White Paper

Smart Grid

The Role of Electricity Infrastructure in Reducing Greenhouse Gas Emissions

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October 2008

Cisco Internet Business Solutions Group (IBSG)

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Introduction

Most of the world's electricity system was built when primary energy was relatively inexpensive. Grid reliability was mainly ensured by having excess capacity in the system, with unidirectional electricity flow to consumers from centrally dispatched power plants. Investments in the electric system were made to meet increasing demand—not to change fundamentally the way the system works. While innovation and technology have dramatically transformed other industrial sectors, the electric system, for the most part, has continued to operate the same way for decades. This lack of investment, combined with an asset life of 40 or more years, has resulted in an inefficient and increasingly unstable system.

Climate change, rising fuel costs, outdated grid infrastructure, and new power-generation technologies have changed the mindset of all stakeholders:

- Electric power causes approximately 25 percent of global greenhouse gas emissions, and utilities are rethinking what the electricity system of the future should look like.
- Renewable and distributed power generation will play a more prominent role in reducing greenhouse gas emissions.
- Demand-side management promises to improve energy efficiency and reduce overall electricity consumption.
- Real-time monitoring of grid performance will improve grid reliability and utilization, reduce blackouts, and increase financial returns on investments in the grid.

These changes on both the demand and supply side require a new, more intelligent system that can manage the increasingly complex electric grid.

Recognizing these challenges, the energy community is starting to marry information and communications technology (ICT) with electricity infrastructure. Technology enables the electric system to become "smart." Near-real-time information allows utilities to manage the entire electricity system as an integrated framework, actively sensing and responding to changes in power demand, supply, costs, quality, and emissions across various locations and devices. Similarly, better information enables consumers to manage energy use to meet their needs. According to former U.S. Vice President Al Gore, "Just as a robust information economy was triggered by the introduction of the Internet, a dynamic, new, renewable energy economy can be stimulated by the development of an electranet or Smart Grid."[1]

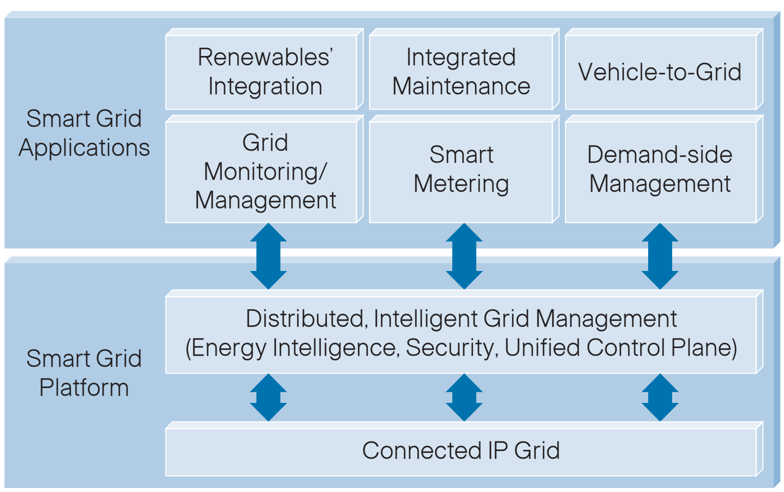
The potential environmental and economic benefits of a Smart Grid are significant. A recent Pacific Northwest National Laboratory study provided homeowners with Smart Grid technologies to monitor and adjust the energy consumption in their homes. The average household reduced its annual electric bill by 10 percent. If widely deployed, this approach could reduce peak loads on utility grids up to 15 percent annually, which equals more than 100 gigawatts, or the need to build 100 large coal-fired power plants over the next 20 years in the United States alone. This could save up to $200 billion in capital expenditures on new plant and grid investments, and take the equivalent of 30 million autos off the road.[2]

Opportunities for Improvement

A technology-enabled electric system will be more efficient, enable applications that can reduce greenhouse gas emissions, and improve power reliability. Specifically, a Smart Grid can:

- Reduce peaks in power usage by automatically turning down selected appliances in homes, offices, and factories
- Reduce waste by providing instant feedback on how much energy we are consuming
- Encourage manufacturers to produce "smart" appliances to reduce energy use
- Sense and prevent power blackouts by isolating disturbances in the grid

Figure 1. Main Applications of a Smart Grid



Source: Cisco IBSG, 2008

The main applications of a Smart Grid include:

- **Smart Grid Platform:** Automating the core electricity grid

Connecting all relevant nodes in the grid is important to collecting information on grid conditions. Whereas in the past, information was gathered only in the high-voltage grid and parts of the medium-voltage grid, a comprehensive view of grid status now is becoming increasingly important. Grid losses in all areas can be identified and renewable generation sources that often feed electricity into previously unmonitored areas can be better managed. The increasing complexity of managing the system efficiently also requires integration of decentralized decision-making mechanisms—in other words, integrating intelligence into the grid. As a result, grid management can be optimized and outages can be significantly reduced.

