

2015 REPORT:

EPRI'S CONTRIBUTION TO THE PUBLIC BENEFIT

The Electric Power Research Institute, Inc. (EPRI) conducts research and development relating to the generation, delivery, and use of electricity for the benefit of the public. An independent, nonprofit organization, EPRI brings together its scientists and engineers as well as experts from academia and industry to help address challenges in electricity, including reliability, efficiency, affordability, health, safety, and the environment. EPRI also provides technology, policy, and economic analyses to drive long-range research and development planning, and supports research in emerging technologies.

EPRI members represent 90% of the electric utility revenue in the United States with international participation in 35 countries. EPRI's principal offices and laboratories are located in Palo Alto, Calif.; Charlotte, N.C.; Knoxville, Tenn.; and Lenox, Mass.

Areas of Focus

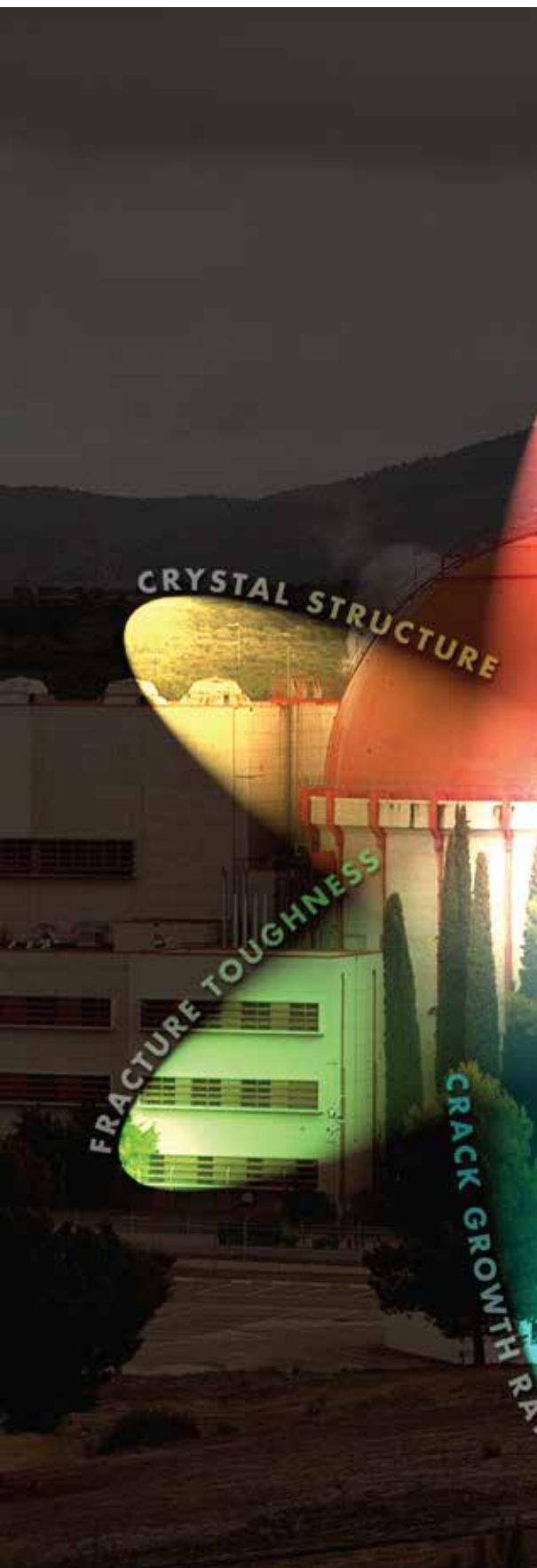
EPRI's collaborative research, development, and demonstration projects help solve specific, near-term problems while addressing long-range strategic challenges. Our research can help mitigate risks and contribute substantially to keeping electricity safe, reliable, efficient, affordable, and environmentally responsible.

Environment

EPRI's environment research provides global thought leadership to shape a sustainable future for electricity through collaborative environmental science and technology research. EPRI Environment conducts cross-cutting research addressing environmental, health, and economic issues from the generation, delivery, and use of electricity. Research focuses on air, land, water, and energy challenges; informs public policy; enables sustainable practices; and improves occupational health and safety.

Generation

EPRI's generation research provides information, processes, and technologies to improve the flexibility, reliability, performance, and efficiency of the existing fossil-fueled and renewable energy generating fleet. These advances will play a critical role in a low-emissions, water-constrained future, enabling utilities to improve current assets and build new, more efficient generating units with advanced technologies that reduce fuel and water consumption; limit emissions; enhance performance, efficiency, and reliability; and enable assets to better respond to changing demands in operations.



Nuclear

EPRI conducts research supporting the safe, reliable, cost-effective, and environmentally responsible use of nuclear power as a generation option. Through global collaboration with nuclear power plant operators, regulatory agencies, and other research organizations, EPRI develops cost-effective technologies, technical guidance, and knowledge transfer tools that help maximize the value of existing nuclear assets and inform the deployment of new nuclear technology.

Power Delivery and Utilization

EPRI's transmission and power delivery and utilization research focuses on technology to enhance the safety, reliability, and resiliency of the bulk power delivery system—connecting load centers and bulk generating stations—and technology to improve the delivery and utilization of electricity from the substation to the end user. Areas of research include smart grid, electric transportation, distribution, cyber security, and energy utilization.

Technology Innovation

EPRI's Technology Innovation program maintains a pipeline of emerging knowledge and technology to support power system transformation. By exploring early-stage, advanced R&D concepts, the program looks across the energy landscape at what will be valuable to EPRI members five to 10 years down the road. The Technology Innovation program is integral to EPRI's R&D portfolio, through which technical experts manage its programs to provide thought leadership, foster innovation, and accelerate the development of new knowledge and technology for commercial application.

EPRI's Articles of Incorporation establish how EPRI fulfills its public benefit mission to conduct and sponsor industry research and development relating to electricity generation, transmission, distribution, and utilization for the benefit of the public.

They require the institute to sponsor scientific R&D with a goal of providing economical, reliable electric service to the public with minimal adverse environmental effects, and to seek solutions to environmental challenges confronting the industry.

Through scientific study, EPRI is to discover and develop ways to protect, conserve, and maximize the efficient utilization of finite natural resources used by the industry, and to share those findings with organizations, people and stakeholders both public and private.

Finally, EPRI should provide forums for coordination and cooperation and for the exchange of information related to electric power scientific R&D, and to publicly disseminate information and data about its research activities.

To review EPRI's Articles of Incorporation click on this link: <http://www.epri.com/AboutUs/Pages/Governance.aspx>

