CEIDS

Consortium for
Electric
Infrastructure to Support a
Digital
Society

Value Assessment

July 10, 2001

An Initiative by EPRI and
The Electricity Innovation Institute

CEIDS Value Statement Introduction:

With the dawn of the "always connected" era, an "always on" world of opportunities has emerged. This, in turn, has formed the foundation for the emergence of the digital economy. The importance of enabling and sustaining the digital economy and consequent growth in productivity cannot be overstated. Simply put, the digital economy is the engine that provides the motive force for economic and social progress, and this engine runs on electricity. However, as illustrated by current events in California, the ability of the current electricity delivery system to provide the quality and reliability of power necessary to serve the needs of the digital economy is very much in question.

In response to the growing demand for high quality electricity supply fostered by the digital revolution, EPRI and its Electricity Innovation Institute (E2I) have initiated an ambitious program designed to meet the needs of a digital society. The Consortium for Electric Infrastructure to Support a Digital Society (CEIDS) will build public/private partnerships to explore state-of-the-art power delivery and end-use technologies, as well as yet-to-be-developed technologies to meet the energy needs of the high-technology industries and businesses tat make up our new, digital-driven society.

CEIDS is conceived as and constructed to be a partnership of all the stakeholders in electricity and the digital society – electricity providers, government policy makers and their constituents, the users and makers of digital equipment, and continuous process industrial firms. Each of these stakeholder groups have a compelling interest in achieving the objectives of the CEIDS program which include:

1. ***Establish leadership in anticipating and meeting tomorrow's electric energy needs by:***
   - Applying a combination of the most advanced technologies
   - Managing the vital link between economic productivity and the quality of electric power supply to customers
   - Identifying the new weak links, pressure points, and critical components being driven by the new uses of the nation's electricity delivery system and makes the system vulnerable to failure or attack.
2. ***Enhance value by:***
   - Maximizing asset utilization; enabling digital loads to be served reliably and profitably; and leveraging the digital infrastructure in ways that both control costs and improve customer satisfaction.
   - Continuing the acceleration of productivity growth; facilitating consumer choice through the introduction of efficient technologies as well as facilitation of truly open markets; and reducing overall energy needs and costs.
   - Assuring the availability of highly reliable premium quality power; reducing energy needs and costs involved in powering digital systems and related physical plant; and facilitating wide-scale choice of providers.
3. ***Create and foster opportunities that Enable digital-quality power supply by:***
   - Leveraging the advantages of distributed resources
   - Defining and facilitating value-added electricity services
   - Providing new Direct Current (DC) electricity supply technologies
   - Developing and employing advanced power conditioning, power quality devices and power electronics
   - Establishing new service quality standards for electricity and related products

By focusing on those objectives and applying them to the new concept of a digitally suited power system delivering "always-on" electricity to fulfill the ever-changing needs of a digital society, CEIDS will create the following **value propositions** for the initiative's participants, players and society at large:

1. ***Establish a long-range strategy to ensure that the electric energy industry will continue to provide the quantity and quality of power required by the digital society by:***
   - Providing leadership in defining service quality standards for electricity and related products that conform to the reliability requirements of the digital society

- Leveraging resources of all stakeholders to evolve the existing power system to meet tomorrow's needs
- Establishing the system and business flexibility to serve the customers of tomorrow
- Ensuring the system is sufficiently robust to withstand the threat of natural and man-made disaster

2. ***Enhance stakeholder value by:***
   - Enhancing asset utilization in transmission systems by at least a factor of two
   - Improving system reliability and providing adequate power quality
   - Allowing power providers and system operators to serve new digital loads profitably and reliably
   - Leveraging the features of the digital infrastructure so as to control costs and improve customer satisfaction
3. ***Develop new markets by:***
   - Leveraging the advantages of distributed resources as a new business option
   - Defining and facilitating the opportunity to provide a range of electricity-related products and services
   - Evolving new opportunities to provide DC power as a profitable business
   - Creating business opportunities by developing new power quality mitigation technologies

Meeting the challenge of defining, designing and building the technologies that will provide the backbone for the infrastructure of the digital society requires a multi-disciplinary program of technology development. CEIDS will concentrate on developing technology and products to support the following four technology platforms:

1. ***The Self-Healing, Digital-Quality Electricity Superhighway*** – Develop science and technology that will increase the control, capacity, and reliability of power systems so as to supply consumers with the quantity and quality of energy they need at competitive prices and provide the necessary "hardening" that will allow the systems to survive conceivable threats from natural and man-made disasters.

2. ***Energy Solutions for End-Use Digital Applications*** **–** Provide options to energy consumers for meeting their energy needs by developing innovative technologies that provide greater tolerance to power disturbances. Options will include changes to the power requirements of digital devices as well as integration with the power system, distributed resources, and power conditioning equipment.

3. ***Value-Added Electricity Services*** **–** Develop and implement technologies that will enable consumers to access a variety of electricity-related business opportunities.

4. ***Digitally Enabled Energy Efficiency*** – Develop innovative technologies that provide options for consumers to manage and use energy more efficiently. Options will include application of solid-state electronics for the control and utilization of electric power and load management programs.

These platforms facilitate the transformation of electricity suppliers, markets and users, enabling a revolution in the way both suppliers and users approach the electricity market. The benefits that can be accelerated and realized through the CEIDS platforms include:

- Supporting wide-scale wholesale transactions through enhancement of the power delivery infrastructure
- Enabling the digital society through enhancement of power quality and reliability
- Enabling productivity through enhancement of reliable networked digital services
- Reducing energy needs through development of efficient technologies
- Enabling a wide range of electricity-related services to enhance customer choice and the value provided by electricity

CEIDS will use the consortium model of collaboration developed and proven by EPRI since its formation in 1973. Under this model, the resources of entire groups of stakeholders are pooled to provide a critical mass of funding that can be used to focus on challenges too large to be effectively met by any single entity.

The leverage and synergy provided by this concentration of funding as well as the advice and direction of industry advisors have allowed EPRI to help the electricity industry meet scientific and technical challenges that would have been impossible for the individual companies. As a result, EPRI has consistently demonstrated value far in excess of industry contributions to its programs.

