



Quadrennial Technology Review 2015

Chapter 1: Energy Challenges

Supplemental Information



Additional Information on Energy Challenges

Agency Information

DOE Energy Technology Roadmaps

& Basic Research Needs

*Representative DOE Energy and Science
Program Workshops*



U.S. DEPARTMENT OF
ENERGY

Quadrennial Technology Review 2015

Chapter 1: Supplemental Information

DOE ENERGY TECHNOLOGY ROADMAPS & BASIC RESEARCH NEEDS

Introduction

The following material provides weblinks to a number of the DOE energy technology roadmaps, basic research needs reports, and other documents addressing energy science and technology research, development, demonstration, and deployment (RDD&D) at the U.S. Department of Energy. These roadmaps and documents reflect extensive engagement with the stakeholder community, including industry, universities, national laboratories, non-profit organizations, civil society, and the public—as detailed in QTR Chapter 1 Supplemental Information Appendix *“Representative DOE Energy and Science Program Workshops”*. Extensive RDD&D is underway on many of the activities identified in these roadmaps and details are described in the respective program webpages at the USDOE website: <http://www.energy.gov/> and national laboratories: <http://www.energy.gov/offices>. Specific weblinks to current RDD&D are provided below for a few areas, and much more information is available on each of the DOE office and national laboratory websites.

Quadrennial Reviews

QUADRENNIAL TECHNOLOGY REVIEW 2015

The Quadrennial Technology Review examines a broad range of science and energy technology opportunities to address key energy challenges—energy security, economic vitality, and environmental quality.

- The Quadrennial Technology Review 2015 (QTR)—this report and its 65 Technology Assessments and Supplemental Information appendices—cover the electric power grid, electricity supply, buildings energy efficiency, industrial energy efficiency, transportation fuels—including biofuels and hydrogen, transportation technologies, science, and others, and can be found at: <http://energy.gov/quadrennial-technology-review-2015> and <https://energy.gov/under-secretary-science-and-energy/quadrennial-technology-review-2015-omnibus>
- The Quadrennial Technology Review 2011 and its 17 technology assessment appendices can be found at: <https://energy.gov/under-secretary-science-and-energy/downloads/first-quadrennial-technology-review-qtr-2011>

QUADRENNIAL ENERGY REVIEW

The Quadrennial Energy Review (QER) has two installments. The first examined U.S. Federal Government-wide policy issues associated with energy infrastructure, and the second examined the U.S. electricity system.

- The first installment of the QER, titled “Energy Transmission, Storage, and Distribution Infrastructure”, was released April 21, 2015. It examines how to modernize our Nation’s energy infrastructure to promote economic competitiveness, energy security, and environmental responsibility, and is focused on energy transmission, storage, and distribution (TS&D), the networks of pipelines, wires, storage, waterways, railroads, and other facilities that form the backbone of our energy system. The QER first installment and supporting analyses and documents can be found on the main QER webpage at: <https://energy.gov/epsa/quadrennial-energy-review-qer>
- The second installment of the QER, titled “Transforming the Nation’s Electricity System”, was released on January 6, 2017. It finds the electricity system is a critical and essential national asset, and it is a strategic imperative to protect and enhance the value of the electricity system through modernization and transformation. This report analyzes trends and issues confronting the Nation’s electricity sector out to 2040, examining the entire electricity system from generation to end use, and within the context of three overarching national goals: (1) enhance economic competitiveness; (2) promote environmental responsibility; and (3) provide for the Nation’s security. The QER second installment and supporting analyses and documents can be found on the main QER webpage at: <https://energy.gov/epsa/quadrennial-energy-review-qer>

Building Energy Technology Roadmaps

The DOE Building Technologies Office (BTO)—at: <https://energy.gov/eere/buildings/building-technologies-office> --develops technology roadmaps and reports, in consultation with industry, university, national laboratory, and other stakeholders and experts. These publications help guide R&D investments by BTO, and quantify the potential impact of these investments on primary energy consumption of residential and commercial buildings in the U.S. Many of these publications, particularly the roadmaps, are regularly updated to reflect technology advances and other changes that affect BTO’s R&D agenda. Feedback on the roadmaps and reports, and/or participation in their updates, is welcome: please contact the relevant Technology Manager indicated on the BTO website at: <https://energy.gov/eere/buildings/emerging-technologies-team>. All of these publications are available free of charge at: <https://energy.gov/eere/buildings/program-plans-implementation-and-results>; the specific roadmaps and reports cited in the QTR are available at the websites indicated below.

BUILDING ENERGY TECHNOLOGY MULTI-YEAR PROGRAM PLAN

- The Department of Energy’s Building Technologies Office’s (BTO’s) “Multi-Year Program Plan” (MYPP) for Fiscal Years 2016-2020 provides a broad overview of the energy use in the buildings sector, the opportunities for cost-effective energy savings, the barriers to their achievement, and BTO’s strategies and goals for achieving significant reductions in building energy use intensity. The body of the plan describes each of BTO’s programs, providing a roadmap for their work over the next five years. Each program section reviews the relevant market characteristics, including key market barriers, the program’s history, and a description of the remaining opportunities for energy savings, followed by a description of each of the program’s goals, the

strategies used to achieve those goals, and a summary of specific program activities and key targets. <http://energy.gov/eere/buildings/downloads/multi-year-program-plan>

TECHNOLOGY ROADMAPS

- The Building Energy Technology Roadmaps currently available can be found at the following address: <http://energy.gov/eere/buildings/listings/technology-roadmaps> and as detailed below.

