Energy:
Challenges, Opportunities, Risks

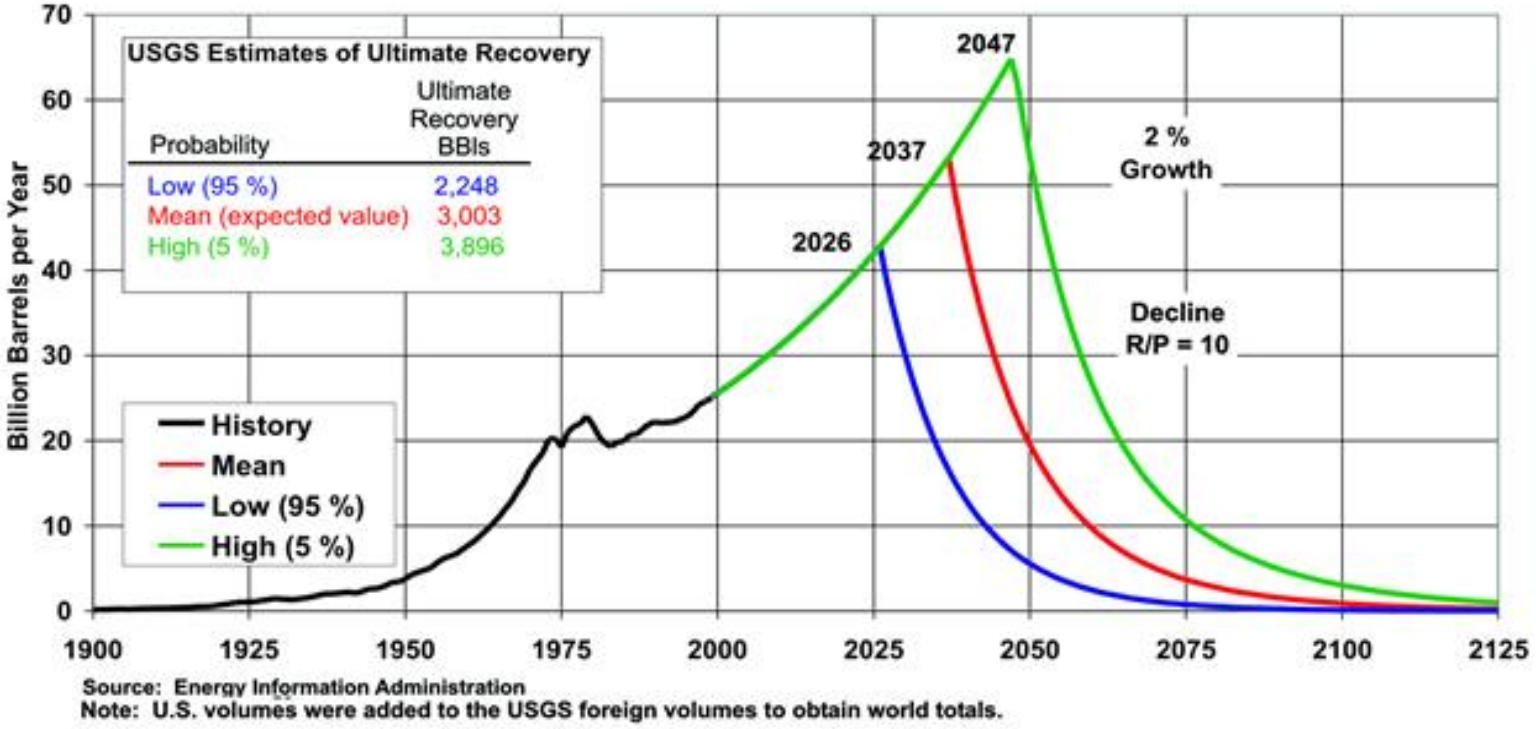
Donald Morelli
Professor and Interim Chairperson
Department of Chemical Engineering & Materials Science
Michigan State University

MSU Institute for Public Policy and Social Research (IPPSR)
Forum on Energy Use in Michigan
Lansing, MI, May 18, 2016