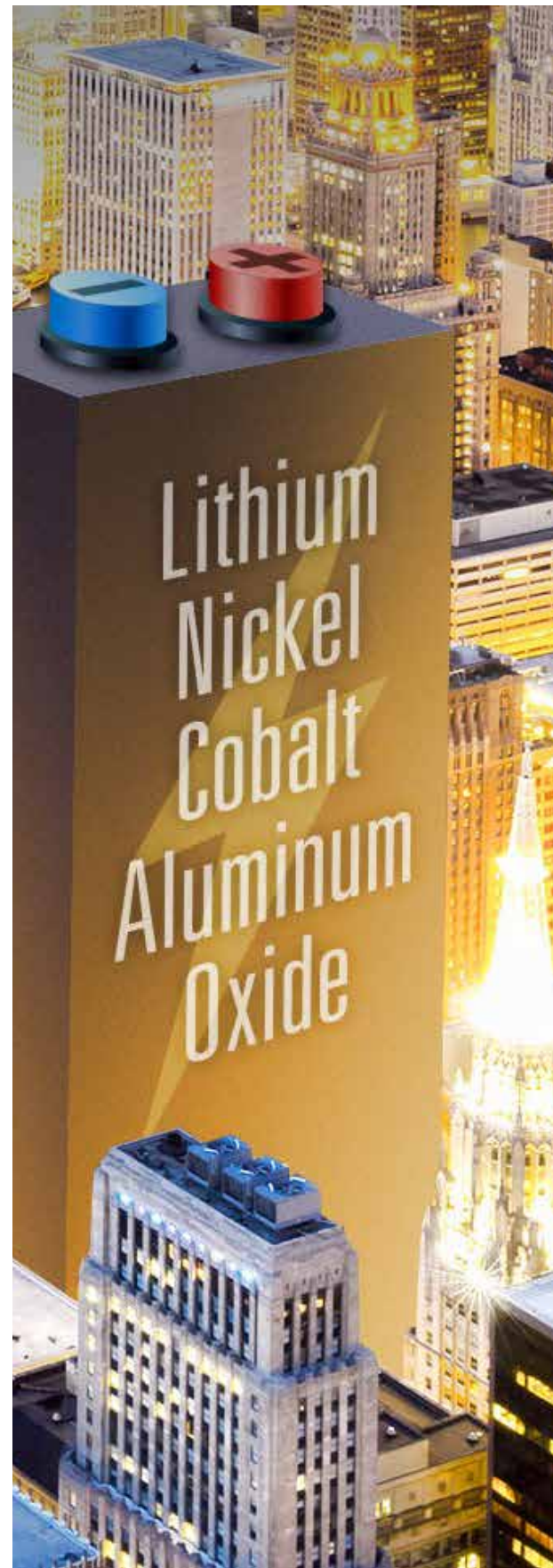
This report summarizes EPRI's stakeholder and communications outreach, which it conducts as part of its public interest mission.

Three key attributes of EPRI's work are:

- **Global Collaboration:** To deploy thought leadership and industry expertise, and provide the benefits of pooled resources, shared knowledge and diverse perspectives.
- **Thought Leadership:** Look at the big picture and the long term to identify and address key issues and challenges.
- **Industry Expertise/Science & Technology Innovation:** Bring together the expertise, experience, knowledge, and know-how to define and conduct the necessary R&D.

This report reviews:

1. EPRI's outreach in communicating key issues and R&D findings to federal/state/international legislators, regulators, and other stakeholders.
2. Technical and scientific information provided to inform policymakers and the energy sector.
3. Major R&D projects that support electric utilities/companies in providing electricity that is affordable, reliable and environmentally responsible. These may include direct and indirect benefits realized through the performance of individual electricity organizations, many of which are EPRI members.



2015 Outreach to Regulators, Legislators and Other Stakeholders

EPRI's 2015 outreach focused on federal/state legislative and regulatory branches of government, as well as increasing EPRI's exposure in non-traditional communities. Growing membership outside the United States has increased EPRI's exposure to electric utility stakeholders and regulators in diverse regions. Global dissemination of timely, accurate technical communications becomes more critical as energy and environmental policy issues assume global dimensions.

Three examples:

EPRI's Integrated Grid analysis continued to receive significant attention. Following the 2014 publication of the concept paper, the *Integrated Grid Benefit-Cost Framework* was released at the February 2015 NARUC Conference, at which NARUC's Board of Directors unanimously approved a resolution commending the analysis and communications outreach. Requests immediately followed for briefings on the benefit-cost framework. Mike Howard was invited by U.S. Senate Energy and Natural Resources Committee Chair, Lisa Murkowski, to open the first of several hearings on grid modernization prior to her introduction of comprehensive energy policy legislation. As in 2014, EPRI received invitations to present its new findings at all five NARUC regional meetings, as well as at individual state public utility commissions. Numerous requests were also received to brief state legislators at the individual state or regional levels.

Also dominating 2015 policy and regulatory considerations was the August announcement of final regulations relative to EPA's Clean Air Act Section 111 (b), 111 (d), and Federal Implementation Plan regarding 111 (d). Considerable interest was expressed in EPRI's *Energy, Environment and Economic Analysis—REGEN model* used in many cross-sector applications, including the institute's Clean Power Plan analysis. To assist state regulators, legislators, and energy/environmental officials in their understanding and possible development of State Implementation Plans, EPRI provided technical briefings to its Advisory Council, national electricity trade associations, non-governmental organizations (NGOs), and in public state venues.

Q4 briefings were held for federal agencies, NGOs, and national electricity trade associations, on *The Road from Paris: The Potential Value of International Emissions Trading Partnerships in Implementing Current and Future Pledges*. This preliminary analysis examined two questions in anticipation of COP21: 1) What might the Intended Nationally Determined Contributions (INDC) pledges mean for global greenhouse gas (GHG) emissions and climate change? 2) What is the value of achieving those commitments if countries engage in international emissions trading?

The Integrated Grid, REGEN analysis, and International Energy & Environmental Assessment are three of many examples where EPRI's technical work contributed relevant information on significant matters, fulfilling its public benefit mission.

2015 highlights:

Federal Executive Branch

- Following recognition of EPRI's contributions to the U.S. Department of Energy's Quadrennial Energy Review, and Quadrennial Technology Review—both issued in 2015—EPRI initiated outreach to the department regarding its second installment: QER 1.2, scheduled for publication in Q4 2016.
- EPRI briefed several agencies, including the U.S. State Department, EPA, CEQ, and DOE, on its International Assessment of Greenhouse Gas Emissions pledges, in anticipation of COP21.
- Rob Manning and Barbara Tyran briefed FERC Chairman Norman Bay and staff on EPRI's research portfolio, including HVDC, cyber security, and reliability.
- Ron Schoff presented the Integrated Grid at the DOE Energy Information Administration Annual Conference.

Congress

- Mike Howard testified before the U.S. Senate Committee on Energy and Natural Resources on EPRI's Integrated Grid.
- Rich Lordan testified before House Science Subcommittees on Energy and Oversight on "Examining Vulnerabilities of America's Power Supply", primarily focused on geomagnetic disturbances and electromagnetic pulse.
- Annabelle Lee testified before House Science Subcommittees on Energy and Research & Technology on cybersecurity for power systems.
- Mike Howard briefed House Grid Innovation Caucus staff on the Integrated Grid.

National Association of Regulatory Utility Commissioners (NARUC) Conferences

- Mike Howard launched EPRI's *Integrated Grid Benefit-Cost Framework* at the February NARUC Conference.
- Mike Howard, Ben York, and Barbara Tyran provided nationwide briefing to state commissioners/staff on the *Integrated Grid Benefit-Cost Framework*.
- NARUC Board of Directors approved a resolution commending EPRI's Integrated Grid technical analyses and communications outreach.





- Jessica Fox briefed NARUC/state public utility commission staffs on sustainability and provided an update to the NARUC Water Committee on EPRI's Water Quality Trading program.
- Integrated Grid presentations were delivered at all five regional conferences: MACRUC (Mark McGranaghan); SEARUC (Mark Duvall); NECPUC (Barbara Tyran); MARC (Bernie Neenan relative to demand response), Clark Gellings (relative to distributed generation); WCPSC (Hank Courtright).
- Three state commissions Integrated Grid briefings: Wisconsin (Ben York and Barbara Tyran); North Carolina (Ron Schoff and Barbara Tyran); Pennsylvania ("Post-COP21 International/U.S. Clean Power Plan Implications, Electric Sector's Role in Economy-wide Emission Reductions, 21st Century Technologies") (Anda Ray and Barbara Tyran).

International Outreach – Key Presentations

- Arshad Mansoor – "Integrated Grid" to Global Sustainable Electricity Partnership (GSEP).
- Hank Courtright – "Encouraging Innovations in Energy Markets" at World Forum on Energy Regulation; "Consumer Behavior: Lessons from the U.S." at CEER Customer Conference.
- Barbara Tyran – "Integrated Grid" at Canadian Association of Members of Public Utility Tribunals (CAMPUT).
- Acher Mosse – "Energy Storage Technologies" to GSEP working group.