THERMAL COMFORT AND VENTILATION

- *Research & Development Roadmap for Emerging HVAC Technologies (Oct 2014)*. Near-term and long-term R&D initiatives in heating, ventilation, and air conditioning (HVAC) technologies are described that can lead to substantial primary energy savings in residential and commercial USA buildings. <http://energy.gov/eere/buildings/downloads/research-development-roadmap-emerging-hvac-technologies>
- *Windows and Building Envelope Research and Development: Roadmap for Emerging Technologies (Feb 2014)*. The roadmap describes the technical and market challenges to be overcome, R&D activities and milestones, key stakeholders, and potential energy savings that could result if cost and performance targets are met for advanced windows and the opaque building envelope. <http://energy.gov/eere/buildings/downloads/research-and-development-roadmap-windows-and-building-envelope>
- *Energy Savings Potential and RD&D Opportunities for Non-Vapor Compression HVAC Technologies (March 2014)*. This technology report identifies alternatives to vapor-compression technology in residential and commercial HVAC applications, characterizes them based on their energy-savings potential, and provides recommendations for their further development. <http://energy.gov/eere/buildings/downloads/non-vapor-compression-hvac-technologies-report>
- *Research & Development Roadmap for Emerging Water Heating Technologies (Sep 2014)*. Key R&D challenges in residential and commercial water heating technologies are described, including both electric and gas-fired technologies. <http://energy.gov/eere/buildings/downloads/research-development-roadmap-emerging-water-heating-technologies>

LIGHTING

- *Solid-State Lighting R&D Plan (June 2016)*. The Solid-State Lighting (SSL) R&D Plan is a consolidation of the Department of Energy (DOE) SSL Multi-Year Program Plan (MYPP) and the DOE SSL Manufacturing R&D Roadmap that DOE has published and updated in previous years. The SSL R&D Plan provides analysis and direction for ongoing R&D activities to advance SSL technology and increase energy savings. <https://energy.gov/eere/ssl/downloads/solid-state-lighting-2016-rd-plan>
- *SSL Market Studies (ongoing)*. A number of lighting market characterization studies, including the *Adoption of Light-Emitting Diodes in Common Illumination Applications (July 2015)*, and *Energy Savings Forecast of Solid-State Lighting in General Illumination Applications (Aug 2014)*, are available. These studies are intended to present objective market analysis based on the most recent, referenceable data available at the time of preparation of the reports. As new information becomes available, DOE will make efforts to update these studies as necessary. <http://energy.gov/eere/ssl/market-studies>

APPLIANCES

- *Research & Development Roadmap: Next-Generation Appliances (Oct 2014)*. The recommended initiatives in this roadmap target high-priority R&D, demonstration, and commercialization activities that, if pursued by DOE and its partners, could significantly reduce residential appliance energy consumption. <http://energy.gov/eere/buildings/downloads/research-development-roadmap-next-generation-appliances>
- *Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment (Dec 2013)*. This report describes the current state of motor technology and estimates opportunities for energy savings through application of more advanced technologies in a variety of residential and commercial end uses. <http://energy.gov/eere/buildings/downloads/motor-energy-savings-potential-report>

SYSTEM LEVEL:

- *Buildings-to-Grid Technical Opportunities: Introduction and Vision (Mar 2014)*. BTO is coordinating strategies and activities with stakeholders to address the integration and optimization of homes and commercial buildings with the nation's energy grid. This report introduces fundamental concepts of transaction-based energy systems, including the role of building technologies, and describes the opportunities they bring to the larger energy system. <http://energy.gov/eere/buildings/downloads/buildings-grid-technical-opportunities-introduction-and-vision>

EMERGING TECHNOLOGIES

- Draft building energy modeling roadmap: The Department of Energy's Building Technologies Office (BTO) seeks input from stakeholders on a draft Building Energy Modeling Roadmap. The draft Roadmap provides background and context, then outlines steps that BTO's contractor recommends to help increase the use of BEM tools for the design and operation of energy-efficient buildings. The draft Roadmap is based in part on stakeholder input received through two workshops and telephone interviews. Stakeholders included experts in all aspects of BEM tool development and real world applications. <http://energy.gov/eere/buildings/downloads/bto-seeks-comments-draft-building-energy-modeling-roadmap>

BUILDING AMERICA

- This report presents the Building America Research-to-Market Plan (Plan), including the integrated Building America Technology-to-Market Roadmaps (Roadmaps) that will guide Building America's research, development, and deployment (RD&D) activities over the coming years. The Plan and Roadmaps will be updated as necessary to adapt to research findings and evolving stakeholder needs, and they will reflect input from DOE and stakeholders. <http://energy.gov/eere/buildings/downloads/building-america-program-research-market-plan>