Challenges: Energy and Climate

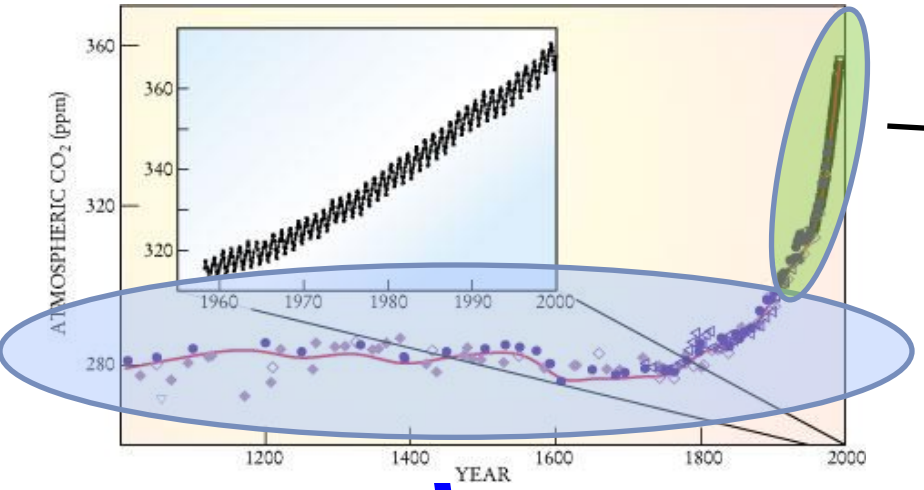
Challenge #1: "Proven" Oil Reserves

Global Oil Production Follows a "Hubbert Curve"



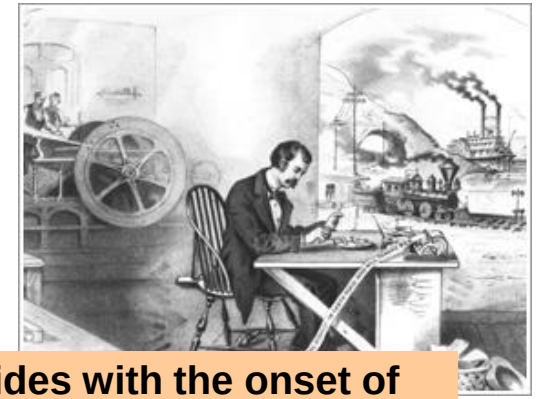
Any finite resource must follow this or similar decay curve

Challenge # 2: Atmospheric CO_2 and Global Average Temperature



→ Atmospheric measurements

→ Ice core data



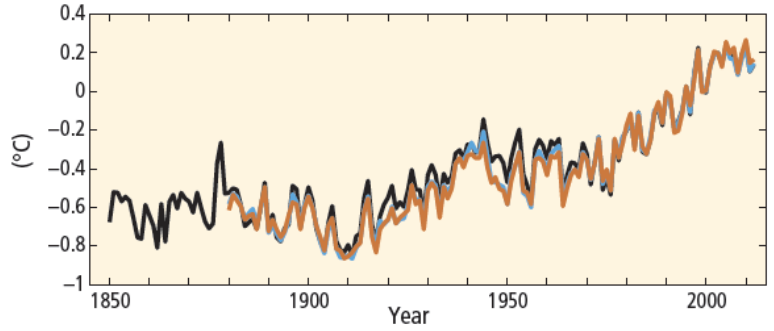
Atmospheric levels of CO_2 have increased from a constant level of 270 ppm before 1850 to a present day level of 408 ppm

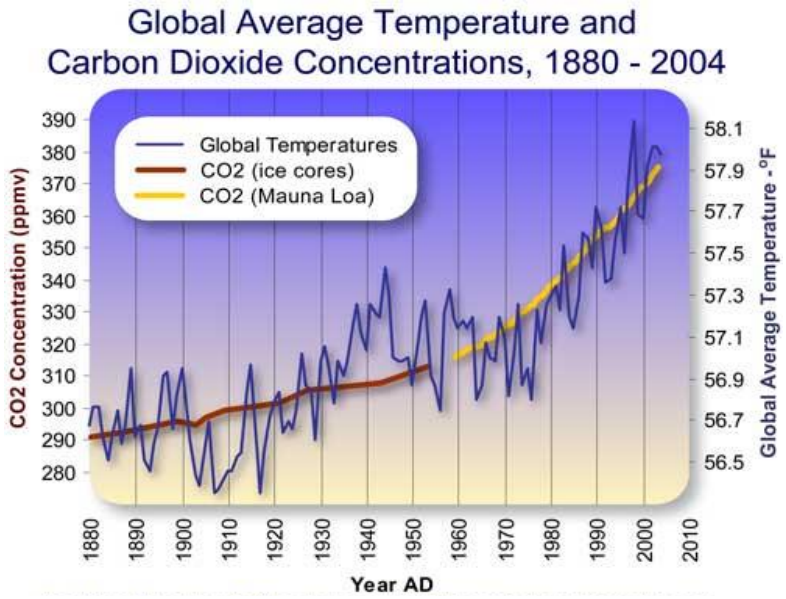
This rise coincides with the onset of the Industrial Revolution and has been attributed to the increased burning carbon containing fossil fuels (wood, coal, oil, gas, etc).

Source: Report of the Intergovernmental Panel on Climate Change

Are Global Temperatures Rising?