State Government Outreach – Key Presentations

- Anda Ray – "Challenges and Opportunities for Electric Industries in the 21st Century" at Kentucky Governor's Energy Conference.
- Integrated Grid to: Council of State Governments, Montana State Senate Energy Committee, state stakeholders (Barbara Tyran); National Governors Association Energy Policy Institute (Ron Schoff); Legislative Energy Horizon Institute, PNWER (Robin Bedilion); National Conference of State Legislators Annual Legislative Summit (Jeff Roark); Kentucky Distributed Energy Workshop (Ben Kaun).

Energy Stakeholder Outreach – Key Presentations

- Mike Howard – EPRI's *Integrated Grid Benefit-Cost Framework* at USEA Annual State of the Energy Industry Forum.
- Mike Howard – "Advancing Energy Technologies" jointly with ARPA-E Director Ellen Williams at ICF Energy Briefing Series.
- Mike Howard and Mark Duvall participated in EPRI-NRDC National Press Club event to release joint report *Environmental Assessment of a*

Full Electric Transportation Portfolio.

- Mike Howard – "Integrated Grid" Update at EEI CEO Conference.
- Arshad Mansoor – "Integrated Grid" at EEI Convention.
- Rob Chapman – "Integrated Grid" at IBEW Annual Conference.
- David Porter – "Integrated Grid" at APPA National Conference.
- Barbara Tyran – "Evolving Distribution Systems" at Center for Public Utilities Current Issues Conference.
- Mark McGranaghan – "Integrated Grid and IT" at IEEE PES General Meeting.
- Omar Siddiqui – two Alliance to Save Energy events: 1) Energy Efficiency Technologies at EE Global Forum; 2) Energy Efficiency at Energy 2030 on the Road.
- Bill Gould – "Integrated Grid" to Mid-Atlantic Distributed Resources Initiative (MADRI).
- Barbara Tyran – "Integrated Grid" at Public Utilities Fortnightly conference at National Press Club.

Association of State Energy Research and Technology Transfer Institutes (ASERTTI)

- Barbara Tyran served as Vice President-Research on ASERTTI's Board of Directors and coordinated an EPRI presentation on advanced manufacturing.

National Association of State Energy Officials (NASEO)

- Barbara Tyran was Co-Chair of NASEO Affiliates, and presented "Integrated Grid" at NASEO Energy Policy Outlook Conference.
- Galen Rasche presented "IT Security and Privacy in an Interconnected, Intelligent Efficiency World" at the NASEO fall meeting.
- Barbara Tyran provided electric transportation briefing at the NASEO Western Conference.

Other State Affiliations

- Barbara Tyran served on Advisory Council: 1) Center for Public Utilities, Santa Fe, NM; 2) Maryland Clean Energy Center.



Media Relations and Outreach to the Public Benefit



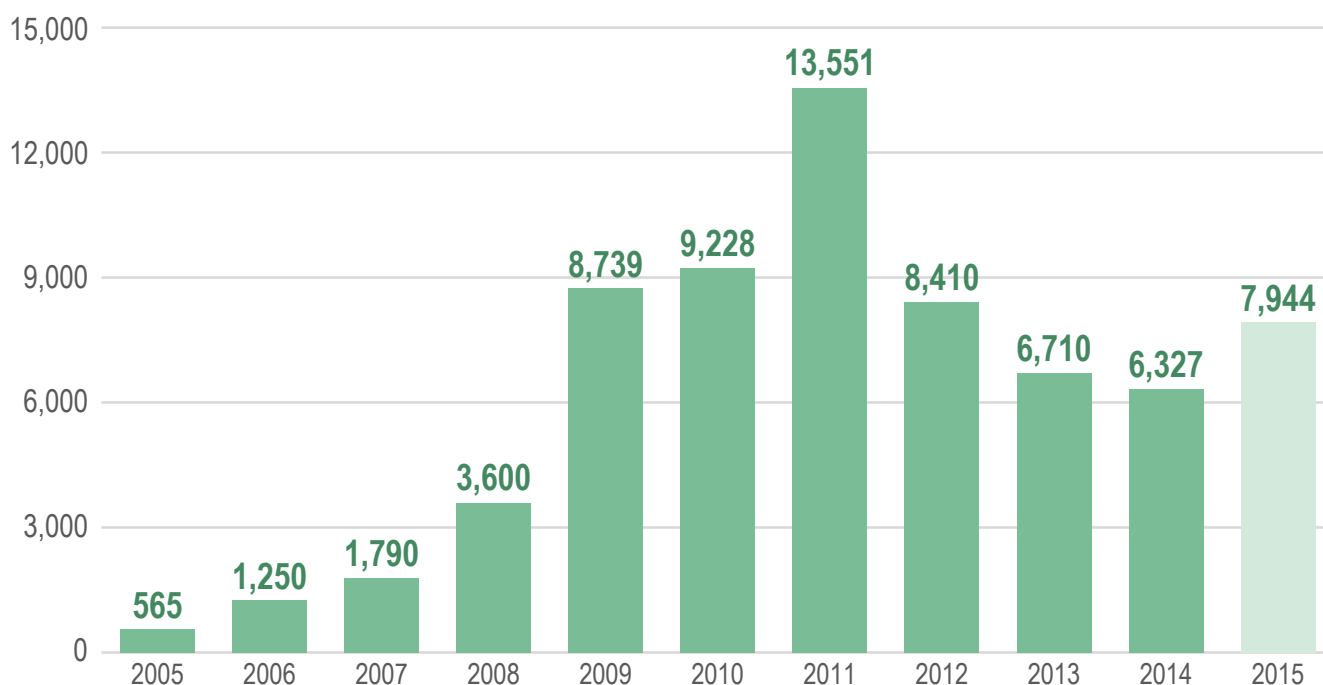
Mass media are critical to EPRI in informing the public, regulators, governments, and other stakeholders about key research and industry issues. Success of EPRI's media outreach and engagement can be measured by coverage of diverse issues spanning EPRI's research portfolio. EPRI research and experts are frequently cited or referenced in newspapers, technical journals, magazines, and broadcast outlets. This results from the effective working relationships of the media relations team with organizations that value EPRI's objective, scientific, and technical information.

EPRI Media Relations maintains strong working relationships with high-impact energy and science reporters at *The Wall Street Journal*, *The New York Times*, *EnergyBiz*, *Associated Press*, *NPR*, *Energy Daily*, *MIT Technology Review*, *CleanTechnica*, *Wall Street Journal*, and *IEEE Spectrum*, among others. In 2015, Media Relations issued 25 press releases and advisories; 12 EPRI Communications Spotlights, a monthly compilation of key media hits and social media metrics; 29 white papers and public reports; conducted 32 in-person informational briefings with EPRI researchers and executives; facilitated about 279 individual interviews; and hosted or co-hosted 5 national media conference calls. More than 113 papers and background information were distributed in response to media requests.

Our 2015 Numbers: EPRI's media hits reached 7,944, up 26% from 2014's 6,327. Our 2015 results represented a three-year high, with

Media Relations by the Numbers

Number of News Clips Per Year



significant traction from the Integrated Grid work, the EPRI-NRDC report, battery storage, nuclear plant operations, physical grid and cyber security protection, and the Clean Power Plan. A good deal of the coverage was driven by officer and staff engagement with international media in the European Union, Asia, and Southern Africa. Our international hits reached 20.55%, compared with 9%—a 120% year-over-year increase.