- **Grid Monitoring and Management:** Using collected information

Expensive power outages can be avoided if proper action is taken immediately to isolate the cause. Utilities are installing sensors to monitor and control the grid in near-real time (seconds to milliseconds) to detect faults early. These monitoring and control systems are being extended from the point of transmission down to the distribution grid. Grid performance information is integrated into utility companies' supervisory control and data acquisition (SCADA) systems to provide automatic, near-real-time electronic control of the grid.

- **Integrated Maintenance:** Optimizing the lifetime of assets

Middle to long term, collected information can optimize the maintenance strategy of grid assets. Depending on utilization, age, and many other factors, the condition of assets can differ significantly. The traditional maintenance strategy, based on defined cycles, is no longer appropriate. Assets can be monitored continuously, and critical issues can be identified in advance. Combined with new communication technologies, information on critical asset conditions can be provided to field technicians to make sure problems are fixed in time. This new way of doing maintenance can significantly increase the lifetime of assets and avoid expensive outages.

- **Smart Metering:** Real-time consumption monitoring

Today's electricity prices on the wholesale market are extremely volatile, driven by demand-and-supply situations based on capacity, fuel prices, weather conditions, and demand fluctuations over time. On average, off-peak prices at night are 50 percent lower than daytime prices. Consumers, however, typically see a flat price for energy regardless of time period. Driven by the regulator, some utilities are now starting to replace traditional mechanical electric meters with "smart meters," allowing customers to choose variable-rate pricing based on time of day. By seeing the real cost of energy they are consuming at that moment, consumers can respond accordingly, shifting their energy consumption from high-price to low-price time periods by turning off appliances. This *load shifting* and *load shedding* has the joint benefit of reducing consumer costs and demand peaks for utilities.

- **Demand-side Management:** Reducing electricity consumption in homes, offices, and factories

Demand-side management works to reduce electricity consumption in homes, offices, and factories by continually monitoring electricity consumption and actively managing how appliances consume energy. It consists of demand-response programs, smart meters and variable electricity pricing, smart buildings with smart appliances, and energy dashboards. Combined, these innovations allow utility companies and consumers to manage and respond to the variances in electricity demand more effectively.

  – *Demand Response:* During periods of peak energy usage, utility companies send electronic messages to alert consumers to reduce their energy consumption by turning off (or down) non-essential appliances. In the future, alert signals will be sent automatically to appliances, eliminating the need for manual intervention. If enough consumers comply with this approach, utility companies will not need to dispatch an additional power plant, the most expensive asset they operate.[3] To increase the number of consumers who comply, utility companies may offer cash payments or reduce consumers' electric bills.

  – *Smart Buildings with Smart Appliances:* Buildings are becoming smarter in their ability to reduce energy usage. Traditional, stand-alone, complex systems that manage various appliances (heating, ventilation, air-conditioning, lighting) are now converging onto a common IT infrastructure that allows these devices to "talk" to each other, coordinating their actions and reducing waste. For example, a manager of 500 commercial buildings reduced energy consumption nearly 20 percent simply by ensuring heaters and air conditioners were not running simultaneously.[4]

  – *Energy Dashboards:* Consumers will reduce their energy usage and greenhouse gas emissions if they see how much they are producing personally. Online energy dashboards provide real-time visibility into individuals' energy consumption while offering suggestions on how to reduce consumption. Recent university studies have found that simple dashboards can encourage occupants to reduce energy usage in buildings by up to 30 percent.[5]

- **Renewables' Integration:** Encouraging home and business owners to install their own renewable sources of energy

  – *Microgeneration:* Some homes and offices are finding it more cost-effective to produce electricity locally, using small-scale energy-generation equipment. These devices include *renewable* devices such as as photovoltaics, and solar thermal as well as *non-renewable* devices, such as oil- or natural-gas-fired generators with heat reclamation.

