Floating structures
- Tethered systems

Wave/Tidal/Hydrokinetic

- Bio-inspired systems

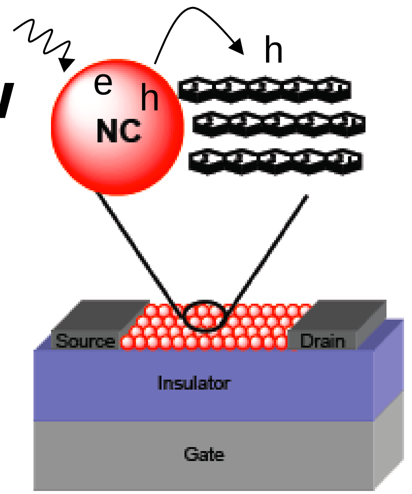


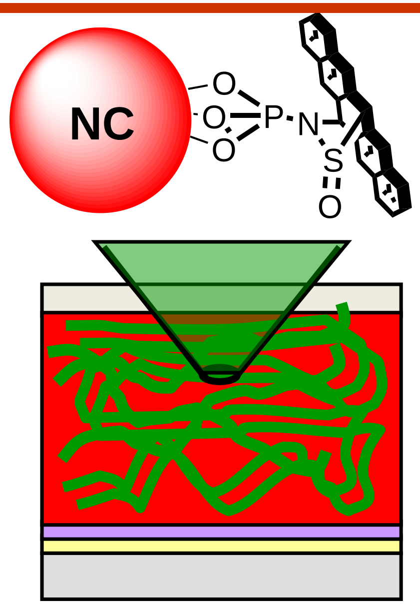
Marilyn Smith, Georgia Tech (CBET 0731034) Advances in Wind Turbine Analysis and Design for Sustainable Energy

NSF Engineering Investments in Solar Photovoltaic (PV) Materials & Devices

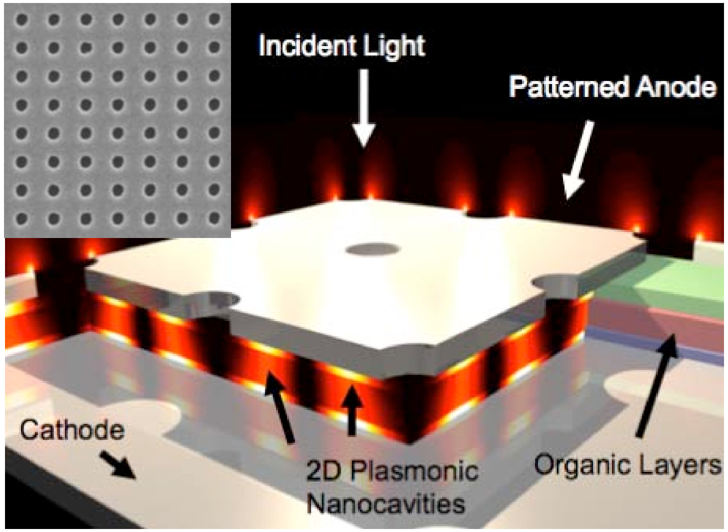
Innovative integration of new materials & devices for 3rd generation PV

- Nanowires, nanotubes
- Nanocrystalline/thin film
- Earth-abundant materials
- Multi-junction/hybrid stacks
- Plasmonic structures
- Photonic structures
- Dye-sensitized solar cells
- Polymer-based photovoltaics
- Self-assembled systems
- Biomimetic/bioinspired systems





Cherie R. Kagan
Univ. of Pennsylvania



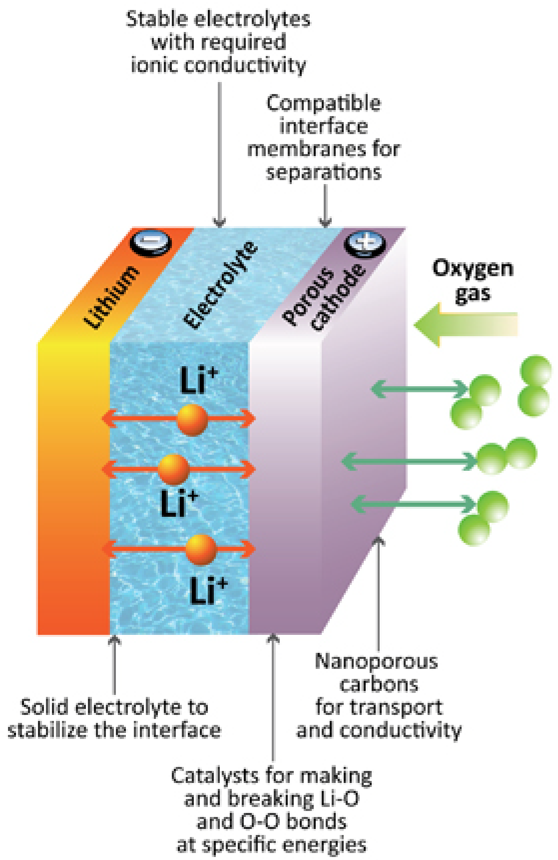
Russel Holmes,
University of Minnesota

CBET Energy for Sustainability Program
Current Investments: Batteries

For Transportation:

High energy and power densities

- Lithium ion
- Sodium ion
- Lithium air
- New cathode chemistries
- Novel electrode materials
- Convection batteries
- All solid-state batteries



Li-air batteries hold the promise of increasing the energy density of Li-ion batteries by as much as 10 fold. (http://www.transportation.anl.gov)

Thanks for your attention

NSF-funded researchers have won more than 200 Nobel Prizes!