

**From University of Maryland Energy
Research Center (UMERC)
to Maryland Energy Innovation
Institute (MEI²)**

www.energy.umd.edu

Eric D. Wachsman, Director
Maryland Energy Innovation Institute



University of Maryland, College Park, USA

UMERC Faculty

Nearly 100 faculty in almost every College/School on campus:



A. JAMES CLARK
SCHOOL OF ENGINEERING



COLLEGE OF
COMPUTER, MATHEMATICAL,
& NATURAL SCIENCES



COLLEGE OF
AGRICULTURE &
NATURAL RESOURCES



SCHOOL OF
PUBLIC
POLICY



COLLEGE OF
BEHAVIORAL & SOCIAL SCIENCES
THE SOLUTION



ARCHITECTURE
PLANNING &
PRESERVATION

UMERC Students

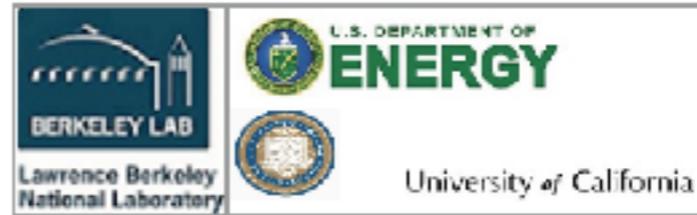


2011 Solar Decathlon - Champion

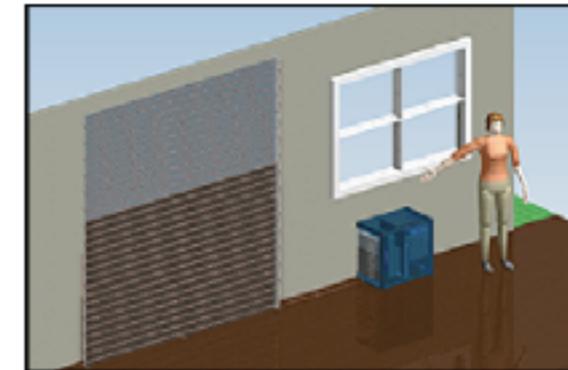


<http://www.pepco.com/community-commitment/watershed-sustainability-center/>

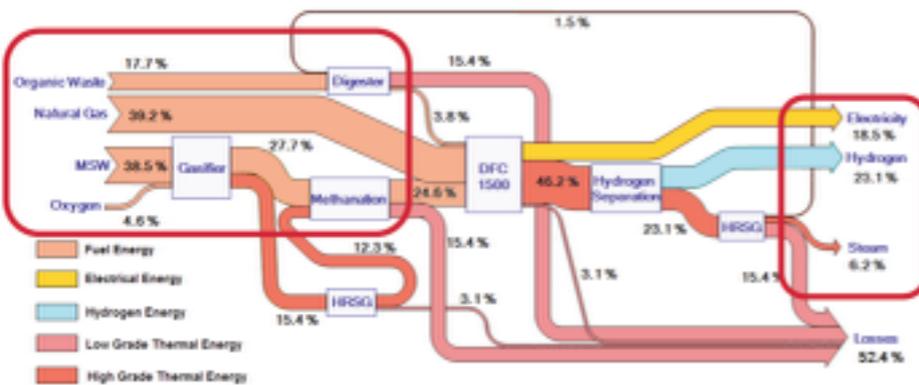
Max Tech and Beyond



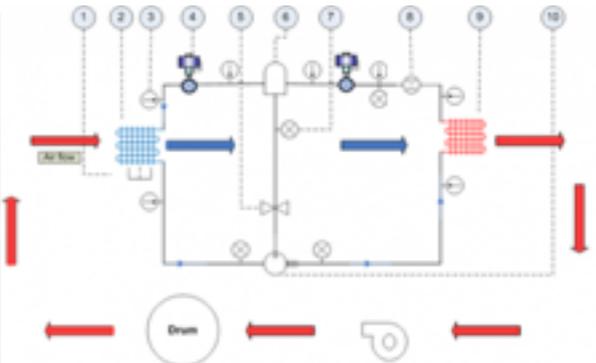
2011- 2012 Champion



A computer simulation of the complete air conditioning system mounted in a house.



2011- 2012 Champion



2012 - 2013 Champion



2013
1st Place:
Particulate
Emissions
Reduction



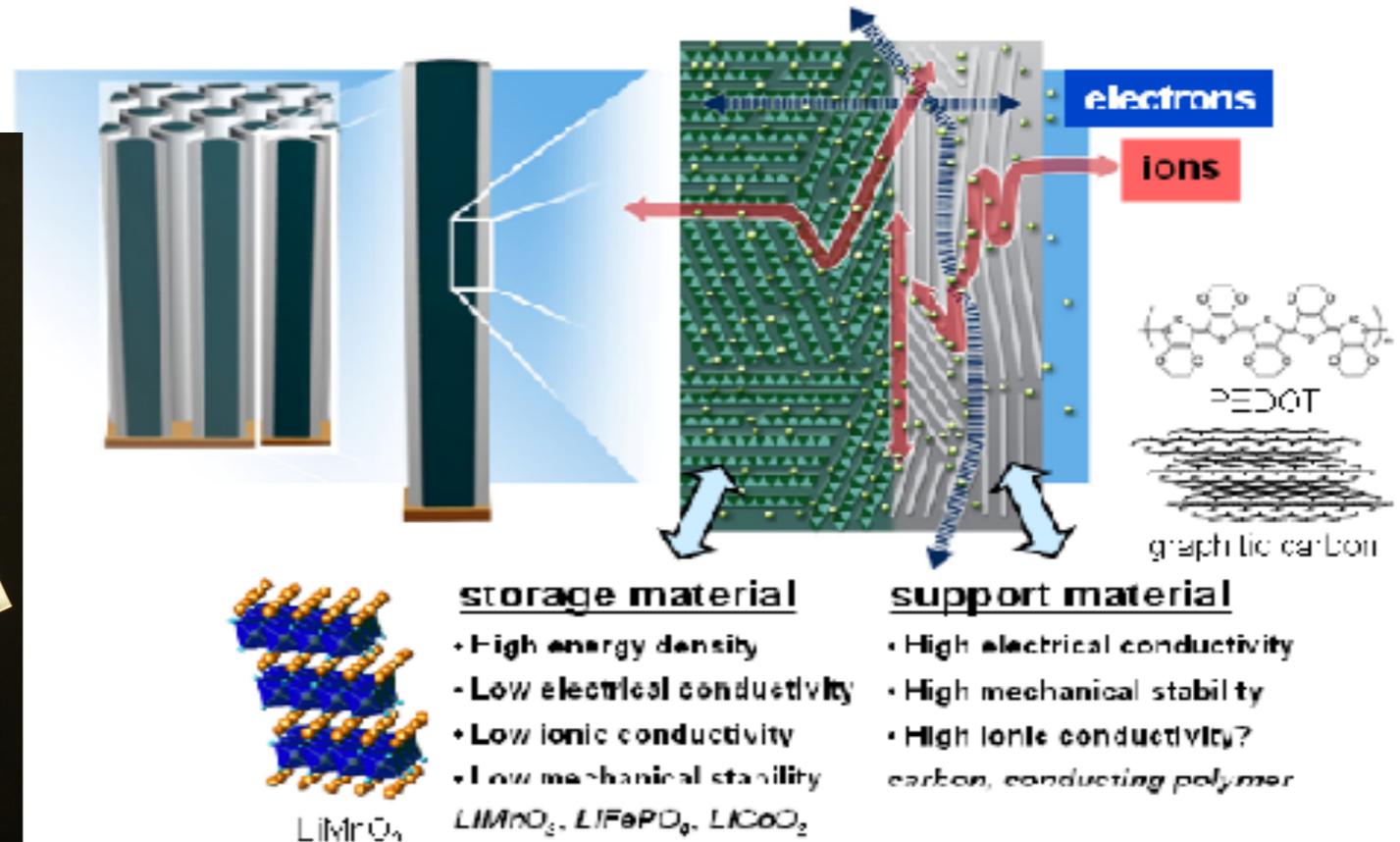
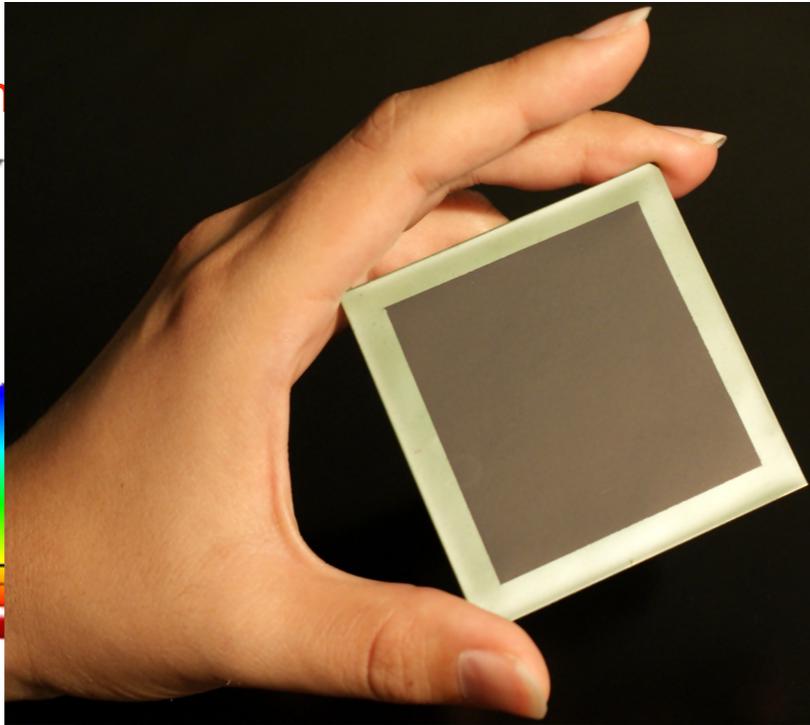
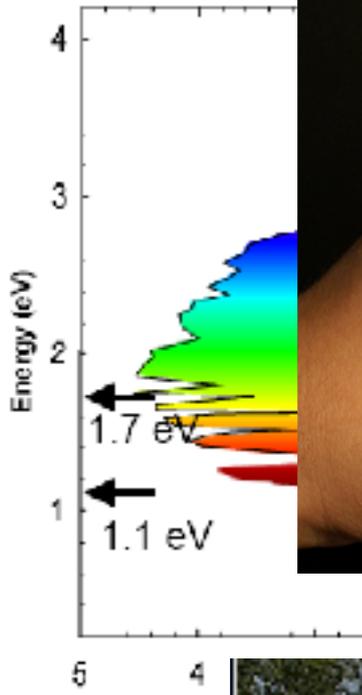
- 2013 Outstanding Student Chapter
- 2014 Student Chapter of Excellence
- 2015 Student Chapter of Excellence
- 2016 Student Chapter of Excellence
- 2017 Outstanding Student Chapter