Advanced Manufacturing Office (INDUSTRY)

Energy bandwidth studies of U.S. manufacturing sectors serve as foundational references in framing the range (or *bandwidth*) of potential energy savings opportunities. The following lists currently and soon-to-be available bandwidth studies:

- DOE/AMO – “Chemical Bandwidth Study”, 2015. <http://www.energy.gov/eere/amo/downloads/bandwidth-study-us-chemical-manufacturing>

- DOE/AMO – “Pulp and Paper Industry Energy Bandwidth Study”, 2015
<http://www.energy.gov/eere/amo/downloads/bandwidth-study-us-pulp-and-paper-manufacturing>
- DOE/AMO – “Energy Bandwidth for Petroleum Refining Processes”, 2015
<http://www.energy.gov/eere/amo/downloads/bandwidth-study-us-petroleum-refining>
- DOE/AMO – “Steel Industry Energy Bandwidth Study”, 2015
<http://www.energy.gov/eere/amo/downloads/bandwidth-study-us-iron-and-steel-manufacturing>

Available Soon:

- DOE/AMO – Draft “Aluminum Manufacturing Bandwidth Analysis”. Draft 2016:
<https://www.energy.gov/eere/amo/energy-analysis-sector#5>
- DOE/AMO – Draft “Titanium Manufacturing Bandwidth Analysis”. Draft 2016:
<https://www.energy.gov/eere/amo/energy-analysis-sector#5>
- DOE/AMO – Draft “Magnesium Manufacturing Bandwidth Analysis”. Draft 2016:
<https://www.energy.gov/eere/amo/energy-analysis-sector#5>
- DOE/AMO – Draft “Advanced High Strength Steel Manufacturing Bandwidth Analysis”. Draft 2016: <https://www.energy.gov/eere/amo/energy-analysis-sector#5>
- DOE/AMO – Draft “Carbon Fiber Reinforced Plastics Composites Manufacturing Bandwidth Analysis”. Draft 2016: <https://www.energy.gov/eere/amo/energy-analysis-sector#5>
- DOE/AMO – Draft “Glass Fiber Reinforced Plastics Composites Manufacturing Bandwidth Analysis”. Draft 2016: <https://www.energy.gov/eere/amo/energy-analysis-sector#5>

The following may also be of interest:

- National Network for Manufacturing Innovation: <http://energy.gov/eere/amo/national-network-manufacturing-innovation> ; <https://www.manufacturing.gov/nnmi-institutes/>
- Materials Genome Initiative: <https://www.whitehouse.gov/mgi> ; “Materials Genome Initiative Strategic Plan”, December 2014,
https://www.whitehouse.gov/sites/default/files/microsites/ostp/NSTC/mgi_strategic_plan_-_dec_2014.pdf
- Energy Materials Network, <http://energy.gov/eere/energy-materials-network/energy-materials-network>
- DOE/AMO – “Manufacturing Energy and Carbon Footprints”. Provides maps of the flow of energy supply, demand, and losses as well as greenhouse gas combustion emissions in U.S. manufacturing, as well as more detailed maps for fifteen manufacturing subsectors, based on 2010 EIA Manufacturing Energy Consumption (MECS) data.
<http://www.energy.gov/eere/amo/manufacturing-energy-and-carbon-footprints-2010-meecs>
- DOE/AMO – “U.S. Manufacturing Energy Use and GHG Emissions Analysis”. Detailed analysis based on 2006 EIA Manufacturing Energy Consumption (MECS) data. 2012
http://energy.gov/sites/prod/files/2013/11/f4/energy_use_and_loss_and_emissions.pdf
- DOE/AMO – “Barriers to Industrial Energy Efficiency, Report to Congress. June, 2015”.
<http://www.energy.gov/eere/amo/downloads/barriers-industrial-energy-efficiency-report-congress-june-2015>

TRANSPORTATION FUELS AND VEHICLES

The following materials examine the production of fuels and vehicles for transportation.

UNCONVENTIONAL OIL AND GAS

For unconventional oil and gas, a key document is the research strategy developed in coordination with the Department of the Interior/US Geological Survey and the Environmental Protection Agency:

- DOE-DOI-EPA “Federal Multiagency Collaboration on Unconventional Oil and Gas Research: A Strategy for Research and Development”, July 18, 2014:
http://unconventional.energy.gov/pdf/Multiagency_UOG_Research_Strategy.pdf

BIOMASS FUELS

For biomass fuels, key documents include biomass resource assessments, the multiyear program plan, and more:

