Electric Energy Systems of the Future - Visions, Challenges, and Opportunities

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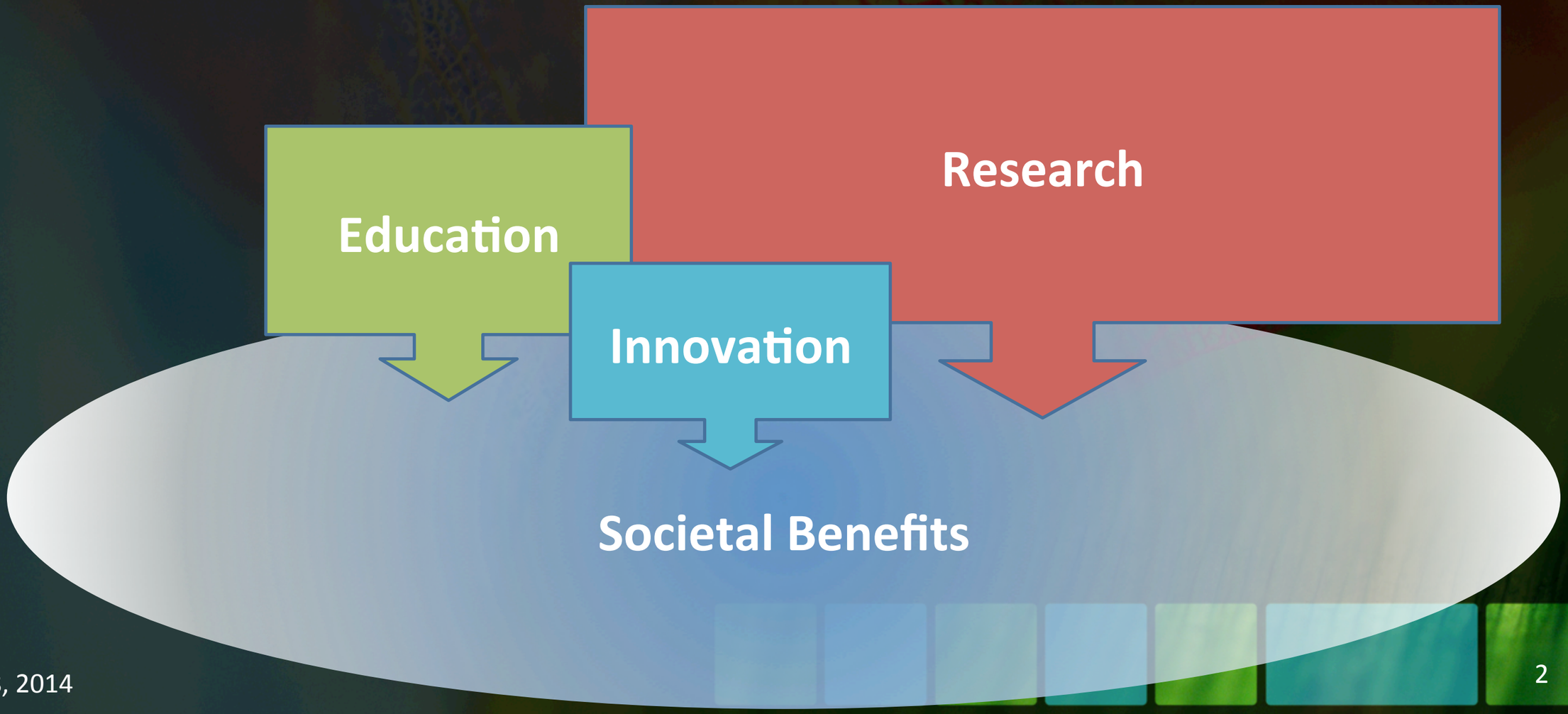
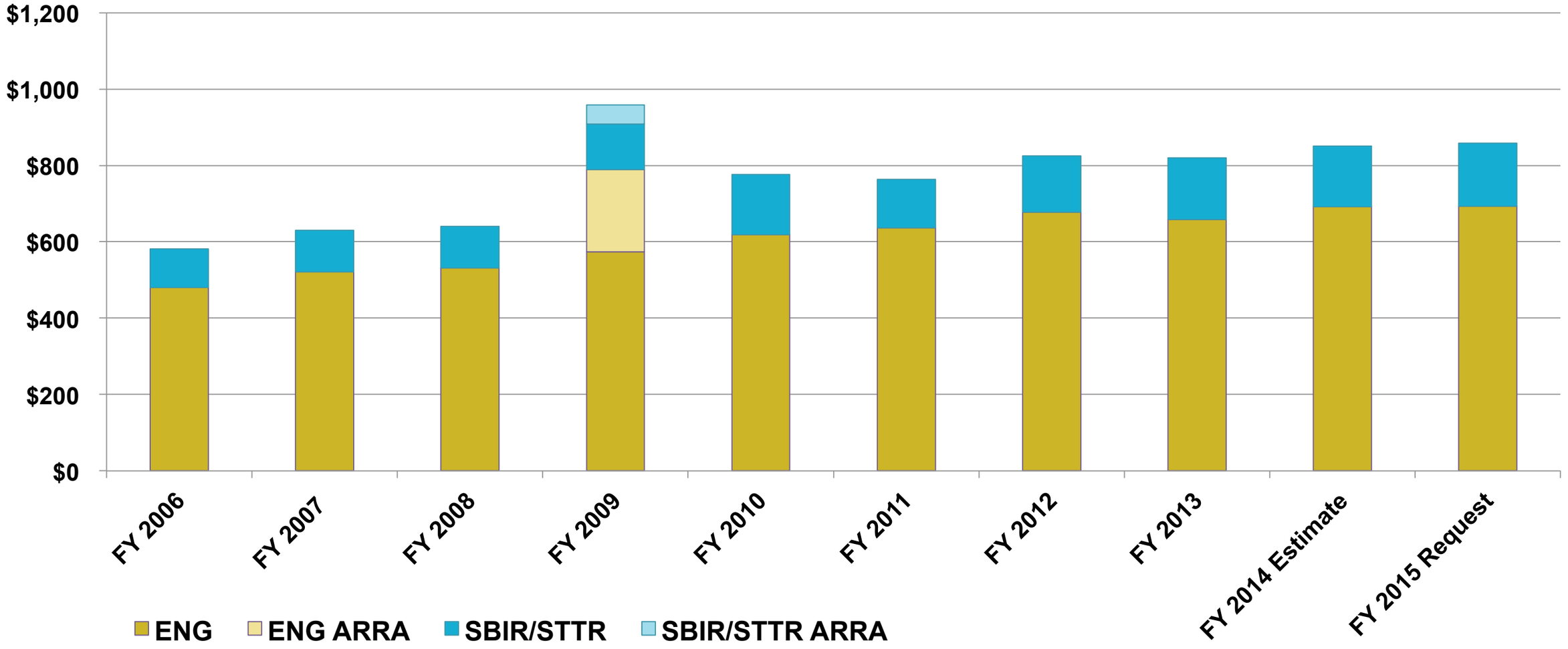
NSF ENG: Investing in engineering research and education to foster innovations for benefit to society