In examining the challenges and opportunities to be addressed by CEIDS, the magnitude of the value that would be created for companies, industries and society at large by successful completion of the four technical platforms demands a similar program, funded and directed by a diverse set of stakeholders from government, power suppliers and end-users. Bottom-line, this value is estimated to be $____________. The CEIDS program will focus on selecting and developing technologies that can fundamentally change the equation currently defining the value of electricity from both the supply- and demand-side.

The value of the CEIDS program will be realized both directly and indirectly, for participants and for society at large. This value will be manifested in a variety of forms: Through direct impacts at the bottom line resulting from increased asset utilization and cost reductions, through cost avoidance by mitigating and minimizing the economic impact of power quality and reliability problems, and indirectly through energy savings realized by development of more efficient end-use devices and processes.

The sheer size of the value inherent in this program as well as its importance in maintaining and enhancing the productivity engendered by a digital economy freed from the constraints of an increasingly inadequate electricity delivery system provide a compelling argument for the diverse set of stakeholders targeted by CEIDS to set aside proprietary, secretive modes of operation in favor of collaborating on a program that will, in effect, help maintain the rising tide of productivity that "raises all boats". Only through such a collaborative effort, funded and directed by the constituents of all stakeholders can CEIDS succeed in providing the needed technology.

EPRI arose out of the Northeast blackouts of the mid-1960's to fill a void in electricity-related science and technology. The current situation, as demonstrated by the problems being experienced in California, dramatically illustrates the need for such a program that focuses not just on the needs of the electricity industry, but on both sides of the meter. CEIDS will examine issues of power quality from the bus bar to the chip, and on developing efficient technologies to help digital enterprises and process industries obtain the most value from each electron. In an era of declining natural resources and rapidly increasing population, such technologies will be vital to maintaining society's ability to provide a reasonable standard of living into the future.

Maintaining our standard of living depends on continuing to increase our productivity which in turn depends on continuing to improve the efficiency and effectiveness with which we utilize our precious natural resources. Electricity is the most efficient form of energy, and increasing the efficiency with which we produce, transport, and utilize electricity is an important ingredient in ensuring that the economic "bang" we receive from each unit of energy we expend continues to increase over the future, so that we can ensure our children and grandchildren will continue to benefit from a high standard of living.

1. Value of the Self-Healing, Digital Quality Electricity Superhighway CEIDS R&D Platform

Goal: ***<u>Provide Customers with Digital-Grade Power from the Transmission and Distribution System</u>***

<u>A. Distribution System Control Methodology</u>

Cost to Implement

Approximately $200 million

General Benefit Statements

- Reduce the frequency of distribution system outages through fault anticipation and widespread deployment of sensor for equipment monitoring.

- Greatly reduce the duration and impact of failures through self-healing methodology – intelligent agents, fiber optic communications, wide-spread deployment of "smart chip" sensors.

Benefit to Society

Key assumptions:

- the cost of power outages to the US economy is at least $50 billion per year
- distribution outages represent 80% of the total power system outages
- eliminate impact of outages by 30%
- this technology is implemented on (case 1) 10% and (case 2) 50% of the distribution systems

Cost savings through the implementation of this technology would be:

$1.2 billion per year assuming 10% implementations
$6 billion per year assuming 50% implementation.

Benefit to Utilities

Key assumptions:

- there are approximately 1600 distribution substations in the U.S
- each substation has approximately 10 failures per year
- the average cost for a utility to repair a failure is approximately $10,000
- the result from this project will eliminate 30% of these failures
- this technology is implemented on (case 1) 10% and (case 2) 50% of the distribution systems

The saving to utilities from this work is: - $48 million per year assuming 10% implementation, - $240 million per year assuming 50% implementation.

Highly visible outages, such as those experienced Chicago and New York during the summer of 1999 and in San Francisco in December 1999, are very costly for utilities. The components of cost are:

- Drop in stock price due to loss of market confidence – between 10% and 30% for the examples cited above;
- Accelerated capital investment due to repairs and improvements ordered by regulatory authorities - measured in multiple tens of millions in NPV, and

- Internal response to outage, such as reporting, studying, dealing with regulatory & city agencies for a protracted time period (multiple years), etc. - measured in several tens of millions

Benefit to end-users

- Assumption – the cost of power outages to various business types is shown below
- Assumption – distribution outages represent 80% of the total power system outages
- Assumption - Eliminate impact of outages by 30%)
- Assumption – this technology is implemented on (case 1) 10% and (case 2) 50% of the distribution systems

Cost savings from reducing the number of outages and disturbances by business type are shown in the table below:

Business Type	**Total Annual Losses**	**Cost Savings Through the Implementation of this Technology**	
		10% implementation	50% implementation
Digital Economy	$13 billion	$0.3 billion	$1.5 billion
Continuous Process Manufacturing	$6 billion	$0.1 billion	$0.5 billion
Transportation and Fabrication	$29 billion	$0.7 billion	$3.5 billion

B. Integration of Distributed Resources into the Distribution System

Cost to implement

The technology developed in this program will reduce the cost of integrating distributed resources (DR) into the transmission and distribution system by 50%.

General Benefits

- Standardized interconnection devices will increase the use of distributed resources (DR) and, more importantly, improve their strategic value.
- The maximum benefit from distributed resources is achieved through cooperation between the owner and the utility. By having dispatch control over a DR device a utility can access it for peak shaving, VAR support or in outage conditions. By making the DR device more valuable to the utility, the owner can expect a greater return.

(source: "Information to Support Distribution Resources (DR) Business Strategies" TR-114272, December 1999

DR can compete with grid power to provide lowest cost delivered power to end-users in only a limited number of applications. Combining multiple commitments, such as backup power/peaking power, combining alleviating transmission and distribution system constraints with other applications, and premium power/low cost energy, in one DR installation greatly improves economics and may be a key to wider acceptance and use of DR. Integration with the transmission or distribution system is necessary for many applications such as providing peaking power (using DR for a limited number of annual hours to lower overall energy costs) and relieving T&D system constraints.