- DOE - U.S. Biomass Resource Assessment "Billion Ton Update" August 2011:
<http://energy.gov/eere/bioenergy/downloads/us-billion-ton-update-biomass-supply-bioenergy-and-bioproducts-industry> and
http://www1.eere.energy.gov/bioenergy/pdfs/billion_ton_update.pdf
And 2016 billion ton update: <https://energy.gov/eere/bioenergy/downloads/2016-billion-ton-report-advancing-domestic-resources-thriving-bioeconomy>
- Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply:
https://www1.eere.energy.gov/bioenergy/pdfs/final_billionton_vision_report2.pdf
- DOE - Bioenergy Technologies Office Multi-Year Program Plan, March 2015:
<http://energy.gov/eere/bioenergy/downloads/bioenergy-technologies-office-multi-year-program-plan-march-2015-update>
Current, March 2016: <https://www.energy.gov/eere/bioenergy/downloads/bioenergy-technologies-office-multi-year-program-plan-march-2016>
- DOE – Bioenergy Technologies Office “National Algal Biofuels Technology Roadmap”:
https://www1.eere.energy.gov/bioenergy/pdfs/algal_biofuels_roadmap.pdf
- White House Office of Science and Technology Policy, “National Aeronautics Research, Development, Test, and Evaluation (RDT&E) Infrastructure Plan”, January 2011:
<https://www.whitehouse.gov/sites/default/files/microsites/ostp/NSTC-Approved-IPlan-04Jan2011.pdf>
- Biomass Research and Development (R&D) Board, "Federal Activities Report on the Bioeconomy", February 2016: <https://energy.gov/eere/bioenergy/downloads/federal-activities-report-bioeconomy>
- Biomass Research and Development (R&D) Board, "National Biofuels Action Plan":
https://www.biomassboard.gov/pdfs/nbap_tac_2014_q2.pdf
- Transportation Energy Futures Report: <http://www.energy.gov/eere/analysis/transportation-energy-futures-study>

See also:

- Midwest Aviation Sustainable Biofuels Initiative (MASBI) - "Fueling a Sustainable Future for Aviation", <http://www.masbi.org>, 2013

HYDROGEN AND FUEL CELLS

- The Department of Energy Hydrogen and Fuel Cells Program Multi-Year Research, Development and Demonstration Plan: <http://energy.gov/eere/fuelcells/downloads/fuel-cell-technologies-office-multi-year-research-development-and-22>
- The Department of Energy's "National Hydrogen Energy roadmap": <https://www.energy.gov/eere/vehicles/downloads/national-hydrogen-energy-roadmap>
- The Department of Energy Hydrogen and Fuel Cells Program Plan: <https://energy.gov/eere/fuelcells/downloads/department-energy-hydrogen-and-fuel-cells-program-plan>
- For information on current research activities, see: "Pathways to Commercial Success: Technologies and Products Supported by the Fuel Cell Technologies Office", January 2016. http://energy.gov/sites/prod/files/2016/02/f29/fcto_2015_pathways_commercial_success.pdf ; and: "DOE Hydrogen and Fuel Cells Program, Annual Progress Report", December 2015: https://www.hydrogen.energy.gov/annual_progress.html

U.S. FEDERAL INTERAGENCY ACTION PLAN

- "Hydrogen and Fuel Cells Interagency Action Plan", December 2011: https://hydrogen.gov/pdfs/hydrogen_fuelcell_interagency_action_plan.pdf

VEHICLE TECHNOLOGIES OFFICE: U.S. DRIVE PARTNERSHIP PLAN, ROADMAPS, AND ACCOMPLISHMENTS

- The Energy Efficiency and Renewable Energy's Vehicle Technologies Office has a number of partnerships, Roadmaps, and accomplishments. The overall page for these is at: <https://www.energy.gov/eere/vehicles/vehicle-technologies-office-plans-and-roadmaps>
The links on this page cover US DRIVE, the National Hydrogen Energy Roadmap, and 21st Century Truck Technology Partnership Roadmap, and others.

USDRIVE PARTNERSHIP ROADMAPS

- The U.S. DRIVE Partnership, which stands for United States Driving Research and Innovation for Vehicle efficiency and Energy sustainability, is a government-industry partnership among the DOE; USCAR, representing Chrysler Group LLC, Ford Motor Company and General Motors; five energy companies – BP America, Chevron Corporation, ExxonMobil Corporation, Phillips 66 Company, and Shell Oil Products US; Tesla Motors; and two utilities – Southern California Edison and Michigan-based DTE Energy and the Electric Power Research Institute (EPRI). An overall page for US DRIVE describing partnerships, roadmaps, and accomplishments is at: <https://www.energy.gov/eere/vehicles/vehicle-technologies-office-us-drive-partnership-plan-roadmaps-and-accomplishments>
See also: "U.S. DRIVE Partnership Releases Updated Technical Roadmaps": <http://www.uscar.org/guest/news/730/U-S-DRIVE-Partnership-Releases-Updated-Technical-Roadmaps>
- For Partnerships specifically, see: <https://www.energy.gov/eere/vehicles/downloads/us-drive-driving-research-and-innovation-vehicle-efficiency-and-energy>
- For accomplishments in 2015 (other years are available through the website above), see: "Vehicle Technologies Office: U.S. Drive 2015 Technical Accomplishments Report" <https://www.energy.gov/eere/vehicles/downloads/vehicle-technologies-office-us-drive-2015-technical-accomplishments-report-0>

Weblinks for each of the US DRIVE roadmaps are at:

- “US Drive Advanced Combustion and Emissions Control Technical Team Roadmap”:
<http://energy.gov/eere/vehicles/downloads/us-drive-advanced-combustion-and-emission-control-technical-team-roadmap>
- “US Drive Electrical and Electronics Technical Team Roadmap”, June 2013:
<http://energy.gov/eere/vehicles/downloads/us-drive-electrical-and-electronics-technical-team-roadmap>
- “U.S. Drive Electrochemical Energy Storage Technical Team Roadmap”, June 2013:
<http://energy.gov/eere/vehicles/downloads/us-drive-electrochemical-energy-storage-technical-team-roadmap>
- “US Drive Grid Interaction Technical Team Roadmap”, June 2013:
<http://energy.gov/eere/vehicles/downloads/us-drive-grid-interaction-technical-team-roadmap>
- “US Drive Materials Technical Team Roadmap”, February 2015:
<http://energy.gov/eere/vehicles/downloads/vehicle-technologies-office-us-drive-materials-technical-team-roadmap>
- “US Drive Fuel Cell Technical Team Roadmap”, June 2013:
<http://energy.gov/eere/vehicles/downloads/us-drive-fuel-cell-technical-team-roadmap>
- “US Drive Hydrogen Codes and Standards Technical Team Roadmap”, June 2013:
<http://energy.gov/eere/vehicles/downloads/us-drive-hydrogen-codes-and-standards-technical-team-roadmap>
- “US Drive Fuel Pathway Integration Technical Team Roadmap”, June 2013:
<http://energy.gov/eere/vehicles/downloads/us-drive-fuel-pathway-integration-technical-team-roadmap>
- “US Drive Hydrogen Storage Technical Team Roadmap”, June 2013:
<http://energy.gov/eere/vehicles/downloads/us-drive-hydrogen-storage-technical-team-roadmap>
- “US Drive Hydrogen Delivery Technical Team Roadmap”, June 2013:
<http://energy.gov/eere/vehicles/downloads/us-drive-hydrogen-delivery-technical-team-roadmap>
- “US Drive Hydrogen Production Technical Team Roadmap”, June 2013:
<http://energy.gov/eere/vehicles/downloads/us-drive-hydrogen-production-technical-team-roadmap>
- “US Drive Vehicle Systems and Analysis Technical Team Roadmap”, June 2013:
<http://energy.gov/eere/vehicles/downloads/us-drive-vehicle-systems-and-analysis-technical-team-roadmap>

ENERGY STORAGE FOR ELECTRIC VEHICLES:

- The 2013 energy storage roadmap for EVs is here:
https://www1.eere.energy.gov/vehiclesandfuels/pdfs/program/eestt_roadmap_june2013.pdf
- See also: <http://energy.gov/eere/vehicles/vehicle-technologies-office-batteries>

HEAVY TRUCKS

- The 21st Century Truck Partnership's overall vision is for our nation's trucks and buses to safely and cost-effectively move larger volumes of freight and greater numbers of passengers while emitting little or no pollution and dramatically reducing the dependency on foreign oil:
<http://energy.gov/eere/vehicles/vehicle-technologies-office-21st-century-truck-partnership>

- “21st Century Truck Technology Partnership”, “Roadmap and Technical White Papers for 21st Century Truck Partnership:
<https://www.energy.gov/eere/vehicles/downloads/roadmap-and-technical-white-papers-21st-century-truck-partnership>

ANNUAL MERIT REVIEW

- For a summary of current work, as presented by the Principal Investigators, see: “Vehicle Technologies Office: Annual Merit Review and Peer Evaluation Presentations”, 2015:
<http://energy.gov/eere/vehicles/vehicle-technologies-office-annual-merit-review-presentations>

ELECTRIC POWER SYSTEMS

Electric power systems include grid operations, transmission, and distribution; electricity supply by central power plants—fossil, nuclear, and renewable—as well as distributed power generation; and end-use equipment that can aid power system operations, such as demand side management systems. The following lists roadmaps for the grid

ELECTRIC POWER GRID

- USDOE, “Grid Modernization Multi-year Program Plan”:
<http://energy.gov/sites/prod/files/2016/01/f28/Grid%20Modernization%20Multi-Year%20Program%20Plan.pdf>
See also: Grid Modernization Laboratory Consortium R&D Funding:
<http://energy.gov/doe-grid-modernization-laboratory-consortium-gmlc-awards>
Earlier work can be found at: “Smart Grid R&D Multi-Year Program Plan (2010-2014) – September 2012 Update”:
<http://energy.gov/oe/downloads/smart-grid-rd-multi-year-program-plan-2010-2014-september-2012-update>
See also: “2014 Smart Grid R&D Peer Review”:
<http://energy.gov/oe/downloads/2014-smart-grid-rd-peer-review>
- Smart Grid Interoperability Standards, “NST Releases Final Version of Smart Grid Framework, Update 3.0”, September 30, 2014:
<http://www.nist.gov/el/smartgrid-100114.cfm>
<https://www.nist.gov/sites/default/files/documents/smartgrid/NIST-SP-1108r3.pdf>
- NIST, “Guidelines for Smart Grid Cybersecurity”:
http://www.nist.gov/manuscript-publication-search.cfm?pub_id=916068
<http://nvlpubs.nist.gov/nistpubs/ir/2014/NIST.IR.7628r1.pdf>
- DOE, Office of Electricity Delivery and Energy Reliability, “Roadmap to Achieve Energy Delivery Systems CyberSecurity – 2011”:
<http://energy.gov/oe/downloads/roadmap-achieve-energy-delivery-systems-cybersecurity-2011>
https://energy.gov/sites/prod/files/Energy%20Delivery%20Systems%20Cybersecurity%20Roadmap_finalweb.pdf
- DOE, Office of Electricity Delivery & Energy Reliability, “EAC Recommendations on Smart Grid Research and Development Needs”:
<http://energy.gov/oe/downloads/eac-recommendations-smart-grid-research-and-development-needs>