UMERC Research

Spans UMD campus energy



- Solar
- Wind
- Matching of In
- E
- C
- C
- N
- E
- E
- Policy

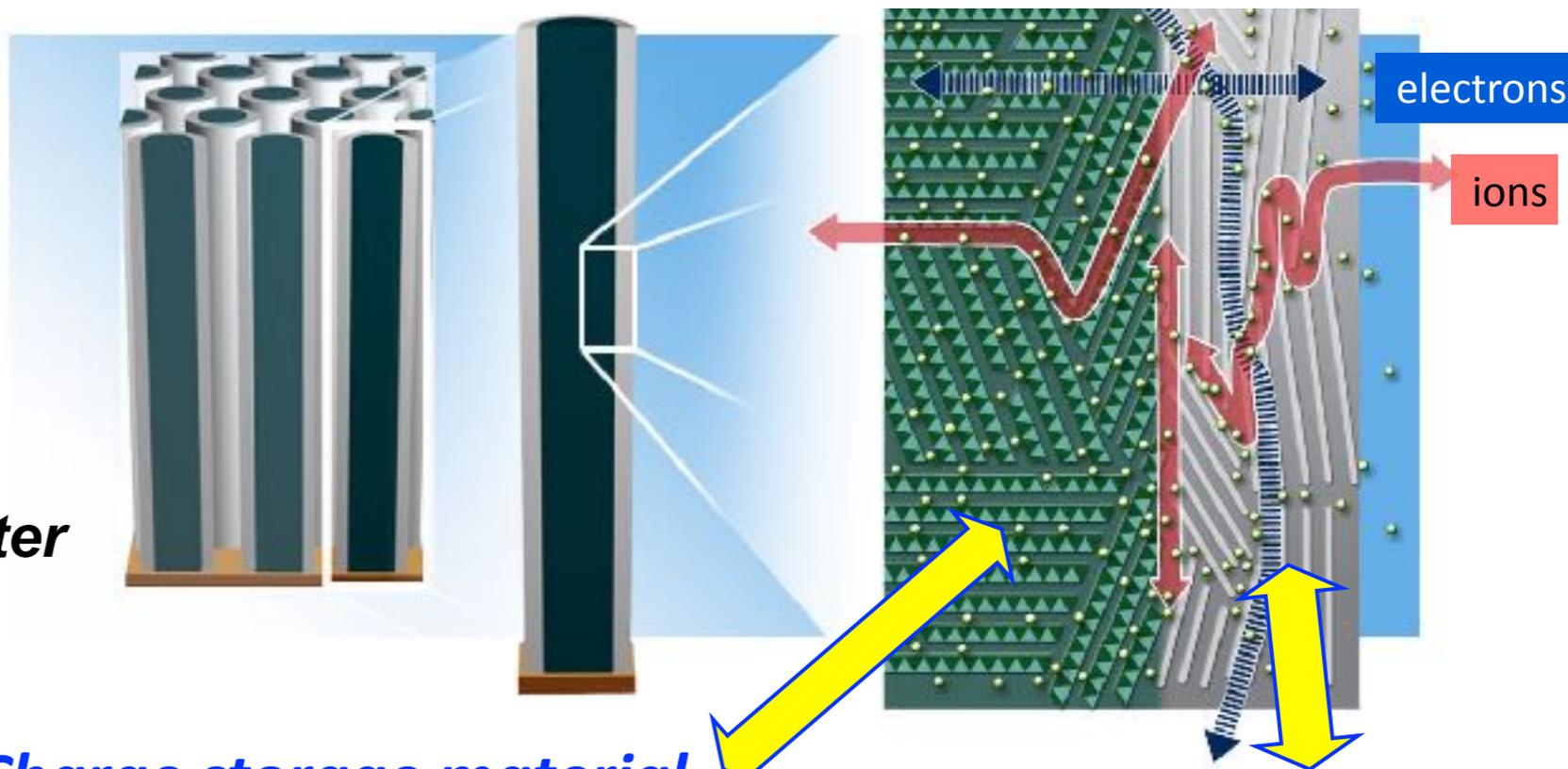


Joint Global Change Research Institute

Electrochemical Energy Storage at UMERC

Nanostructures for Electrical Energy Storage

Multifunctional nanostructures for next generation high performance electrical energy storage



DOE/BES

Energy Frontier Research Center

Lead: University of Maryland

Partners: UCI, UF, Yale, SNL, LANL

Initial \$14M over 5 years

Renewed \$11M over 4 years

Charge storage material

- High energy density
- Low electrical, ionic conductivity
- Low mechanical stability

Cathode: LiMnO_2 , LiFePO_4 , LiCoO_2

Anode: Si

Transport & support material

- High electrical conductivity
- High mechanical stability
- High ionic conductivity