Globally-Averaged Combined Land and Ocean Surface Temperature Anomaly 1850 -2010





Source: Report of the Intergovernmental Panel on Climate change

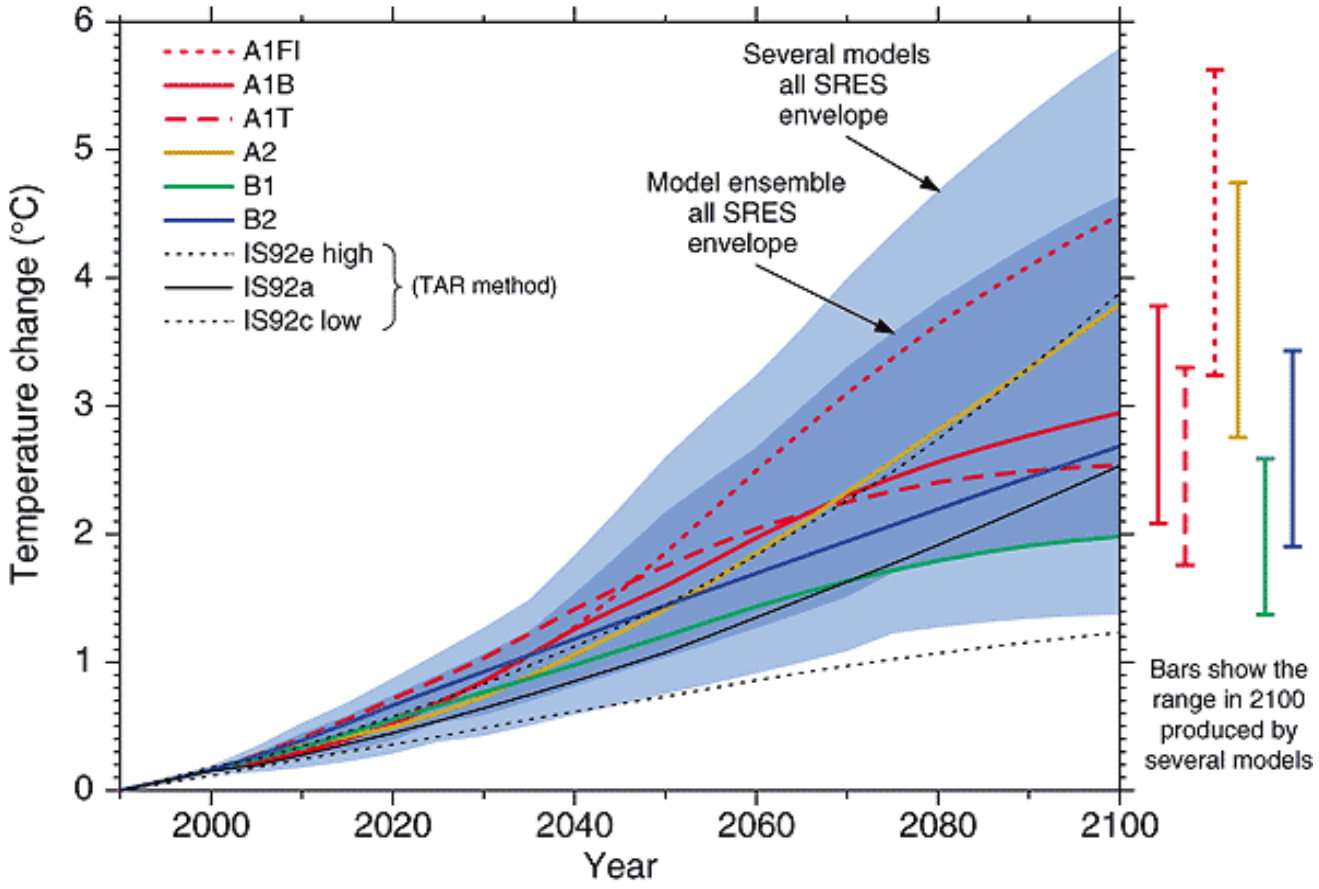
Some facts to consider:

- Global average temperature has increased by about 0.6 º C since 1900.
- The rate of warming has increased in the last 25 years
- This increase has followed the trend of increase in atmospheric CO_2
- Note however that the warming has not been uniform or constant
- Some years have been cooler, for instance 2008 was cooler than the previous 7 years
- The 15 warmest years on record are 1998 and 2001-2015, excluding 2008

Climate is not weather. The latter is isolated events or short periods of climatic activity. The former is what happens over long time periods.

WHAT DO **YOU** THINK?