For example, some utilities provide a credit to customers for allowing DR units to be dispatched during periods when system demand is extremely high. Consider a $3/kW-month credit given to a site that allows it DR unit to be dispatched during times of generation constraint. The year one costs are as follows:

	Not Dispatchable	Dispatchable
Total generation cost (year one)	$10,563	$7,166

By making the unit dispatchable, the total generation cost (for year one) has been reduced by 32%. This type of credit would increase the number of potential DR premium power applications from 382,000 to 833,000.

Benefit to utilities

1. Value of avoiding construction of new transmission lines

Key assumptions:

- that there is currently 750 GW of generation in the US.
- At 2% annual load growth, 15 GW of new generation must be brought online each year.
- that 15 GW of transmission must be constructed to transport this power.
- Assume that (case 1) 10%, 1.5 GW, and (case 2) 50% of this new generation, 7.5GW, will be DR and that 1.5 and 7.5 GW of generation require no new transmission. Therefore the cost of avoiding 1.5 and 7.5 GW of transmission is the value of DR.
- Each line would be 50 miles long and that 5 and 25 lines would be needed at a cost of $1 million per line per mile. (*source – estimate by Don Von Dollen*)

The net benefit would be: $250 million per year assuming 10% implementation - $1.25 billion per year assuming 50% implementation.

2. Value of avoided losses in transmission lines not built

Key assumptions:

- Approximately 500,000 miles of transmission lines in the U.S.
- About 3% of energy is lost as I2R losses in the transmission system
- In 1998, 3,620 billion kWh were generated in the U.S. what at the average value of 6.75 cents per kWh had a retail value of $244 billion.
- The amount of energy lost as I2R losses on the transmission system in 1998 was .03 x 3620 billion kWh = 109 billion kWh with a retail value of $7.3 billion.
- Therefore the annual cost of losses per mile of transmission line is $7.3 billion/500,000 mile = $15K per mile.

Assume that the constructions of 5 and 25 lines, each 50 miles in length, are avoided by installing DG. Therefore, the cost of avoided losses from these lines are:

5 lines x 50 miles x $15K/mile = $3.8 million per year
50 lines x 50 miles x $15K/mile = $38 million per year

The total benefit to utilities would be: - $254 million per year assuming 10% implementation - $1.29 billion per year assuming 50% implementation.

Benefit to society

N/A

Benefit to end users (Really referring to commercial/industrial)

Key assumptions:

- The average size of a DR unit is 500 kW (this size is associated with commercial or industrial facilities as opposed to resident @ N Skw) *(source: this is the mean of the projected DR installations from "Information to Support Distribution Resources (DR) Business Strategies" TR-114272, December 1999)*
- The average installed cost of a DR unit is $925 per kW or $462,500 per unit. *(source: "Information to Support Distribution Resources (DR) Business Strategies" TR-114272, December 1999)*
- The cost of interconnection is approximately $100 per kW or $50,000 per unit. *(source: estimate by Frank Goodman)*
- The technology developed under this project will reduce the interconnection cost by 50% - from $50,000 to $25,000. *(source: estimate by Frank Goodman)*
- 60% of the 833,000 potential applications actually occur. *(source: estimate by Don Von Dollen)*
- (case 1) 10% and (case 2) 50% of the digital economy companies will implement DR. *(source: estimate by Don Von Dollen)*

<u>The total savings in interconnection costs for digital economy companies would be: $1.3 billion assuming 10% implementation and $6.5 billion assuming 50% implementation.</u>

C. Distribution Solid State Power Electronics

Solid-State Transformer

Cost to implement

The cost of the solid state transformer will be approximately 10% less than the cost of conventional transformers.

General Benefits

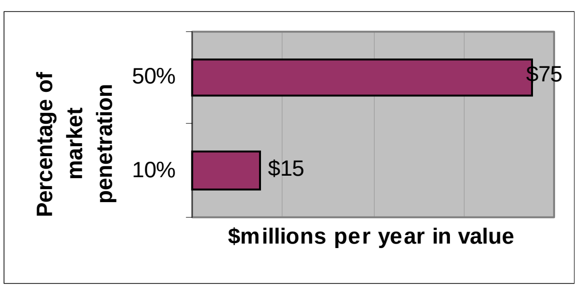
The most tangible benefit of the solid state transformer is that it will cost approximately 10% less than conventional transformers.

The solid state transformer will also have several “secondary” benefits:
- Provide the ability to regulate voltage
- Provide a DC bus
- Present less environmental risk by have substantially less dielectric fluid (oil)
- Reduce utility stores of transformers

Benefit to utilities

Assumptions:
- Approximately 1 million distribution transformers are purchased each year.
- The average cost of a distribution transformer is approximately $1500.
- The solid-state transformer will cost approximately 10% less than a conventional transformer.
- Solid state transformer achieves (case 1) 10% and (case 2) 50% market.

Therefore, the total savings from the solid-state transformer is $15 million per year assuming 10% market penetration and $75 million per year assuming 50% market penetration.



Additional benefit to utilities is through reduction of stores – currently utilities have large facilities for storing a vast assortment of spare transformers.

Benefit to society

Reduced risk of environmental contamination from dielectric fluids

Benefit to end users

NA

Goal: <u>Increase the Control, Capacity and Reliability of High Voltage Transmission Grids</u>

Transmission System Control Methodology

Cost to implement

The cost to implement the technology developed through this project is approximately $200 million over a decade for fielding, testing and integration into the system (including $40-50M for total R&D).

General Benefits

- Reduce the frequency of transmission system outages through fault anticipation, improved state/topology estimation, monitoring, protection, wide-area control for working closer to margins and a more effective use of controllers bridging the gap between dynamic on-line security assessment and wide-area control with intelligent substations.
- Greatly reduce the duration and impact of failures through self-healing methodology – intelligent agents, fiber optic communications, wide-spread deployment of "smart chip" sensors and actuators.
- Eliminate the risk of cascading failures.

