Response to PSC Questions by Paul J. Elston, Senior Consulting Associate, Center for International Earth Science Information Network, Earth Institute, Columbia University (3/7/05)

This is a response to Public Service Commission (PSC) Staff request for comments on 14 questions concerning the future of the System Benefit Charge. I offer the comments on behalf of Center International Earth Science Information Network (CIESIN), Earth Institute, Columbia University, and in consultation with Roger Anderson, Doherty Senior Scientist and Albert Boulanger, Senior Staff Associate, of the Lamont-Doherty Earth Observatory, Earth Institute, David Waltz, Director, Center for Computational Learning, School of Engineering and Applied Science, Columbia University and Chris Jones and Robert Yaro at the Regional Plan Association.

The primary focus of my comments will be on the transmission and distribution (T&D) system (Question 12), although my comments will also touch on issues raised in Questions 1, 2, 3, 4, 5, 8, 9 and 13, but in the context of the T&D system.

As a general matter, we believe the investment of the System Benefit Charge (SBC) funds in energy efficiency and equity programs is an outstanding model for clean energy programs nationally and is essential for addressing public objectives not adequately achieved through competition and market forces. Based on NYSERDA evaluation of the potential for additional productive investment, we also believe there is a strong case for continuing the program and substantially increasing the size of the program.

Question 12: Should SBC funds be extended to programs that encompass research and development into transmission and distribution of the State's energy resources?

Yes, SBC funds should be extended to programs that encompass transmission and distribution of the State's energy resources. SBC is meant to address issues of systems efficiency and equity that are not adequately addressed by competitive markets. The existing T&D system, although essential for competition in the electricity market, is highly regulated and investment decisions are not the product of competition or market forces.

Transmission and Distribution (T&D) issues are the most difficult to address through market forces, because the system is operated as an oligarch. We think there is no sense in decentralizing ownership because the interests of the public will be best served if it is examined and operated as one interconnected system. Unlike generation, where many owners can produce competition that encourages cost savings and innovation, the significant problems and opportunities for improving the T&D system require much better coordination among all the stakeholders, owners and customers alike. Significant improvement and modernization of the T&D system in the state will require a sharing of knowledge and experience and of physical changes across ownership boundaries, an ability to see all parts of the system even beyond New York assets, an elimination of duplication and redundancy, and open, instantaneous and efficient access to information about the system.

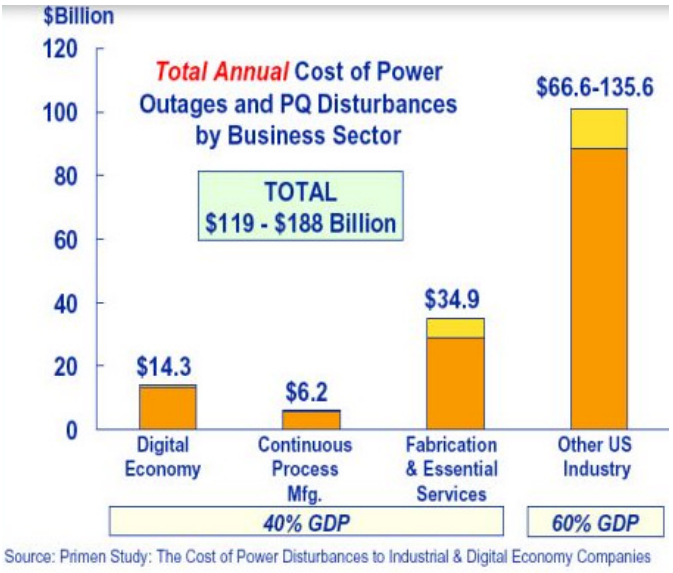
The technical research and development work needed to improve the T&D system must consider the entire electric grid system as one in order to achieve the needed improvements. However, research and demonstration of the technologies that will improve the system is not sufficient. There is significant evidence that existing regulation has discouraged adequate investment in the system, and that investment decisions are being driven by a narrow definition of short-term cost savings at the expense of much larger costs to society over the long term. The technical research and development work should be complemented with a significant evaluation of the regulations that have created disincentives for investments, and both must be informed by an assessment of the full costs to society.