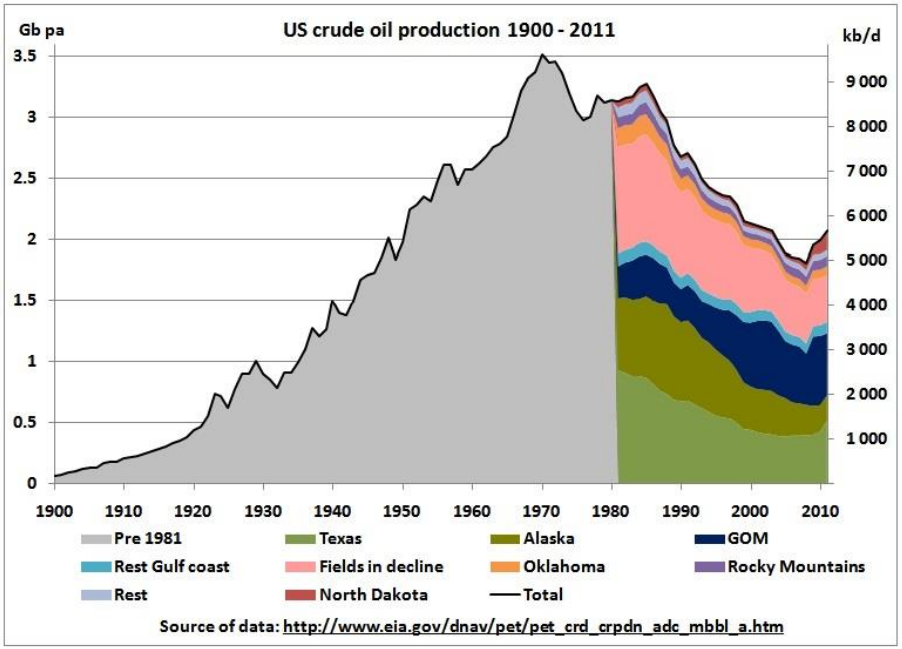
And will they continue to rise?