Benefit to utilities

Key assumptions:

- Improved state estimation for real-time topology monitoring and validation leading to operating closer to the system limits, savings in asset utilization, and improved security (DSA/VSA will run on the real-time topology estimator):

Real-time State Estimation: Saving due to improved asset management	
Number of Interfaces	10
Increased Capacity of Interface	500
Cost difference across interface	$100.00 - $500,000
Number of hours of operation in a year	100
Cost savings in a year	$50,000,000
Real-time State Estimation: Savings due to loss minimization	
Peak Demand	650000 MW
Transmission Losses @ 3%	19500
Capacity Factor	0.3
Average Losses	5850 MW
Average Costs of losses @ $50/MWH	$292,500
Cost of total losses over the year 8760 hours	$2,535,975,000
Savings due to loss minimization 5%	$126,798,750

Table 1: Impact of real-time state estimation

- Assumption - there are approximately 300 transmission substations in the U.S.
- Assumption - each substation has approximately 5 failures per year.
- Assumption - the average cost for a utility to repair a failure is approximately $40,000.
- Assumption - the result from this project will eliminate 50% of these failures.
- Assumption - (case 1) 10% implementation and (case 2) 50% implementation.

The savings to utilities from this work is: - $3 million per year assuming 10% market implementation - $15 million per year assuming 50% implementation.

Highly visible outages, such as those experienced Chicago and New York during the summer of 1999 and in San Francisco in December 1999, are very costly for utilities. The components of cost are:

- Drop in stock price due to loss of market confidence – between 10% and 30% for the examples cited above;
- Accelerated capital investment due to repairs and improvements ordered by regulatory authorities - measured in multiple tens of millions in NPV, and
- Internal response to outage, such as reporting, studying, dealing with regulatory & city agencies for a protracted time period (multiple years), etc. - measured in several tens of millions

<u>Total value to utilities from this work is approximately $180 million per year.</u>

Benefit to society

Key assumptions:

- Assumption – the cost of power outages to the US economy is at least $50 billion per year
- Assumption – transmission outages represent 20% of the total power system outages.
- Assumption - Eliminate impact of outages by 50%
- Assumption – (case 1) 10% implementation and (case 2) 50% implementation.

The cost savings through the implementation of this technology is: - $500 million per year assuming 10% implementation - $2.5 billion assuming 50% implementation.

Benefit to end users

Key assumptions:

- Assumption – the cost of power outages to various business types is shown below.
- Assumption – transmission outages represent 20% of the total power system outages.
- Assumption - Eliminate impact of outages by 50%.
- Assumption – (case 1) 10% implementation and (case 2) 50% implementation.

Business Type	Total Annual Cost of Losses	Cost Savings Through the Implementation of this Technology	
		10% implementation	50% implementation
Digital Economy	$13 billion	$140 million	$0.7 billion
Continuous Process Manufacturing	$6 billion	$60 million	$0.3 billion
Transportation and Fabrication	$29 billion	$300 million	$1.5 billion

<u>B. Post Silicon Power Electronics</u>

Cost to implement

The technology developed under this project will reduce the cost of FACTS devices by a factor of two. *(source: estimate by Ben Damsky)*

General Benefits

While solid state power components make up only a fraction of the cost of FACTS devices, that increase power flow over transmission and distribution lines, they are the limiting and defining items. When they are improved in ratings, the cost and performance of the entire circuit can be improved. The new generation devices envisioned in this project, if fully successful, might reduce the overall circuit cost a factor of two while improving efficiency and reliability.

Advanced power electronics devices based on new materials and processing concepts will enable precise control and tuning of all power circuits for maximum performance, cost effectiveness and reliability. Within the electric enterprise, they hold the potential to increase asset utilization and power throughput, reduce capital and operating and maintenance costs, and create value-added services and other business opportunities. These advantages will help companies adapt to and exploit the emergence of deregulated, competitive energy markets.

Introducing integrated circuit-like control capabilities to the power grid will protect and enhance reliability in the deregulated energy marketplace as the volume and magnitude of bulk power transactions grow. In addition, advanced power electronics will enable more complete use of the existing energy infrastructure while ensuring adequate safety margins. This will free up society's resources for uses other than the capital intensive upgrade or construction of transmission facilities.

Benefit to utilities

A large FACTS device that uses silicon carbide GTOs will be approximately 50% less expensive than silicon-based device. For example, a STATCOM currently costs $50/KVA *(source: estimate by Ben Damsky)*. A silicon carbide based device would cost $25/KVA *(source: estimate by Ben Damsky)*. This substantial cost reduction will result in more devices installed. 1000 to 2000 MVA in FACTS devices is projected to be installed per year, beginning in 2010 *(source: estimate by Robert Schainker)*.
The primary benefit of a FACTS device is to increase the capacity of an existing line thus avoiding or deferring the construction of a new line and/or substation. TVA has documented that they saved $14 million by installing a 100 MVA STATCOM by avoiding the expansion of a substation *(source: Innovator In-107577 "Statcom provides cost-effective voltage support for TVA's growing load. June 1997).* Projecting these savings over the 1000 to 2000 MVA projected to be installed yields a **net savings of $165 million to $330 million per year.**

Similarly, distribution FACTS devices, such as the DSTATCOM, allow utilities to avoid or defer new additions to their distribution system. For example, AEP projects the savings of installing a DSTATCOM to be $600,000 *(source: Innovator In-111241, AEP applies DSTATCOM to help industrial customer expand operations", Oct. 1998).* Anticipating that 50 to 100 of these devices will be installed per year starting in the year 2010 *(source: estimate by Robert Schainker).* The net savings of these devices will be **$30 million to $60 million per year**.

Therefore, the total savings to utilities from this technology is $195 million to $390 million per year.

Benefit to society

NA

Benefit to end users

NA

C. Superconducting Power Applications

Cost to implement

Second generation superconducting wires will be 1/10th the cost of current superconducting wires on a per KA-meter basis.

General Benefits

(The source for the information given in this section is a report entitled "High Temperature Superconductivity: The products and their benefits", by, Bob Lawrence & Assoc., January 2000. Funded by the U.S. DOE.)

Benefit to utilities

This low-cost, high capacity superconducting wire will enable devices such as superconducting transformers, generators and fault current limiters to be commercially viable and will allow for the wide-spread application of superconducting cables. For example, ABB has halted its development of superconducting transformers until second generation wire becomes available. Their reason for doing this is that superconducting transformers cannot be cost competitive without this new wire.

The benefit of superconducting devices is primarily the increased power density - same power in a smaller space or more power in the same space. The power density increase is advantageous for expanding capacity in large, congested urban centers.