- DOE, Office of Electricity Delivery & Energy Reliability, “Energy Storage Program Planning Document (2011)”:
<http://energy.gov/oe/downloads/energy-storage-program-planning-document-2011>
See also: “Grid Energy Storage” Report, December 2013:
<http://energy.gov/oe/downloads/grid-energy-storage-december-2013>
- Storage Plan Assessment Recommendations:
<http://energy.gov/oe/downloads/2014-storage-plan-assessment-recommendations-us-department-energy-september-2014>
- Energy Storage Safety Strategic Plan:
<http://energy.gov/oe/downloads/energy-storage-safety-strategic-plan-december-2014>
- Advanced Materials and Devices for Stationary Electrical Energy Storage Applications:
<http://energy.gov/oe/downloads/advanced-materials-and-devices-stationary-electrical-energy-storage-applications>
- Electricity Storage Handbook:
<http://energy.gov/oe/downloads/doeepri-2013-electricity-storage-handbook-collaboration-nreca-july-2013>
- Microgrid Workshops:
<http://energy.gov/oe/downloads/microgrid-workshop-report-august-2011> ;
<http://energy.gov/oe/downloads/2012-doe-microgrid-workshop-summary-report-september-2012>
- Advanced Microgrids:
<http://energy.gov/oe/downloads/advanced-microgrid-integration-and-interoperability-march-2014>
- Resilient Electric Distribution Grid:
<http://energy.gov/oe/downloads/resilient-electric-distribution-grid-rd-workshop-june-11-2014>
- Materials Innovation for Next Generation Grid Components:
<http://www.osti.gov/scitech/biblio/1225432-materials-innovation-next-generation-grid-components-workshop-summary-report>
- Transmission Needs Workshop:
<http://energy.gov/oe/downloads/gtt-2012-transmission-workshop-documents>
- Distribution Needs Workshop:
<http://energy.gov/oe/downloads/gtt-2012-distribution-workshop-documents>
- HVDC Workshop:
<http://energy.gov/oe/downloads/hvdc-workshop-april-22-2013>
- Computational Needs Workshop:
<http://energy.gov/oe/downloads/proceedings-computational-needs-next-generation-electric-grid-workshop-april-19-20-2011>
- North American Synchrophasor Initiative Technical Reports:
<http://energy.gov/oe/downloads/north-american-synchrophasor-initiative-naspi-technical-reports>

The following may also be of interest:

- Smart Grid:
<https://www.smartgrid.gov/>
- Future Grid:
<http://energy.gov/oe/downloads/future-grid-evolving-meet-america-s-needs-december-2014>
- Advanced Distribution Management Systems:

https://www.smartgrid.gov/document/insights_advanced_distribution_management_systems.html

- ICEF Distributed Solar and Storage Roadmap:
http://www.icef-forum.org/distributed_solar_and_storage-icef_roadmap_1.0.pdf

POWER SUPPLY

FOSSIL POWER

CCS ROADMAPS

- DOE/NETL (2010) (update underway)
<http://www.netl.doe.gov/File%20Library/Research/Carbon%20Seq/Reference%20Shelf/CCSRoadmap.pdf>
- DOE, Office of Fossil Energy, “Carbon Capture Technology Program Plan”, January 2013
<https://www.netl.doe.gov/File%20Library/Research/Coal/carbon%20capture/Program-Plan-Carbon-Capture-2013.pdf>

SEE ALSO:

- Carbon Sequestration Leadership Forum (CSLF) (2013)
http://www.cslforum.org/publications/documents/CSLF_Technology_Roadmap_2013.pdf

NUCLEAR POWER

- Nuclear Energy Roadmap:
<http://energy.gov/ne/downloads/nuclear-energy-research-and-development-roadmap>. (update underway).
- Advanced Reactor Concepts Technical Review Panel:
<http://www.energy.gov/sites/prod/files/2014/12/f19/Advance%20Reactor%20Concepts%20Technical%20Review%20Panel%20Public%20Report.pdf>
- Development Of Light Water Reactor Fuels With Enhanced Accident Tolerance – Report To Congress:
<http://www.energy.gov/sites/prod/files/2015/06/f23/Report%20to%20Congress%20-%20Accident%20Tolerant%20Fuels.pdf>
- Nuclear Energy Research and Development Roadmap: Report to Congress;
http://energy.gov/sites/prod/files/NuclearEnergy_Roadmap_Final.pdf
- LWRs Program and EPRI Long-Term Operations Program - Joint R&D Plan:
http://www.energy.gov/sites/prod/files/INL-EXT-12-24562_LWRS-LTO_Joint_RD_Plan_Rev_4_0.pdf
- Light Water Reactor Sustainability Program - Integrated Program Plan:
http://www.energy.gov/sites/prod/files/FY-15_LWRS_IPP_Final_0.pdf
- Assessment Of Disposal Options For DOE-Managed High-Level Radioactive Waste And Spent Nuclear Fuel:
http://www.energy.gov/sites/prod/files/2014/10/f18/DOE_Options_Assessment.pdf
- Evaluation Of Options For Permanent Geologic Disposal Of Spent Nuclear Fuel And High-Level Radioactive Waste:
<http://www.energy.gov/ne/downloads/evaluation-options-permanent-geologic-disposal-spent-nuclearfuel-and-high-level>