Source: Report of the Intergovernmental Panel on Climate Change

Opportunities in Energy

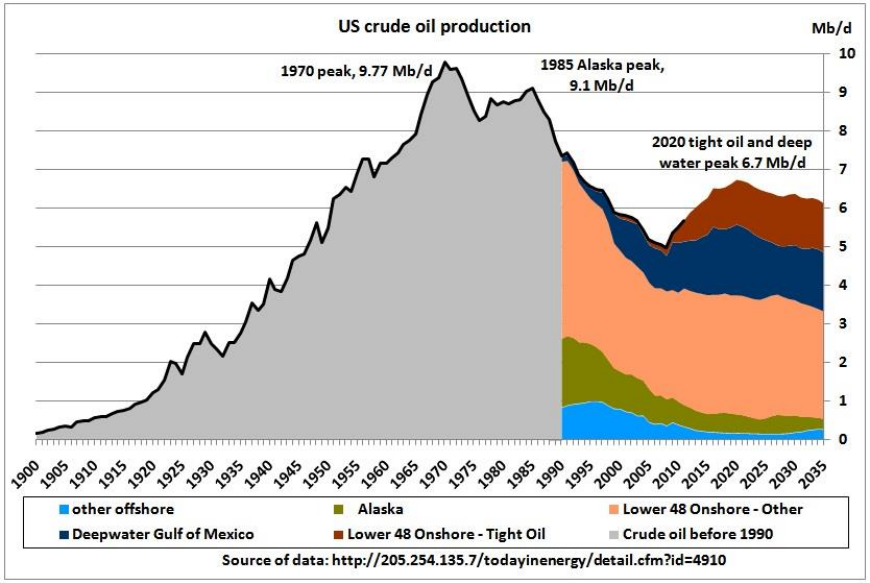
Opportunity: US oil supplies



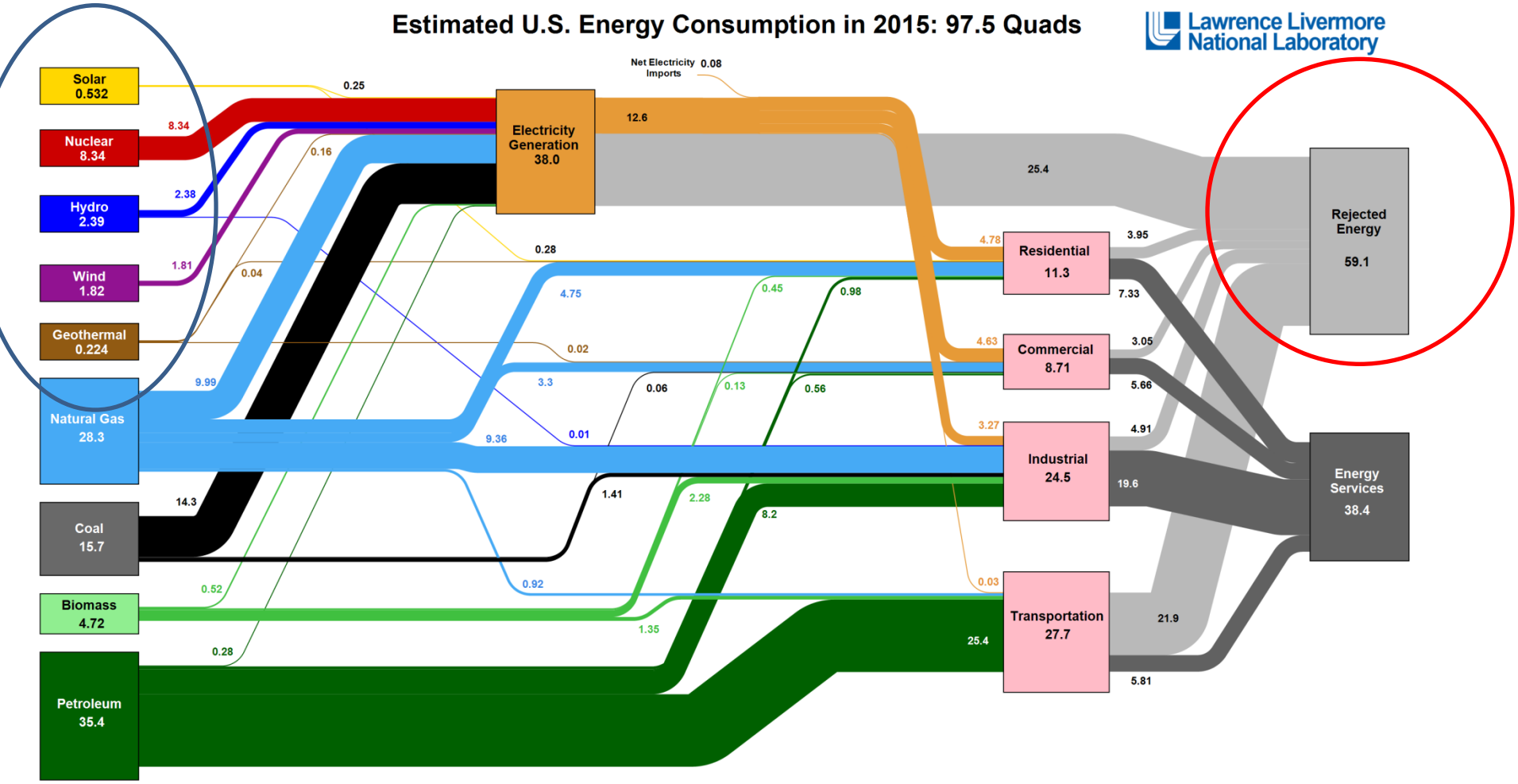
New technologies like horizontal drilling and fracking has led to an increase in oil production, primarily in the Midwest

This has led to an increase in the Hubbert curve for US crude oil production in the last few years

However, regardless of its form or location, oil is a finite resource, and projections are that oil production will again peak in the 2025-2030 time frame



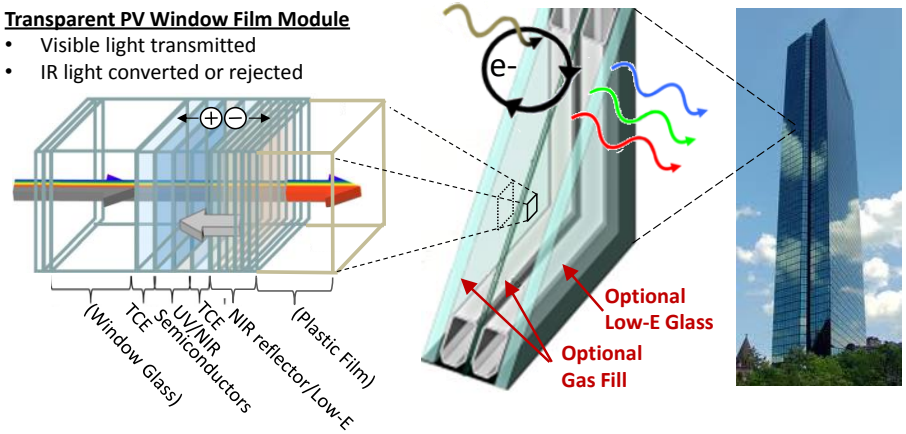
Opportunity: Renewable Energy and Energy Efficiency