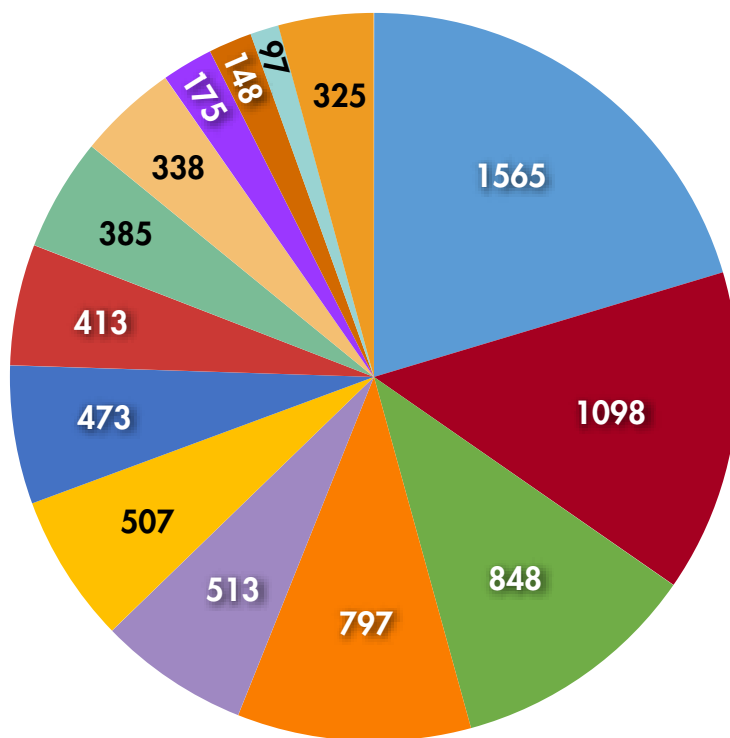
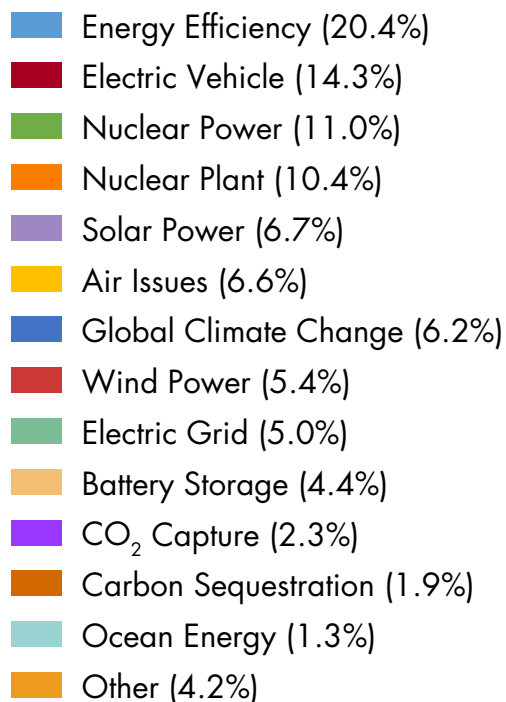
Hot Issues: The “Hot Issues” category compiles EPRI mentions, citations, and quotes in media as they relate to key industry issues. “Energy Efficiency (EE)” accounted for about one-fifth of EPRI’s 2015 media hits. This broad category includes topics such as improving the heat rate in fossil generation, variable-speed motor drives, programmable thermostats, and the impact of building code efficiency standards in lowering demand. “Electric Vehicle” results (14.3%) were driven by the impact EVs may have on a more integrated grid and by the EPRI-NRDC Report on the environmental impact of widespread adoption of electric transportation; “Nuclear Power/Nuclear Plant” (at 21.4%) was pushed by EPRI’s long-term operations and decommissioning involvement at Fukushima and San Onofre generating stations; The “Electric Grid” (5.0%) was heavily driven by the Integrated Grid work, especially related to renewables and the grid; and coverage of “Solar



EPRI’s Annabelle Lee discussing efforts to address cyberthreats facing E.U. countries (E&E TV)

The Hot Issues in 2015

January 1 – December 31



The logo for ScienceDaily, with "Science" in blue and "Daily" in brown.The logo for Forbes, in a large, bold, black serif font.The logo for greentechmedia:, with "greentech" in black and "media:" in green.

Power", "Air Issues", "Global Climate Change" and "Wind Power" (25%). Coverage of these issues was influenced by the COP21 in Paris and the Clean Power Plan.

Following are examples of EPRI's contributions to the "Hot Issues" in the industry (medium, headline, and summary):

Energy Efficiency

- *Science Daily* – "Thin Coating on Condensers Could Make Power Plants More Efficient" – The improvement in condenser heat transfer could lead to an overall improvement in power plant efficiency of 2% to 3%, enough to make a significant dent in global carbon emissions.
- *Forbes* – "This Earth Day Let's Start Using Analytics to Conserve Energy" – EPRI estimates the average energy bill will jump by 400% by 2050 if smart grids aren't deployed.

Electric Vehicles

- *Forbes* – "Why the Rise in Electric Cars and a Cleaner Grid is a Good Thing" – EPRI and NRDC report shows why electric cars and renewable energy generation will benefit the environment.
- *CNN* – "About Greener Driving" – A broadcast segment focused on the air quality impact of electric vehicles.

Electric Grid

- *Public Utilities Fortnightly* – "Getting Smart About the Integrated Grid" – A detailed commentary that makes the case for EPRI's Integrated Grid.
- *Greentech Media* – "Beyond Energy: Making the Distributed Grid Capacity Efficient"— This story examined EPRI's energy versus capacity concept.
- *NRDC Switchboard* – "A New Tool to Assess the Cost and Benefits of Distributed Energy" – This article was based on EPRI's assessment of the value of DER related to the Integrated Grid.
- *E&E News* – "Technology—A Missing Building Block in the Clean Power Plan" – This article examined EPRI's assessment of the impact of the Clean Power Plan on the industry.

Nuclear Plant/Nuclear Power

- *CNBC* – "No More Nukes? How About 80 Years of Them" – The network examined EPRI's role in looking at the viability of extending nuclear plant operating licenses out to 80 years.
- *Forbes* – "Who Says Nuclear Can't Smooth Out Erratic Wind?" The magazine looked at EPRI's work on flexible operations of nuclear plants.

- *Los Angeles Times* – “Edison Looks Into Best Dry Storage Options for San Onofre Nuclear Waste.” The newspaper cited EPRI’s assessment of the integrity of spent fuel canisters.

Solar Power

- *MIT Technology Review* – “Solar Thermal Power Heats Up Outside the US” – EPRI foresees a decline in the cost of solar thermal.
- *The New York Times* – “David Crane Leaves NRG” – Anda Ray comments on the utility business model.
- *Yahoo Finance* – “EPRI to Lead Research to Maximize Solar and Energy Storage Integration.” This article focused on EPRI research to facilitate integrating renewables onto the grid.

Global Climate Change

- *United Nations Association–UK* – “The New Power Generation 2020” – This was an EPRI commentary about the future of the global generation portfolio.
- *Forbes* – “How a Global Carbon Price is Slipping Through the Back Door” – This article covered EPRI’s idea of a global carbon trading market that was presented in the Paris climate talks.
- *Huffington Post* – “Tough Issues Linger in New Climate Deal Draft” – This story explained the difficulty in implementing an international carbon trading regime proposed by EPRI at the Paris climate talks.

Battery Storage

- *CleanTechnica* – “Energy Storage at an Inflection Point” – This article explored utility-scale storage and the California mandate, and sought an assessment by EPRI.
- *The Wall Street Journal* – “Will Homeowners Shell Out Thousands for Tesla Battery?” The Journal sought EPRI’s expertise to answer this question.
- *CNBC* – “Tesla’s New Bet – A Home Battery to Slash Energy Costs” – EPRI projects a payback period for wall-mounted battery.