Low-D carbon, conducting polymer

DEPARTMENT OF ENERGY

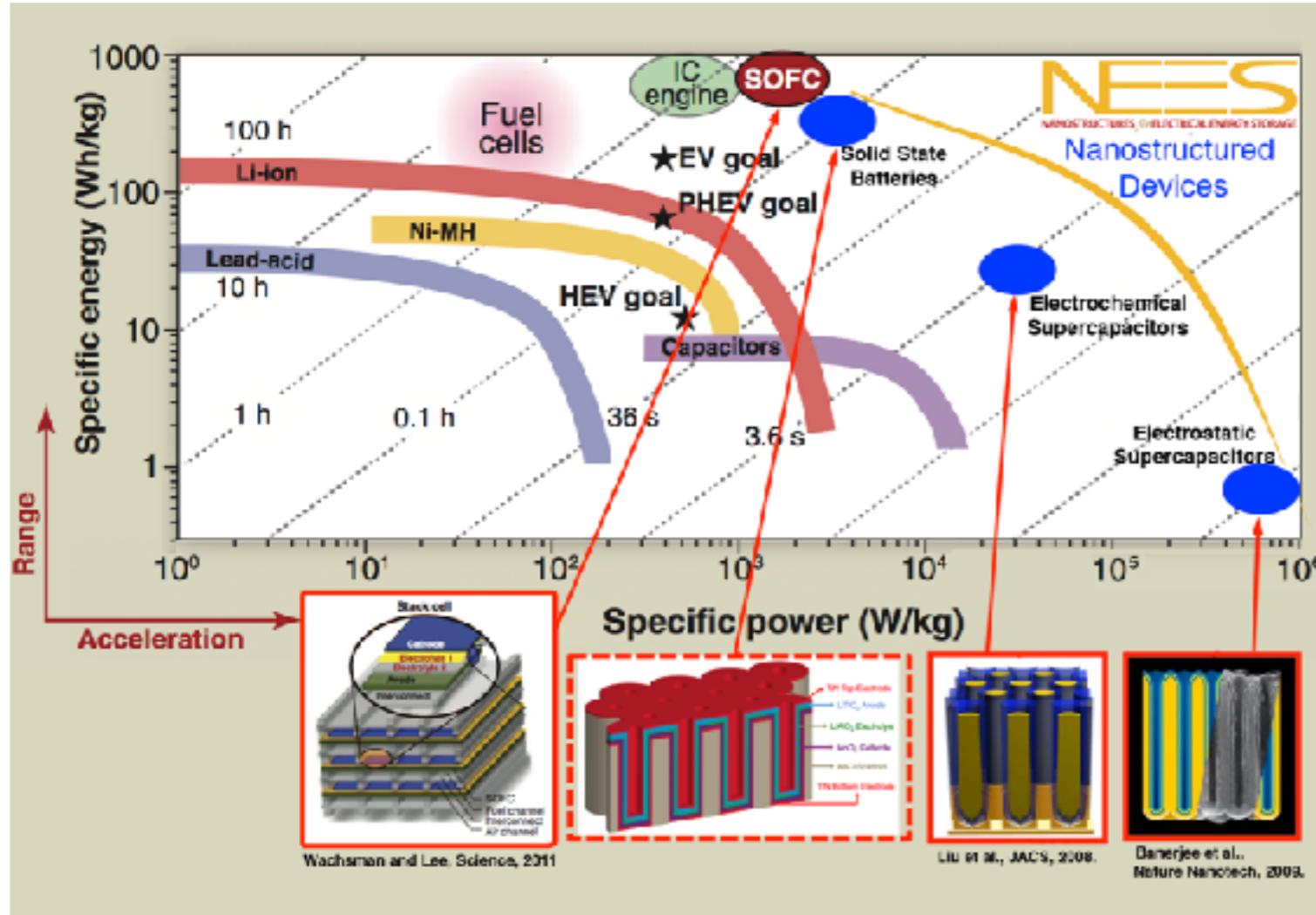
NEES

NANOSTRUCTURES for ELECTRICAL ENERGY STORAGE



Electrochemical Energy Storage at UMERC

Center for Research in Extreme Batteries



CREB
CENTER FOR RESEARCH IN EXTREME BATTERIES

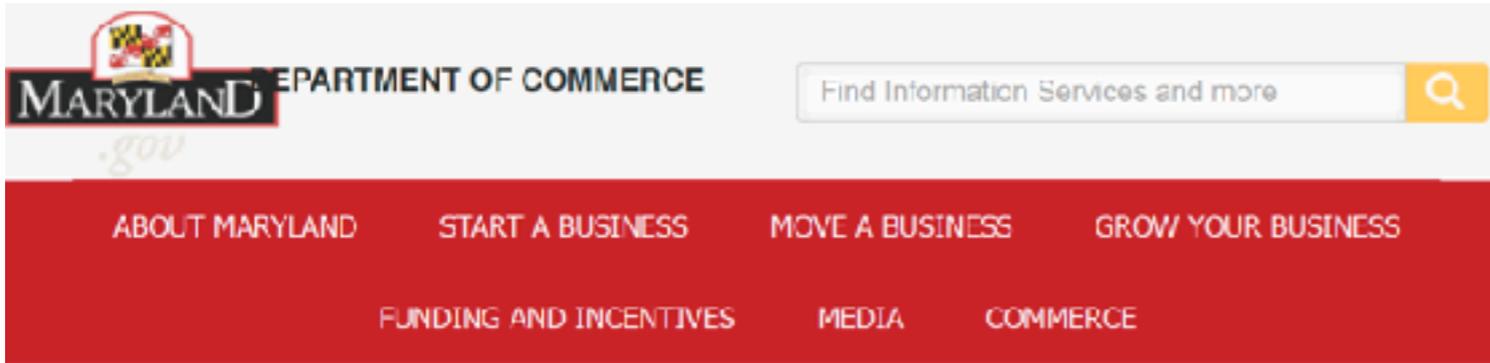
**Extreme Performance,
Environment & Safety
for *Defense, Aerospace
& Biomedical* industries**

- Established as collaborative research (CRADA) and shared facilities between ARL-UMD-NIST as founding partners
- Expanded to NYBEST, Stony Brook University, Argonne and Brookhaven National Labs
- In discussions with NASA, NIH, and others...



Electrochemical Energy Storage at UMERC

Center for Research in Extreme Batteries



Maryland Commerce > About Maryland

Key Industries

About Maryland

- + Why Maryland
- + Maryland Economy
- + Employer and County Facts
- + Taxes
- + Quality of Life
- + Workforce and Education
- + Transportation
- + Rankings and Statistics
- + International
- + Key Industries
 - > Aerospace and Defense
 - > BioHealth and Life Sciences
 - > Energy and Sustainability
 - > IT and Cybersecurity
 - > Manufacturing
 - > Military and Federal

Maryland's industry clusters are at the forefront of innovation and technology, fueling economic growth and opportunity. Why focus on certain industries? Because they complement Maryland's economic and geographic strengths of being close to the nation's capital and having a strong federal job presence, such as the Aerospace & Defense and Cybersecurity industries.

A strong university system, the world's leading hospital in Johns Hopkins and the nation's #1 public schools in the country fuel industries like Information & Technology and BioHealth & Life Sciences. The state's diverse topography makes Maryland ideal for Energy & Sustainability companies.

These industries not only provide a strong synergy for all business involved, but also high paying jobs, giving Maryland a strong tax base and helping citizens to enjoy a high quality of life.

Key industry sectors and focus areas:

- ▶ Aerospace & Defense
- ▶ Energy & Sustainability
- ▶ BioHealth & Life Sciences
- ▶ International
- ▶ IT & Cybersecurity
- ▶ Military & Federal
- ▶ Manufacturing

**Extreme Performance,
Environment & Safety
for *Defense, Aerospace
& Biomedical* industries**



Electrochemical Energy Storage at UMERC

Vehicle Technologies Program



“Overcoming Interfacial Impedance in Solid-State Batteries”

Eric Wachsman, Liangbing Hu & Yifei Mo

October 2014 to September 2017; \$1.2M

“High Conductivity and Flexible Hybrid Solid State Electrolyte”

Eric Wachsman, Liangbing Hu & Yifei Mo

October 2016 to September 2019; \$1.2M

“3D Printed, Low Tortuosity Garnet Framework For Beyond 500 Wh/kg Batteries”

Eric Wachsman & Liangbing Hu

July 2017; \$400K - Phase 1

“Advanced electrolytes to limit dendrite growth in lithium-metal cells”

Chunsheng Wang

July 2017; \$400K - Phase 1

“Innovative iron-based materials for high energy cathodes for high energy lithium ion battery technologies”

Chunsheng Wang

July 2017; \$400K - Phase 1

Academic Institution	EERE Battery Awards
University of Maryland	5
Texas A&M	4
Stanford	3
University of Texas, Austin	3
Pitt	3
MIT	2
Penn State	2
Stony Brook	2
UC San Diego	2

UMERC: Research - ARPA-E Awards



UMERC Research – ARPA-E Awards

Energy Storage



RANGE - Robust Affordable Next Generation Energy Storage Systems

Eric Wachsman, “Safe, Low-Cost, High-Energy-Density, Solid-State Li-Ion Batteries”

January 2014 to February 2020

\$4.7M

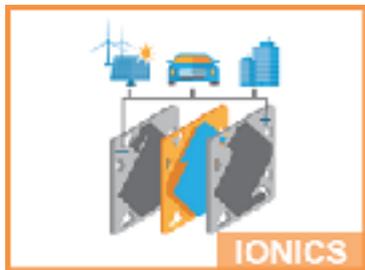


RANGE - Robust Affordable Next Generation Energy Storage Systems

Chunsheng Wang, “Multiple-Electron Aqueous Battery”

March 2014 to January 2020

\$4.1M



IONICS - Integration and Optimization of Novel Ion-Conducting Solids

Chunsheng Wang, “Self Forming Solid State Batteries”

January 2017 to July 2018

\$1M



OPEN IDEAS – Open Innovative Development in Energy-Related Applied Science

Liangbing Hu, “Highly Conductive, Robust, Corrosion-Resistant Nanocarbon Current Collectors for Aqueous Batteries”

April 2018 to April 2017

\$0.5M

UMERC Research – ARPA-E Awards

Advanced Materials



REACT - Rare Earth Alternatives in Critical Technologies

Ichiro Takeuchi, “MnBi Based Permanent Magnets”

January 2012 to September 2015

\$5.4M



OPEN IDEAS – Open Innovative Development in Energy-Related Applied Science

YuHuang Wang, “Melt Epitaxy of Carbon: A Silicon-inspired approach to next-generation electrical wires”

February 2015 to April 2018

\$0.5M

Efficient Transportation Networks



TRANSNET - Traveler Response Architecture using Novel Signaling for Network Efficiency in Transportation

Lei Zhang, “Integrated, Personalized, Real-Time Traveler Information and Incentive Technology for Optimizing Energy Efficiency in Multimodal Transportation Systems”

October 2015 to March 2018

\$3.8M

UMERC Research – ARPA-E Awards

Energy Efficiency



BEETIT - Building Energy Efficiency Through Innovative Thermodevices

Ichiro Takeuchi, “Thermoelastic Cooling”

October 2010 to January 2016

\$3.3M



OPEN IDEAS – Open Innovative Development in Energy-Related Applied Science

Michael Ohadi, “Dry Cooling for Thermoelectric Power Plants”

July 2014 to July 2015

\$0.5M



ARID – Advanced Research in Dry Cooling

Michael Ohadi, “Novel Polymer Composite Heat Exchanger for Dry Cooling of Power Plants”

\$2.0M



ARID - Advanced Research in Dry Cooling

Bao Yang “Novel Microemulsion Absorption Systems for Supplemental Power Plant Cooling”

September 2015 to August 2018

\$3.0M

UMERC Research – ARPA-E Awards

Energy Efficiency



DELTA - Delivering Efficient Local Thermal Amenities

YuHuang Wang, “Meta-Cooling Textile with Synergetic Infrared Radiation and Air Convection for Bidirectional Thermoregulation”

May 2015 to April 2018

\$3.0M



DELTA - Delivering Efficient Local Thermal Amenities

Reinhard Radermacher, “Robotic Personal Conditioning Device”

March 2015 to May 2018

\$2.6M

UMERC Research – ARPA-E Awards

Power Generation

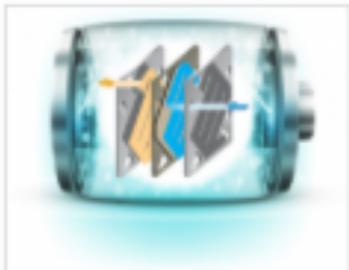


REBELS - Reliable Electricity Based on Electrochemical Systems

Eric Wachsman, “Low Temperature Solid Oxide Fuel Cells for Transformational Energy Conversion”

October 2014 to September 2017

\$5.3M

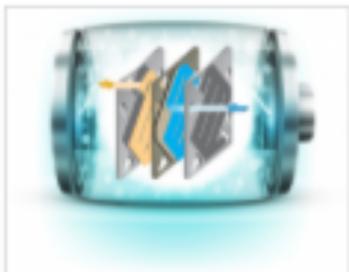


REBELS – Reliable Electricity Based on Electrochemical Systems

Eric Wachsman, “Bi-functional Ceramic Fuel Cell Energy System”

October 2014 to September 2017

\$3.2M



REBELS – Reliable Electricity Based on Electrochemical Systems

Ichiro Takeuchi, “Metal Supported Proton Conducting Solid Oxide Fuel Cell Stack”

October 2014 to September 2017

\$3.5M

**UMERC Faculty have lead or participated in \$50M in ARPA-E awards since 2014
Currently participate in more ARPA-E awards than any other university in the US**

Maryland Energy Innovation Institute



Gov. Hogan Signs into Law \$7.5M Maryland Energy Innovation Institute at UMD

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Contacts: [Pamela R.M. Phetphongsy](#), 301.405.6266

ANNAPOLIS, Md. — Maryland Governor Larry Hogan held a signing ceremony today that included a bill authorizing \$7.5 million in funding to create the Maryland Energy Innovation Institute (MEI2) at the University of Maryland (UMD), an initiative that will catalyze clean energy research programs at academic institutions in the state and attract and develop private investment in clean energy innovation and commercialization. The Institute will bolster economic jobs in the clean energy industry sector in Maryland, and also promote the deployment of clean energy technology throughout the state.

