

## **Electricity Technology in a Carbon-Constrained Future**

### **Questions and Answers**

**Q: Why did EPRI conduct this analysis?**

A: Given the growing interest in reducing greenhouse gas emissions in the U.S., EPRI undertook a technical analysis of the potential for significant CO<sub>2</sub> reductions from the U.S. electric power sector within the next 25 years.

**Q: What does your work show?**

A: Our analysis found that it is technically feasible to significantly reduce U.S. electric sector CO<sub>2</sub> emissions over the next 25 years through an accelerated investment in electric technology R&D and aggressive deployment of the resulting technologies.

**Q: Does this mean EPRI supports mandatory legislation to control CO<sub>2</sub> emissions?**

A: Our work is intended to inform the overall discussion on climate policy, but it does not support or oppose any particular approach.

**Q: How do your results compare to the goals of various legislative proposals in Congress?**

A: Our analysis showed that the technical potential exists for advanced electricity technologies to contribute to an overall effort to reduce U.S. greenhouse gas emissions on the scale comparable to that currently under discussion in Congress. However, we presumed the existence of several low-cost, low-carbon technology options that do not yet exist. EPRI believes this is an important aspect of climate policy that should be considered in any informed discussion.

**Q: Is there consensus in the electricity industry around the EPRI analysis?**

A: This analysis represents an assessment of the technical potential for reducing CO<sub>2</sub> emissions from the U.S. electricity sector. It does not represent consensus industry goals or targets.

**Q: Where did your technology deployment assumptions come from?**

A: We drew our assumptions from a variety of sources, including public-private technology roadmaps, observed penetration rates of existing energy technologies, and EPRI expert judgment.

**Q: How did you translate your technology assumptions to CO<sub>2</sub> reduction estimates?**

A: For energy efficiency, CO<sub>2</sub> emissions were reduced in proportion to the reduction in electricity consumption from the impacted sectors.

For renewables and nuclear, an equivalent amount of existing generation (with representative fuel mix and CO<sub>2</sub> emissions) was replaced with generation from these non-emitting sources.

For advanced coal, we calculated the reduction in coal use (and CO<sub>2</sub> emissions) resulting from replacing all new coal generation coming online in the EIA Base Case with advanced coal generation using our higher efficiency assumptions.

For carbon capture and storage, we reduced the CO<sub>2</sub> emissions from new plants coming online in the EIA Base Case by the amount of CO<sub>2</sub> they were assumed to capture and store.

For distributed energy resources, we computed the reduction in CO<sub>2</sub> emissions resulting from a displacement of existing generation (with fuel mix and CO<sub>2</sub> emissions as in the Base Case) with higher efficiency DER sources (e.g. combined heat-and-power units).

For plug-in hybrid vehicles, we used the CO<sub>2</sub> intensity of the modeled generation mix to calculate the emissions per mile of the PHEV operated in all-electric mode, and we added this to the CO<sub>2</sub> emissions per mile resulting from operations in gasoline-hybrid mode for the rest of the time. These were compared against the CO<sub>2</sub> emissions per mile for a standard light-duty vehicle in the EIA model, and then multiplied by number of PHEVs and miles traveled.

**Q: Can you apply this model to other sets of technology deployment assumptions?**

A: Our model is capable of looking at a wide range of technology deployment assumptions, and we welcome the opportunity to work with collaborators on analysis of other scenarios.

**Q: What CO<sub>2</sub> price do you assume in your model?**

A: We do not assume a specific CO<sub>2</sub> price. We have identified specific needs for research, development, deployment and demonstration of electric technologies that, if successful, would result in a low-cost, low-carbon portfolio of options with comparable economics.

**Q: Why didn't you consider (*economic, regulatory, policy*) factors? Aren't they important?**

A: This initial analysis is an evaluation of technical potential to reduce CO<sub>2</sub> emissions from the power sector. We are continuing to refine our analysis considering additional factors, such as economics, regulatory barriers, and potential policy drivers.