EPRI officers played a visible and valuable role in public outreach about our research activities, either by contributing commentaries to publications or by sharing their expertise in media interviews. Among officer contributions were:

During 2015, 65 EPRI employees participated in media interviews as primary or secondary sources of information, providing scientific or technical information in the development of news stories.

EPRI’s media relationships and reputation continue to be reflected in its credibility and coverage. Indicative of EPRI’s credibility in the media is

Los Angeles Times

**MIT
Technology
Review**

The New York Times

**YAHOO!
FINANCE**



THE HUFFINGTON POST

**Clean
Technica**

THE WALL STREET JOURNAL.

The following section summarizes key EPRI research initiatives in 2015.

Environment

International Climate Policy: EPRI participated in the United Nations Framework Convention on Climate Change (UNFCCC) 21st session of the Conference of the Parties (COP21), held from November 30 to December 11, 2015, in Paris. Three sessions showcased EPRI research and expertise, continuing its long history of involvement in international climate policy. EPRI's presence included an official side event on market mechanisms co-hosted with the Nicholas Institute at Duke University and the International Emissions Trading Association (IETA). The Paris negotiations and domestic policies set the stage for decisions where nations and states decided whether to link with other jurisdictions. This event explored the value and challenges of bilateral and multilateral market mechanisms with new analyses, perspectives, and lessons on implementation. EPRI experts also covered the social cost of carbon (SCC), a monetary estimate of the climate change damages to society from an additional unit of CO₂ emissions. Despite their use in policy to value CO₂ reductions, SCC estimates are difficult to interpret and evaluate. This session offered an in-depth look into the state of current modeling and understanding of potential damages, identifying issues and opportunities relevant to public discussion and future climate research and application. The third session covered international emissions trading markets. Given the scope of the climate challenge, it is important to look beyond economic sectors, national borders, and the near-term to explore potential policy designs and identify measures that could reduce mitigation costs. In addition to considering potential emissions consequences of pledges, session participants explored potential opportunities for international partnerships for emissions trading, characterizing those opportunities, and examining the implications and benefits for society.

ENV-Vision (Environmental Vision – International Electricity Sector Conference): Environmental issues facing the electricity sector are changing as rapidly as the dynamic global economy and evolving regulatory policy. There is an urgent need to anticipate future environmental challenges, identify major science and technology gaps, and design a research approach to enable sustainable and cost-effective solutions to those challenges. The first ENV-Vision Conference was held in 2015 to comprehensively focus on existing and emerging environmental challenges in the electricity sector. There were about 240 attendees at the conference, which attracted leaders, managers, and researchers to promote discussions on electricity sector environmental research and information needs and develop a vision for future electricity

Public Benefit Derived From EPRI's Technology R&D Programs





sector environmental research. The second edition of the conference will build on this success and continue enabling high-level discussions on current and future environmental challenges facing the electricity sector, identifying knowledge gaps, and defining research needed to solve those challenges. The 2016 conference will be held Tuesday, May 10, 2016 – Wednesday, May 11, 2016, at The Watergate Hotel in Washington, DC.

State-Specific Analysis and Research on the Clean Power Plan: The Clean Power Plan, combined with the final regulations on new fossil generation, are expected to significantly alter the mix of assets that generate, transmit, and use electric energy. Billions of dollars are at stake in capital investment and operating costs needed for compliance. The Clean Power Plan holds states responsible for creating implementation plans and provides an array of choices for these plans. These choices set the fundamental structure of the state response (rate-based vs. mass-based greenhouse gas reduction pathways), determine ease of access to cost-saving markets with other states, and impact the likelihood of federal approval of state plans. As the states develop and implement their respective compliance strategies, EPRI is providing comprehensive analyses of how the rules impact the power sector at state and regional levels. EPRI's state-specific analysis identifies and evaluates the key issues relating to state plans while providing a deep understanding of the trade-offs for the state's alternative compliance pathways to better inform compliance policy dialogues. On February 9, 2016, the U.S. Supreme Court temporally halted implementation of the Clean Power Plan. While this "stay" remains in effect, EPRI will continue to evaluate the economic and system impacts of the Clean Power Plan, possible associated modifications to the rule, and any new proposed policies related to greenhouse gas mitigation. EPRI's ongoing research, in this area, will continue to focus on evaluating the cost-effective approaches to reducing GHG, including the effects of GHG policies on the consumer, the economy, and the power sector.

Endangered and Protected Species Research: Federal wildlife agencies have committed to clear lengthy backlogs of candidate species for listing as threatened or endangered, and the electric power industry, with assets that literally crisscross the country, has deep interests in ensuring that listing decisions are scientifically sound. In response, EPRI is working with the industry and regulators to develop constructive, collaborative approaches to collecting scientific data and advancing research on at-risk species and their habitats. In 2015, EPRI launched a new Endangered and Protected Species Research Program, which has been extremely popular across the industry. This area poses potential risk and cost to the industry with more than 251 potential new listings of

endangered species in 2016 and more than 600 being evaluated. This program develops forward-looking, in-depth studies of methodologies, ecological/spatial models, regulatory developments, and economic implications at the intersection of electric power company (and other commercial) activities and endangered and protected species. Candidate Conservation Agreements with Assurances (CCAAs) are one approach EPRI is evaluating. These negotiated agreements may preclude the need for formal listing, and lower the costs for species' protection, by creating plans to manage an ecosystem to benefit multiple species. A key goal of EPRI's work is development of a collaborative forum in which federal agencies and stakeholders can discuss the critical challenges and opportunities for cooperative actions before listing decisions are made. Workshops have been held with federal officials, helping EPRI identify areas where research can provide the scientific data federal agencies need for their decisions.

Air Quality Regulatory Benefits Assessment Tools Evaluation: EPRI has been conducting research to optimize benefits assessment tools for several years, with the research primarily centered on the Environmental Protection Agency's (EPA's) Benefits Mapping and Analysis Program (BenMAP), the tool most commonly used by the EPA to assess air quality regulatory benefits. Regulatory impact analyses (RIAs) are performed for any proposed EPA regulation that sets limits for air pollutants. RIAs consider both the costs to comply with a proposed standard and the public health benefits gained by compliance. To ensure that cost and benefit assessments of proposed regulations are based on sound science, it is critical that analytic tools employed reflect both the full spectrum of scientific knowledge and the scientific uncertainties around that knowledge. When EPRI examined BenMAP, researchers found it was based on just a few studies and did not adequately account for uncertainties. EPRI's research explored ways to improve the tool and obtain more scientifically sound results, giving the EPA additional information to draw upon in its rule makings and analytic processes. The research was effectively used in official comments to the EPA on various rule makings. This use helps communicate the need for better informed, science-driven improvements to benefit analyses of air quality rule making and standards, and the EPA is engaged with EPRI about ways to improve these assessments.

Generation

Water Management Technologies: Demands to supply water to a growing population are increasing worldwide and are having profound impacts on the use of limited water resources. The electric power industry requires large amounts of water and is frequently subject to





water shortages. It also discharges water that is no longer usable within the power plant, and needs to be able to comply with a wide range of global regulations on discharge limits and for improving water utilization for electricity generation. EPRI's Water Management Technology program identifies, evaluates, and demonstrates cost-effective and reliable treatment technologies. It also evaluates the performance, operability, reliability, and cost of advanced cooling technologies designed to reduce water withdrawal and consumption while minimizing the impact on plant thermal efficiency. Some of the research in both areas is conducted at the Water Research Center (WRC) at Georgia Power's Plant Barry. In 2012, a 14-member EPRI collaborative worked with Southern Company, Georgia Power, and Southern Research (SR) to develop the WRC, which provides generating companies, research organizations, and vendors access to full-scale infrastructure, treatable water, monitoring and analysis facilities, and specialized staff to research advanced cooling water technologies, biological and inorganic wastewater treatments, zero-liquid-discharge options, solid landfill water management, and water conservation.