"We are proud to sign legislation to create the Maryland Energy Innovation Institute, which will develop and attract private investment and commercialize clean energy innovation in our state," said Governor Hogan. "We thank the legislature for working with our administration on these bipartisan efforts to grow clean energy investment and jobs, and ensure that Maryland continues to lead the charge when it comes to protecting our environment."

MEI2 is a collaboration between the [Maryland Clean Energy Center \(MCEC\)](#) and the [University of Maryland Energy Research Center \(UMERC\)](#) within UMD's [A. James Clark School of Engineering](#). UMD is an established leader in energy research, with more than 100 faculty and students developing innovations that harness the power of clean energy such as solar photovoltaic technology, solar heating, geothermal, wind, biofuels, ethanol, and other sources.

"The University of Maryland continues to lead the way in clean energy research, moving discoveries and technology into the commercial space," said University of Maryland Provost Mary Ann Rankin. "This is the perfect means to bring together expertise in science, government and industry to bring value to the State of Maryland."

"The University of Maryland has made numerous breakthroughs in battery, fuel cell, solar, wind, and energy efficiency technologies," said Eric Wachsman, University of Maryland professor and director of MEI2. "The Maryland Energy Innovation Institute will provide the critical infrastructure to enable these breakthroughs to become commercially viable companies benefiting both the economy and the environment of the State of Maryland."

UMERC, which has been led by Wachsman for eight years, is a multidisciplinary university initiative dedicated to advancing the frontiers of energy science and technology, with a focus on energy storage, efficiency, and clean energy generation. The center has attracted approximately \$70 million in funding and has spun off six companies, to-date.

"This policy and funding commitment allows MCEC to move forward in our efforts to advance the Maryland Clean Energy economy," said Josh Green, Vice President of Government and Industry Affairs, A. O. Smith Corporation and Chairman of the MCEC Board of Directors. "The board looks forward to continuing our partnership with the University of Maryland."

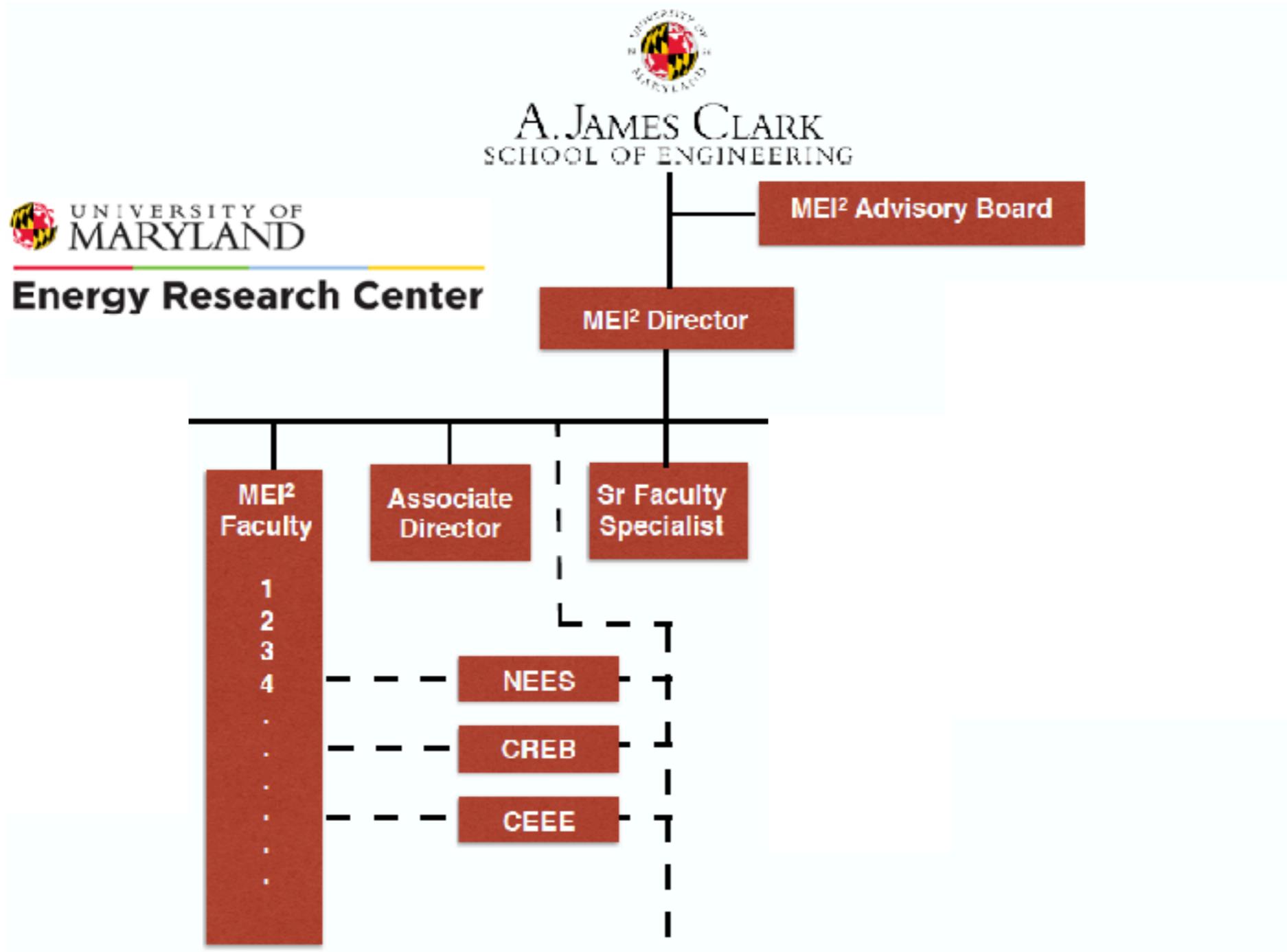
MCEC was created by the General Assembly of Maryland to support innovation and technology deployment to achieve renewable energy generation, energy conservation, and greenhouse gas emission reduction goals. MCEC uses statute enabled financing authority to leverage private capital investments and provide financing to assist residential, commercial, municipal, and not-for-profit consumers.

MEI2 is one of several programs in Governor Hogan's 2017 Environmental Package, which includes market-based solutions to protect and preserve Maryland's environment and natural resources.

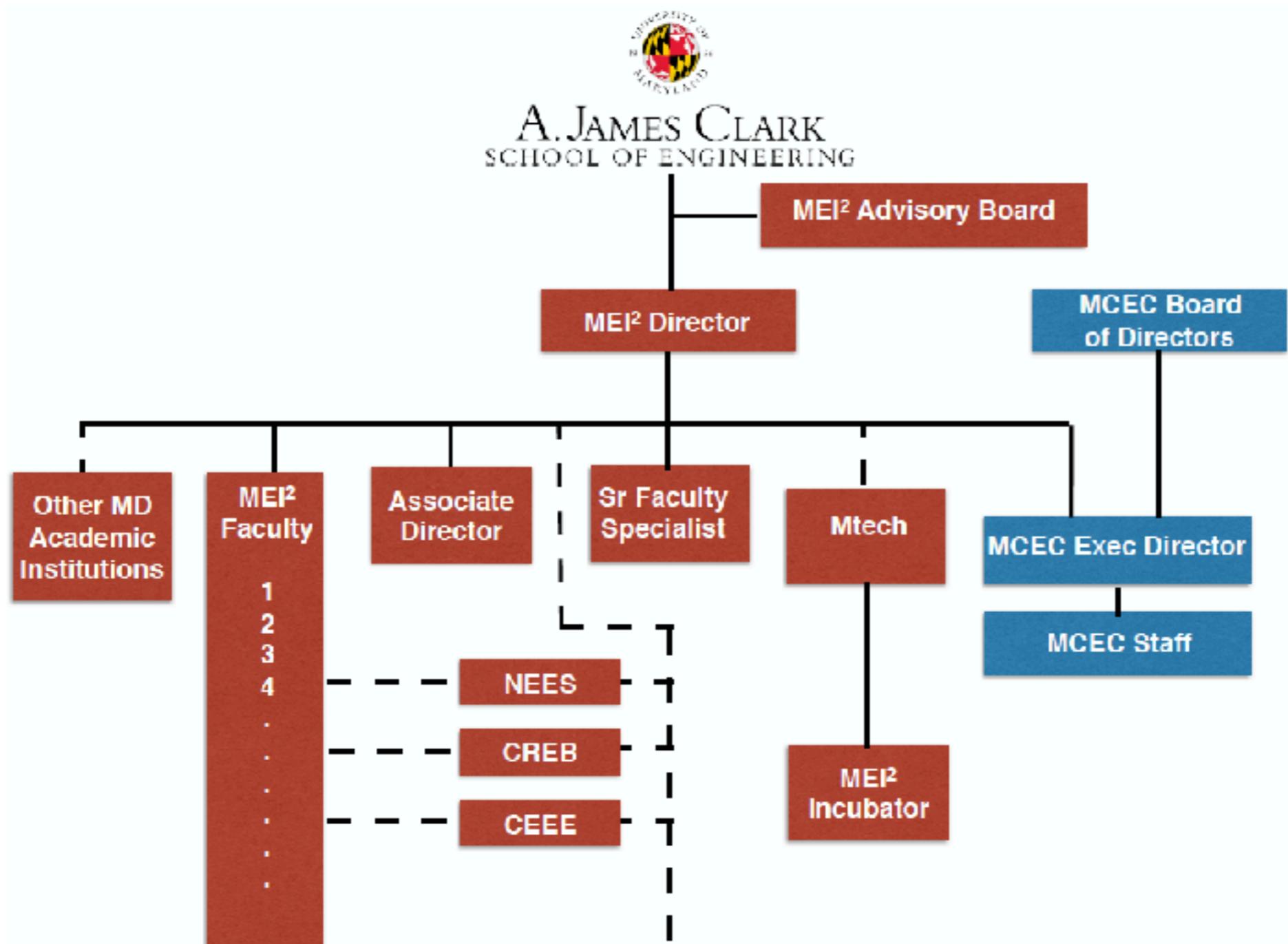
(10-829) MEI² Purpose:

- Collaborate with Academic Institutions in the State to participate in Clean Energy Programs
- Develop and Attract Private Investment in Clean Energy Innovation and Commercialization in the State

Maryland Energy Innovation Institute



Maryland Energy Innovation Institute



MEI² will integrate energy research & innovation with incubation and financing under a single organization at UMD to advance the State of Maryland energy economy

MEI² Advisory Board

Chair:

Victor Der - Retired, Assistant Secretary of Fossil Energy, US DOE

Vice Chair:

Ellen Williams - Distinguished University Professor UMD
former Director, US DOE ARPA-E
former Chief Scientist, BP

Joseph Dominguez - Sr. Vice President, Exelon Corp.