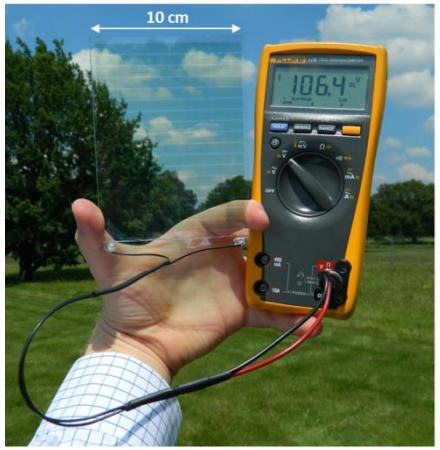


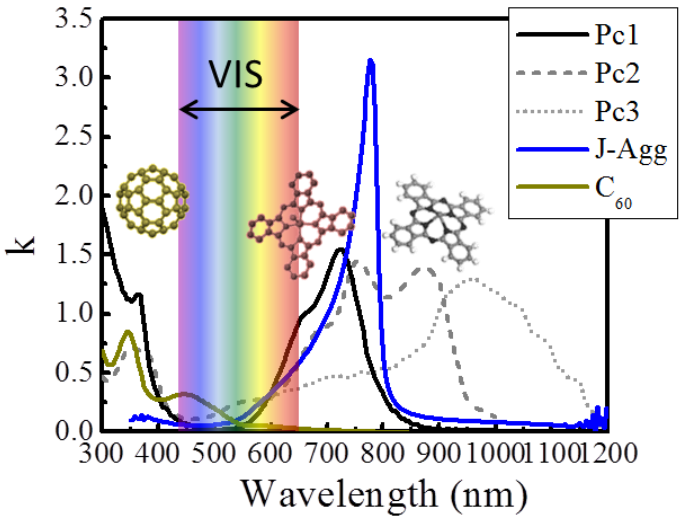
Source: LLNL March, 2016. Data is based on DOE/EIA MER (2015). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant heat rate. 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 0.65% for the residential sector, 0.65% for the commercial sector, 0.8% for the industrial sector, and 0.21% for the transportation sector. Totals may not equal sum of components due to independent Rounding. LLNL-MI-410527

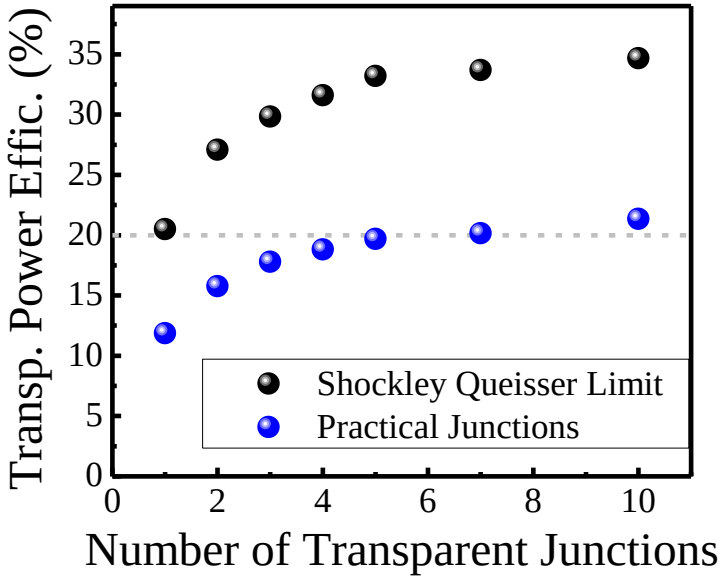
Transparent Photovoltaics

Design UV-NIR Selective Harvesting Structures
Richard Lunt, MSU









Batteries and Energy Storage

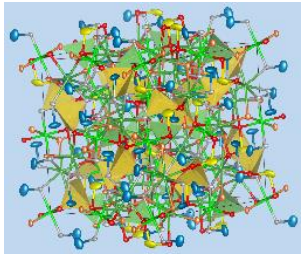
Batteries with high performance, lower cost, greater safety

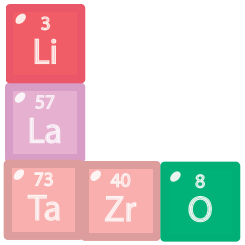
Wei Lai, MSU

Nonflammable solid electrolytes

flammable batteries

nonflammable garnet electrolytes



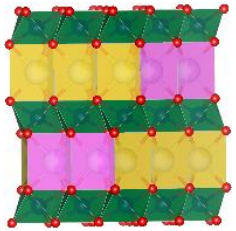


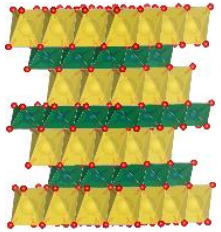
- Reported one of highest ionic conductivities of solid electrolytes
- Revealed the conduction mechanism to improve and design materials

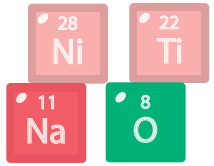
Bi-functional Na electrodes

- Lithium: scarce and geographically limited
- Conventional wisdom:
  positive 25 Mn 26 Fe 27 Co 28 Ni negative 22 Ti

Na and bi-functional







- Sodium >1000 times more abundant
- Combining Ni and Ti
- Studying two model systems to understand the correlation between electronic structure and ionic transport