A benefit of HTS power devices will be an increase in efficiency (reduction in losses) that will mean that consumers can use energy that is currently lost in the power delivery system. This will result in fewer power plants being built. When fully implemented into the electric generation and utilization sectors of our economy, this technology is expected to save $8 billion per year in retail value of presently lost electricity.

$8 Billion per year can be saved with the installation of superconducting transformers and motors. Yet another $2.24 billion or so can be saved by full implementation of HTS generators. Therefore, the fully implemented benefits of this technology will be $18.24 billion per year. However, these benefits are not expected until 2020. Therefore, the present value of these savings is $3.6 billion for the first year's savings.

The table below shows the year to 50% market penetration for various superconducting power devices.

Equipment:	Motors	Transformers	Generators	Cables
This year sales: 50% of market	2016	2015	2021	2013

Benefit to society

A benefit of HTS power devices will be an increase in efficiency (reduction in losses) that will mean that consumers can use energy that is currently lost in the power delivery system. This will result in fewer power plants being built. When fully implemented into the electric generation and utilization sectors of our economy, this technology is expected to save $8 billion per year in retail value of presently lost electricity. However, these benefits are not expected until 2020. Therefore, the present value of these savings is $1.6 billion for the first year's savings.

Benefit to end users

NA

2. Value of Energy Solutions for End-Use Digital Applications CEIDS R&D Platform

Goal: **<u>To investigate and develop a variety of technological options to change or accommodate the power requirements for digital devices and their supporting systems.</u>**

<u>A. System Compatibility of Consumer Digital Components with Energy Systems</u>

Cost: Approximately $6M as R&D effort only

Scope – Defines the degree of incompatibility between end use equipment and standard grade power, pinpoints weak links and quantifies differences.

General Benefits Statement:

Value estimate – is based on building knowledge-foundation for other projects rather than instant ROI

- Impact assessment of costs to end-user
- Identification and linking with equipment manufacturers
- Gauging the potential standards of influence

Note: Total energy use for digital equipment in the Dot-Coms including telephone central office is 38.5 Twh/year and 4.4 GW Ave. power level.

Specifically:

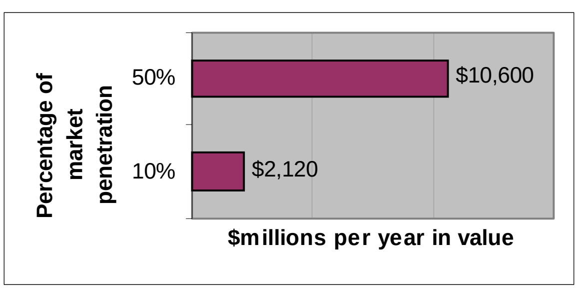
1. Uninterrupted Power Supply:

Key assumptions:

- Research into switching devices for chargers and inverter technologies will inherently increase energy efficiency. In addition, research with ultracapacitors has the potential to provide as much as ten percent increase in UPS system charging efficiencies. Most importantly, successful penetration of UPS and other power conditioning technologies stands to increase
- The most recent EPRI estimates put the losses to industry for momentary outages and power quality variations at approximately 21.2 billion dollars.
- Outages less than 3 seconds account for half of all outage losses

Cost savings:

- PQ problems for industrial customers is half of 6.7 billion per year
- Assuming a 50% penetration of power conditioning technologies on affected processes, there is a potential for a 10.6 billion dollar impact, primarily in the area of improved productivity.



2. Adjustable Speed Drive

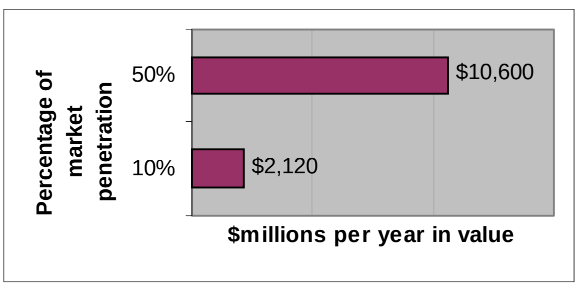
- It is estimated that over 50 percent of all power used in industrial facilities is consumed by electric motors. The potential for energy savings alone with a greater penetration and proliferation of power quality friendly adjustable speed drives could reduce peak consumption in key areas where distribution systems are overburdened by as much as 25 percent while concurrently improving system power factor as a by product.
- The most recent DOE estimates indicate that energy consumed by motors in the industrial sector is nearly 5 trillion kWh per year.
- With an improved drive penetration to 50 percent and motor efficiency improvements averaging 20 percent when drives are installed, the potential return value is approximately 23 billion dollars per year. Half of this estimate is anticipated to be achieved as a result of the CEIDS effort

Benefit to Society:

- To initiate dialogue with a number of manufacturers to enable programming techniques for ASD's that keep the drives on line during moderate power line variations thereby improving process uptime and customer perceptions of electric power quality.

Key assumptions:

- 21.4% (ind motor contribution) * 3,625trillion kWh/year * $0.03/kWh for industrial customers yields 23.27 Trillion dollars spent on motor operation in industrial facilities.
- Drive penetration at 50% with an average efficiency improvement of 20 percent yields a potential saving of 23 billion dollars per year.
- A ten percent penetration would yield 4.6 billion dollars per year.
- Cut this in half as drive penetration is happening already but it can be accelerated and effectively doubled.



3. Programmable Logic Controller

General Benefits Statement:

- The programmable logic controller is an industrially hardened computer with the ability to monitor and control all aspects of a manufacturing process.
- The logic controller has the ability to substantially improve process production and efficiencies.
- The logic controller and its larger scale predecessor the distributed control system are becoming more and more common in every facet of manufacturing and production.

Benefits to Society:

- CEIDS research into more efficient and reliable technologies will inherently increase energy efficiency and improve overall customer satisfaction with their power supplier.
- In addition, research with ultracapacitors and other embedded solutions has the potential to provide as much as a 10.6 billion dollar reduced process downtime improvement for the US industrial market.

Key Assumptions:

Using the same rationalization on costs of PQ that were used for the Industrial UPS section, we can assume that any embedded solutions are going to reduce the need for the power conditioning (and should cover any event lasting less than 3 seconds including momentary outages.