Abigail Hopper - CEO, Solar Energy Industry Association
former Director, US Bureau of Ocean Energy Management
former Director, Maryland Energy Administration

Philip Perconti - Director, Army Research Laboratory

Jigar Shah - CEO and Founder, Generate Capital
Founder, Sun Edison

Mary Beth Tung - Director, Maryland Energy Administration

Joshua Greene - Chair of the Board, Maryland Clean Energy Center
VP Government & Industry Affairs, A.O. Smith

MEI² “Powers” (10-834)

- Coordinate and promote energy research and education at UMD, including its relevant energy centers as well as at other academic institutions in the State;
- Provide energy policy innovation advice to State and federal units;
- Collaborate with other academic institutions, governmental units, foundations, and industrial companies for clean energy research and innovation;
- Pursue grants other funds, and in-kind contributions for clean energy research and innovation;
- Provide seed grant funding to academic institution-based entrepreneurs or entities, in order to promote the commercialization of clean energy technologies developed wholly or partly by an academic institution;
- Work with the Maryland Technology Enterprise Institute to jointly manage, operate, and maintain facilities for a clean energy incubator at UMD;
- Work with the Maryland Technology Enterprise Institute to expand Maryland Industrial Partnership awards to promote the commercialization of clean energy technologies developed wholly or partly by an academic institution;
- Work with Maryland Technology Enterprise Institute and UMD Office of Technology Commercialization to:
 - Identify energy technologies at academic institutions that may be viable for commercialization; and
 - Provide grant funding and investment financing to cover patent facilities, and other costs not allowed under federal or state research grants to an academic institution-based entrepreneur or entity, in order to promote the commercialization of clean energy technologies developed wholly or partly by an academic institution;
- Coordinate incubation and potential financing of academic institution-based entrepreneurs or entities with resources provided by the Maryland Clean Energy Center; and
- Work closely with state units, industrial partner, nongovernmental organizations, and federal agencies and laboratories to ensure effective implementation and execution of the State’s energy mission and vision, in collaboration with the administration.

MEI² Planned Programs

- ***Entrepreneurship Seed Grant*** - This will be an open annual funding solicitation to overcome the “Valley of Death” between previously obtained academic transformative laboratory research results and prototype demonstrations of sufficient scale to obtain investor interest.
- ***MEI² Industry Research Program*** - We will develop an industry research consortia program focused on pre-competitive energy technologies of interest to those companies. As research is pre-competitive IP will remain with the Maryland academic institutions. MEI² will thus provide matching funds (1:1 to 1:2) as a multiplier incentive for industry sponsorship of this research on an open solicitation basis to Maryland academic institutions. We are currently preparing proposal for BGE and have received interest from LG Chem through their Technology Center of America program.
- ***MEI² Matching Fund Program*** - To expand Maryland energy research and increase academic faculty participation, MEI² will provide State-matching funds for MEI² affiliated faculty pursuing Federal energy research grants as opportunities arise. These are typically in the ~10-20% of federal funds received level. In particular, we will look to attract major MEI² aligned federally funded centers such as DOE Advanced Manufacturing Office (AMO) or NIST Manufacturing Hubs.
- To avoid any conflicts of interest in making awards under the above programs MEI² will stand up the ***MEI² Investment Committee***.