  Microgeneration technologies are becoming more affordable for residential, commercial, and industrial customers. Depending on the technology type and the operating environment (location, utilization, government or state subsidies), they can be competitive against conventional generation, and at the same time reduce greenhouse gas emissions. Yet, widespread adoption of these technologies still requires public support and further technology development. Microgeneration technologies, combined with a Smart Grid, will help consumers become an "active part of the grid," rather than being separate from it—and will integrate with, not replace, central generation. In addition, a Smart Grid would allow utilities to integrate distributed generation assets into their portfolios as "virtual power plants."

- **Vehicle-to-Grid:** Until recently, pumped water storage was the only economically viable option for storing electricity on a large scale. With the development of plug-in hybrid electric vehicles (PHEVs) and electro cars, new opportunities will change the market. For example, car batteries can be used to store energy when it is inexpensive and sell it back to the grid when prices are higher. For drivers, their vehicles would become a viable means to arbitrage the cost of power, while utility companies could use fleets of PHEVs to supply power to the grid to respond to peaks in electricity demand.

Potential Impact

Worldwide demand for electric energy is expected to rise 82 percent by 2030.[6] This demand will primarily be met by building many new coal and natural gas electricity-generation plants. Not surprisingly, global greenhouse gas emissions are estimated to rise 59 percent by 2030[7] as a result.

Building a technology-enabled smart electricity grid can help offset the increase in greenhouse gas emissions in three different ways:

(1) Reduce Growth in Demand for Electricity

Electricity Consumers:

- Enable consumers to monitor their own energy consumption, with a goal of becoming more energy-efficient
- Provide more accurate and timely information to consumers on electricity variable-pricing signals, allowing them to invest in load-shedding and load-shifting solutions—and to shift dynamically among several competing energy providers based on greenhouse gas emissions or social goals

Power Utility Companies and Regulators:

- Broadcast demand-response alerts to reduce peak energy demand and the need to start reserve generators
- Provide remote energy-management services and energy-control operations that advise customers, giving them the choice to control their homes remotely to reduce energy use
- Enable utility companies to increase their focus on creating "Sav-a-Watt" or "Nega-Watt" programs instead of producing power. These programs are effective because offsetting a watt of demand through energy efficiency can be more cost-effective and CO2-efficient than generating an extra watt of electricity.[8]

Equipment Manufacturers:

- Encourage building-control systems companies to standardize data communications protocols across systems, eliminating proprietary and non-standard protocols that inhibit integration and management
- Incent manufacturers to produce goods (air conditioners, freezers, washers/dryers, water heaters) that more effectively monitor and manage power usage. For example, a refrigerator and air-conditioner compressor could "communicate" to ensure they don't start at the same time, thus reducing peak electricity demand.
- Enable and encourage electrical equipment manufacturers to build energy-efficiency, management, and data-integration capabilities into their equipment

Building Architects & Owners:

- Take an integrated approach to new building construction, incorporating smart, "connected building" communication technologies to manage and synchronize operation of appliances, to turn off lighting in rooms not in use, to turn on reserve generation when price-effective, and to manage overall energy use