- Nuclear Energy Advanced Modeling And Simulation (Neams) Program Plan:
<http://www.energy.gov/sites/prod/files/2013/07/f2/NEAMS%20Executive%20Program%20Plan.pdf>
- Strategy For The Management And Disposal Of Used Nuclear Fuel And High-Level Radioactive Waste:
<http://www.energy.gov/sites/prod/files/Strategy%20for%20the%20Management%20and%20Disposal%20of%20Used%20Nuclear%20Fuel%20and%20High%20Level%20Radioactive%20Waste.pdf>
- Nuclear Science User Facility:
<https://atrsuf.inl.gov/>
- Gateway for Accelerated Innovation in Nuclear (GAIN):
<https://gain.inl.gov/SitePages/Home.aspx>

SEE ALSO:

- GEN IV Technology Roadmap:
<https://www.gen-4.org/gif/upload/docs/application/pdf/2014-03/gif-tru2014.pdf>
- Consortium for Advanced Simulation of Light Water Reactors (CASL):
<http://www.casl.gov/>

RENEWABLE POWER

Renewable energy resources and technologies for power generation include biomass power, geothermal (hydrothermal and enhanced geothermal (EGS)), hydropower, solar PV, Concentrating Solar Thermal Power (CSP), Wind (onshore and offshore), and water (marine hydrokinetic, thermal, salinity, etc.) An analysis of how all of these technologies might work together and be integrated into the grid can be found at: Renewable Electricity Futures, with 80% Renewable Electricity by 2050: http://www.nrel.gov/analysis/re_futures/ The following provides specific roadmaps and related information in many of these technology areas.

GEOHERMAL

- Geothermal Exploration Technologies:
<http://energy.gov/eere/geothermal/downloads/roadmap-strategic-development-geothermal-exploration-technologies>
http://energy.gov/sites/prod/files/2014/02/f7/exploration_technical_roadmap2013.pdf
- Enhanced Geothermal Systems (EGS):
<http://energy.gov/eere/geothermal/downloads/technology-roadmap-strategic-development-enhanced-geothermal-systems>
http://www1.eere.energy.gov/geothermal/pdfs/stanford_egs_technical_roadmap2013.pdf
- Low Temperature Co-produced Geothermal:
http://energy.gov/sites/prod/files/2014/02/f7/litcg_strategic_action_plan.pdf
- Basic Science, “Controlling Subsurface Fractures and Fluid Flow: A Basic Research Agenda”, May 22, 2015:
http://science.energy.gov/~media/bes/pdf/reports/2015/BES_CSFFF_rtp.pdf

SOLAR

- DOE, Office of Energy Efficiency and Renewable Energy, “On the Path to Sunshot”
<https://energy.gov/eere/sunshot/path-sunshot>
See also: SunShot Vision:

<http://energy.gov/eere/sunshot/downloads/sunshot-vision-study-february-2012-book-sunshot-energy-efficiency-renewable>

- For descriptions of recent and current work, see:
<http://energy.gov/eere/sunshot/2014-sunshot-initiative-portfolio-book>
Current competitive RDD&D awards are listed at:
<http://energy.gov/eere/sunshot/photovoltaics-competitive-awards>

WATER

- Hydropower Vision:
<http://energy.gov/eere/water/new-vision-united-states-hydropower>

WIND

- Wind Vision:
<http://energy.gov/eere/wind/maps/wind-vision>
Report in pdf:
http://www.energy.gov/sites/prod/files/WindVision_Report_final.pdf

ENERGY STORAGE

- Energy Storage Strategic Plan:
<http://energy.gov/oe/downloads/energy-storage-safety-strategic-plan-december-2014>

POWER ELECTRONICS

- Power Electronics Research and Development Program Plan:
<http://energy.gov/oe/downloads/power-electronics-research-and-development-program-plan>
- Wide Bandgap Semiconductors:

DOE OFFICE OF INDIAN ENERGY POLICY AND PROGRAMS

The U.S. Department of Energy Office of Indian Energy's Strategic Roadmap 2025 outlines a tactical action plan for maximizing the development and deployment of beneficial energy solutions for American Indians and Alaska Natives.