Future Energy Generation



The IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation

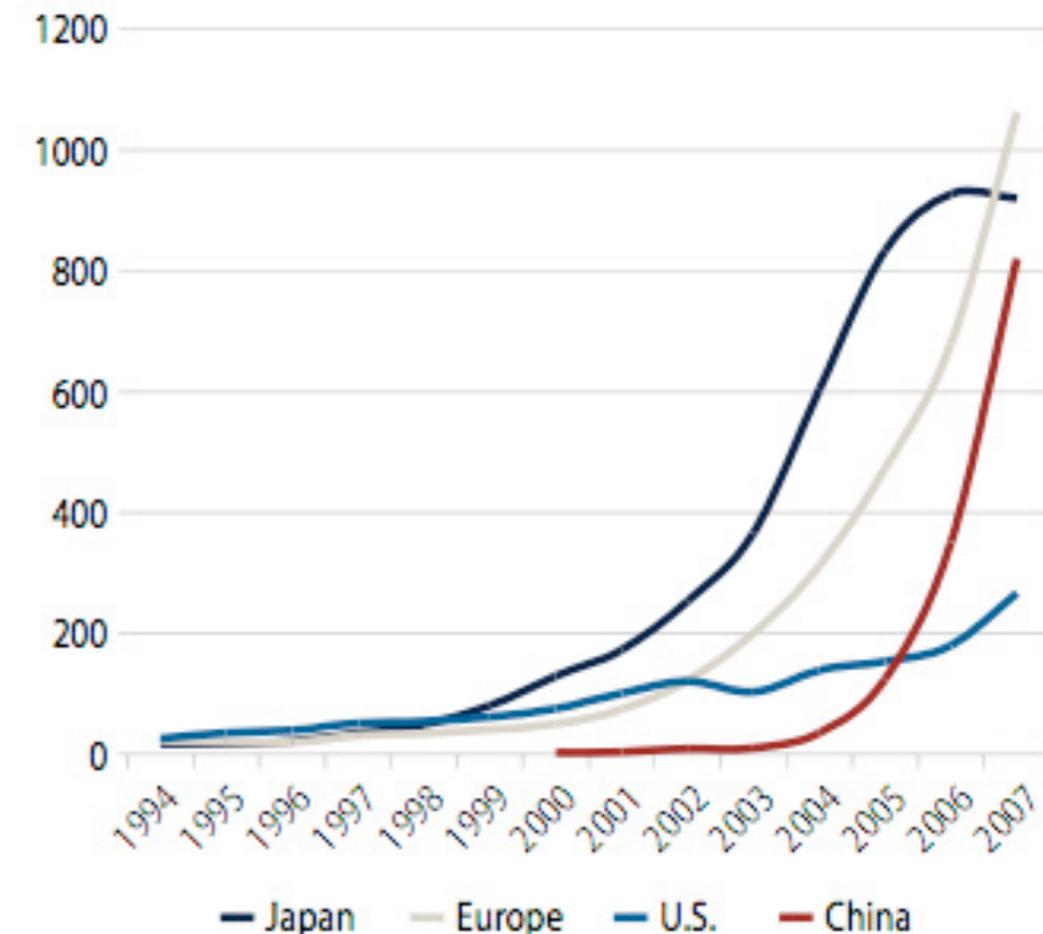


IPCC report, by 2050 ~80% of world's energy supply could be from renewables

- Due to demand growth in underdeveloped countries

Annual solar cell production

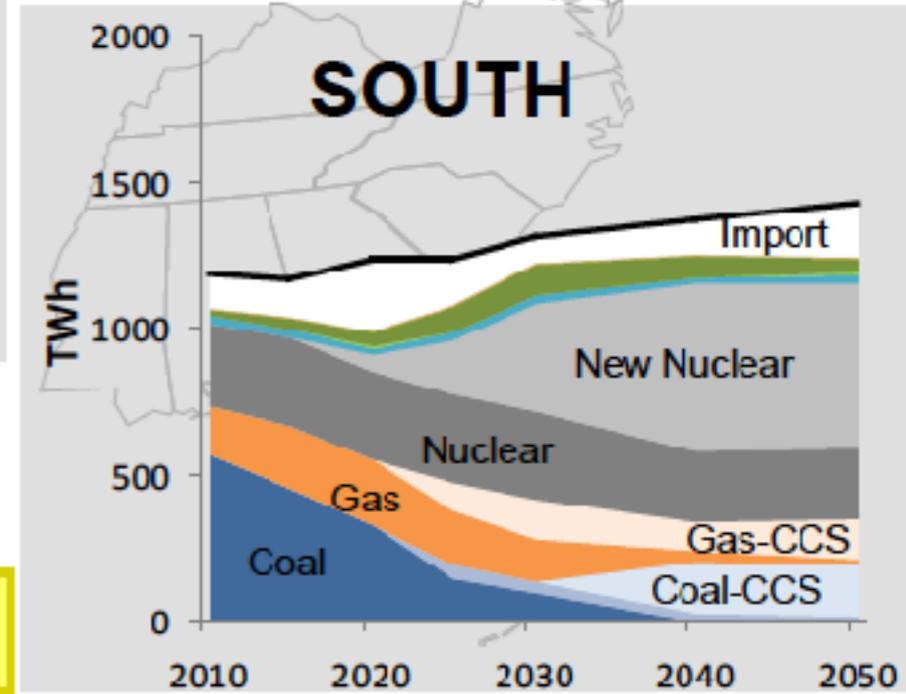
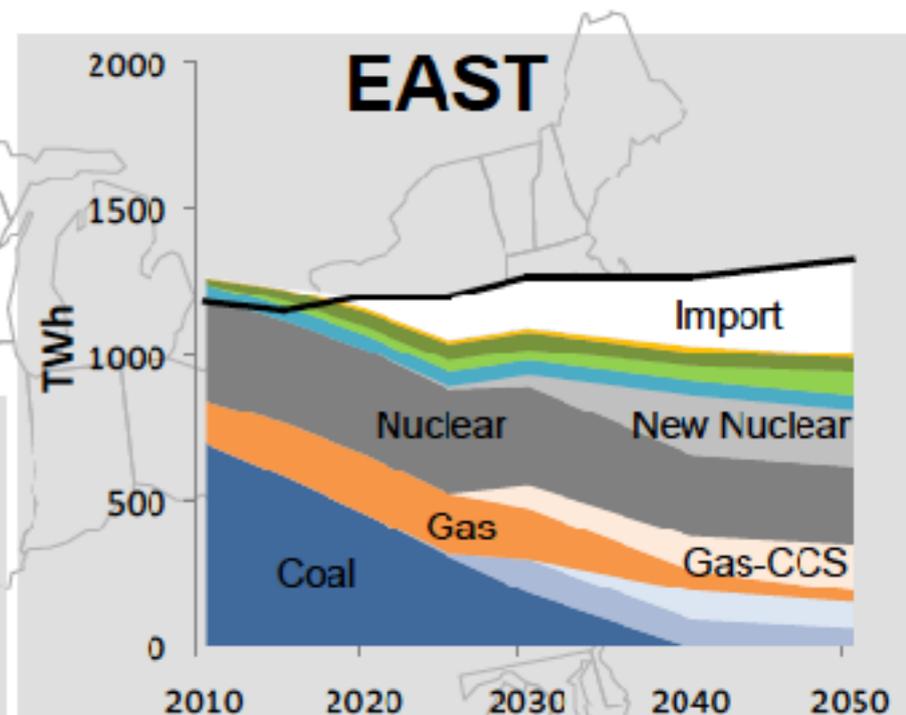
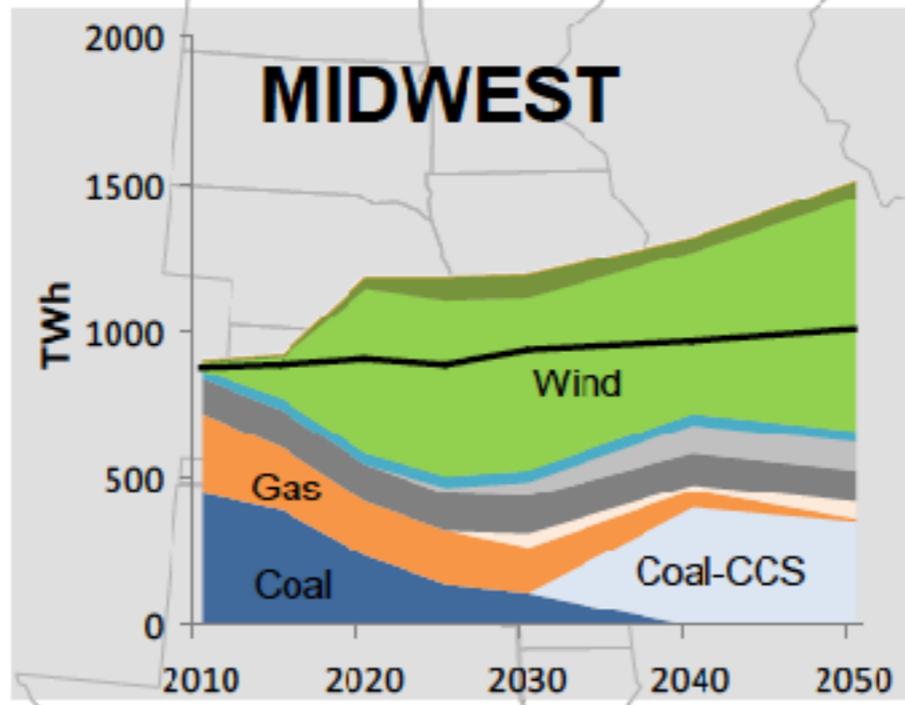
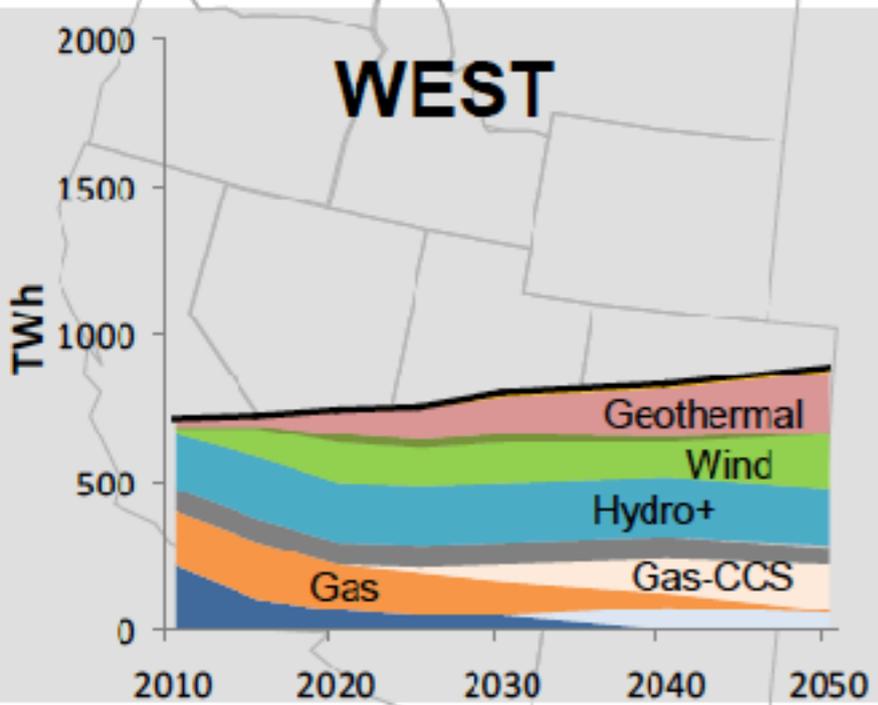
Megawatts



Resultant job growth depends on policies to encourage investment

- EU & Japan adopted incentives
- China recently mandated renewable energy
- US policy vacillates depending on party in control