ENG and SBIR/STTR R&RA Budgets ($M)



ENG

Office of the Assistant Director

Emerging Frontiers in Research and Innovation (EFRI)

Engineering Education and Centers (EEC)	• Engineering Centers • Engineering Education • Engineering Workforce
Chemical, Bioengineering, Environmental, and Transport Systems (CBET)	• Chemical, Biochemical, and Biotechnology Systems • Biomedical Engineering and Engineering Healthcare • Environmental Engineering and Sustainability • Transport and Thermal Fluids Phenomena
Civil, Mechanical, and Manufacturing Innovation (CMMI)	• Advanced Manufacturing • Mechanics and Engineering Materials • Resilient and Sustainable Infrastructure • Systems Engineering and Design
Electrical, Communications, and Cyber Systems (ECCS)	• Electronics, Photonics, and Magnetic Devices • Communications, Circuits, and Sensing Systems • Energy, Power, and Adaptive Systems
Industrial Innovation and Partnerships (IIP)	• Academic Partnerships (GOALI, I/UCRC, PFI AIR, and PFI BIC) • Small Business Partnerships (SBIR, STTR)

Electric Power Systems

- Critical infrastructure for society
- Large scale spatially distributed nonlinear dynamic systems with multiple time scales
- Hierarchical control and management system involving cyber-physical components, sensors, algorithms, and economic markets
- Techno-socio-economic system with multiple stakeholders
- Regulation and policy

Major Trends and Drivers

- Aging infrastructure in developed world and new infrastructure in the developing world
- IHS Global Insight estimates $12 trillion to be spent on electric grid between 2014-2020
- Integration of renewable electric energy from wind and solar
- Need for greater resilience in the face of natural and man-made disasters
- Cybersecurity

Technological Drivers

- Decreasing cost of solar PV
- Novel power electronics devices with significant new capabilities
- Growing deployment of synchrophasors
- Infusion of computing, communications and controls into the physical power system
- Electric energy storage
- Electric and hybrid vehicles
- Fuel cells,
- Natural gas stirling engines - micro generation
- …

How can (will) the electric grid be transformed into a sustainable, reliable, and economic electric energy system for society?