Flexible Operations: The operating missions of traditional baseload generating units are rapidly changing. They are now being operated more flexibly for load following, low-load operations, rapid ramping, peaking, and more frequent reserve shutdowns. EPRI is working to address a number of challenges related to these new missions — turndown strategies for outputs well below previously established minimums; minimizing emissions controls impacts of low-load operations; boiler impacts of low-load operations; and new plant designs that increase operating flexibility and minimize cycling damage. EPRI also is investigating advanced controls, revised operating procedures, designs, and chemistries to mitigate negative reliability impacts while maintaining environmental compliance for coal and gas units. As part of that R&D, EPRI has established a Missions Profiles Working Group and has conducted a series of comprehensive “deep dives” into technical issues experienced by central-station generation units operating under new missions, helping EPRI and participating companies establish a holistic, prioritized knowledge base of technical issues. This is the starting point for an industry-wide resource for managing the impacts of these new operating modes. EPRI also has led multiple demonstration projects at member coal-fired plants that have significantly advanced understanding of the impacts and boundaries of operating environmental control systems — such as selective catalytic reduction (SCR) — at significantly lower loads than originally designed. This is forecast to save on the order of \$1 million at a single plant via the avoidance of unit startup costs, as well as minimizing power generated at a loss during slack demand periods.

And lower emissions will result from the ability to operate the SCR NO_x (nitrogen oxide) reduction system over a broader load range, which in turn makes easier the transition from coal-fired to reduced-carbon technologies.

Renewable Generation: Renewable energy is fundamentally changing the electricity industry's strategic landscape. Industry engagement in development and deployment of renewable energy for power generation has increased significantly, but over the long term, renewable energy investment will depend on the ability of assets to operate cost-effectively without mandates or subsidies. Targeted research is necessary to advance technologies that reduce the cost of renewable generation and improve overall reliability. EPRI's large-scale renewable generation R&D includes a new and expanded focus on hydropower, with increased focus on operations and maintenance, as well as wind and solar technologies. Two key EPRI R&D centers are the Solar Technology Acceleration Center (SolarTAC) in Aurora, Colo., a venue to collaboratively test, validate, and demonstrate advanced solar energy technologies and products, and the Southeastern Solar Research Center (SSRC) at Southern Research (SR) in Birmingham, Ala. EPRI is conducting evaluations at SolarTAC focused on independent field testing and performance assessment of innovative solar photovoltaic (PV) technologies. These offer the potential for dramatically lowering the cost of electricity. Multiple PV system R&D projects, ranging from tracking and orientation and equipment aging to automatic panel cleaning, also are underway at the SSRC, a facility developed by the Southern Company, its subsidiary Alabama Power, SR, and EPRI to evaluate the performance and operating characteristics of PV systems in the high heat, high humidity, high precipitation and high pollen environment typical of the Southeastern U.S. The SSRC includes multiple configurations of PV solar panel arrays, microinverters, and advanced energy-monitoring systems. EPRI also has explored the potential benefits of unmanned aerial systems (UAS, more commonly known as drones) for PV O&M applications; the results are available in *Utilizing Unmanned Aerial Systems as a PV O&M Tool* (EPRI document [3002006216](#)).

Improved Materials and Repairs: The Generation Sector's materials program conducted a large R&D project which found improved component repair performance was possible through elimination and/or reduction of post-weld heat-treatment (PWHT), combined with a novel step design process. The industry has implemented these research findings through new National Board Inspection Code (NBIC) rules for repair of tubing, group qualifications, and internal welding procedures. These new, innovative welding methods are more valuable for the significant reductions in time required for repairs. The cost savings by the first two





early utility adopters is estimated at more than \$1 million on the basis of the time saving alone. As utilities experience more damage due to cyclic operation of high-temperature components in flexible modes, these rapid repair technologies are becoming increasingly critical to provide cost-effective reliability in fossil (both coal and gas) power generation.

Carbon Reductions and Advanced Power Cycles: Sustainability and greenhouse gas emissions regulations are driving changes in the global power industry, but fossil fuels will remain an important part of generation. EPRI is working to develop new methods for generating power from fossil fuels that are dramatically more efficient and have lower CO₂ emissions. That research includes a portfolio of advanced coal- and natural gas-based generation technologies, including Rankine cycles with steam temperatures exceeding 1200°F (650°C); closed Brayton cycles using CO₂ as the working fluid; integrated gasification combined cycles (IGCCs) based on gas turbines with firing temperatures exceeding 2700°F (1500°C); oxygen-blown combustion processes (for pulverized coal [PC]); circulating fluidized-bed combustion and gas turbine combined-cycle units; and power generation concepts based on chemical looping and fuel cells. EPRI recently published a white paper, *Can Future Coal Power Plants Meet CO₂ Emission Standards Without Carbon Capture and Storage* (EPRI report [3002006770](#)), which examines the potential contributions of many advanced power technologies for carbon emission reductions. And, EPRI managed the successful 14-year U.S. Department of Energy/Ohio Coal Development Office industry collaborative project to develop materials to allow Rankine cycles to operate at temperatures up to 1400°F – an important R&D accomplishment. Among the expected benefits are a three to four percentage-point increase in thermal efficiencies of steam Rankine cycle power plants (resulting in reduced CO₂ emissions), advanced implementation of closed Brayton cycles with supercritical CO₂ (enabling even greater efficiency improvements and applicable to advanced nuclear cycles), and use of thinner steam piping, which should allow for more rapid ramping of power plants.

Advanced Sensors: Tube failures in heat recovery steam generators (HRSGs) is a primary cause of lost combined-cycle plant availability. Generation research has successfully demonstrated application of acoustic emission technology for determining if water or steam was flowing in certain parts of HRSGs in combined-cycle power plants. This application and the related work on design modifications is expected to provide substantial cost savings (installation is projected to cost less than \$100,000 per plant, compared to more than \$1 million for conventional solutions in the more than 2,400 HRSGs in operation worldwide) by

eliminating condensate flow tube failures and/or expensive controls and retrofits. This project was featured in an EPRI Journal [article](#).

Power Delivery and Utilization

The Integrated Grid Initiative: In early 2015 EPRI released the Integrated Grid Benefit-Cost Framework, which assessed the economics of integrated grid investments related to the integration of distributed energy resources (DER).

EPRI also developed analytic tools to help utilities identify the optimal path for integrating DER into the grid, including: an Integrated Modeling Requirements Tool; an Energy Storage Valuation Tool (ESVT); and, the streamlined hosting capacity tool.

EPRI then launched a series of Integrated Grid pilot projects that were aimed at assessing DER technologies, and how to optimally integrate them into the grid. The project spans six areas, including:

- Utility-Scale Solar: Explores ways to integrate utility-scale solar photovoltaic (PV) and the resultant benefits and costs.
- Utility-Scale Solar with Energy Storage: Evaluates the integration, benefits, and costs of utility-scale solar with energy storage.
- Distributed Energy Storage: Assesses options to integrate distributed energy storage and evaluates the associated benefits and costs.
- Microgrids: Explores a variety of microgrid integration options along with resultant benefits and costs.
- Electric Vehicle (EV) Charging Infrastructure: Evaluates the integration, benefits, and costs of EV charging infrastructure.
- Customer-Side Technologies: Assesses approaches for integration of customer-side technologies.

More than a dozen utilities across the United States committed to host a pilot project.

Electric Vehicles and Public Impact: EPRI and the Natural Resources Defense Council (NRDC) completed a report on the value of electric transportation in improving air quality and achieving emission goals. The report found that widespread adoption of electric transportation, including electrification in the off-road sector, could lead to substantial reductions in greenhouse gas (GHG) emissions and could improve air quality.

