SCENARIOS FOR U.S. ELECTRICITY IN 2030

CENTER FOR CLIMATE AND ENERGY SOLUTIONS

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Affordable, reliable electricity is a central pillar of modern life. At the same time, the generation of electricity is responsible for nearly 40 percent of U.S. carbon dioxide emissions. New technologies and policies are driving enormous change in the power sector, affecting its ability to provide affordable and environmentally sustainable electricity for decades to come. This brief describes three scenarios for the state of U.S. electricity in 2030 as a way of articulating key challenges and opportunities facing this critical sector in the years ahead.

OVERVIEW

This paper describes three scenarios for the state of U.S. electricity in 2030. The primary purpose of these scenarios is to articulate challenges and opportunities for U.S. electricity in the years to come, in order to help the electricity sector and its many stakeholders find the best path forward in meeting their shared objectives.

The scenarios were developed by Center for Climate and Energy Solutions (C2ES) under the guidance of Dr. Alexander Van de Putte, Professor of Strategic Foresight at IE Business School and Dr. David Gates, an independent consultant, with input from a broad range of businesses—including power companies, fuel suppliers, technology suppliers, energy-intensive industries, and the investment community—as well as residential consumer, environmental, and labor representatives and former public utility commissioners. (See Appendix B for a brief description of the process by which the scenarios were developed.)

Each scenario illustrates the extent to which U.S. electricity in 2030 could be affordable, reliable, safe, and environmentally sound—attributes demanded by the public—and describes the resilience of the electricity system to a range of possible shocks. As a group, the scenarios are intended to be plausible, alternative, divergent, and internally consistent.

Scenario A: "Awash in Gas"—With no major changes in policy, abundant inexpensive natural gas is the primary new source of electric generation capacity. Technologies related to gas utilization (including gas-powered distributed generation), solar photovoltaic (PV), and information technology (IT) continue to advance, while energy efficiency, most renewables, nuclear power, and carbon capture and storage (CCS) do not progress as much. The U.S. power sector's carbon dioxide (CO_2) emission levels remain about the same as they were in 2013.

Scenario B: "Price-Driven Technology"—A growing economy drives up demand for electricity and yields a broader range of energy technologies. The economy grows more quickly than in Scenario A, driving up demand for electricity. Natural gas sees sharply rising demand and a growing export market, stricter regulation and other factors increasing natural gas prices and volatility. Technology breakthroughs drive the deployment of a broad range of new energy technologies and improvements in transmission and distribution infrastructure – as well as increased use of conventional coal power. Electricity prices rise, as do CO_2 emissions.

Scenario C: "Policy-Driven Technology"—The economic growth and increased deployment of new energy technologies seen in Scenario B creates a growing public and business constituency for policies promoting even more such deployment. Continued extreme weather events also lead to increased public support for action to address climate change. These two factors lead to significant CO_2 emissions reduction policies. By 2030, the deployment of a broad range of energy efficient and low emitting technologies rises sharply, significantly reducing. CO_2 and other emissions. Slower growth in electricity demand and increased distributed generation reduces sales for some utilities, requiring adjustment of business and regulatory models—in particular, to avoid disadvantaging low-income consumers and small businesses.

SCENARIO INSIGHTS

The following challenges are found to varying degrees in all three scenarios:

- The need to reduce the environmental impacts associated with U.S. electricity.
- The need for the business and regulatory models of the power sector to adjust to evolving customer and public expectations and advances in technology.
- The need to manage the range of responses that residential and business customers will have to the sweeping technological changes and opportunities that will occur under any scenario
- The need to build and improve transmission, distribution, and other infrastructure.
- The need to improve and maintain the diversity of energy sources in order to reduce vulnerability to developments relating to any one energy source.