"Much of the 157,810 miles of high-voltage wires, towers, transformers and substations that form North America's power grid comprises what is now considered to be an aging system. Meanwhile, new power plants have been added to the transmission system over the last three decades but upgrades in transmission infrastructure have not kept pace. The capacity of the transmission system of the United States as measured by MW-miles per MW peak demand has decreased by 16.2 percent from 1989 to 1998, says the Edison Electric Institute. Over the course of the next decade, however, demand is projected to increase by more than 20 percent while power line mileage is expected to grow by only 4.2 percent, it adds."
Source: Utilipoint's E-newsletter.

The existing electric grid is built with fifty-year-old technology and designed to meet the needs of an analog economy – and it is at its limits in many ways. At present, the grid is not equipped to deal with the large increases in congestion and electricity traffic being stimulated by the long-distance demands of the new power trading and deregulation of U.S. electricity markets. Slow response times of mechanical switches, lack of automated analysis of problems, and inability to “see the whole grid”, are contributing to a troublesome increase in failures of the grid. These problems which have caused a dramatic increase in blackouts and brownouts across North America since 1998 (Anderson, and Boulanger, ASME, Power 2004, 2004), will propagate cascading failures of the grid more and more frequently unless we migrate to a new ”smarter” or more intelligent grid control system because decision speeds increasingly are becoming too fast for humans to manage. As demand, sources of energy, and distances between demand and supply increase, the grid will become more and more vulnerable to blackouts.

The events of 9/11/01 focused attention on the vulnerability of the grid, and the blackout of 8/14/03 demonstrated the economic losses associated with failure of the grid. The grid is exhibiting more and more behavior characteristic of chaotic systems. A major source of this non-linearity is the grid’s own protection mechanisms and equipment. Analog control of this equipment affects the flow of electricity in unpredictable ways, causing cascading failures like that experienced in the northeast blackout. Standard and Poor estimates that economic losses from the 8/14 failures totaled approximately $6 billion. The Electric Power Research Institute (EPRI) estimates that power outages and power quality disturbances cost U.S. businesses more than $120 billion per year.

Reliability improvement mandated by cost of outages



August 14th Blackout
By-The-Numbers

- **2** Canadian Provinces
- **3** deaths
- **4** Days Big-3 Automakers out
- **8** U.S. states
- **12** airports closed
- **23** cases of looting in Ottawa
- **100** power plants out
- **9,266** square miles affected
- **61,800** MW of power lost
- **1.5 million** Cleveland residents without water for 4 days
- **50 million** people with no power
- **$4-6 billion** in economic activity lost

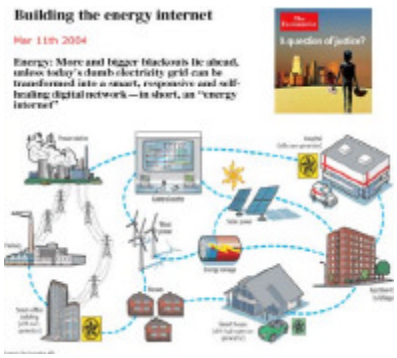
As viewed by the U.S. Department of Energy: "The size, importance, and complexity of the grid are difficult to underestimate. Each day, over 10,000 power plants deliver electricity to customers over 157,000 miles of high voltage electric transmission lines to 131 million customers. The nation spends $247 billion on electricity a year, and the total asset value of the grid is estimated at $800 billion. While the grid is a technological marvel, it is also reaching the limit of its ability to meet the nation's electricity needs. A variety of factors are impacting the performance of the grid, including aging equipment, the presence of transmission bottlenecks, the effects of deregulation and regulatory change, and jurisdictional issues associated with the numerous stakeholders who control, regulate or impact parts of the grid. In recent years, these factors have combined to discourage private sector investment in upgrading the nation's grid and in developing new transmission and distribution-related technologies. Upgrading the grid to meet the electricity needs of our nation in the 21st century will be a vital step towards ensuring our nation's economic viability and national security in the coming years".

The Energy Future Coalition, in their report, *Challenge and Opportunity: Charting a New Energy Future*, point out that deployment of a Smart Grid will cost tens of billions of dollars and will require a major new Federal funding program complemented by incentives to stimulate private investment. EPRI estimates that $200 Billion is required to upgrade the national system.

(New York needs to develop and evaluate similar information on the operation of the T&D system within the State. The costs resulting from outages to New York businesses and residents needs to be fully documented and analyzed in order to gain both business and public support for the investment in the New York grid that is needed.)