The report, *Environmental Assessment of a Full Electric Transportation Portfolio*, (EPRI report [3002006881](#)) projects GHG emissions through 2050 and air quality impacts in 2030. It found that GHG emissions from light-duty vehicles could drop as much as 64% below today's





levels. Widespread use of electric vehicles (EVs)—including lawn and garden equipment and heavy industrial equipment such as forklifts—could improve air quality, particularly in densely populated urban areas.

Use of electric vehicles would achieve greater reductions in GHG emissions, corresponding to the rate that the electric grid becomes cleaner, through greater reliance on renewables and low- and non-emitting generation.

Transmission and Substations Research: EPRI's Transmission and Substations team (T&S) completed its Vegetation Management Clearance guidelines for the North American Electric Reliability Corporation (NERC) (EPRI report [3002006078](#)). These guidelines help transmission operators and planners understand how much foliage can be in proximity to transmission lines or towers. T&S continues to build on experience in asset performance through an international asset performance database. This asset management program now provides specific asset guidance across the industry. Work continues to expand resiliency performance in areas such as physical and cyber security, weather hardening, and high-impact, low-frequency threats.

Grid Operations and Planning: The transmission Grid Operations and Planning team completed analyses and recommendations for fault ride-through performance of distributed energy resources, which serves as part of the foundation for the IEEE standard for future interconnection requirements. As more inverter-based distributed generation such as solar PV and energy storage comes online, these standards will be necessary to ensure these distributed resources contribute to overall system reliability. The Grid Operations and Planning team continues to refine DER integration models and analysis methods for deriving the maximum benefits of DER on both transmission and distribution systems. Grid Operations and Planning also provided industry-wide guidance on planning for geomagnetic disturbances, ensuring faster system restoration after disturbances, and continued to refine system protection tools and applications.

Distribution Grid Resiliency: The increased frequency and severity of recent storms has focused national attention on the need to enhance the resiliency of the distribution system from downed power lines to transformer damage. In 2015 EPRI completed a three-year, multi-deliverables research project on distribution grid resiliency (DGR) to help utilities determine the best improvements for enhancing the resiliency of distribution systems to enable more rapid recovery during extreme weather or man-made events.

Information and Communications Technology (ICT): The ICT program provides members with near-term results that can provide immediate value as well as longer-term research that realizes the vision of a highly integrated, interoperable electrical system.

The program conducts R&D in the following areas:

- Interoperability
- Data integration and management
- Telecommunications
- Enterprise architecture
- IT/OT convergence
- Business value of ICT
- Distributed intelligence
- Connected workforce

In November, the ICT program published its R&D Roadmap (EPRI report [3002006885](#)), which provides the strategic direction and research activities that the program will perform over the next four years. The Roadmap is a valuable tool for ICT program advisors because it communicates a vision for the future and identifies gaps that exist in realizing that vision.

Cyber Protection: Cyber security has become a critical priority for electric utilities. The evolving electric sector is increasingly dependent on information technology and telecommunications infrastructures to ensure the reliability and security of the electric grid. Cyber security measures must be designed and implemented to protect the electrical grid from attacks by nation-states and hackers. Cyber security also supports the grid's resiliency against natural disasters and inadvertent threats such as equipment failures and user errors.

(EPRI's) Cyber Security and Privacy Program addresses the emerging threats to an interconnected electric system through collaborative research on cyber security technology, standards, and business processes to protect the electric grid.

Ongoing program activities include:

- Security management and protection technology for power delivery systems
- Threat management for power delivery systems
- Methodologies for assessing and monitoring risk
- Metrics to support the risk assessment activities
- Improving security architecture methodologies





Nuclear

Frequency-Scanning Eddy Current Technique (F-SECT): To ensure adequate margins exist that support nuclear fuel operability and integrity, as well as address new regulations, technologies are being developed for plant operators that allow margins to be assessed on-site as opposed to time consuming and costly measurements at specialized off-site facilities. One such technology is EPRI's Frequency-Scanning Eddy Current Technique (F-SECT) which has been demonstrated at two nuclear plants and is near full commercialization. This technology is capable of measuring corrosion of fuel components and how much hydrogen has been absorbed by them.

Response to Li-7 Supply Issues: Western-style pressurized water reactors (those based on Westinghouse, Babcock and Wilcox, and Combustion Engineering designs) utilize lithium hydroxide (enriched in Li-7 to reduce tritium production) to control at-temperature pH at slightly alkaline conditions and to meet "shall" elements of the EPRI Pressurized Water Reactor (PWR) Primary Water Chemistry Guidelines (EPRI report [3002000505](#)). Ultimately this element supports management of materials reliability, fuel reliability, and reducing radiation fields. In 2015, several utilities in the US and abroad encountered difficulties in procuring Li-7 due to production issues. With the support of the United States Department of Energy and EPRI Emerging Issues funding, EPRI also initiated work on new technology to recover Li-7 from spent water purification resin. EPRI also initiated work to identify technical gaps associated with moving to potassium hydroxide for at-temperature pH control rather than Li-7 enriched lithium hydroxide.

Nuclear Power Plant Transformer Vulnerability: A vulnerability (known as the "Open Phase Issue") was identified with the large power transformers that provide electrical power to nuclear power plants. EPRI created an innovative and cost-effective solution that improves safe and reliable operation of the power plants. The solution was developed, and field tested through an EPRI cross-sector Nuclear and Power Delivery & Utilization initiative. The "Open Phase Issue" affects many nuclear and non-nuclear power plants worldwide. The open phase is often not noticeable through normal plant operation and not detectable by traditional methods yet can cause significant plant operational disruption and equipment damage. This solution provides a simple and cost-effective answer to the problem. The conservative cost benefit over other, less effective, industry solutions is \$1 million per power plant.

Cathodic Protection for Buried Assets at a Nuclear Power Plant: Buried pipe and tanks at nuclear power plants can be protected from corrosion

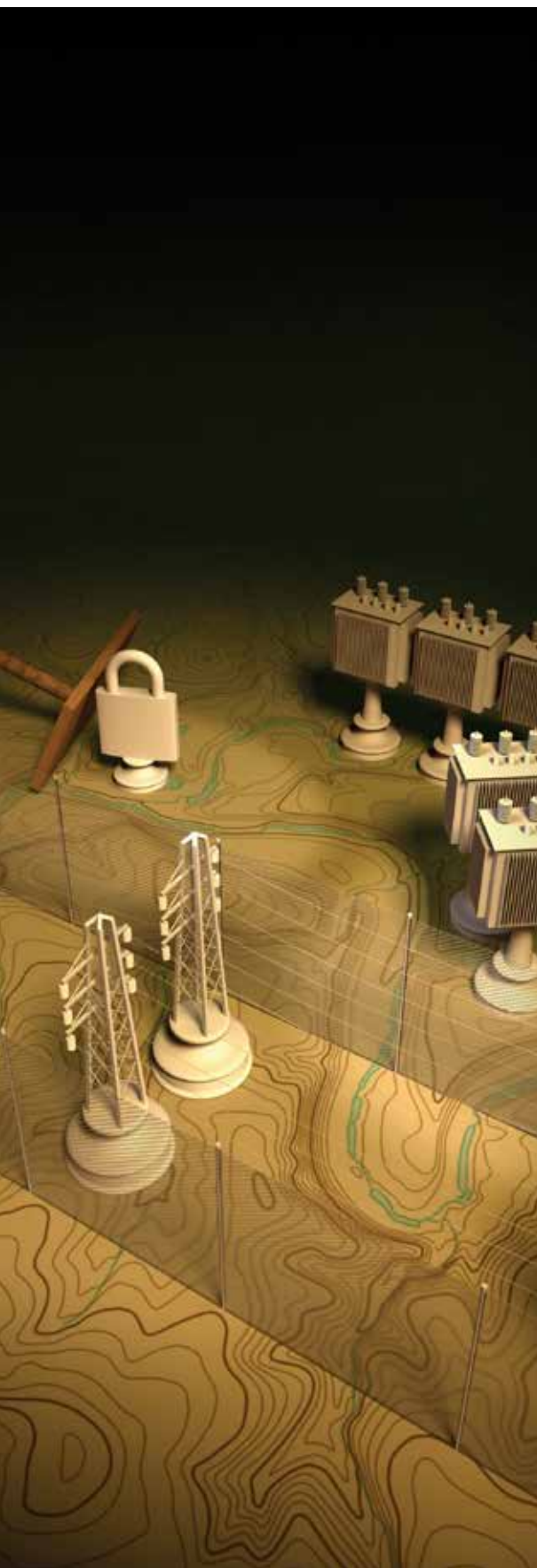
through cathodic protection. Unlike the straight, long runs of pipe in the oil and gas industry, the pipes at a nuclear power plant are close to other pipes, are in a spaghetti-like configuration, and may be attached to a copper grounding grid. As owner/operators look toward operating nuclear power plants longer, installing a cathodic protection system, upgrading an existing system, or identifying deficiencies in an existing system are key methods to cost effectively extend the life of the asset. EPRI developed a process that can be used to systematically establish an engineering basis for installing or upgrading cathodic protection of buried piping and tanks and for evaluating local plant areas that do not meet cathodic protection system acceptance criteria. Application of this process results in a well-engineered cathodic protection system that can protect the buried asset from corrosion and avoid pipe replacement and leaks that cost millions of dollars.