SCENARIO A: "AWASH IN GAS"

With no major changes in policy, abundant inexpensive natural gas is the primary new source of electric generation capacity

The "Awash in Gas" Scenario is the scenario one might expect if current trends continue unabated (the "official future," in the parlance of scenarios planning). U.S. Gross Domestic Product (GDP) growth continues at a modest annual average of 2.5 percent through 2030, and total demand for U.S. electricity grows at a correspondingly-modest annual average of 0.8 percent (of which 0.7 percent is supplied by the grid).[1]

Technological developments and new drilling methods continue to make the United States the world's leading producer of natural gas. Natural gas prices range between $4–5.50 per million British thermal unit (MMBtu) in real terms, a relatively low price which makes gas the primary new source of electric generation capacity. Coal, however, continues to be the largest source overall.

Solar PV prices continue to drop,[2] leading to greater deployment, primarily in the form of rooftop projects on residences, factories, retail outlets and commercial buildings. The rate of deployment varies across the country, with greater deployment of solar PV in the service districts of utilities with high electricity rates and states with favorable policy incentives in place. While new deployment of wind generation continues in some locations, its broader deployment is inhibited by transmission and integration challenges. Greater deployment of intermittent renewables, including solar and industrial-scale wind, favors complementary use of natural gas generation as a backup.

The provision of electricity remains largely centralized, except for the above-mentioned solar PV and a moderate increase in natural gas-powered distributed generation. Power companies invest heavily in upgrading transmission and distribution infrastructure, and in modifying their plants and practices to comply with U.S. Environmental Protection Agency (EPA) mercury and air toxics (MATS) rule[3], cross-state air pollution rule (CSAPR)[4], and other new regulations[5]. The coal fleet becomes increasingly efficient due to retirement of older units and technological improvements for newer units.

EPA promulgates CO_2 standards which require modest improvements in heat rates at existing coal and natural gas plants.[6] Otherwise, there is little enactment of new policy at the federal level, and in particular, no federal renewable energy standard, clean energy standard, or carbon pricing law, and little federal support for research and development (R&D) for low-emitting energy technologies. California and several northeastern states implement clean/renewable energy standards and energy efficiency requirements. At the same time, some states repeal or scale back their existing renewable energy and energy efficiency requirements.

Technologies related to gas utilization, solar PV, and IT continue to advance, due in part to developments originating from outside the power sector and outside the United States. Nevertheless, there is very little new deployment of nuclear power, renewable energy, CCS, and efficiency, except as driven by state-specific policies.[7] There is little penetration of electric vehicles, though penetration of natural gas vehicles, especially in fleets, is somewhat greater. By 2030, the United States lags the international market for some critical low-emitting energy technologies.

Several factors put pressure on the business and regulatory models of the power sector: an increase in

distributed generation; customer, regulatory, and political interest in demand side management technologies (DSM); modest economic growth; and rising electricity prices in certain areas of the country.

Affordability: Average real retail electricity prices and bills are flat or falling initially, rising modestly by 2030, with significant variation across sectors, states, and regions. Electricity bills, in real terms, are relatively static.[8]

Reliability: Routine reliability remains largely the same as in 2013.

Safety: There are incremental improvements in safety.

Environmental soundness: CO_2 emission levels remain roughly the same as in 2013. Other emissions (e.g., mercury, sulfur dioxide) are significantly lower than in 2013, because of both the shift from coal to gas and investments to bring coal plants into compliance with new standards.

Resilience: Utilities increase their capacity to utilize natural gas, while retaining much of their capacity to utilize coal, which decreases vulnerability to unexpected developments relating to either fuel. Limited investment in non-fossil fuel energy sources, however, allows continued vulnerability to developments that could impact fossil fuels generally, such as the establishment of a significant price on CO_2 emissions. Also, there has been an increase in extreme weather events leading to more outages, with an increasingly expensive impact on the electricity sector and the economy. Finally, utilities must implement additional measures and face increased costs due to the threat of cyber-attack.