4. Robotics

General Benefits Statements:

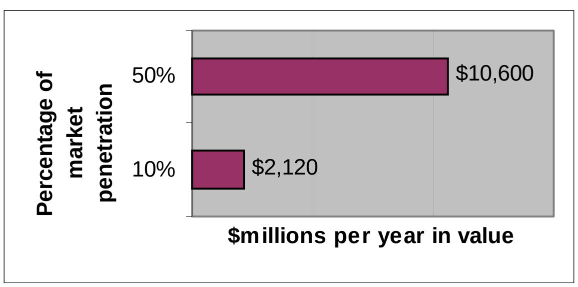
- Robotics and automation systems for industrial facilities include everything from metals fabrication machines to welding equipment.
- Power quality and electromagnetic compatibility (EMC) impact the performance, productivity, and product quality of any processes that use modern robotics and automation systems.
- The increased sensitivity of power electronic and digital automation systems to momentary interruptions, voltage sags, transients, and harmonics make understanding the power quality environment essential.

Benefits to Society (Customers):

- The research will focus on procedures to investigate and resolve known incompatibility problems where electric utilities are called upon to help.
- In addition, the research will work toward developing enabling technologies to eliminate the electromagnetic problems currently plaguing these industries.
- The CEIDs research into embedded solutions is going to promote greater industrial productivity and less dependence upon power conditioning solutions.

Key Assumptions:

Using the same rationalization on costs of PQ that were used for the Industrial UPS section, we can assume that any embedded solutions are going to reduce the need for the power conditioning (and should cover any event lasting less than 3 seconds including momentary outages) therefore, whether you use power conditioning or embedded solutions the savings are the same.



Embedded Solutions for Digital Equipment Cost to Implement

Cost : Approximately $12M as R&D effort only

<u>Scope</u>: Identify weak-links in process equipment such as metal press and incorporate different controls and devices to increase immunity.

Metals Press

General Benefits Statements:

Value estimate is based on avoided cost of upstream power conditioning less the much lower cost to immunize candidate equipment.

- CEIDS will be working with manufacturers to develop technologies that enable reduction of the voltage fluctuation effects on process equipment such as to develop flicker reduction technologies and will work with industry standards organizations to develop better methods of measurement and characterization of flicker in order to reduce impact on the utility system and customers.

Benefits to Society:

- The CEIDS research into embedded solutions is going to promote greater industrial productivity and less dependence upon power conditioning solutions.
- CEIDS research with ultracapacitors and other embedded solutions has the potential to provide as much as a 10.6 billion dollar reduced process downtime improvement for the US industrial market.
- Currently little value is place on embedded solutions by manufacturers due to the inability to pass on the added costs to the customers.
- EPRI and member utilities have had good success in the past convincing individual manufacturers and select industries to change programming parameters to improve electric system compatibility but this effort must be primarily driven by end users.
- Without the market demand for embedded solutions that CEIDS can help promote, future designs will very likely become even more sensitive to electric power variations.
- Candidate equipment = 20% x IT $_{\text{Total (4.4GW)}}$ = 0.44 GW
- Cost for UPS protection = $500/kW
- <u>Cost for Embedded Solutions</u> = $50/kW

Estimate value = $450/kW x 0.44 GW = $198 M

Key assumptions:

Using the same rationalization on costs of PQ that were used for the Industrial UPS section, we can assume that any embedded solutions are going to reduce the need for the power conditioning (and should cover any event lasting less than 3 seconds including momentary outages).

<u>C. Reinventing Switch-Mode Power Supplies</u>

Approximately: $10 M as R&D effort.

Scope: Work with IT industry to enhance power supply specifications with, 5-10% efficiency increase, sag ride-through and surge withstand increased by three times, and harmonic <u>standards</u> met by reduction from 90% to 5%.

AC/DC Converter Box

General Benefits Statements:

- Sensitive electric and electronic industrial control equipment is easily upset by power quality variations. A time proven means of enhancing the performance of this equipment is through the utilization of direct current (dc) instead of alternating current (ac).
- Much of the equipment already converts the ac power to dc before utilizing it anyway so this technique is not uncommon.

Benefits to Utilities:

- CEIDS research will focus on determining the feasibility of a “Premium” DC powering configuration for sensitive loads that might benefit for the AC/DC converter box.

- The research will also assess opportunities to cost effectively integrate storage and power ride through into the converter box to improve power quality, system reliability and potentially reduce peak demand requirements at the industrial process level.
- The CEIDS research will also evaluate DC “mini grid” concepts at the plant level as a means of providing enhanced system reliability.

Key assumptions:

- Over 50 Billion dollars per year can be attributed to losses due to power fluctuations and well over 15 Billion of this is in the industrial sector.
- The CEIDS research into DC/DC conversion technologies will promote greater industrial productivity and less dependence upon power conditioning solutions.
- In addition this research will provide a third alternative to the options of either embedded solutions or applied power conditioning.
- Using the same rationalization on costs of PQ that were used for the Industrial UPS section, we can assume that the DC bus will be identical in cost savings to the embedded solutions or the power conditioning.

Higher conversion efficiency, reduced harmonic losses in building wiring at $0.6/kWH, and better immunity avoiding conditioning for an estimated 25% of dot com IT load (4.4GW).

- Efficiency saving = 7.5% x 25% $IT_{Total\ (38,5Twh)}$ = $43.3M
- Wiring loss saving = 2% x 25% IT_{Total} = $11.6M
- Conditioning saving = $200/kW x 25% $IT_{4.4GW}$ = $220 M

*IT industry claims that IEC standards forcing lower harmonic emissions will cost consumers $10.9 B

3. Value Added Electricity Services CEIDS R&D Platform

Goal: <u>To develop and implement technologies that will enable traditional and non-traditional energy providers as well as their customers to access a variety of electricity-related service opportunities.</u>

General Benefits Statements:

- CEIDS research lead to new enterprises for both electric utilities and digital companies by expanding markets for data and information, increased bandwith, communication speed
- Growing demand for the forward- and real-time bidding of megawatts into a power exchange will require new tools for real-time expedited trading
- Will accelerate development of market for integration of communication, information, and energy into one delivery system that provides right of ways and broadband access

A. Using Power Lines for Broadband Communication

Scope: Combine power and data networks incorporating digital power line technology (URL) to enable high-speed data communications – up to 10 times faster than ISDN.