Improving the Characterization of Risk Information for Use in Decision-Making: EPRI has assembled a practical process to aid decision-makers using complex information relating to nuclear power plant risks, including how uncertainties shape understanding of those risks. See *An Approach to Risk Aggregation for Risk-Informed Decision-Making*, (EPRI report [3002003116](#)).

In response to challenges related to developing an appropriate perspective on the overall, or aggregate, risk of operating a nuclear power plant, EPRI has assembled a process to facilitate better understanding of quantitative estimates of risk and the insights that can be drawn from formal risk assessments. Because risk estimates inherently carry with them uncertainties, developing an appropriate understanding can be challenging. The EPRI process encompasses what are intended to be a framework and corresponding language that are more accessible for decision-makers who are not experts in the use of formal risk techniques. The process draws on the ability to consider multiple attributes, including elusive concepts such as inherent margins of safety and layers of protection (referred to as “defense in depth”). This process should support decisions that will lead to more effective allocation of resources available to improve nuclear safety.

High Burnup Fuel Demo: Nuclear plants have been shifting from lower burnup to higher burnup fuels in recent years, and continued research is needed to better understand the impacts, if any, of dry storage on high burnup fuel. EPRI is leading a multiyear research project through the U.S. Department of Energy to evaluate the safe storage of spent nuclear fuel in dry storage casks. EPRI is designing and implementing a test plan for a full-scale field assessment. The target date for loading fuel into the instrumented cask is mid-2017. EPRI is working with project participants





to complete fabrication of the modified cask that will allow monitoring over time through the period of loading and storage.

Circuit Cards: EPRI has developed technical guidance, called the “Gold Card,” for aging management of circuit cards. Analog circuit cards control virtually every significant safety-related and many non-safety-related systems in nuclear plants. However, the cards are subject to degradation from high temperatures, dust, humidity, bad power signals, and aging. EPRI initiated the Gold Card program in 2009 in response to an increase in circuit card failures across the nuclear power industry. EPRI collected knowledge about the circuit card components and developed guidance to prioritize cards, identify degradation mechanisms and failure risks, and appropriate handling and maintenance of cards. Since the publication of the Gold Card and adoption by the nuclear industry, there has been a dramatic decrease in critical circuit card failures.

Technology Innovation

A significant component of EPRI’s Technology Innovation (TI) program is providing thought leadership to the industry. A number of recently released, public white papers explore topics relevant to the issues the power industry expects to face and what should be considered today to prepare for a transformed future power system. TI is also leading EPRI’s engagement with the U.S. Department of Energy with the Incubatenergy Network to foster collaboration among entrepreneurs and identify promising new technologies.

Electric Power System Flexibility: Power system flexibility is the ability to adapt to dynamic conditions, and to provide affordable electricity while operating safely, reliably, and sustainably. What is driving the need for increased flexibility? Variable generation, such as wind and solar, uncertainty in fuel prices, changing consumer behavior and preferences that come with owning solar on the rooftop, plug-in electric vehicles in the garage, and smart appliances in the house.

EPRI’s white paper on flexibility describes innovative technologies that EPRI and electricity sector stakeholders are developing and applying to address these challenges. *Electric Power System Flexibility: Challenges and Opportunities* (EPRI report [3002007374](#)).

Electric Power System Connectivity: Connectivity becomes critical with the widespread deployment of communicating equipment that provides access to data streams and functionality that can inform decisions and behaviors, from the power plant to the consumer. Connectivity is instrumental in the grid’s transformation from a network providing one-

way power flow to one providing the interactive, two-way flow of power and information.

EPRI's white paper on connectivity shares challenges and opportunities in taking full advantage of emerging technology innovations to improve communication across the grid. *Electric Power System Connectivity: Challenges and Opportunities* (EPRI report [3002007375](#)).

Electric Power System Resiliency: In the context of the power system, resiliency describes hardening the system to withstand and to recover quickly from high-impact, low-frequency events that result in power system outages. For utilities, customers, and communities as a whole, extended outages have a range of impacts, including financial, health, and safety.

EPRI's white paper on resiliency examines the operational and technological aspects of grid resiliency and looks at innovations EPRI and others are developing to address the related challenges. *Electric Power System Resiliency: Challenges and Opportunities* (EPRI report [3002007376](#)).

The Integrated Grid: TI provided strategic and financial support for development of EPRI's *Integrated Grid Benefit-Cost Framework* white paper, which presents a transparent, consistent, four-part methodology for assessing the benefits and costs of transitioning to a more optimally integrated grid. This approach quantifies the impacts of distributed energy resources (DERs) on the interrelated distribution and bulk power systems, and monetizes these impacts to inform decision-making. As a result of the Integrated Grid Framework, EPRI's Power Delivery and Utilization team launched a series of pilot projects to dive deeper into researching DERs and supporting technology. The team is working with more than a dozen utilities, nationwide, to optimally integrate DERs into the system. *The Integrated Grid: A Benefit-Cost Framework* (EPRI report [3002004878](#)).

Incubatenergy Network: [The Incubatenergy Network](#) was launched in early 2015 with the U.S. National Renewable Energy Laboratory. EPRI is leading this effort with co-funding from the U.S. Department of Energy. The network connects leading clean energy incubators and related organizations to share best practices and expand collaboration in supporting entrepreneurs, advancing concepts to commercialization, and driving innovation in the electric sector and related industries. With more visibility on the startup companies being cultivated by Incubatenergy members, EPRI is identifying novel ideas that merit further exploration plus new technologies ready for field demonstration in energy production, delivery, storage, and utilization applications.



The Electric Power Research Institute, Inc. (EPRI, www.epri.com) conducts research and development relating to the generation, delivery and use of electricity for the benefit of the public. An independent, nonprofit organization, EPRI brings together its scientists and engineers as well as experts from academia and industry to help address challenges in electricity, including reliability, efficiency, affordability, health, safety and the environment. EPRI also provides technology, policy and economic analyses to drive long-range research and development planning, and supports research in emerging technologies. EPRI members represent 90% of the electric utility revenue in the United States with international participation in 35 countries. EPRI's principal offices and laboratories are located in Palo Alto, Calif.; Charlotte, N.C.; Knoxville, Tenn.; and Lenox, Mass.

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