With an objective of increasing energy efficiency and reducing our dependence on fossil fuel, New York is promoting creation of distributed and renewable energy generation and end-use management – all of which create new demands on the grid and complicate the management of the gird. At the same time, deregulation of generation means that the transmission and distribution utility responsible for performance of the grid does not control important parts of the system. The growing needs of the digital economy have radically altered the nature of the demand for the quality of the electric load.

How to build the "Energy Internet"



- Internet-like flexibility
  - Electric grid to rigid and brittle
- Internet-like routing of traffic and control of congestion
  - Current electric grid all downhill
- Internet-like controlled failures
  - Grid now shuts down and must be black started

Taken together, these factors and their economic and environmental implications create a powerful case for the Smart Grid. The nation and the State need to develop and deploy such a digitally controlled, fully networked transmission and distribution system that can support distributed generation and storage. The Smart Grid would improve efficiency, security, reliability and adaptability of the system. A robust, secure electricity grid that can meet ever-increasing demands is an essential foundation for the growth of our economy. Use of advanced technologies will be needed to create such a Smart Grid. The new grid should be a system that incorporates cutting-edge electrical and systems engineering, sophisticated sensing and monitoring technology, computer information and learning technology and secure communications.

Silicon, and soon, nanotechnologies will provide pervasive monitoring and "distributed intelligence" creating the capacity for instantaneous corrections to the system -- the self-healing characteristic of the Smart Grid. Digital substation controllers will allow rerouting of power around congestion and equipment failures. Fault current limiters will absorb spikes in the power and produce the high quality electricity required by the microprocessor-based industries. New super-batteries, flywheels, and superconducting magnetic energy storage will create distributed capability to store energy and make the grid more resilient. Superconductivity and nanotechnology will dramatically increase the throughput capacity of the lines and increase the speed of control. The Smart Grid will support fuel cells, wind farms and solar generation and the communications capacity of the Grid will enable users to manage their energy use, increasing efficiency and reducing energy costs.

Goals for a New York Smart Grid Effort

A Smart Grid effort in New York should be grounded in an agreed upon set of public policy goals. We suggest the following specific goals for the Smart Grid:

1. Smart Grid should Improve Security and Reliability

Long Term Goals for Smart Grid

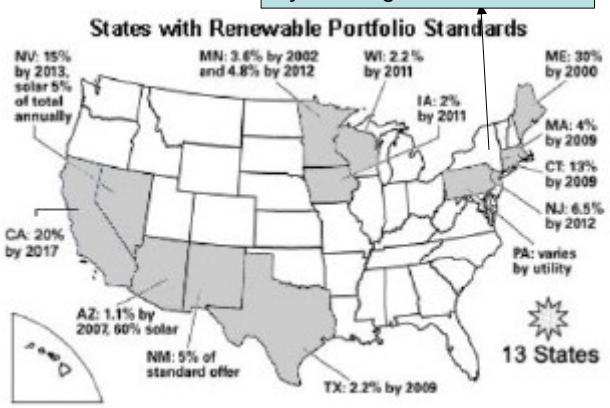
- Improve security and reliability:
  - Secure from physical and cyber threats
  - Self-healing
- Enable movement towards a carbon-free energy system:
  - Renewable sources
  - Distributed generation
  - End-use efficiency
- Provide quality electricity for the digital economy:
  - Digital-age electric system
  - Distributed storage
- Protect value of the investment in the integrated system
- Permit expanded capacity for growth within the existing footprint

After 9/11, the nation's concern about terrorism has focused attention on the vulnerability of the electric grid system. Security concerns make it essential that the electricity grid be upgrade so that it is capable of real-time management and instant correction. New management control capability, distributed intelligence, last-mile monitoring combined with improved information management capability will create a gradual degradation capacity similar to the Internet. High-speed digital controllers will redirect electricity around problems.

2. Smart Grid should enable Renewable Energy

Most government policies promote the use of renewable energy sources and distributed generation (such as cogeneration and fuel cells) because they can produce significant environmental benefits. New York State has set a goal to increase the use of renewable energy sources to 25% of the total. Global climate change makes it a necessity to

NY 25% - 17% now with Hydro - Highest in Nation



- Government Goals to increase efficiency and reduce fossil fuel consumption promote a carbon - free system:
  - Distributed generation
  - Renewable energy
  - End-use management
- Led by States

incorporate wind, solar and other green generation sources into the grid, but this type of energy creates variable loads on the system that stretch the capacity of the existing grid. New management control capability, last-mile monitoring combined with improved information management capability and distributed storage will help meet the new demands on the system.