Thermoelectrics for Converting Waste Heat to Electricity

New, abundant materials that turn wasted energy into electrical power

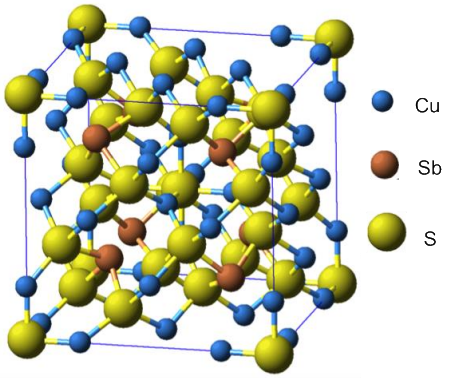
Donald Morelli, MSU

The Center for Revolutionary Materials for Solid State Energy Conversion

MSU-led DoE-funded Center

- Focused on understanding the fundamental science governing how materials convert heat to electricity
- Developed materials with record-high conversion efficiency
- Discovered how to make materials from earth-abundant sources that allows for application on large scale

Materials by Design



OEM's implementing technology on vehicles for increased fuel economy

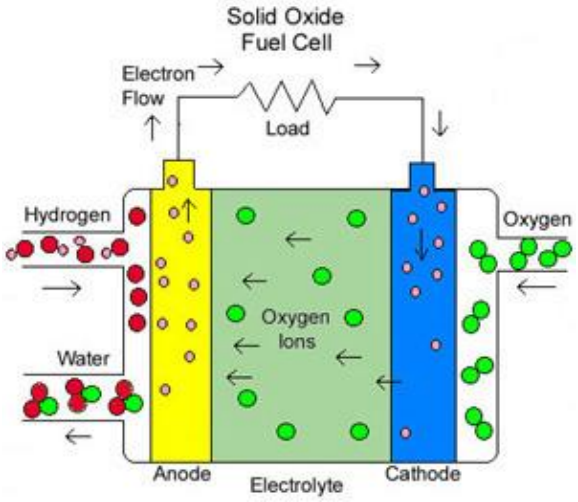
Production of power from large stationary diesel engines

MICHIGAN STATE UNIVERSITY
NORTHWESTERN UNIVERSITY
THE OHIO STATE UNIVERSITY
UCL
WAYNE STATE UNIVERSITY
OAK RIDGE NATIONAL LABORATORY
Managed by UT-Battelle for the Department of Energy
[efrc] RMSSEC Revolutionary Materials for Solid State Energy Conversion
U.S. DEPARTMENT OF ENERGY | Office of Science

Solid Oxide Fuel Cells (SOFCs)

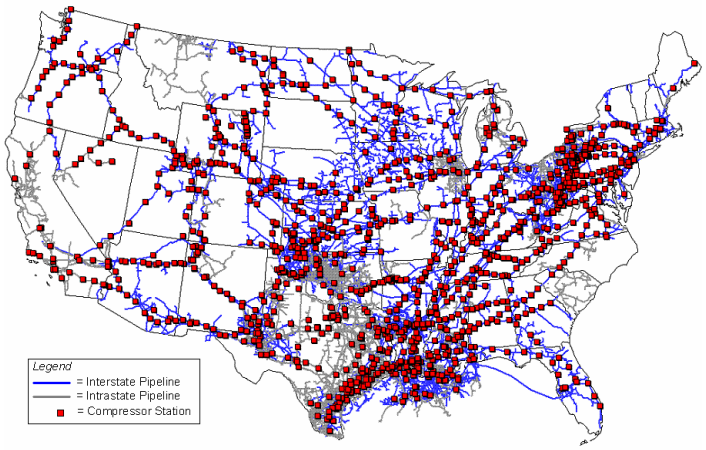
Modular, scalable, fuel-flexible technology for electricity production

Jason Nicholas, MSU

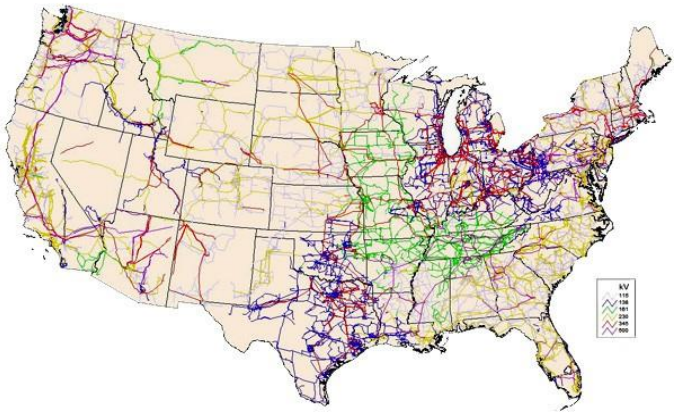


SOFCs allow natural gas to be transformed into electricity and vice-versa, allowing the possibility of having the natural gas grid stabilize the electrical transmission grid