(2) Accelerate Adoption of Renewable Electricity-generation Sources

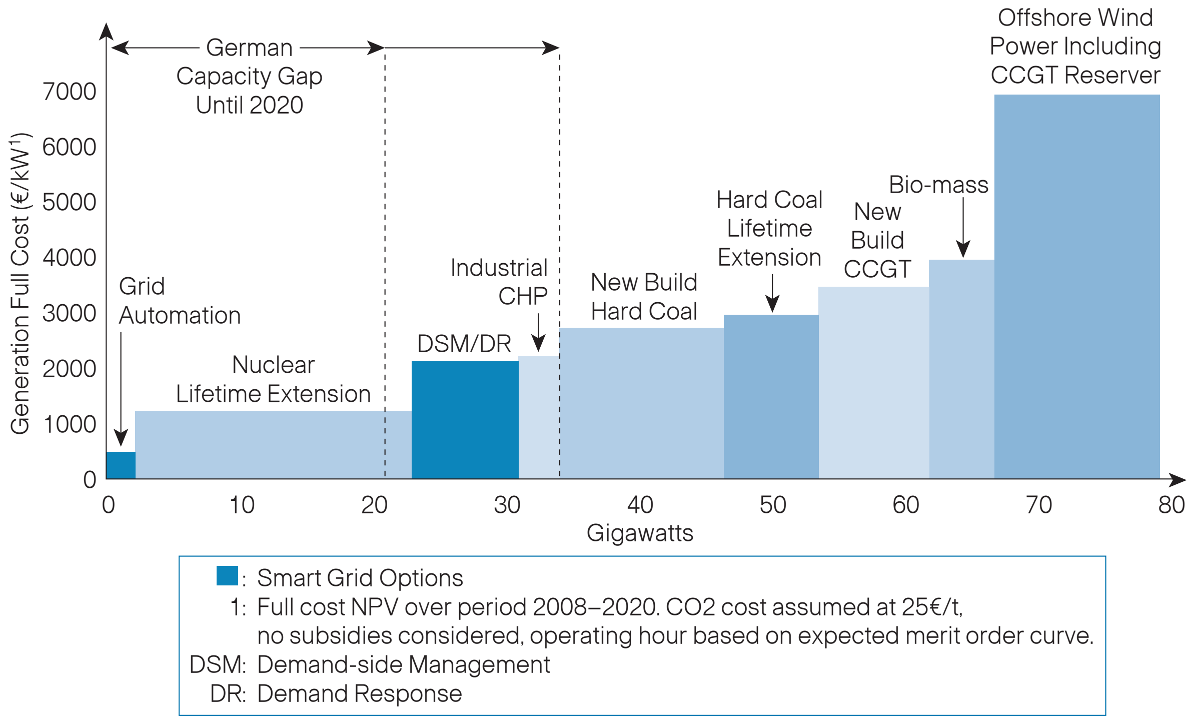
- Encourage home and building owners to invest in highly efficient, low-emissions microgeneration technologies to supply some of their own energy and offset peak demand on the electric grid—thereby reducing the need for new, large-scale power plants
- Create virtual power plants that include both distributed power production and energy-efficiency measures
- Accelerate the introduction of PHEVs to provide temporary electricity storage as well as incremental energy generation to offset peak demand on the grid

(3) Delay Construction of New Electricity-generation and Transmission Infrastructure

- It is estimated that by 2030, the cost to renew and expand the world's aging transmission/distribution grid and its power-generation assets will exceed $6 trillion and $7.5 trillion, respectively.[9] Utility companies that implement electronic monitoring and management technologies can prolong the life of some electric grid components, reducing new construction costs for power-generation assets and the greenhouse gas emissions that accompany them.

Figure 2. Options for Closing Future Capacity Gap (Scenario Based on German Electricity Market)

Cisco IBSG analysis for the German market showed that Smart Grid is the cheapest way to free up capacity. In addition, it is the most environmentally friendly option.



Source: Cisco IBSG, 2008

Current Initiatives

Practically speaking, most of the technologies required to create a Smart Grid are available today.

Forward-looking utility companies are already offering demand-response technologies that, for example, detect the need for load shedding, communicate the demand to participating users, automate load shedding, and verify compliance with demand-response programs.

Many utility companies are also implementing large numbers of smart electric meters to offer variable pricing to consumers and to reduce manual meter-reading costs.

Major building automation companies, such as Johnson Controls, Siemens, and Honeywell, all have smart building solutions that integrate their various HVAC systems. Several competing communication protocols (BACnet, LONnet, oBIX), however, are still vying to become the standard through which all building devices can intercommunicate. This inability to agree upon a common industry standard has delayed the vision of connecting every electric device and spawned several middleware and gateway companies, such as Cimetrics, Gridlogix, Richards Zeta, and Tridium. As expected, many white goods manufacturers, including GE, Whirlpool, and Siemens, are making appliances that can connect to a building's network.

In addition, several public and private organizations have implemented energy-consumption dashboards. Typically, these are custom-designed internally or provided by small software integrators. Oberlin College has a good example of an online energy dashboard showing energy consumption at its college dormitories.[10]

A variety of companies, ranging from Honda Motor Company and GE Energy to Microgeneration Ltd. and BluePoint Energy, are developing microgeneration devices. A host of technology companies provide technology required to make the Smart Grid "smart," including Current Technologies and BPL Global for broadband-over-powerline, Silver Spring Networks and Cellnet for RF wireless communications, and many other small and specialized companies.

So far, however, nobody has been able to define an industry architecture that spans the entire Smart Grid—from high-voltage transformers at the power plant down to the wall sockets in homes and offices.

Role of Utility Companies

Here are three ways utility companies can help make the Smart Grid a reality:

1) Drive Smart Grid standards and architectures by forming alliances and partnerships.

Many utility companies are now reaching out to other utility companies to learn from their findings and share ideas. In addition, strategic partnerships, both within and outside the utility industry, are being formed. Utility companies should also partner more closely with energy regulators to determine their current position on recapturing costs through tariff increases, while at the same time evaluating how to influence policies to accelerate their own Smart Grid investment plans.