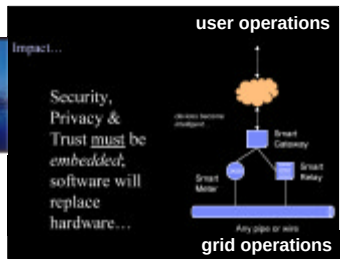
3. Smart Grid should Increase End-Use Efficiency

New York has a strong program to promote end-use-management to improve efficiency and reduce customer energy costs. But the effectiveness of these management systems is limited because they require grid-related communications capabilities to allow customers to schedule energy use to take advantage of real-time electricity pricing, incentive-based load reduction signals, or emergency load reduction signals. Last-mile monitoring combined with improved information management capability combined with smart devices in homes and offices will materially increase end-use efficiency.

Smart Grid will stimulate end-use efficiency

- New intelligence on the wire to maximize efficiency and conservation
  - Smart devices
  - Two-way devices intelligence to communicate back and forth.

Every Million Grid Friendly controllers distributed into homes and offices will provide the intelligence to increase end-use efficiency and eliminate the need for 100 new Power Plant



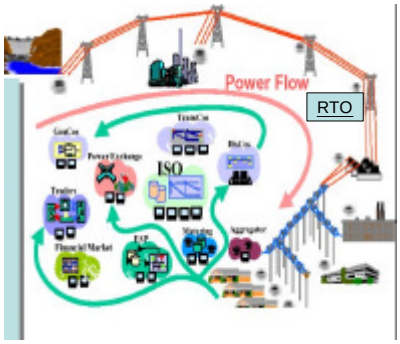
4. Smart Grid should meet requirements of the Digital Economy

The growing demand for high quality, digital-grade electricity has taxed the electrical infrastructure to its limit, particularly in NYC. Microprocessor-based technologies have radically altered the nature of the electrical load, resulting in electricity demand that is incompatible with a power system that was created to meet the needs of an analog economy.

According to the Energy Futures Coalition, this has led to problems with the power quality for high-tech industries such as telecommunications, data storage and retrieval services, the financial industry, biotechnology, electronics fabrication and other businesses that use continuous-process manufacturing. Development of a self-healing transmission and distribution system capable of automatically responding to disturbances will be essential to meeting the future needs of business that rely on digital technology. New high-speed management control capability, distributed intelligence, last-mile monitoring combined with improved information management capability, fault current limiters and distributed storage will materially upgrade the grids capability to meet the new demand for high quality electricity.

5. The Smart Grid should support application of market forces

Deregulation added Complexity to the Grid



- Requires coordination & transparency
  - Wholesale transaction growth 400% in last decade
  - New players:
    - ISO
    - RTO
    - NECC
    - Distribution
    - Independent generation
    - traders
    - aggregators

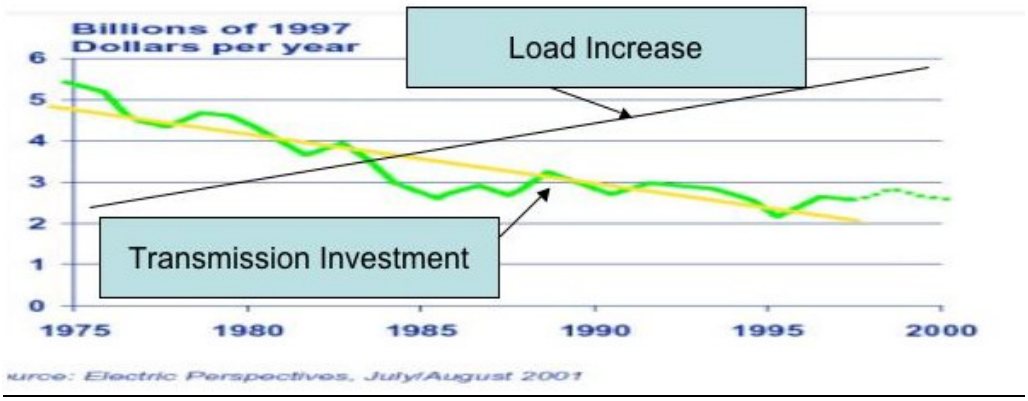
Deregulation of generation, with independent operators owning and operating generation means more competition and less control by Transmission and Distribution utilities. The Smart Grid will facilitate the market and encourage the competitiveness that is the goal of deregulation. New management control capability, last-mile monitoring combined with improved information management capability and distributed storage will help meet the new demands on the system.