Electric Power and Energy Research – NSF Role

- Energy, Power, and Adaptive Systems Cluster in the ECCS Division
  - Samir El-Ghazaly, Division Director, ECCS
  - Eyad Abed, Kishan Baheti, and Paul Werbos, program directors
- Energy for Sustainability in CBET Division
  - JoAnn Lighty, Division Director, CBET
  - Greg Rorrer, Bruce Hamilton, program directors
- Cyber-Physical Systems (CPS) [CISE+ENG]
- Science, Engineering and Education for Sustainability (SEES)
  - Sustainable energy pathways (SEP)

Engineering Research Centers

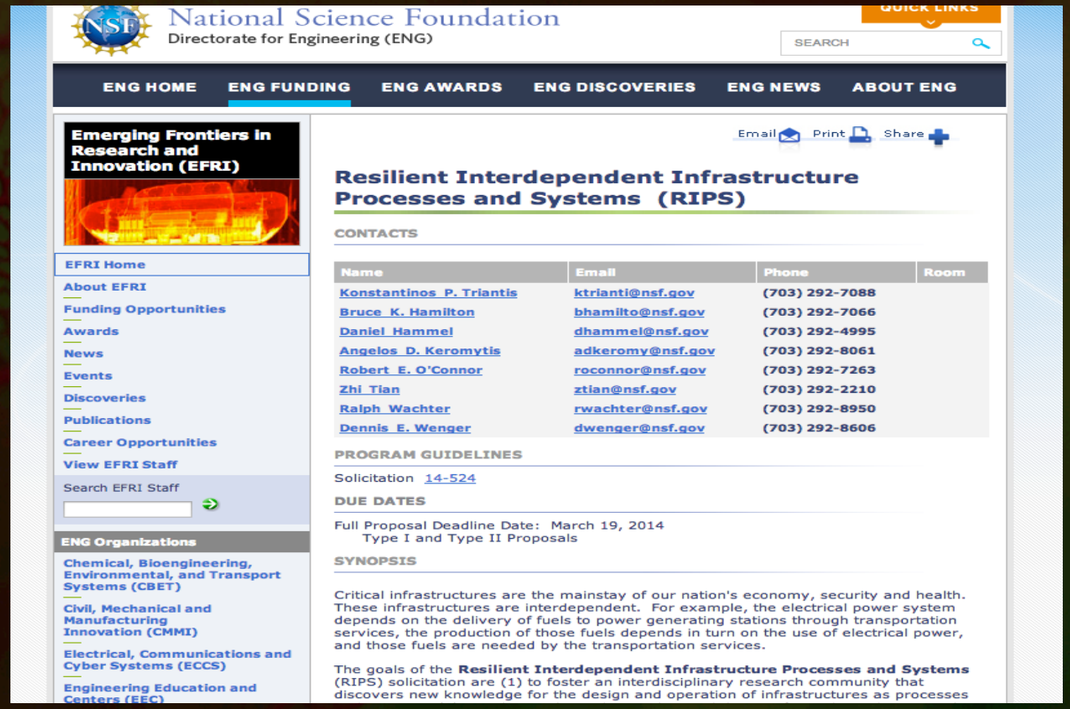
- Future Renewable Electric Energy Delivery and Management Systems Center (FREEDM)
- Center for Ultra-Wide Resilient Electric Energy Transmission Networks (CURENT) – joint with DoE
- Quantum Energy and Sustainable Solar Technologies (QUEST)- joint with DoE
- Smart Lighting
- New ERC Competition *underway*

Industry-University Cooperative Research Centers

- Power Systems Engineering Research Center (PSERC)
- Energy-Smart Electronic Systems (ES2)
- Energy Harvesting Materials and Systems (CEHMS)
- Grid-Connected Advanced Power Electronic Systems (GRAPES)
- Advanced Vehicle and Extreme Environment Electronics (CAVE3)
- Novel High-V/T Materials and Structures (HVT)
- Next Generation Photovoltaic
- Silicon Solar Consortium
- Wind Energy Science, Technology and Research (WindSTAR)