2) Evaluate Smart Grid solutions and vendors.

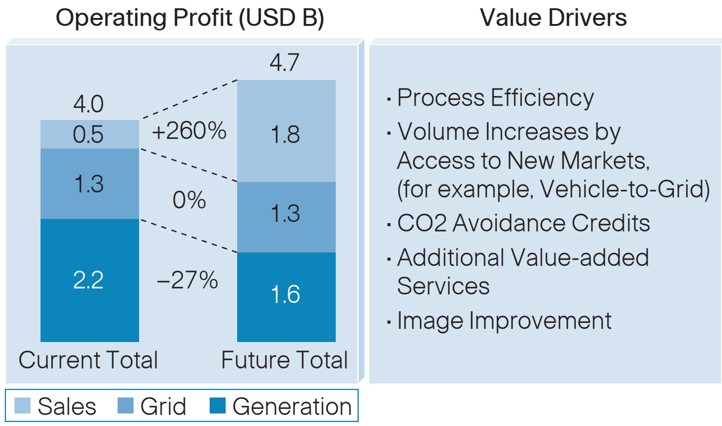
While there is still significant "churn" in various Smart Grid technologies, waiting a couple years for the Smart Grid industry to converge around a single set of standards and solutions may leave some utility companies behind.

3) Plan for the financial impact of the Smart Grid on their organizations.

Utility companies should start by understanding the costs related to developing the Smart Grid, including carbon pricing, grid upgrades, raw energy, and the indirect cost of competition from other utility companies offering energy-efficient services. Once these costs are understood, utility companies should estimate the economic impact Smart Grid solutions could have on their profits. This exercise will help utility companies quantify the effect of the Smart Grid on their bottom line.

Figure 3. Smart Grid's Potential Financial Impact on Utilities (Cisco IBSG Simulation for an Integrated Utility)

IBSG analysis of the financial impact on utilities shows that a proactive strategy can significantly increase profitability. Whereas wholesale price reductions lower power-generation profits, significant opportunities exist on the sales side. Some of these opportunities are tied to required changes in the legal framework and utilities' business model. In a Smart Grid world, utilities will benefit from energy efficiency, not from energy consumption.



Source: Cisco IBSG, 2008

Role of Government

While the technologies for Smart Grid solutions are mainly available today, the real challenge to accelerating adoption stems from the various industries that need to work together to create a viable, integrated system. For example, Smart Grid requires utility companies to work with IT companies, and building owners to work with energy technology companies. Bringing together their various perspectives to design and build complex systems often proves difficult. Given this complexity, the role of government is to create working organizations and policies to incentivize open partnerships. Government can play four key roles to accelerate Smart Grid adoption:

1. Develop cost-recovery mechanisms that allow utilities to include investments in their regulated asset base. Some European countries already incentivize new investments by increasing the return on regulated asset base by 1 to 2 percent above the standard return in the grid tariff.

2. Provide a clear framework that incentivizes investments in energy efficiency that are not part of the regulated grid or metering business. Solutions for demand-side management decrease energy consumption and, therefore, CO_2 emissions. Just as utilities must pay for CO_2 emissions in some countries, there should be a system in place for receiving CO_2 credits based on investments in energy efficiency. Similar frameworks are already in place in Italy and France ("White Certificates").

3. Quickly develop critical communication standards. The connected building industry, in particular, battled with several standards for the past 10 years. In today's electricity grids, approximately 360 different protocols are unable to communicate with each other. A well-crafted, government-led standards body could have ended this issue years ago.

4. Increase transparency and flexibility in the electricity market, giving consumers the ability to purchase electricity from the most efficient provider.

Role of the ICT Industry

There are several imperatives for the ICT industry to help accelerate adoption of the Smart Grid:

- **Partnering for Systems Integration:** From an ICT perspective, building the Smart Grid is a fairly straightforward technical challenge—most of the core technologies exist and have been proven. The real challenge, however, is integrating the various technologies into a single, working solution. It is a significant systems integration challenge to tie various devices, constituencies, and telecommunications protocols together seamlessly. No single company has the capabilities to implement the Smart Grid; each industry brings a piece of the solution. The challenge, especially for ICT companies, is to stop operating as "islands." Rather, they need build the alliances and partnerships required to ensure their technology fits into the larger, cross-industry ecosystem that constitutes the Smart Grid.
- **Increase Risk-taking:** In a recent discussion with technology companies, Jim Rogers, CEO of Duke Energy, said that because Smart Grid ideas are evolving so quickly, technology companies must become more comfortable with taking risks and applying their technologies to new applications. Rather than wait for the perfect IT solution or comprehensive standard to be developed, companies should expedite taking their solutions to market for testing and vetting.[11]
- **Companies Make Markets; Markets Don't Make Companies:** Large, successful, established companies often pursue a "fast follower" strategy, waiting for the market to be proven and many customers to be identified. This often makes sense before investing significant R&D resources. The Smart Grid, however, may evolve in a way that makes the fast-follower strategy undesirable. The core technology and communications standards that will enable widespread Smart Grid adoption are currently being developed. Once protocols are established, they will be built into a capital infrastructure (power plants, substations, buildings, powerlines) that has a useful life of 30-plus years. This is a much longer than the traditional ICT solution lifecycle. Once Smart Grid standards are set, they will be around for a while. Woe to the company that finds itself on the wrong end of that solution.

Conclusion

Rising fuel costs, underinvestment in aging infrastructure, and climate change are all converging to create a turbulent period for the electricity industry. To make matters worse, it's becoming more expensive to expand power-generation capacity, and public opposition to new fossil stations—particularly coal-fired stations—is increasing. As a consequence, reserve margins for system stability have reached a critical level in many countries. As utility companies prepare to meet growing demand, greenhouse gas emissions from electricity generation may soon surpass those from all other energy sources.[12]

Fortunately, the creation of a Smart Grid will help solve these challenges.

A Smart Grid can reduce the amount of electricity consumed by homes and buildings, significantly reduce peak demand, and accelerate adoption of distributed, renewable energy sources—all while improving the reliability, security, and useful life of electrical infrastructure.

Despite its promise and the availability of most of the core technologies needed to develop the Smart Grid, implementation has been slow. To accelerate development, state, county, and local governments, electric utility companies, public electricity regulators, and IT companies must all come together and work toward a common goal.

The suggestions in this paper will help the Smart Grid become a reality that will ensure we have enough power to meet demand, while at the same time reducing greenhouse gases that cause global warming.

Endnotes

1. Al Gore speech at NYU Law School, September 2006 (http://thinkprogress.org/gore-nyu)
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3. "GridWise Demonstration Project Fast Facts," Pacific Northwest National Laboratory, December 2007
4. State of Missouri, Mr. Dave Mosby, Director of Facilities, December 2007
5. 2005 Dormitory Energy Competition at Oberlin College, Cleveland, Ohio. "On average, dorms reduced electricity use by 32 percent during the competition. The two dorms with real-time feedback won with 56 percent reductions in electricity." (http://www.oberlin.edu/dormenergy/news.htm)
6. International Energy Outlook 2007, Energy Information Administration, U.S. Department of Energy, Figure 6, "World net electricity generation grows by 85 percent in the IEO2007 reference case, from 16,424 billion kilowatthours in 2004 to 22,289 billion kilowatthours in 2015 and 30,364 billion kilowatthours in 2030." (http://www.eia.doe.gov/oiaf/ieo/highlights.html)
7. International Energy Outlook 2007, Energy Information Administration, U.S. Department of Energy, Figure 6, "World carbon dioxide emissions continue to increase steadily in the IEO2007 reference case, from 26.9 billion metric tons in 2004 to 33.9 billion metric tons in 2015 and 42.9 billion metric tons in 2030, an increase of 59 percent over the projection period." (http://www.eia.doe.gov/oiaf/ieo/highlights.html)
8. Jim Rogers, CEO of Duke Energy, briefing to Gridwise Alliance meeting, Charlotte, North Carolina, December 2007
9. World Energy Outlook, 2006
10. 2005 Dormitory Energy Competition at Oberlin College, Cleveland, Ohio. "On average, dorms reduced electricity use by 32 percent during the competition. The two dorms with real-time feedback won with 56 percent reductions in electricity." (http://www.oberlin.edu/dormenergy/)
11. Jim Rogers, CEO of Duke Energy, briefing to Gridwise Alliance meeting, Charlotte, North Carolina, December 2007
12. Stern Review on the Economics of Climate Change, 2006

Notes

More Information

The Cisco Internet Business Solutions Group (IBSG), the global strategic consulting arm of Cisco, helps CXOs and public sector leaders transform their organizations—first by designing innovative business processes, and then by integrating advanced technologies into visionary roadmaps that address key CXO concerns.

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