ELECTRIC POWER RESEARCH INSTITUTE

EPRI Overview

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Energy Efficiency & Industrial Studies
EPRI
May 11, 2007

Together…Shaping the Future of Electricity

Collaborative Research & Development

Non-Profit

Serving Members and Society

ELECTRIC POWER RESEARCH INSTITUTE

Overview

- The Electric Power Research Institute was established in 1973 as an independent, nonprofit center for public interest energy and environmental research.
- EPRI brings together members, participants, the Institute's scientists and engineers, and other leading experts to work collaboratively on solutions to the challenges of electric power.
- These solutions span nearly every area of electricity generation, delivery, and use, including health, safety, and environment.
- EPRI's members represent over 90% of the electricity generated in the United States. International participation represents nearly 15% of EPRI's total research, development, and demonstration program.

EPRI Facts

- 33-year history
- 450 participants in over 40 countries
- 66 technical programs
- 1600+ research and demonstration projects annually
- 10 to 1 average funding leverage

Extensive Technology Portfolio

Generation & Distributed Resources

- Environmental Controls
- Major Component Reliability
- Combustion Turbines
- Maintenance, Operations and Workforce
- Advanced Coal Plant Portfolio
- Distributed and Renewable Generation Resources
- Generation Planning: Economics and Fuels

Nuclear Power

- Material Degradation/Aging
- High Performance Fuel
- Radioactive High-Level Waste & Spent Fuel Management
- NDE & Material Characterization
- Equipment Reliability
- Instrumentation & Control Hardware and Systems
- Nuclear Asset-Risk Management
- Safety/Risk Technology & Application
- New Nuclear Plant Deployment
- Environmental Benefits
- Low-Level Waste & Radiation Management

Power Delivery & Markets

- Strategic Initiatives
- Security
- Power Markets & Risk
- Assets, Planning & Operations
- Power Quality
- Transmission Reliability & Performance
- Distribution Reliability & Performance
- Energy Utilization
- Enterprise Asset Management

Environment

- Air Quality
- Global Climate Change
- Land & Groundwater
- Water and Ecosystems
- EMF Health Assessment and RF Safety
- Occupational Health and Safety

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Energy Utilization

Electric Transportation

Distributed Resources/Storage

Intelligent Power Delivery Infrastructure

Smart End-Use Devices

Infrastructure

Analytics

Energy Efficient Technologies

Dynamic Energy Management Initiative Platform

Program 170

Energy Efficiency

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Why This Initiative?