**Q: Who is going to pay for all of this technology development?**

A: To achieve these results, a significant amount of additional investment in electricity technology R&D will be required, mainly to demonstrate that emerging technologies in today's laboratories can work at a commercial scale. Some of this R&D funding can come from the Federal government, but some of it must also come from the private sector, particularly with respect to first-of-a-kind deployments of low-carbon or carbon-free electricity technologies.

**Q: Isn't your work just a rehash of existing work in this area, like the Princeton wedges?**

A: No. Unlike most "top-down" analyses of climate policy (such as the Princeton "wedges"), our work is a "bottoms-up" analysis of the technical potential for electric sector CO<sub>2</sub> reductions. Using EPRI's technical expertise, we made reasonable assumptions about the development and deployment of carbon-free technologies, and calculated the potential climate mitigation benefit.

**Q: Where can I get a copy of your work?**

A: We have posted a presentation of our work online at <http://www.epri.com>, and will post additional materials as appropriate and as our work evolves in the coming months.

**Q: Will you make your model public?**

A: We expect to publish these and related findings in the peer-reviewed literature, and welcome potential reviewers and collaborators in this ongoing effort.

### Energy Efficiency

**Q: What were the assumptions you used in calculating the contribution by energy efficiency?**

A: We assumed a 2% per year improvement in the energy efficiency of new residential, industrial, and commercial stock (buildings, appliances, etc.) coming online in the years 2007-2017. Over that same period, we also assumed that the entire existing residential, industrial and commercial stock was upgraded with an equivalent amount of energy efficiency.

**Q: How can the electric sector take credit for efficiency improvements made by end users?**

A: While consumers are ultimately responsible for deploying smart end-use devices, electric utilities can deploy advanced sensors and grid communications technologies that provide additional information to consumers to help them better manage their energy consumption and costs.

**Q: Why doesn't the total electric demand in 2030 change under your technology scenario?**

A: The reduction in electricity demand from energy efficiency and distributed energy resources (DER) are approximately offset by the increase in electric load from the increased sale of new plug-in hybrid vehicles (PHEVs).

### Renewable Energy

**Q: What were the assumptions you used in calculating the contribution by renewable energy?**

A: We assumed that investments in renewable energy will be sufficient to meet State-level Renewable Portfolio Standards (RPS) over the next 10 years, and then assumed that another 2 GW of renewables would be built each year thereafter, to a total of 70 GW by 2030.

**Q: How do you respond to those who say we can do it all with renewable energy?**

A: Once renewable energy becomes a significant fraction of electricity placed on the grid, a number of challenges arise related to intermittency, energy storage, and backup power. Unless these challenges are addressed, we will continue to require non-emitting sources of base load electricity to meet consumer demand.

### Nuclear Energy

**Q: What were the assumptions you used in calculating the contribution by nuclear energy?**

A: Following the technology roadmap developed by EPRI and the Idaho National Laboratory, we assumed that advances in materials science would allow the existing nuclear fleet to continue operating through 2030, and we further assumed that a new generation of advanced light-water reactors would start deploying in 2015, leading to 64 GW new nuclear capacity by 2030.

**Q: Can we really count on new reactor deployment given the impasse over Yucca Mountain?**

A: EPRI believes that any reasonable climate change policy must include a role for nuclear energy, and that doing so also means we must develop a viable strategy for managing spent nuclear fuel.

### Advanced Coal

**Q: What were the assumptions you used in calculating the contribution by advanced coal?**

A: Following the technology roadmap developed by EPRI and the Coal Utilization Research Council (CURC), we assume an increase in new plant efficiency from 38-40% in the EIA Base Case to approaching 49% by 2030. Over that same period, we also assumed that roughly half of the existing coal fleet (150 GW) will re-power to achieve the increased efficiency of new plants.

**Q: Given your assumptions on nuclear and renewables, aren't you significantly reducing the amount of coal being used in the future?**

A: No. Under our technology assumptions, coal retains nearly a 54% share in 2030, even with substantially increased amounts of nuclear and renewable generation. In fact, the amount of coal-based generation goes up in real terms, as electricity demand is expected to increase by 40% in the EIA Base Case. Presently, coal accounts for roughly 51% of today's electricity mix.