Infrastructure Systems – *A New Paradigm*

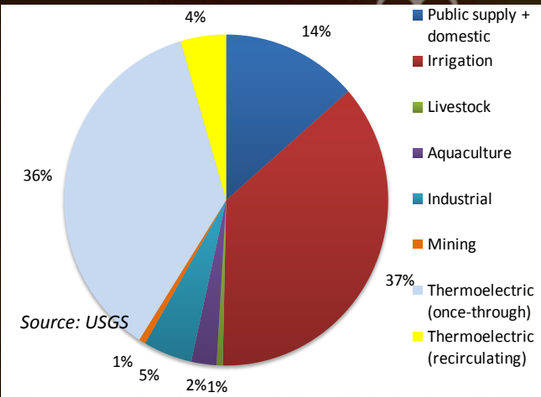
- Idea: Rethink infrastructure systems as providing needed services
- Resilient Interdependent Infrastructures Processes and Systems (RIPS)
- Deadline: March 19, 2014
- http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504971&org=EFRI&from=home



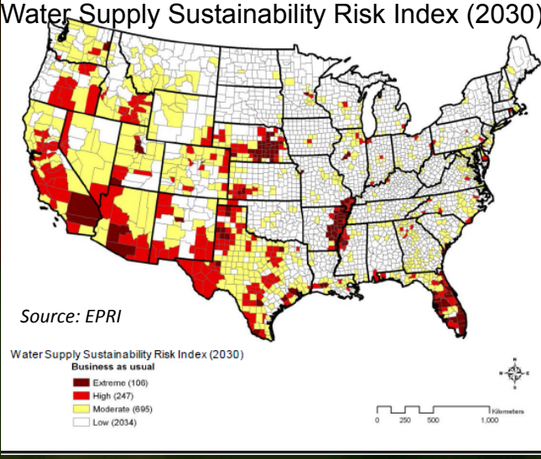
Eliminate Water Use in Electricity Generation-
An NSF-EPRI Partnership

- Nearly 40% of the freshwater withdrawal in the US is for Thermal-electric power plants; 90% of this is used for cooling.
- EPRI study suggest lack of water in many regions that put nearly 25% of power production at risk.
- Goal of the NSF-EPRI Collaboration: To eliminate or minimize the use of water for cooling in Thermal-electric power plants. Likely impact will be very significant in terms of water availability for other sectors
- Twelve projects exploring novel transformational ideas funded at universities with industry participation/oversight; NSF & EPRI contribute equally.

U.S. Freshwater Withdrawal (USGS 2005)



Water Supply Sustainability Risk Index (2030)



Energy Harvesting

- Objective: Recover waste heat; automobiles; industrials; buildings
- Potential Impact: In 250M automobiles, Thermoelectrics can be used to convert waste heat to electricity - 5% fuel savings ($250B)
- Innovations: Materials with improved conversion efficiency, Low cost manufacturing, System design and integration

http://www1.eere.energy.gov/vehiclesandfuels/technologies/engines/solid_state.html

Fairbanks et al. 2010, 2013

2010 NSF/DOE Partnership on Thermoelectric Devices for Vehicle Applications

White House announced new corporate average fuel economy (CAFÉ) standards of 54.5 mpg by 2025

F-PACE: Foundational Program to Advance PV Cell Efficiency

- DoE SunShot: Advanced Solar Photovoltaic (PV) Technologies
- Goal: reduce the total cost of solar energy systems by about 75% before the end of the decade
- F-PACE: DoE-NSF partnership
- Solar device physics, improved PV cell performance, and reduced module costs for commercial applications
  - $38.5M awarded in FY12

Opportunity in Electrical Engineering Education

- Despite tremendous efforts by the engineering education community, major issues stubbornly remain and progress modest
- Retention, diversity, preparation, depth vs breadth vs professional skills, K-12 issues, …
- Can sustainable electric energy theme make a big impact on student and education issues in electrical (and computer) engineering departments?
  - Retention, diversity, enrollments, …
- What kinds of collaborations will be necessary to achieve breakthrough results?
- Could there an alternative track with energy and sustainability theme? Will it be viable and attractive to employers?

Graduate Level Issues

- Smart grid opportunity to modernize the grid
- How can the power systems curriculum be rethought and restructured to bring in students from controls, communications, networking, computing, software backgrounds?
- What are the industry needs?

QUESTIONS?

IDEAS, THOUGHTS!

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