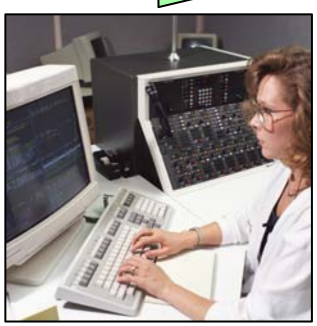
Increasing

Electricity prices

Shortage of new capacity

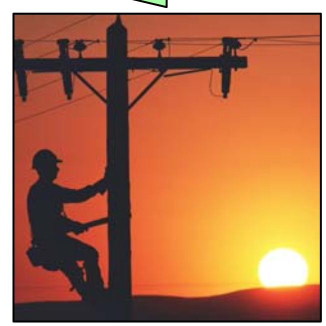
Vulnerability to foreign imports

Awareness to climate and the environment



Consumers are demanding change

Regulators and policy makers are demanding action



Utilities are responding

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Program Elements

Analytics

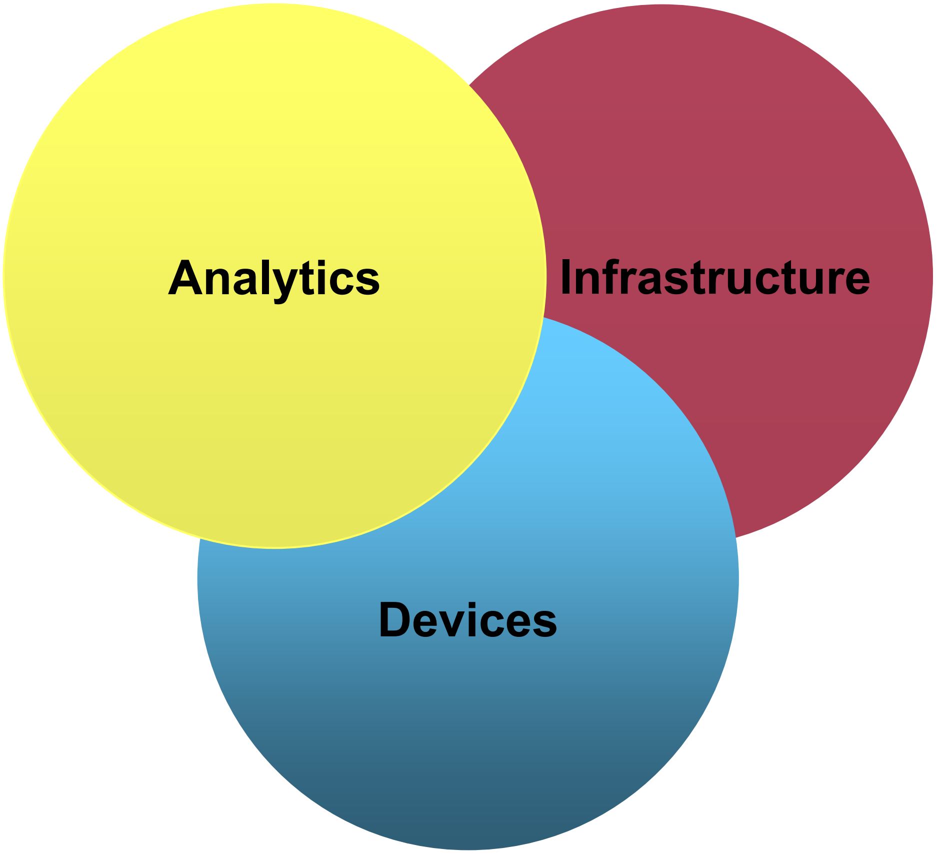