SCENARIO B: "PRICE-DRIVEN TECHNOLOGY"

A growing economy yields a broader range of energy technologies

In the "Price-Driven Technology" Scenario, several factors drive the broad deployment of various energy technologies. Most importantly, the economy picks up, moving from an annual average GDP growth of 2.5 percent from 2013 to 2014, to 2.9 percent from 2015 through 2030. Growth in total demand for electricity correspondingly increases to an annual average of 1.2 percent (of which 1.0 percent is supplied by the grid).[9]

The growing economy drives demand for natural gas in the power, manufacturing and transportation sectors, and in export markets. These factors, as well as stricter regulation of hydraulic fracturing, more rapid depletion of hydraulic fracturing wells than expected, and large swings in average winter temperatures, drive up natural gas prices and associated volatility. Natural gas prices range from $4–7 per MMBtu.

Breakthroughs in key technologies relevant to electricity occur more rapidly than expected, including in other sectors and countries. Examples range from research in aeronautical engines informing the design of natural gas turbines to tools arising from the fields of IT, nanotechnology, 3D printing, and bioengineering. The export potential for U.S.-developed energy technologies grows.

The combination of the growing economy, the increases in gas prices and volatility, and the advancements in key technologies drives the deployment of a broad range of new energy technologies. These include, in particular, smart meters, smart appliances, distributed automation, electricity storage, solar PV, small modular nuclear units, and CCS in combination with enhanced oil recovery. Due to breakthroughs in battery technology, penetration of electric vehicles is somewhat greater than in the previous scenario.

The increased demand for electricity, which boosts deployment of low-emitting technologies, also increases demand for conventional coal-generated electricity. Fewer coal plants are retired than in the previous scenario, and there is an increase in the utilization of existing coal generation capacity.

The provision of electricity remains largely centralized, in part because the price and volatility of natural gas dampen growth of gas-powered distributed generation. The distributed generation which does occur puts additional stress on infrastructure as well as rates.

EPA promulgates modest CO_2 standards, and there is little enactment of new major policy at the federal level, as in the previous scenario.[10] Several states, however, in addition to California and the Regional Greenhouse Gas Initiative (RGGI) states, enact policies that go beyond the requirements of the EPA standard, largely in the form of clean/renewable energy standards and energy efficiency requirements.

Affordability: Electricity costs and bills rise significantly, with significant variation by sector, state and region.

Reliability: Routine reliability generally remains the same as in 2013.

Safety: There are incremental improvements in safety.

Environmental soundness: CO_2 emissions from the electric power sector rise significantly above 2013 levels, largely a result of an increase in coal utilization. Other pollutants decline because of the measures undertaken to comply with the various EPA regulations and technological advancements.

Resilience: As in the previous scenario, there is an increase in extreme weather events leading to more outages, with an increasingly expensive impact on the electricity sector and the economy. Utilities must implement additional measures and face increased costs due to the threat of cyber-attack. Broader deployment of efficiency, various energy technologies and improved planning tend to make the system more secure and resilient.

SCENARIO C: "POLICY-DRIVEN TECHNOLOGY"

Policy drives low-emitting technologies

In the "Policy-Driven Technology" Scenario, the combination of a growing economy, increases in gas prices and volatility, and advancements in key technologies drives the deployment of a broad range of new energy technologies, just as in the previous scenario. This, in turn, creates growing business and public constituencies supportive of policy favorable to the deployment of even more low-emitting technologies and supporting infrastructure.

In addition, the United States continues to experience extreme weather events on the scale of the droughts, floods, wildfires, heat waves, and "Super storm" Sandy of 2012, further building public support for climate change policy.

These factors combine to drive business and public support for a comprehensive policy approach. A significant CO_2 emissions reduction policy is established mid-decade and goes into effect in 2020. Several states, including California and the RGGI states, enact policies that go beyond the federal requirements, including a variety of clean/renewable energy standards and energy efficiency requirements.

Federal spending for R&D and deployment of low-emitting technologies increases sharply. Federal agencies, including EPA, U.S. Department of Energy (DOE) and Federal Energy Regulatory Commission (FERC), address barriers to the deployment of various low-emitting technologies. Innovative private sector financing mechanisms for low-emitting technologies are highly deployed. Innovative technologies from other sectors and countries spill over into the energy sector at unprecedented rates.