The Future of Energy is Regional

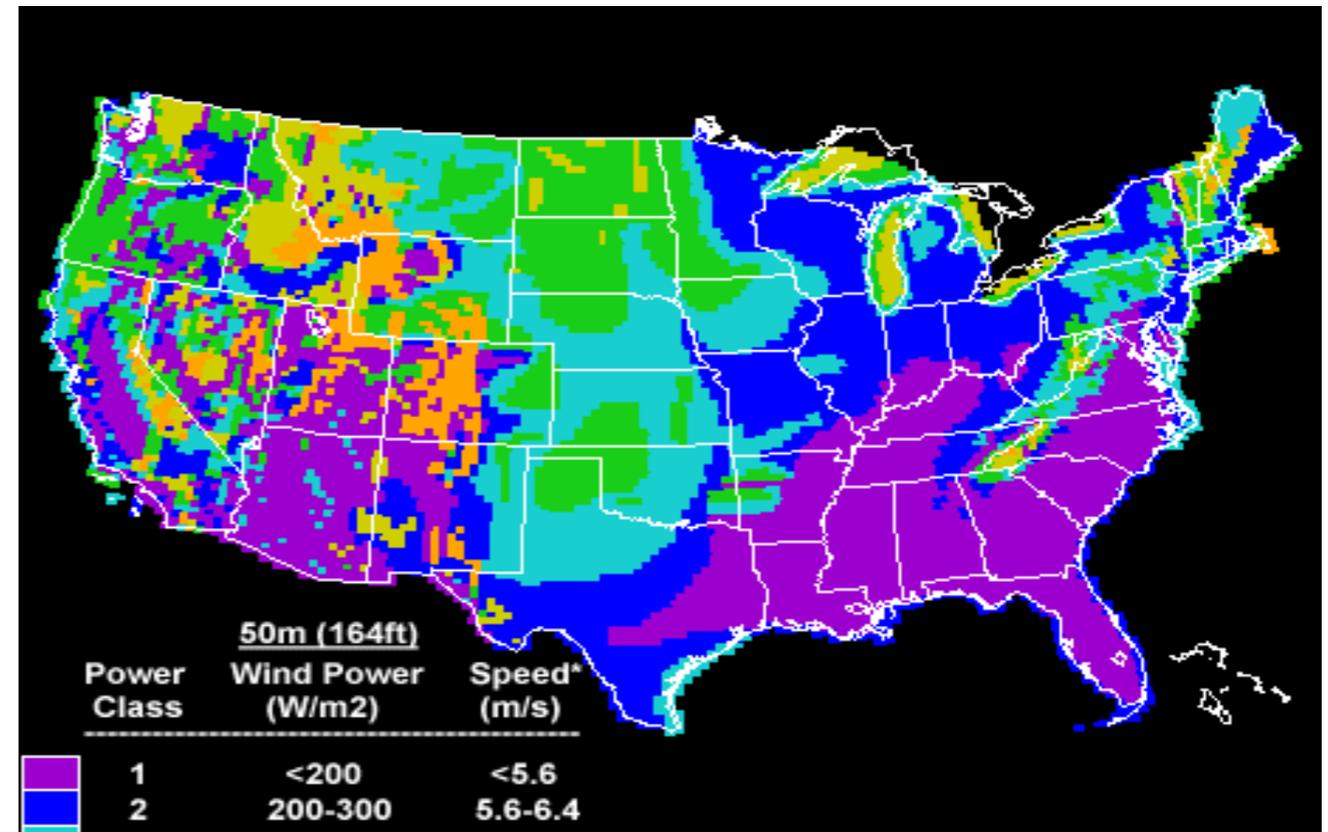
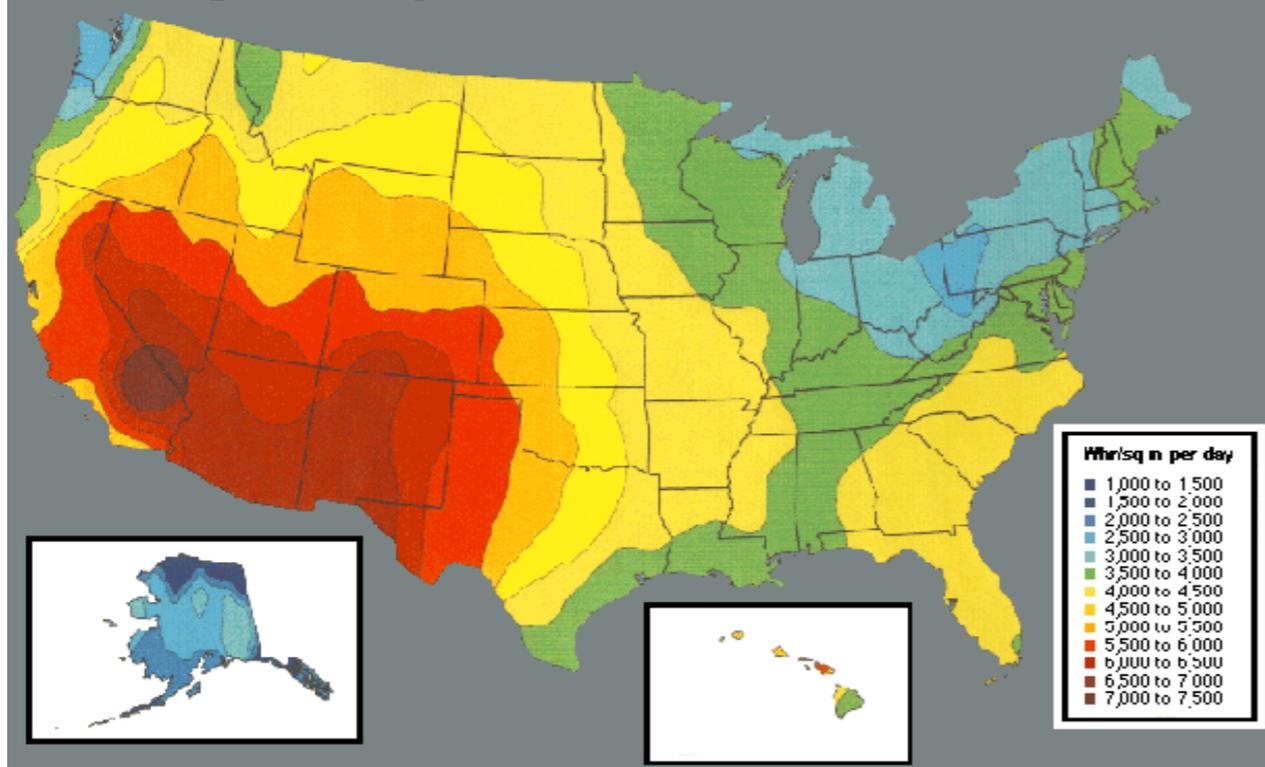


Responses to CO₂ policy differ greatly by region

Regional and Distributed

- Independent of policy solar and wind will grow in most economical regions, but rate of growth is policy dependent

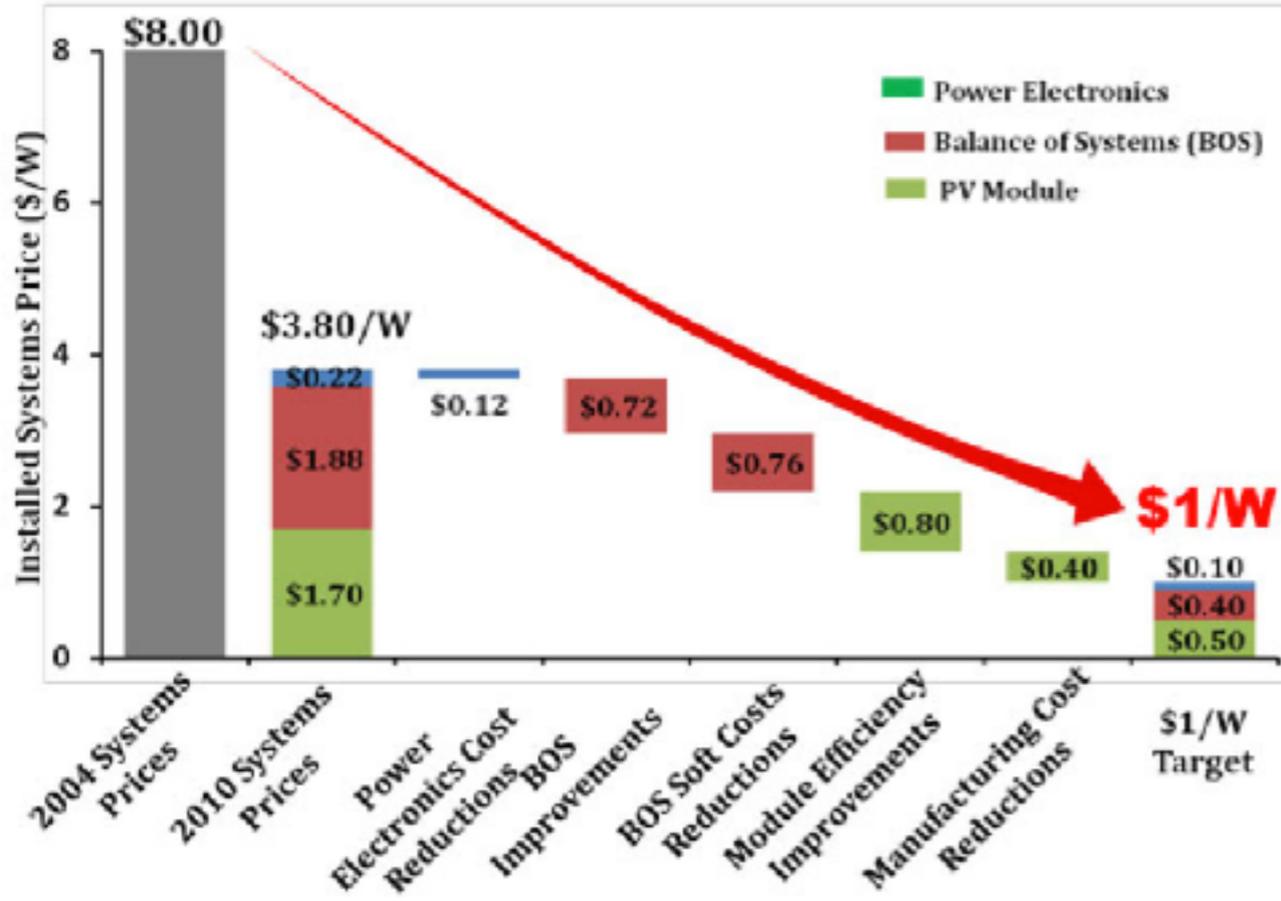
Average daily solar radiation, 1961-1990



- Natural gas will continue to dominate, but I believe will shift more to smaller scale distributed CHP thus providing 2-3X improvement in efficiency and GHG reduction
- Small modular nuclear reactors would be a game changer, but strongly dependent on policy

Solar Energy Cost

DOE SunShot Program



Bloomberg

Obama's Solar Goal Has Been Met, Trump's Energy Department Brags

The Trump administration announced Tuesday that former President Barack Obama's goal of slashing the cost of solar power has been achieved early, taking credit for milestone even though the new administration is skeptical of renewable power.

"With the impressive decline in solar prices, it is time to address additional emerging challenges," said Daniel Simmons, the Energy Department's acting assistant secretary for energy efficiency and renewable energy.

"As we look to the future, DOE will focus new solar R&D on the secretary's priorities, which include strengthening the reliability and resilience of the electric grid while integrating solar energy," Simmons said.