- Technical, economic and environmental tools and assessments

Infrastructure

- Enabling communications and control to provide “prices to devices”

Devices

- Smart & efficient end-use devices that are IP addressable with control and meet highest efficiency standards



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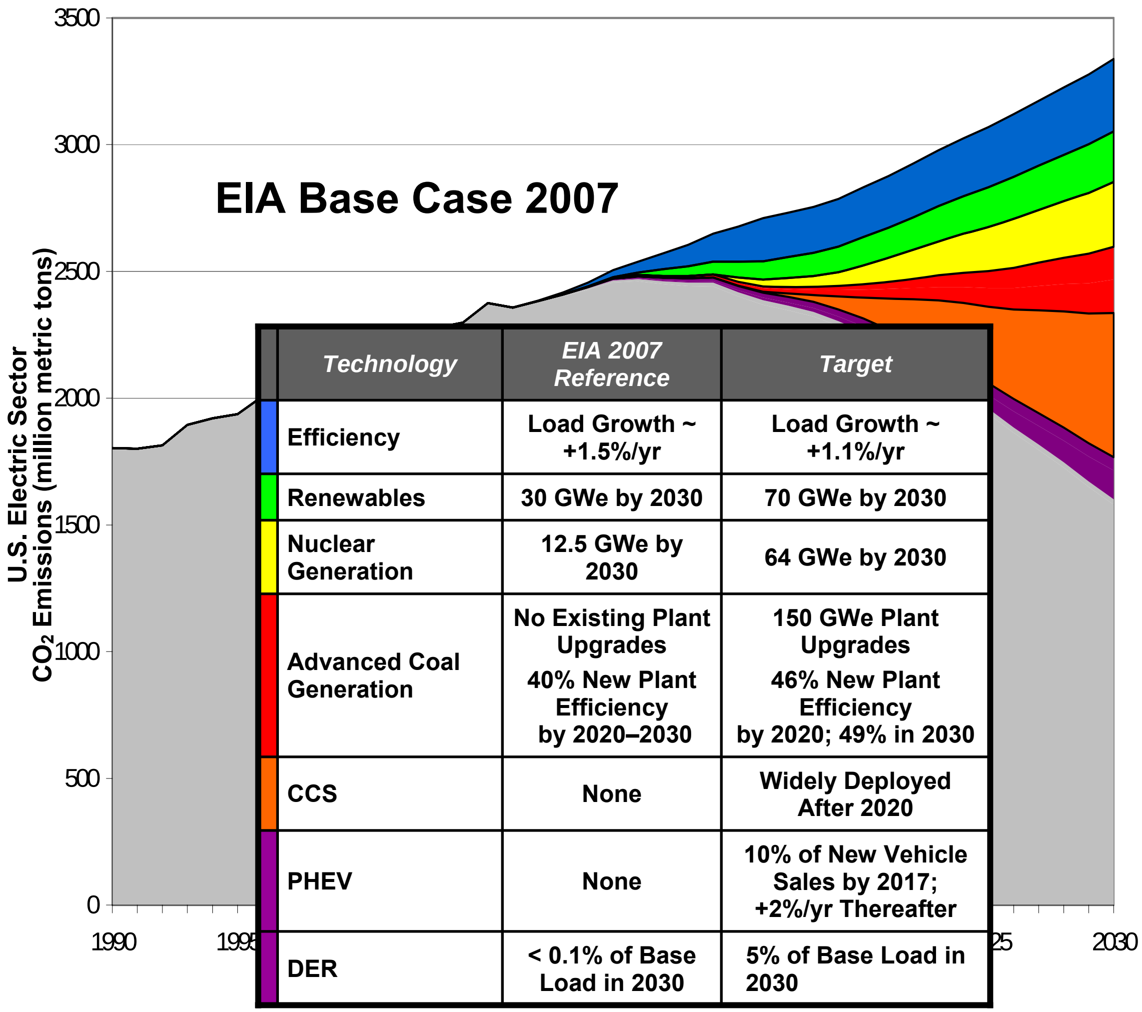
Analytics: Economic and Environmental Assessment