By 2030, the deployment of energy efficient and low-emitting technologies, including distributed generation, renewables, nuclear power, CCS, and electric vehicles, is rising sharply, and the United States is a global leader in these technologies. The smart grid, equipped with the latest technology for reacting to events, improving reliability and efficiency, and enabling a more distributed and networked system, is highly deployed. There is increasing coordination between grid operators and facilities with distributed generation. There is an increase in demand response, reducing the need for electricity at peak times. A growing segment of the population is willing to pay a premium for electricity generated by low-emitting technologies.

Increased energy efficiency reduces growth in total demand for electricity to an average of 0.4 percent per year (of which 0.1 percent is supplied by the grid).[11]

Affordability: With increased distributed generation and spending by regulated utilities on new equipment, the average price of utility-delivered electricity increases. Many residential and commercial users pay reduced electricity bills as a result of energy efficiency programs, tax incentives, rebates, and government-sponsored projects. There is, however, a risk that low-income consumers and small businesses may not have easy access to these programs, and that they, along with taxpayers, will bear much of the increased cost of utility-delivered electricity. Electricity rates and bills continue to vary significantly by sector, state and region.

Reliability: Investments in maintenance and performance tend to enhance reliability, while the deployment of distributed generation and various new technologies increases the complexity of maintaining reliability.

Safety: There are incremental improvements in safety.

Environmental soundness: CO_2 and other emissions from the electric power sector decline sharply from 2013 levels.

Resilience: Extreme weather events result in fewer widespread outages due to the deployment of the smart grid and an increase in distributed generation. Because of the diversity of energy sources, the electricity system is more capable of responding to unexpected developments related to any particular energy source than in the above scenarios. Consequences of individual events are more contained. The increased computerization of all aspects of the system, however, increases vulnerability to cyber-attack and utilities must implement additional measures and face increased costs due to this threat.

ISSUES RAISED BY THE SCENARIOS

The three scenarios are intended, among other things, to articulate some of the key challenges and opportunities U.S. electricity could face by 2030. The following challenges are found in all three scenarios to varying degrees:

- The need to reduce the environmental impacts associated with U.S. electricity. This is especially acute in the first and second scenarios, in which CO_2 emissions remain level or rise.
- The need for the business and regulatory models of the power sector to adjust to evolving customer and public expectations and advances in technology. This is especially acute in the third scenario for those utilities that could see a decline in sales due to reduced growth in demand for electricity and increased distributed generation. Adjustments must be made in particular to ensure that those low-income customers and small businesses lacking access to energy efficiency programs and distributed generation resources do not carry most of the burden of the sweeping changes the industry will see under any scenario.
- The need to manage the range of responses that residential and business customers will have to the sweeping technological changes and opportunities that will occur under any scenario: some will resent any change, including perceived intrusions by the utility into their privacy and decision-making, for example, through the installation of smart meters and appliances; some will demand access to technology (e.g., smart meters and appliances) the utility is not yet ready to provide; some will install self-generation assets, for example, solar PV, and resent the utility's request to charge them to pay for the infrastructure and centralized generation capacity necessary to provide back-up power; some will be indifferent and unresponsive to efforts by the utility to engage and empower them; and in some there will be a latent untapped willingness to pay a premium for clean energy generation and services.
- The need to build and improve transmission, distribution, and other infrastructure. Improvements are needed to: ensure the resilience of the system against physical attack, cyber attack, and increasing extreme weather events; ensure the reliability of the system as it becomes less centralized, including through distributed generation and demand response programs; transmit electricity from large remote wind and solar installations to population centers; utilize IT advances for the smart grid; and transport captured CO_2 from coal and natural gas plants to areas where it can be used for enhanced oil recovery or otherwise sequestered.
- The need to improve and maintain the diversity of energy sources in order to reduce vulnerability to developments relating to any one energy source. This is especially acute in the first scenario, when modest growth in demand for electricity and relatively low coal and natural gas prices make it difficult to advance proposals to build new renewable and nuclear generation capacity.