The U.S. Natural Gas Grid



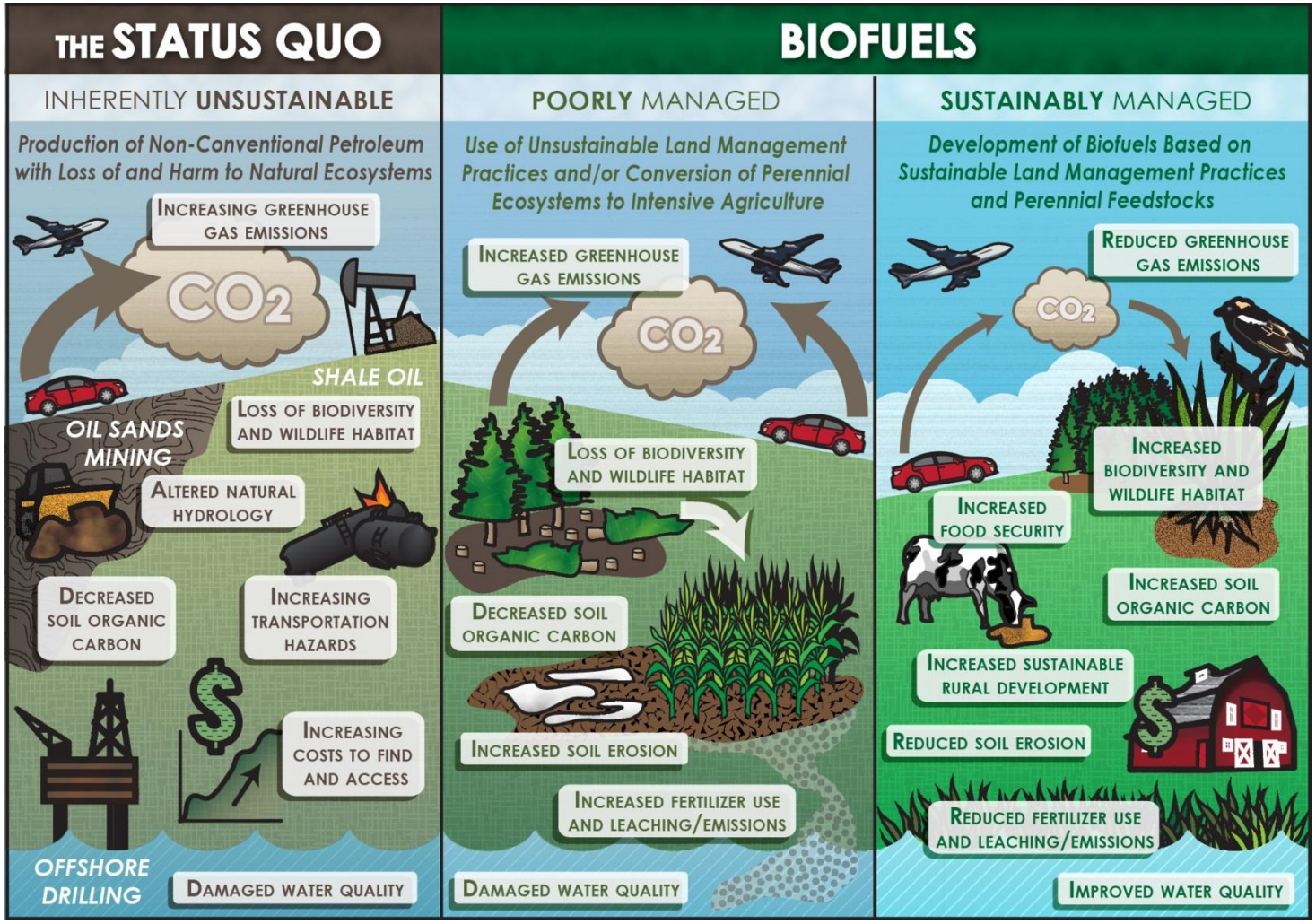
The U.S. Electrical Transmission Grid



Sustainably-Managed Biofuels

Responsible and sustainable commercialization of biomass-to-fuel

Bruce Dale, MSU



Risks

Climate

- Can we afford to do nothing, and risk not acting before it is too late?
- Can we do too much, and negatively impact economic development?

Energy

- What is the impact of fracking/horizontal drilling on the environment?
- Can new technologies like solar, wind, thermoelectric, biomass, etc. provide large scale, cost effective alternatives to traditional energy sources?

“The stone age didn’t end because we ran out of stones...”

--Sheik Ahmed Zaki Yamani,
Former Saudi Oil Minister