	Technology	EIA 2007 Reference	Target
	Efficiency	Load Growth ~ +1.5%/yr	Load Growth ~ +1.1%/yr
	Renewables	30 GWe by 2030	70 GWe by 2030
	Nuclear Generation	12.5 GWe by 2030	64 GWe by 2030
	Advanced Coal Generation	No Existing Plant Upgrades 40% New Plant Efficiency by 2020–2030	150 GWe Plant Upgrades 46% New Plant Efficiency by 2020; 49% in 2030
	CCS	None	Widely Deployed After 2020
	PHEV	None	10% of New Vehicle Sales by 2017; +2%/yr Thereafter
	DER	< 0.1% of Base Load in 2030	5% of Base Load in 2030

Credible data on economic and environmental impact from dynamic energy management and smart end-use devices

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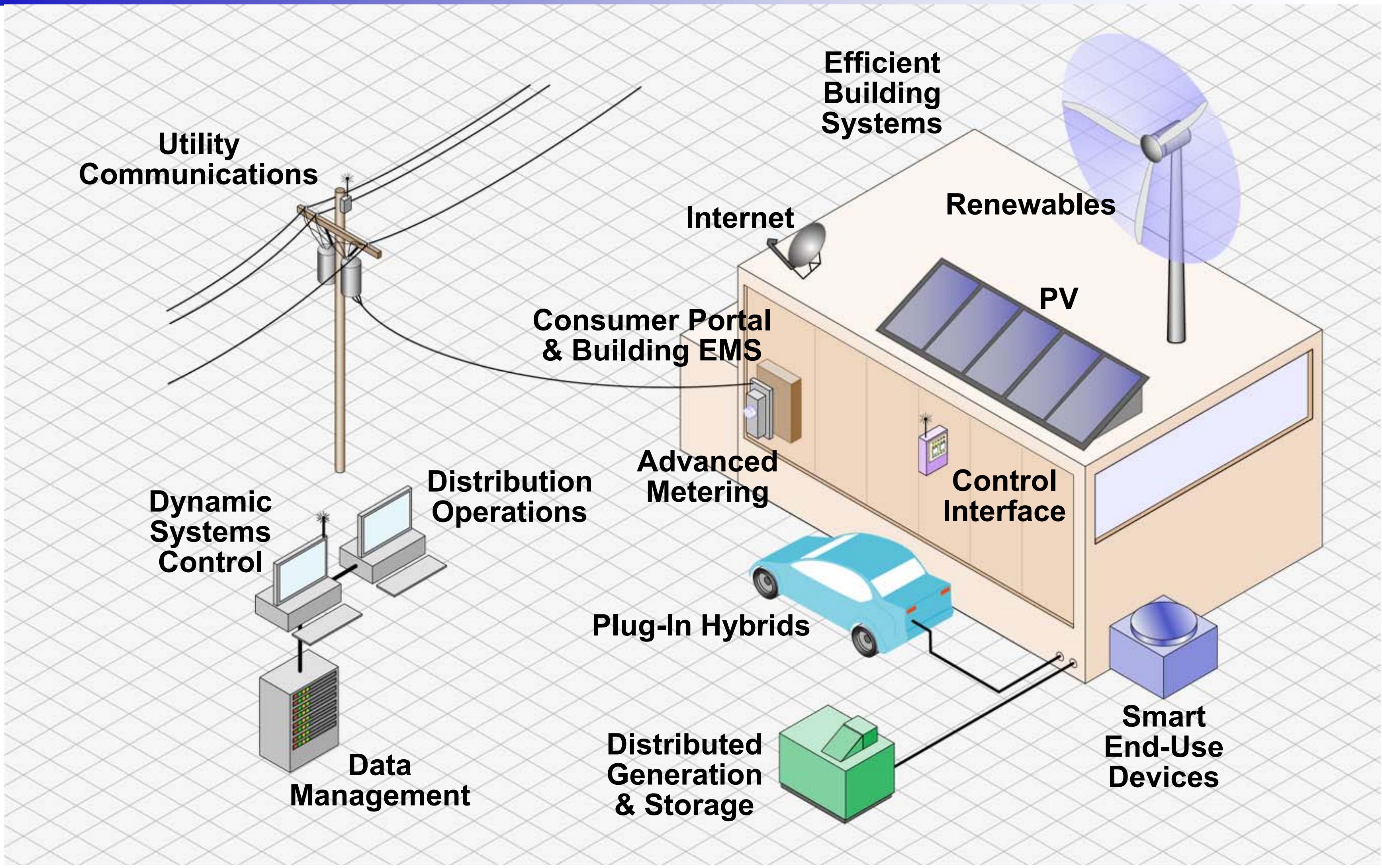
Dynamic Systems Infrastructure: Consumer Opportunities