6. Smart Grid should protect the existing investment in the grid and allow growth within the existing footprint of the grid.

Throughput must be Sustained

- During the past 25 years
  - Load on the Transmission Grid increased 35%

  BUT
  - Transmission Investment has fallen each year



New materials such as aluminum composite cables and Quantum wires made from nanotechnologies can enhance the transmission and distribution capacity without requiring construction of additional lines.

Need for a Stakeholder Process

The PSC should not pursue an objective to upgrade the T&D system in the same manner that it has pursued innovation and efficiency in generation and renewables. Unlike generation where the objective of the SBC investment has be designed to facilitate alternatives to traditional generation, the investment in the T&D system must be designed to affect the investment decisions of the existing owners of the system and to improve their coordination. We recommend consensus building through a Stakeholder Process that is led by the State, governed by a Steering Committee of the State and the grid owners, and includes selected advisors from among the numerous stakeholders in a reliable, secure, efficient and flexible electric grid in New York. The Stakeholders should oversee the initial phases of research and engineering that will lead to the Smart Grid

The Stakeholder Process should bring together the parties who have an interest in the Smart Grid in order to build consensus on the definition, the characteristics and specifications for the future grid in New York. Under the leadership of the State, the grid owners should oversee the 10-year research and demonstration effort that is necessary to create a Smart Grid in NY. Through the Stakeholder Process, the Stakeholders can begin to define and show the implications of the new systems and hardware that will be part of the future Smart Grid.

We recommend that the Stakeholders be defined to include:

- State officials
- Owners of the grid in New York
- Users of the grid
- Consumers of electricity
- Energy technology companies
- Environmentalists
- Federal and other state representatives
- R&D institutions

The Stakeholder Process will allow the owners of the grid to pool their resources, expertise and experience in an effort that would benefit all of the owners. This joint effort will recognize the need to consider the grid as “one integrated whole” and will allow a systems engineering consideration of the whole grid. Participation by the State will better enable the owners to focus on the long-term vision and requirements for the grid and will ensure the effort fully reflects the public’s interest in the grid.

We also recommend that the effort initially focus on the creation of a virtual grid on computer systems prior to actual implementation on the grid that is essential to so much of NY’s economy. The upgrade that we envision must be implemented in a manner that ensures that the grid is not disrupted. In addition to providing this safeguard, beginning with a computerized virtual grid holds several additional advantages:

- The State and grid owners will have a common evaluation tool that considers the "whole" value of the system;
- Working through the Stakeholder Process, the modeling that constitutes the virtual grid will be a precise expression of the Smart Grid and will also allow for several versions of the Smart Grid to be considered;
- The virtual grid will provide the least cost way to arrive at an optimal definition of the Smart Grid and to assess the its implications; and
- The virtual grid will create a vision of the future grid in NY that will allow grid owner, regulators, equipment suppliers and researchers to work toward a common objective, and provide a uniform testing mechanism for new systems improvements and new hardware.

We define a virtual grid as a computer model with fast simulation capacity and modern computational learning "smarts." Our operational premise, learned through collaboration with diverse industries such as automotive, pharmaceutical and aerospace companies over the recent past, is that much more time must be spent on the computer-aided design of the new systems, processes or products than in their physical construction and testing.

At Boeing, for example, the ratio of computer-aided design to assembly line manufacturing time went from 1:5 before their experience with development of the 777 aircraft to 5:1 after that aircraft. They are 4 generations beyond that plane now, and they have succeeded in cutting the time and cost by 50% for each new generation of plane.

We are proposing the same Lean[1] principals for the Smart Grid: integration across functional departments, systems engineering in addition to component engineering, process management, and above all, simulation and modeling of possible outcomes before implementation. Grid control, capacity management, performance monitoring, risk assessment, restoration planning, and even security analyses can be simulated before they are physically tested. Grid owners and consumers can then be certain that they have maximized the capacity of the grid while at the same time minimizing its cost and impact on the environment.