**Q: How realistic is your assumption of 150 GW of re-powered existing coal plants given the regulatory barriers to doing so, such as New Source Review (NSR)?**

A: Many of these existing plants will likely have to make significant modifications in order to continue operating under increasingly tight air pollution standards, and we believe that plant operators will find it economic to also improve their heat rates and CO<sub>2</sub> emissions performance in a carbon-constrained world, even with regulatory barriers to doing so.

### Carbon Capture and Storage (CCS)

**Q: What were the assumptions used in calculating the CO<sub>2</sub> capture and storage contribution?**

A: We assumed that pilot projects starting in 2015 would capture 20% of the CO<sub>2</sub> emitted by 20% of the new commercial-scale coal power plants coming online in that year. These fractions were increased steadily over each of the next five years to reach 90% of CO<sub>2</sub> from 90% of new coal-based power plants coming online in 2020 and each year thereafter. CO<sub>2</sub> emissions from these new plants were reduced by the appropriate amount.

**Q: Why is the CCS contribution so much greater than any of the other “slices”?**

A: The EIA Base Case adds nearly 100 GW of new coal-fired capacity between 2020 and 2030, and this represents more than half of the new generation capacity added over that time period. Given the relatively high carbon emissions intensity of coal-fired generation and the high capacity factor of these plants, CCS helps prevent a significant amount of CO<sub>2</sub> emissions.

**Q: Did you assume any retrofits of existing coal plants to capture and store their CO<sub>2</sub>?**

A: No. In most cases, the retrofit of an existing coal plant to capture and store CO<sub>2</sub> would involve significant re-engineering and construction costs that will likely be comparable to building a new coal plant with CCS from scratch. In addition, many existing plants do not have the available space within their footprint to allow for the addition of facilities for CO<sub>2</sub> capture.

**Q: Did you account for the efficiency losses associated with the capture and storage of CO<sub>2</sub>?**

A: Yes, these were factored into our calculation through higher heat rates and greater CO<sub>2</sub> emissions from the base plant. However, the capture and storage of significant amounts of CO<sub>2</sub> from each plant more than makes up for the increased emissions resulting from reduced efficiency.

### Distributed Energy Resources (DER)

**Q: What were the assumptions you used to calculate the contribution from DER?**

A: We assumed that in each of the next 20 years, an additional 0.25% of U.S. electricity consumption would be met with distributed energy resources, rather than grid-connected electricity, such that 5% of total demand is met in 2025 and thereafter through DER.

**Q: How did you account for the variety of DER possibilities and their different CO<sub>2</sub> emissions?**

A: For the purposes of this calculation, we assumed that the average CO<sub>2</sub> emissions intensity of the DER additions corresponded to the projected performance of a “state-of-the-art” combined heat-and-power unit, as defined in EIA’s Base Case. On average, specific DER units will have CO<sub>2</sub> emissions perform better (rooftop solar) or worse (natural gas micro-turbine) than this average.

### Plug-In Hybrid Vehicles

**Q: What were the assumptions you used to calculate the contribution from PHEVs?**

A: We assumed that the fraction of new cars sold as PHEVs increased from zero in 2007 by 1% per year for the next 10 years, and by 2% per year for the next 10 years after that, to reach 30% by 2027. The performance attributes (all-electric range, hybrid fuel economy, etc.) are derived from EPRI's technical work in this area, in partnership with several automakers and suppliers.

**Q: What assumptions do you make about the increasing fuel economy of gasoline vehicles?**

A: We assume that the fuel economy of new passenger vehicles and light-duty trucks increases at the same rate as in the EIA Base Case, to reach 32.8 mpg for passenger cars and 25.3 mpg for light trucks by 2020, with increases thereafter.

**Q: How does this rate of penetration of PHEVs compare to other advanced vehicle technologies?**

A: Hybrid vehicles made up slightly more than 3% of passenger car sales in 2006, six years after their market introduction. By comparison, we assume that when PHEVs enter the market, they will initially gain share at a rate of 1% per year – roughly twice the observed rate for hybrids.

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