Key assumptions:

- According to the IPTS European Commission Report the potential market is 40 million homes in seven countries in Europe and Asia.
  - Extrapolating this for US household there is a potential for at least 20 million homes
  - At an estimated of $5/month revenue per household for access to high speed internet through power line

Estimate revenue = $1.2 Billion/year

B. Communication Architecture for E-Business

Scope: Create new products for integrated control and communications that expedite data exchange, real-time operations and management of a decentralized communication complex.

Key assumptions:

- A share of demand trading market through Internet enabling the real-time bidding of megawatts into a power exchange, to maximize financial positions
- Realizing improved billing and settlement systems providing accurate and timely verification of payments and inter-company performance

Estimate = TBD

C. Copper-Plus-Fiber Delivery Options for High-Demand Users

Scope: Evaluate fiber infrastructure business to provide single source for both fiber and power, e.g. case of I-Park development and trend of using copper in communication links as Hybrid Fiber Coax (HFC).

Key assumptions:

- Based economy of single source serving 10% of IT market that is concentrated in internet parks where integration of copper/fiber delivery is feasible
  - Ipark Energy Revenue = cost/kwh x IT $_{\text{Total(38.5 Twh)}}$ = $.06/kwh x 3850 Gwh = $231M/year
  - Ipark Comm. Revenue = $150M/year

Estimate = reduction in cost of energy/comm.
= 30% x $831M = $114.3M/year

4. Digitally Enabled Energy Efficiency

Goal: <u>To develop innovative technologies and services that can provide options for consumers to use energy more efficiently.</u>

<u>A. Energy Management Technologies and Programs</u>

Approximately: $15 M in R&D effort

1. Commercial Sector – EMS

Key Assumptions:

- US electrical generation = 3.625 trillion kWh/yr.
- EMS systems have been projected to save up to 2.5%.

Savings:

- The commercial sector (at 33% of overall U.S. electricity consumption / 33% industrial and 33% residential (rough rule of thumb)), savings = 2.5% x 3.625 x 33% x $0.06/kWh = $1.8B.

2. Commercial Sector – Computers

General Benefit Statements:

- Computers are improving the productivity of workers while reducing the extent of travel and shipment of documents.
- CEIDS will outline the necessary steps to overcome existing barriers such as high initial cost of enhanced power supply, requirement for higher energy density in smaller packaging thus resulting in new switch-mode power supplies to keep computer systems on line.

Key Assumptions:

- Assuming a 0.5% gain in worker productivity by avoiding downtime:

0.5% x $30,000/yr x 150M workers = $22.5B.

3. Fuel Cell-based Hybrid Electric Vehicle (HEV)

General Benefit Statements:

- CEIDS ultra capacitor and flywheel research elements are key enabling technologies for the HEV.
- The same short-term energy storage technologies that are used as embedded ride-through solutions for critical appliances in buildings also enable regenerative braking in the HEV.
- This recapture of energy is one of the most important advantages of the HEV over conventional electric vehicles, particularly in typical cases of stop and go driving.
- When these HEVs are parked and interconnected they become distributed generators with on-board storage.
- CEIDS interconnection and distributed generation research will investigate this interesting potential of HEVs to generate and to store energy.

Public Benefit Statements:

- DOE and Industry studies have shown that HEVs offer a dramatic reduction in fuel use by storing utility electricity, employing regenerative breaking and proving high-efficiency auxiliary power units.

- Health benefits of reducing urban ozone concentration with clean burning fuel cells
- An "insurance policy" against sudden oil price shocks or political blackmail, coming from enhanced HEV efficiency. A risk that would otherwise cost an estimated $6 to $9 billion;
- Reduced military costs of maintaining energy security reserves, which according to some estimates are costing the US approximately $.5 to 50 billion annually;
- Potential savings form reduced oil prices resulting from decreased oil demand;
- Increased leverage on the climate change problem with huge potential costs.

Key Assumptions and Savings:

In the NREL report "Policy Implication of Hybrid-Electric Vehicles," (from DOE web site, http://www.ott.doe.gov/pdfs/nevcor.pdf) a 15-mile battery range and 55 mi/gal economy from the auxiliary power unit would displace, on average, ***69% of gasoline fuel*** relative to today's 27.5mi/gal fuel efficiency levels. The direct savings in reduced oil imports by 2010 is in the range of $10 billion for each 10% reduction. And the indirect savings are also significant according to Office of Technology Assessment report, Advanced Automotive Technology, US Govt. Printing Office, Wash. DC 1995:

B. New Digital Systems to Reduce Electricity Use

Approximately: $20 M in R&D effort

1. Residential Sector – Space Conditioning

General Benefits Statements:

- In standard air conditioning equipment, 33 percent of total energy use is required for humidity control. It is estimated that desiccant systems have the potential to save 240 trillion Btu of energy annually and can reduce carbon dioxide emissions by 24 million tons by 2010.
- By incorporating a desiccant system, energy required for humidity control by the air conditioning equipment is reduced to 11 percent.
- Depending on the application, total air conditioning electricity consumption can be reduced up to 40 percent with dessiccant systems alone.

Key Assumptions:

- Higher residential energy rates and consumer rebates will drive consumer incentives to purchase and implement new technologies.
- The Air Refrigeration & Tech Institute estimates a further reduction in HVAC energy consumption of 30% is possible with the proper incentives.
- EIA estimates 11.2 quads for Y2010 for home space conditioning, water heating and refrig. This equals 3,280B kWh/yr.

Savings:

- As noted in DOE's Energy Savers Guide, 44% of residential utility bills goes for heating and cooling, while 14% is for water heating, 9% for refrigerators, and 33% for lighting, cooking and other appliances.
- Space conditioning = 44/[44 +14 +9] x 3280 = 2154B kWh. A 30% savings at $.06/kWh = $38B/yr.