THE HILL

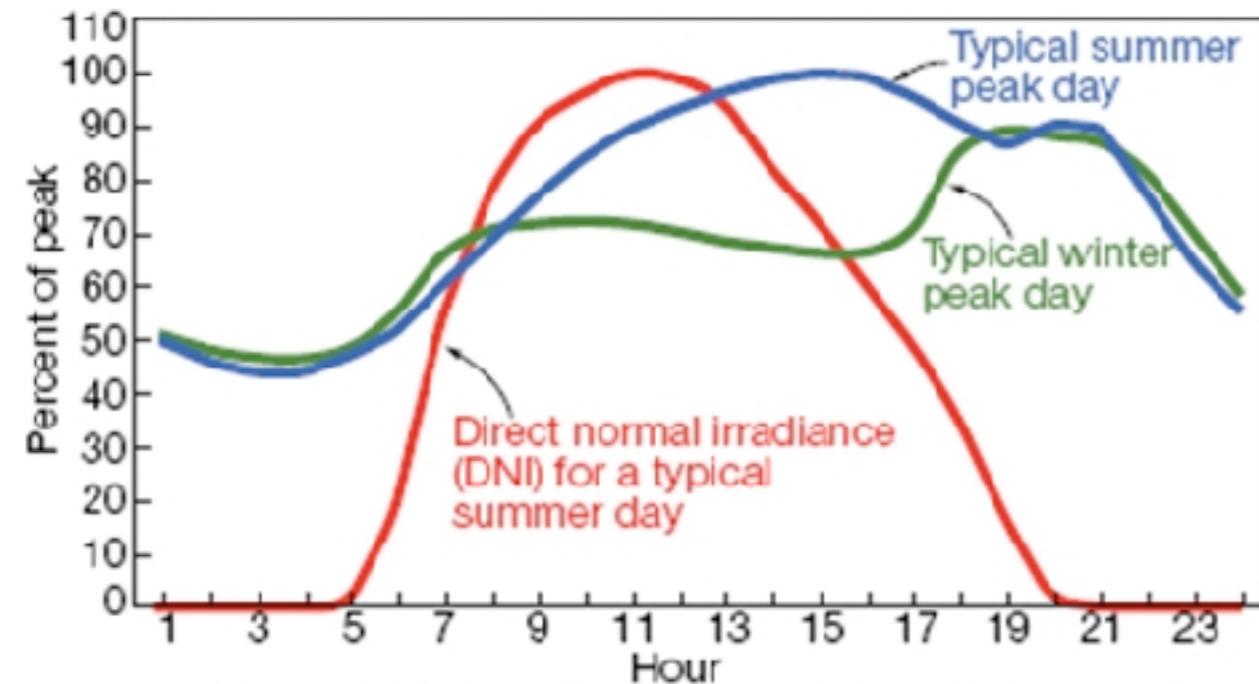
The price of electricity generated by utility-scale solar photovoltaic systems fell to \$0.06 per kilowatt hour this year, achieving a 2020 goal of the SunShot program three years early. Prices for residential and commercial systems are 86 percent and 89 percent toward achieving their price goals, the Energy Department reported.

The Energy Department said it will spend \$82 million to research energy storage and grid reliability technologies for solar power.



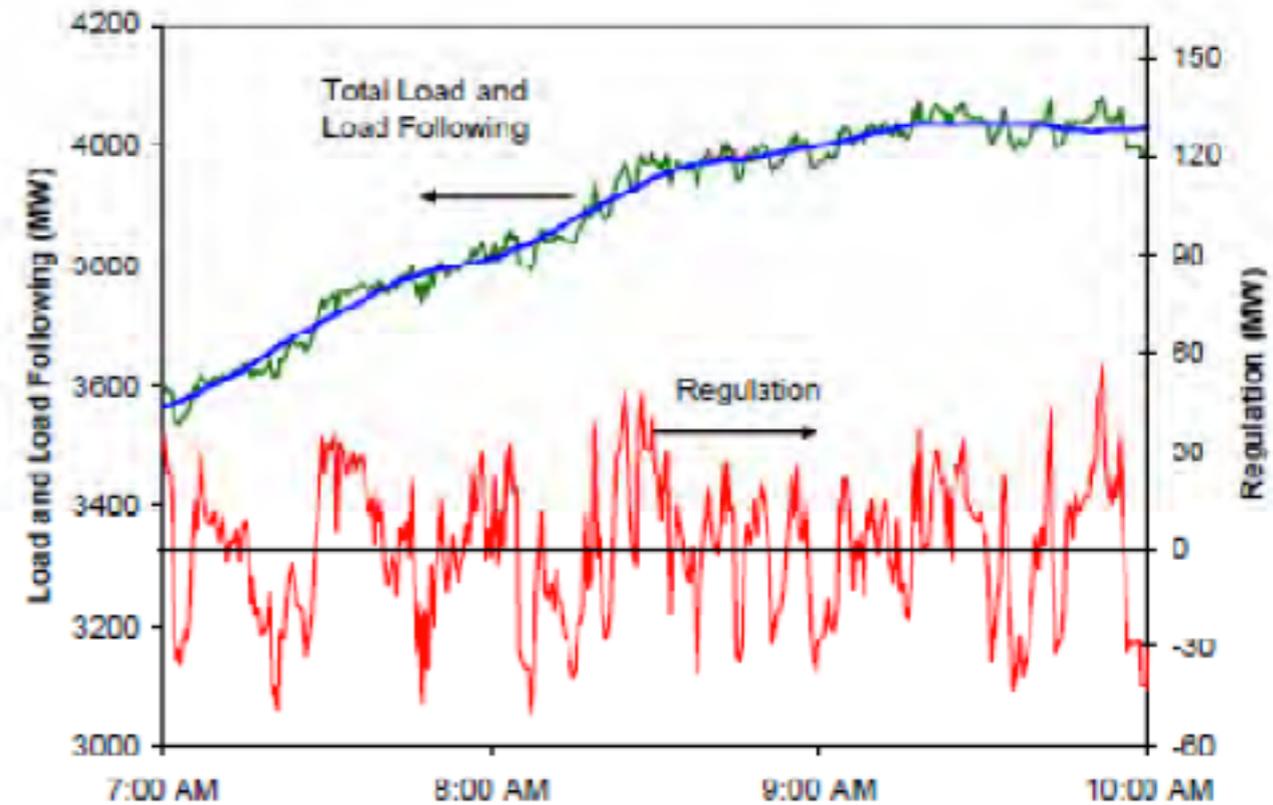
Requires Storage

Time of day generation vs. demand



24. Solar power produced at maximum DNI is stored in a battery and released later in the day when demand is highest

Generation transients vs. demand transients



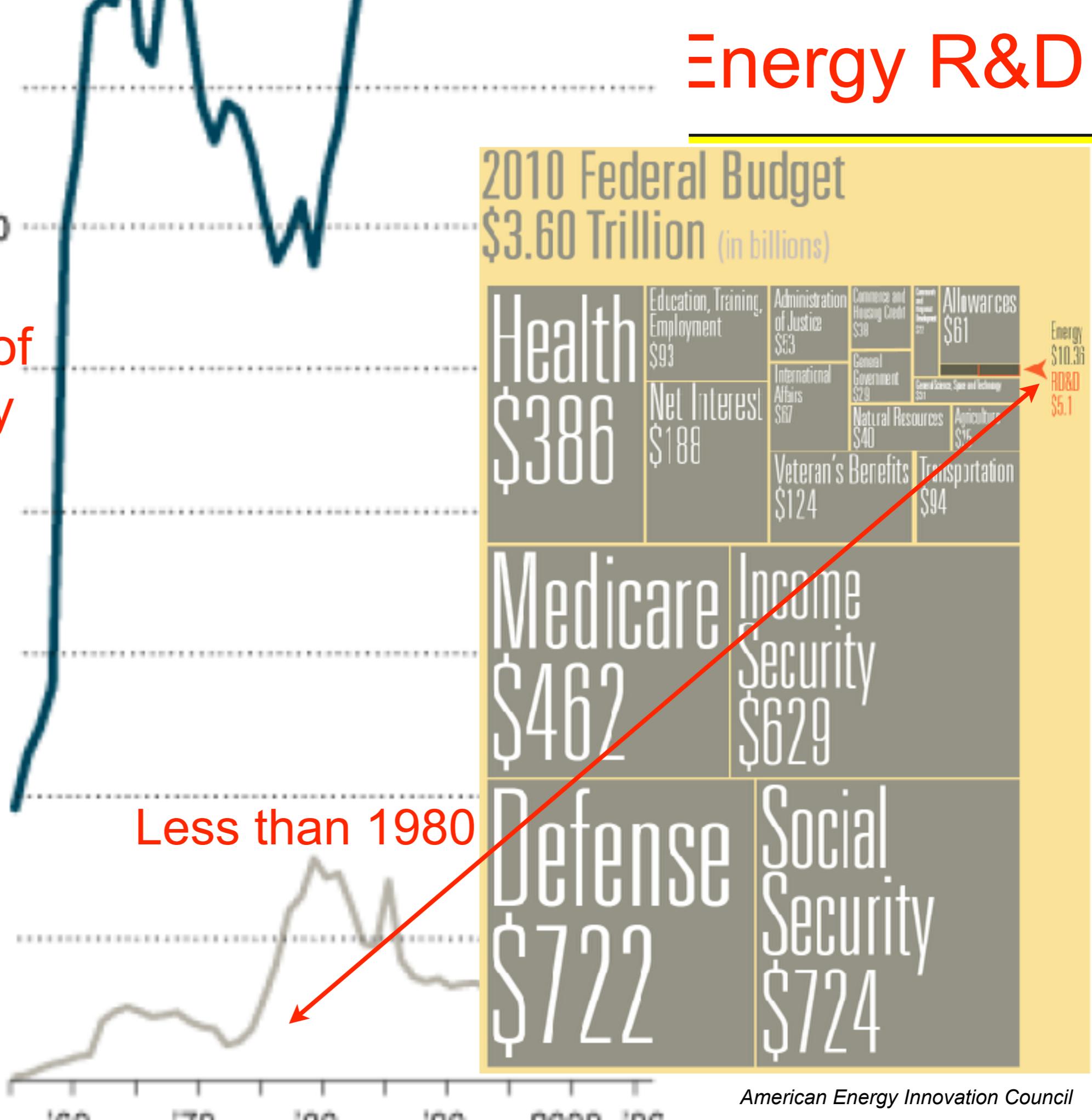
Storage not only enables greater solar and wind deployment, but also:

- Enables vehicle electrification reducing petroleum use and GHG emissions
- Displaces peaking power generation reducing natural gas and coal use and GHG emissions

U.S. Govt

Energy R&D

Biggest energy
budget in
the world
Priority is lack of
consistent policy
and sufficient
R&D funding



Prognosis for Future

America First **A Budget Blueprint to Make** **America Great Again**



Office of Management and Budget

- Eliminates Advanced Research Program Agency (ARPA-E)
- Eliminates Advanced Technology Vehicle Manufacturing Program
- Eliminates Innovative Technology Loan Guarantee Program
- Eliminates Weatherization Assistance Program
- Reduces Office of Science \$900M
- Reduces Energy Efficiency and Renewable Energy, Nuclear, Fossil Energy, Office of Electricity \$2B