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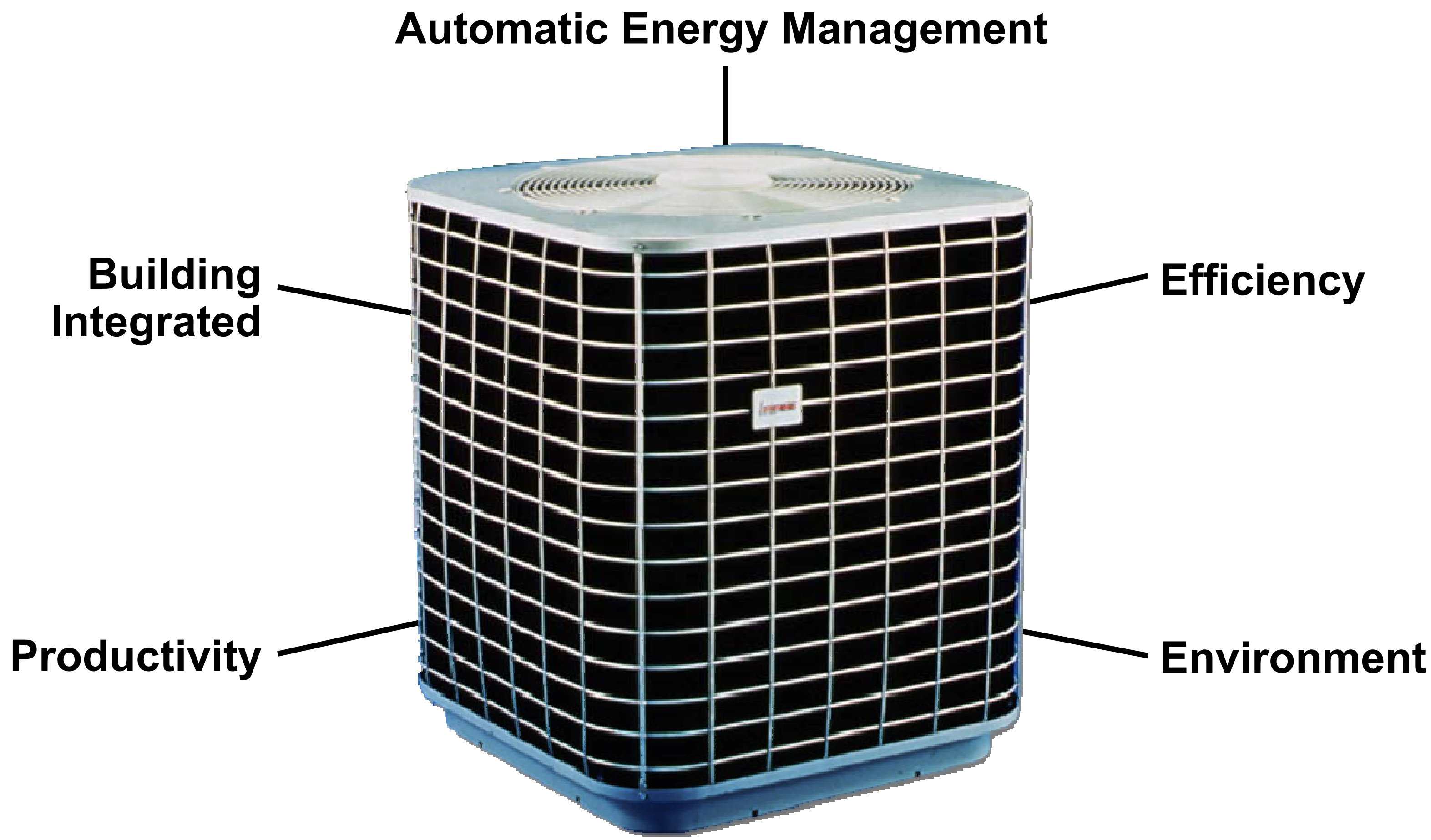
Smart End-Use Devices



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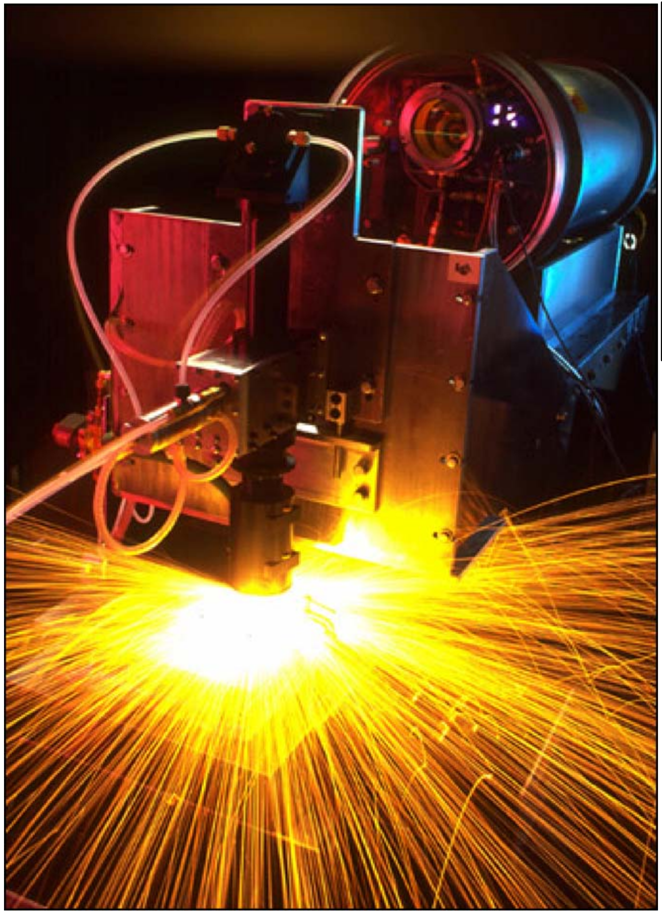
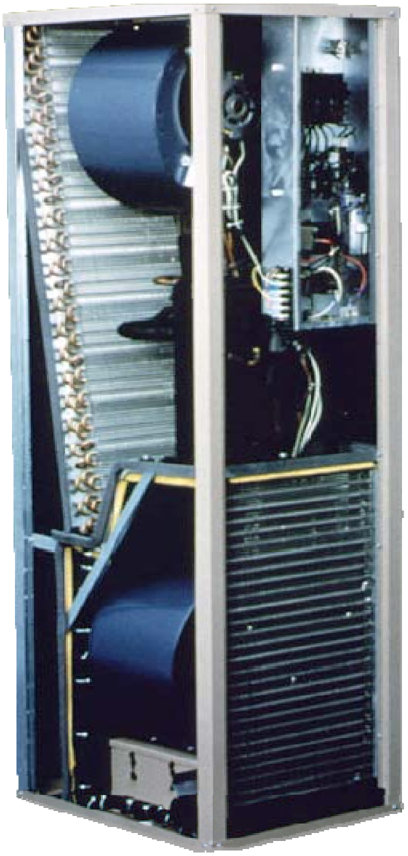
Smart End-Use Devices: Industrial, Commercial, and Residential