This virtual grid would be New York's version of the fast simulation-modeling (FSM) project of E2I's IntelliGrid effort with an early implementation specifically for the State's electric grid. Real code built into real models implemented specifically for the New York electric grid can be created rapidly and concisely through the collaboration of all the stakeholders in the State.

This virtual grid can be used to evaluate options for the Smart Grid and can eventually mature into a Management Control System that can be used to increase the fidelity of the models of the actual grid system and build a hardware interface to implement eventual tests of new hardware through what we call a "Hybrid" Test Bed. The Management Control System that emerges can be used to operate the Hybrid Test Bed, a micro-grid

[1] c.f. http://leanenergy.ldeo.columbia.edu and http://lean.mit.edu

with new hardware and software controls. We think that deployment of some of the technology and hardware required for the Smart Grid may begin in two or three years, but that most deployment will not begin until the owners gain significant experience with the Hybrid Test Bed. The State must also facilitate commercialization of the software in order to stimulate the investment needed to deploy the software and firmware, and to provide the maintenance capacity the systems will require. (See answers to Questions 8 and 9 below).

Regulatory, Financial and Environmental Analysis

In addition to the computer intelligence, systems integration, technology and hardware efforts described above, the State must focus on the regulatory, financial and environmental dimensions of the T&D issues.

National figures indicate that during the past 25 years the load on the electric grid has increased 35% while each year investment in the grid has fallen. EPRI estimates greater than $100 million in outage costs to end-users nationally. Working with the owners and regulators of the electric grid, the Stakeholder effort should establish the fact base for NY and evaluate the implications for the electric grid in New York. This requires a joint financial and regulatory analysis. The assessment should identify the improvements possible for both the transmission system of the state and for the several distribution systems in New York, urban networks and radial, and document investment by each of the owners. In addition, the effort should identify and document information on outages on the transmission system and each of the distribution systems and the causes of the outages, and try to identify the relationship between the outages and the state's lack of investment in each part of the grid. The analysis should also consider the operations and maintenance requirements of the modern smart grid.

The product of this effort needs to be coordinated with the information on the cost of outages to end users to assess the relationship among traffic on the grid, investment in the grid, outages on the various grids and end-user's costs. Collection of the information on the transmission system and each of the distribution systems will allow for comparisons among the distribution systems and comparisons with national data.

Economic Impacts and Business Participation

The economic return on an investment as large and complex as the Smart Grid is both immense and difficult to estimate. The effects will be ubiquitous, touching nearly every aspect of commercial, industrial and consumer activity. Its implementation and impacts will also play out over several decades and will be affected not only by New York State's own level of investment and strategic decisions regarding the grid, but also by how effective these are relative to capital upgrades in other regions.

The impacts will also vary substantially by both industrial sector and geography. Manufacturing, financial services, information services and other sectors will have their own particular capacity and reliability issues. In addition, different regions of the state—

upstate and downstate, and the metropolitan and non-metropolitan areas within them—have different densities, industry structures and demographic patterns that will give them different sensitivities to power upgrades.

In spite of these complexities, it can be safely assumed that the benefits of Smart Grid investments will be enormous. The same universality that makes the benefits difficult to calculate also insures that any improvement in capacity, efficiency or delivery will have pervasive effects on productivity and economic growth. As a basic infrastructure system, it will provide a platform for growth just as improvements in transportation, communications and power have set the stage for new eras of expansion throughout history.

The Stakeholder process should fully engage the end-users of the system. The potential benefits and issues for specific economic sectors should be determined. The engagement with end-users should be designed to obtain structured responses to questions related to the value of the proposed investments, such as the relative importance of reliability, security, cost and other factors, how energy infrastructure affects business location and expansion decisions, the costs and risks of disruptions, end-user investments (such as back-up generation) made to overcome the impacts of outages. Participants should include executives from major employers and representatives from statewide and regional industry associations, and representatives of residential users. A particular effort should be made to understand the ramifications for small businesses, which are generally underrepresented in these types of considerations.

The sector and regional analysis, as well as the engineering, system and financial information that will be developed in the project, will provide inputs that will help to quantify the economic impacts of this new generation of energy infrastructure. For example, estimates of the costs of power outages for different sectors can be combined with project estimates for how often these outages would occur under different scenarios.
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Environmental Assessment

The starting hypothesis for investment in a Smart Grid in New York is that it will result in environmental improvement by:

- Enabling more extensive use of renewable energy sources,
- Enabling more extensive use of distributed generation and distributed storage,
- Increasing end-use efficiency, and
- Creating additional capacity to serve growth in the use of the grid within the existing footprint of the grid.
-

These hypothesis need to be confirmed through the Stakeholder Process.