- Office of Indian Energy Strategic Roadmap:
<http://energy.gov/indianenergy/downloads/doe-office-indian-energy-strategic-roadmap-2025>

SCIENCE

The Office of Basic Energy Sciences has sponsored a series of "Basic Research Needs" workshops that leverage the relevant scientific communities to identify priority research directions for longer term energy planning. A list of the workshops and links to the reports can be found at:

<https://science.energy.gov/bes/community-resources/reports/>

and includes the following:

- "Basic Research Needs for Advanced Nuclear Energy Systems":
- "Basic Research Needs for Carbon Capture: Beyond 2020"
- "Basic Research Needs: Catalysis for energy"

- “Basic Research Needs for Clean and Efficient Combustion of 21st Century Transportation Fuels”
- “Basic Research Needs for Electrical Energy Storage”
- “Basic Research Needs for Geosciences: Facilitating 21st Century Energy Systems”
- “Basic Research Needs for the Hydrogen Economy”
- “Basic Research Needs for Materials Under Extreme Environments”
- “Basic Research Needs for Solar Energy Utilization”
- “Basic Research Needs for Solid-State Lighting
- “Basic Research Needs for Superconductivity”
- “Computational Materials Science and Chemistry: Accelerating Discovery and Innovation through Simulation-Based Engineering and Science”
- “From Quanta to Continuum: Mesoscale Science”
- “New Science for a Secure and Sustainable Energy Future”
- “Science for Energy Technology: Strengthening the Link between Basic Research and Industry”
- “Controlling Subsurface Fractures and Fluid Flow: A Basic Research Agenda, and Basic Research Needs for Environmental Management”
- “Challenges at the Frontiers of Matter and Energy: Transformative Opportunities for Discovery Science”
- And many more.

Advanced Scientific Computing Research needs and connections with computing needs for Science and Energy Technology R&D can be found in more than 80 reports listed at:

- Advanced Scientific Computing Research (ASCR), Community Resources, ASCR Program documents:
<http://science.energy.gov/ascr/community-resources/program-documents/>

The following do not have roadmaps, per se, but useful information about their activities can be found as indicated.

ENERGY FRONTIER RESEARCH CENTERS

- <http://science.energy.gov/bes/efrc/>

HUBS

- Joint Center for Energy Storage Research:
<http://www.jcesr.org/>
- Joint Center for Artificial Photosynthesis:
<http://solarfuelshub.org/>
- Critical Materials Institute:
<http://cmi.ameslab.gov/>
- Consortium for Advanced Simulation of Light Water Reactors (CASL):
<http://www.casl.gov/>

SEE ALSO:

- CFD Vision 2030 Study: A Path to Revolutionary Computational Aerosciences:
<http://ntrs.nasa.gov/search.jsp?R=20140003093>
- Strategic Plan 2014, Oak Ridge National Laboratory Neutron Sciences Division:
<https://neutrons.ornl.gov/sites/default/files/NScD-Strategic-Plan-2014.pdf>

- Molecular Foundry 5-year Strategic Plan:
<http://foundry.lbl.gov/assets/docs/TMF-Strategic-Plan.pdf>
- U.S. Department of Energy Joint Genome Institute: A 10-Year Strategic Vision:
<http://jgi.doe.gov/wp-content/uploads/2013/05/10-Year-JGI-Strategic-Vision.pdf>
- A National Strategy for Advancing Climate Modeling:
http://download.nap.edu/cart/download.cgi?&record_id=13430

CROSSCUTTING RESEARCH

The following roadmaps and related materials are for RDD&D that cuts across programmatic boundaries:

- Clean Energy Manufacturing Initiative:
<http://energy.gov/eere/cemi/clean-energy-manufacturing-initiative>
- Critical Materials:
<http://energy.gov/epsa/initiatives/department-energy-s-critical-materials-strategy>
See also: Critical Materials Institute:
<http://cmi.ameslab.gov/>
- Electricity Grid Modernization (above): Grid Modernization Multi-year Program Plan:
<http://energy.gov/sites/prod/files/2016/01/f28/Grid%20Modernization%20Multi-Year%20Program%20Plan.pdf>
See also: Grid Modernization Laboratory Consortium R&D Funding:
<http://energy.gov/doe-grid-modernization-laboratory-consortium-gmlc-awards>
- Energy-Materials:
<http://www.energy.gov/eere/energy-materials-network/energy-materials-network>
and for the Materials Genome Initiative, see:
<https://www.mgi.gov/>
and for the Materials Genome Initiative Strategic Plan, see:
https://www.whitehouse.gov/sites/default/files/microsites/ostp/NSTC/mgi_strategic_plan_-_dec_2014.pdf
- SubSurface Technology and Engineering RD&D Crosscut:
<http://energy.gov/subsurface-technology-and-engineering-rdd-crosscut>
- SuperCritical CO2 Power Cycles:
<http://energy.gov/supercritical-co2-tech-team>
See also:
<http://www.netl.doe.gov/research/coal/energy-systems/turbines/supercritical-co2-power-cycles>
and for the Advanced Turbines Technology Program Plan, see:
<http://www.netl.doe.gov/File%20Library/Research/Coal/energy%20systems/turbines/Program-Plan-Adv-Turbines-2013.pdf>
- Water-Energy Nexus:
<http://energy.gov/downloads/water-energy-nexus-challenges-and-opportunities>