CONCLUSION

Decisions made in the next 15 years will have lasting repercussions for the future of our nation's electricity supply. Will we be able to ensure that electricity in the United States is affordable, reliable, safe and environmentally sound? What will be the best path for achieving these often conflicting objectives? The scenarios described here articulate some of the most significant challenges we will face as we move forward.

APPENDIX A: Comparison of the Scenarios

KEY CHARACTERISTICS	SCENARIO A AWASH IN GAS	SCENARIO B PRICE-DRIVEN TECHNOLOGY	SCENARIO C POLICY-DRIVEN TECHNOLOGY
GDP Growth (annual average)	2013–2030: 2.5%	2013–2014: 2.5% 2015–2030: 2.9%	2013–2014: 2.5% 2015–2030: 2.9%
Electricity Demand Growth (annual average)	0.8% total 0.7% grid-supplied	1.2% total 1.0% grid-supplied	0.4% total 0.1% grid-supplied
Price of Natural Gas (Henry Hub, in real dollars)	\$4–5.5 per MMBtu	\$4–7 MMBtu	\$4–7 MMBtu
Total Generation (Billion kWh)	4777	5089 6.5% more than Scenario A	4378 8.4% less than Scenario A
Energy sources in 2030	Ranking of energy sources as a percentage of electric generation in 2030: • Coal • Natural gas • Nuclear • Hydro • Wind • Biomass • Solar	Ranking of energy sources as a percentage of electric generation in 2030: • Coal • Natural gas • Nuclear • Hydro • Wind • Biomass • Solar The fraction each source makes up of the total is essentially unchanged from Scenario A.	Ranking of energy sources as a percentage of electric generation in 2030: • Natural gas • Nuclear • Coal • Wind • Hydro • Biomass • Solar There is a significant reduction in coal and a significant increase in all other sources from Scenarios A and B.
Climate and Energy Policy	EPA promulgates modest CO_2 standard. California and northeastern states enact policies that go beyond the requirements of the federal standard, while some other states scale back or repeal their existing renewable energy and energy efficiency requirements.	EPA promulgates modest CO_2 standard. Some federal support for energy technologies. California and northeastern states, and some other states, enact policies that go beyond the requirements of the federal standard.	A significant CO_2 emissions reduction policy is established mid-decade and goes into effect in 2020. Significant federal support is given to low-emitting energy technologies. Several states enact policies that go beyond the federal requirements.

KEY CHARACTERISTICS	**SCENARIO A AWASH IN GAS**	**SCENARIO B PRICE-DRIVEN TECHNOLOGY**	**SCENARIO C POLICY-DRIVEN TECHNOLOGY**
Affordability	Average real retail electricity prices are relatively inexpensive initially, rising modestly by 2030, with significant variation across sectors, states, and regions. Electricity bills rise modestly, as well.	Average electricity prices and bills are significantly higher than in Scenario A, with significant variation by sector, state, and region.	Average electricity prices are significantly higher than in Scenario A, with significant variation by sector, state, and region. Energy efficiency and other programs make it possible for some users to pay lower bills. Measures must be taken to prevent those end-users without easy access to such programs from paying disproportionately.
Reliability	Remains largely the same as in 2013.	Remains largely the same as in 2013.	Investments in system maintenance and performance tend to enhance reliability, while distributed generation and new technologies tend to increase complexity of managing reliability issues.
Environmental Soundness	CO_2 emission levels remain roughly the same as in 2013. Other emissions (i.e. mercury, sulfur dioxide) decrease compared to 2013 levels.	CO_2 emissions are significantly higher than in 2013. Other emissions decline, though are somewhat higher than in Scenario A.	CO_2 and other emissions decline sharply from 2013 levels.
Resilience	Increased parity between coal and natural gas use make the system less vulnerable to developments related to either coal or natural gas. Limited investment in non-fossil fuel energy sources increases system vulnerability to developments that impact fossil fuels generally.	A broader range of technologies and improved planning tend to make the system more resilient and secure.	With the greatest diversity in energy mix, the system is less vulnerable to factors affecting any given source of energy. Increased distributed generation, microgrids, and smart technology may increase resilience, but are also more complex to manage. Pressures on the business models of some utilities may make them less resilient to a range of factors.
	Increases in extreme weather events lead to more outages, with increasingly expensive impacts on the electricity sector and the economy. Utilities must implement additional measures and face increased costs due to threat of cyber-attack.		