The virtual grid model should be designed to identify, document and measure potential environmental benefits of the Smart Grid, as well. For example, an enhanced capacity to gather information on the grid, to process the information, to provide the information to

end-users and to automate the response by end-users may materially increase the potential efficiencies achieved by end-users. Similarly, enhanced exchange of information about the grid and the use of electricity by the consumer should help overcome the impediments to net-metering and allow more extensive use of electricity provided by end-users and better management of loads by the supplying utilities.

The Stakeholder Process should engage the environmental community to provide its own assessment of the environmental characteristics of the existing patterns of electricity supply in New York, help develop the environmental parameters that are be built into the virtual grid and evaluate the results of simulations.

Amount of Funding and Length of Program

Because the current grid system is fragile and the cost of disrupting the system is so great, and because the Smart Grid must be an integrated system with numerous new technologies, we believe this new Smart Grid development effort must be initially demonstrated off-line, in a Test Bed. Developing the ability to insert system upgrades and install new hardware -- such as remote wind and solar farms, superconductors, super-storage devices and next generation nanotechnologies -- will require testing and development prior to actual deployment. We believe that at a minimum this process will take at least ten years.

We are not sure how much is required to create a substantial upgrade of the grid in New York. However, we expect that a realistic estimate will be produced through the work of the Stakeholders. On one hand we think it will cost about $15 million and take 5 years to fully design the upgraded system and create a virtual grid that can be used to evaluate outcomes of grid investments. But we also see a need to create a Hybrid Test Bed (computer and hardware) and a Physical Test Bed (micro-system) starting in year three of the effort and we think this may cost in the range of $200-$500 million within the initial ten years of the effort.

However, if we look to the EPRI estimate that the US will need to invest $200 Billion nationally to achieve the Smart Grid and estimate that a normal major capital project will require at least 10% to plan and specify the project, we can envision a front-end investment of $20 Billion nationally for the Smart Grid. Since NY accounts for 4% of energy consumption, New York should plan on a Smart Grid R&D budget of $250-$800 million over a ten year program.

Questions 8 and 9: How can SBC funded programs be more responsive to the needs of New York's energy customers? How can SBC funded programs be marketed more effectively?

A key measure of success for the SBC program should be: does it lead to change in investment decisions, AND does it lead to important products that penetrate the market. A premise of our answer is that if NYSERDA handled the Intellectual Property (IP) issues better, they would be getting better penetration of technologies now. Look at the

experience of the Federal Government. Because of the extensive evidence that IP is best left in the hands of the inventors, universities and business enterprises to commercialize, Congress enacted the bipartisan Bayh-Dole Act of 1980 in 1980. The Bayh-Dole Act of 1980 allows for the transfer of exclusive control over government-funded inventions to universities and businesses operating with federal contracts for the purpose of further development and commercialization. The contracting universities and businesses are then required to exclusively license the inventions to other parties. The federal government, however, retains "March-in" rights to license the invention to a third party, without the consent of the patent holder or original licensee, where it determines the invention is not being made available to the public on a reasonable basis, (in other words, to issue a compulsory license.)

Twenty-five years of subsequent studies of the effects of the Act have accumulated a large database of positive technological fallout from the Act. This experience suggests that no state agency should consider imposing state-ownership of the IP from efforts like the SBC. Back up for this statement is very widespread. Hotlinks are included below to the text of the bill, followed by commentary on its progress by the authors, and recent analyses from the Council on Governmental relations and the Association of American Universities.

Onerous IP ownership requirements have prevented many of the great research universities of America from collaborating with EPRI (Columbia included). The T&D problem in NY State is of too great a common need to do the same in our own backyard.

Text of the Bayh-Dole Act (35 USC 200-212).

April 11, 2002. Birch Bayh and Bob Dole's letter to the editor of the Washington Post in response to the March 27 op-ed on the Bayh-Dole Act. Our Law Helps Patients Get New Drugs Sooner.

1999. The Council on Governmental Relations (made up of faculty from a number of US universities.), from http://www.ucop.edu/ott/bayh.html

June 2, 1998. Association of American Universities. University Technology Transfer of Government-Funded Research Has Wide Public Benefits.