Range depending on market penetration:

10%	50%
$3.8B	$19B

2. Residential Sector - Appliances

General Benefits Statements:

- Per DOE/EIA Household Energy Consumption report for 1993, appliances account for about 40% of household's electricity consumption (excluding lighting), with refrigerators at another 14%, water heating at 10%.
- Manufacturers of the electronic controllers claim they will improve the efficiency and life expectancy of electric appliance motors.
- Since the controller continuously applies the correct power to the motor, the motor operates consistently at its peak efficiency and cooler. Cooler operation increases motor life expectancy.
- CEIDS participation will validate claims and field test innovative designs.

Key Assumptions:

- The DOE states that motors consume 64% of the electricity in the US, and that an efficiency gain of 12% is possible.
- Assuming 33% residential; 33% commercial; 33% industrial split of electricity consumption and using 40% appliances:

Savings:

3.625 trillion kWh/yr(annual US electricity use) x 33% x 40% x 12% x $0.06/kWh = $3.4B.

Range depending on market penetration:

10%	50%
$340M	$1.7B

3. Residential Sector – Lighting

General Benefits Statement:

- Per DOE/EIA Household Energy Consumption report for 1993, lighting accounts for 9.4% of residential electricity consumption.
- Lighting manufacturers claim development of multi-photon phosphor technology can double the efficacy of lights in lumens per watt.

Key Assumptions:

50% reduction in power supply to maintain the current light output:

Savings:

3.625 trillion kWh/yr x 33% x 9.4% x 50% x $0.06/kWh = $3.37B.

Range depending on market penetration:

10%	50%
$337M	$1..685B

4. Residential Sector – Entertainment Eqpmt & Computer/Internet

General Benefits Statement:

- Integrating services and incorporating energy management and electricity supply will open up opportunities for new services to residential consumers, adding value in quality of life enhancements to communities.
- Savings can be measured in avoided trips as services are brought into the home.
- Energy savings will accrue due to real-time pricing and remote energy management.

Key Assumptions:

- Demand response in CA was shown to get 1065 MW reduction (medium case) or 2.5% of ISO load.
- This level achieved a reduction in electricity cost of $160/MWh from a base of $750/MWh.
- Forecasting 30 alerts for Y2001 at 3 hours each, savings = $600M. CA represents 14% of the US economy.
- Residential represents 33% of national consumption.

$600M / 14% x [33%] = $1.4B.

Range depending on market penetration:

10%	50%
$140M	$700M

5. Commercial Sector – Space Conditioning

General Benefit Statements:

- In the commercial sector, HVAC accounts for ~ 40% of annual energy use.
- EPA in 1997 estimated semiconductor fab facilities could save up to 15% in energy with optimized airflow design alone in their HVAC systems.
- Improved space conditioning will also improve worker productivity.

Key Assumptions:

- DOE/EIA estimated commercial energy consumption in 1995 for space conditioning, water heating &refrig = 3.1 quads.
- Assume 4% annual growth to 5.6 qauds in 2010. 5.6 quads = 1.6 trillion kWhs. 15% = 240B kWhs.

Savings:

- At $.06 = $14.4B in energy savings.
- A1% gain in worker productivity at $30,000/yr for 150M workers = $45B.

6. Commercial Sector – Lighting

- The DOE/EIA report on Commercial Buildings Energy Consumption for 1995 listed commercial lighting as consuming 1.2 quads of energy e.g., one installation of two prototype sulfur lamps at the DOE's Forrestal building replaced 280 HID mercury fixtures and reduced power consumption by approximately 65 percent, resulting in about an $8,000 annual savings on energy.
- An additional $1,500 was saved as a result of reduced maintenance costs.
- VCSEL lamps could be used in any industrial, commercial, or residential indoor lighting and will last five to 10 times longer than fluorescent bulbs and can be grouped several hundred to a postage stamp-sized chip.
- Improved lighting will also improve worker productivity.

Key Assumptions:

- Using a 65% reduction in power as a goal.

Savings:

- x 10^{15} Btus x 1 kWh/3412 Btus x 65% x $0.06/kWh = $13.7B.
- A 1% gain in worker productivity at $30,000/yr for 150M workers = $45B.

7. Commercial Sector – Electric Chillers

General Benefit Statements:

- CEIDS will develop business partnership with key manufacturers of electric chillers to jointly work on increasing energy efficiency of the system and flexibility in accommodating changing load conditions.
- The DOE/EIA report on Commercial Buildings Energy Consumption for 1995 listed commercial space cooling as consuming 0.4 quads of energy and refrigeration at 0.25 quads.

Key Assumptions:

Based on $0.06/kWh energy cost and 2000 hours of operation per year, replacing an old 1,000 ton chiller at 0.8 kW per ton rating with a new chiller at 0.52 kw per ton (35% savings) is possible and can save more than $32,000 in energy cost per year.

Savings:

0.65 x 10^{15} Btus x 1 kWh/3412 Btus x 35% x $0.06/kWh = $4B.

8. Medical Equipment

General Benefits Statements:

- Medical care provided at home increased from $3.9 billion to $20.5 billion in Medicare home expenditures from 1990 to 1997 and is continually increasing.
- Hospitals are increasingly sending patients with terminal illness home.
- The value of CEIDS research would also be measured in the number of medical calls made to homes to reset medical equipment malfunctioning from power-related problems, fewer utility claims resulting from medical equipment damaged in the home, and lives saved with continuous monitoring capability of higher reliability power.
- In addition, the health care community and insurance companies will reap enormous saving through greater use of home care from medical equipment operated by digital-grade power as opposed to in-hospital care.

Key Assumptions:

- Value of in-home care example: For patients with congestive heart failure, intensive homecare monitoring resulted in a decrease from 3.2 hospitalizations per year to 1.2 with the length of stay decreasing from 26 days per year to 6 days per year.
- There is an economic requirement of discharging patients due to the expense of maintaining patients in a hospital - $21,570 per month for a ventilation system in a hospital versus $7,050 per month with leased equipment at home.

Savings:

Assuming a 10% of the population have a medical condition that could benefit from home care, a 10% market penetration, and a savings of 10% in insurance premiums (assumed to be $5,000/yr per person) resulting from utilizing home care – the value amounts to $1.4 billion. This value estimate does not reflect savings from lives saved.