APPENDIX B: SCENARIO DEVELOPMENT METHODOLOGY

The scenarios were developed by C2ES over a six-month period under the guidance of Dr. Alexander Van de Putte, Professor of Strategic Foresight at IE Business School, and Dr. David Gates, an independent consultant, through the following process:

- Convene representatives of a broad range of businesses, including power companies, fuel suppliers, technology suppliers, business customers, and the investment community, as well as residential consumer advocates, environmental and energy nonprofit organizations, labor, and former public utility commissioners. The following steps were taken as a collective exercise of the group.
- Develop a central question and time horizon to be answered by each of the scenarios: "How affordable, reliable, safe, and environmental sound can U.S. electricity be in 2030?"
- Identify the many factors expected to be significant in determining the affordability, reliability, safety and environmental soundness of U.S. electricity in 2030,
- Assess the relative significance of these factors and the relative certainty in our ability to project their values in 2030 in order to identify "key givens" and "key uncertainties."
- Sketch three plausible (i.e., credible and realistic), divergent (i.e., very different, but still within the boundaries of plausibility), and internally consistent (i.e., reflecting plausible cause and effect relationships between different factors from time period to time period) scenarios for the affordability, reliability, safety, and environmental soundness of U.S. electricity in 2030.
- Incorporate within each scenario the same key givens, while reflecting a range of the key uncertainties.
- Add details to the scenarios and the events which could lead to them and quantify key aspects in order to assess the scenarios' plausibility. Make any necessary adjustments.
- Describe the scenarios in a final document (the present document).

ENDNOTES

1 U.S. Energy Information Administration, “Annual Energy Outlook 2013,” January 2013. Available at: http://www.eia.gov/forecasts/archive/aeo13.

2 A McKinsey study projects that photovoltaic manufacturing capacity will double in the next three to five years and underlying costs will drop by as much as 10 percent annually until 2020. Aanesen, Krister, Stefan Heck, and Dickon Pinner, McKinsey & Company. May 2012. *Solar power: Darkest before dawn*, available from: http://www.mckinsey.com/client_service/sustainability/latest_thinking/solar_powers_next_shining.

3 Center for Climate and Energy Solutions, “Mercury Rule,” last modified June 24, 2013, http://www.c2es.org/federal/executive/epa/mercury-rule.

4 Center for Climate and Energy Solutions, “Cross-State Air Pollution Rule,” last modified June 26, 2013, http://www.c2es.org/federal/executive/epa/cross-state-air-pollution-rule.

5 For an overview of relevant EPA regualtions, see Center for Climate and Energy Solutions, “EPA,” last visited, May 23, 2014, http://www.c2es.org/federal/executive/epa.

6 Center for Climate and Energy Solutions, “Carbon Pollution Standards,” last visited May 23, 2014, http://www.c2es.org/federal/executive/epa/carbon-pollution-standards-power-plants.

7 Center for Climate and Energy Solutions, “U.S. States & Regions,” last visited May 23, 2014, http://www.c2es.org/us-states-regions.

8 U.S. Energy Information Administration, “Annual Energy Outlook 2013,” Reference Case.

9 U.S. Energy Information Administration, “Annual Energy Outlook 2013,” High Economic Growth Case.

10 Center for Climate and Energy Solutions, “Carbon Pollution Standards.”

11 Data taken from U.S. Energy Information Administration, “Annual Energy Outlook 2013,” High Demand Technology” Case where high-efficiency technologies are assumed to penetrate end-use markets at lower consumer hurdle rates and “Greenhouse Gas $25” case.

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The Center for Climate and Energy Solutions (C2ES) is an independent nonprofit organization working to promote practical, effective policies and actions to address the twin challenges of energy and climate change.

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