Plasma Arc Torch

DC in Data Centers

Building Automation



Heat Pump

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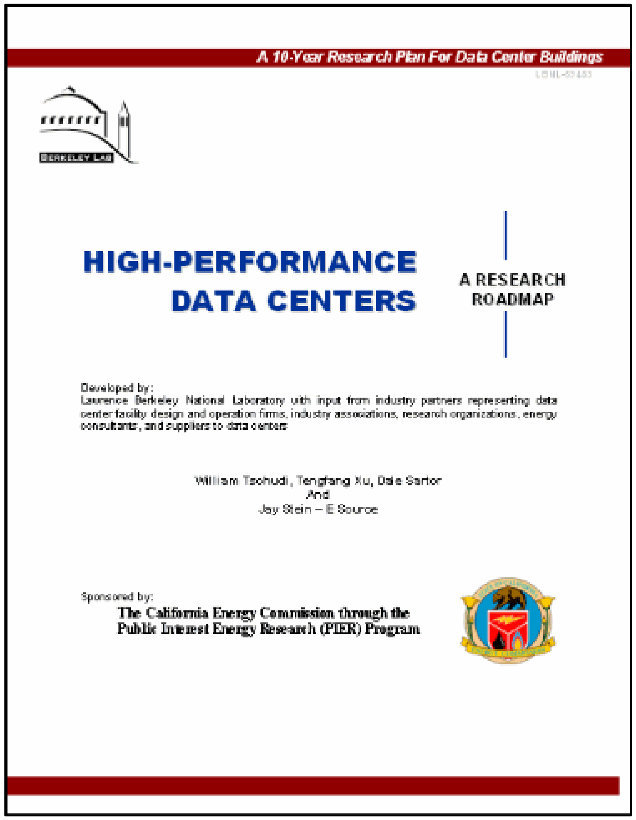
California Energy Commission

Public Interest Energy Research

High-tech Buildings Project

- Research, develop, and demonstrate, innovative energy efficient technologies
- 10-year initiative focusing on high-tech industries – e.g. data centers
- Help move market to more efficient technologies
- Research and demonstration projects include technology transfer


A 10-Year Research Plan For Data Center Buildings

HIGH-PERFORMANCE DATA CENTERS

A RESEARCH ROADMAP

Developed by:
Laurence Berkeley National Laboratory with input from industry partners representing data center facility design and operation firms, industry associations, research organizations, energy consultants, and suppliers to data centers

William Tschudi, Tengfang Xu, Dale Sartor
And
Jay Stein – E Source

Sponsored by:
The California Energy Commission through the Public Interest Energy Research (PIER) Program

Sponsored by:
California Energy Commission (CEC)—Public Interest Energy Research (PIER),
California Institute for Energy Efficiency (CIEE).

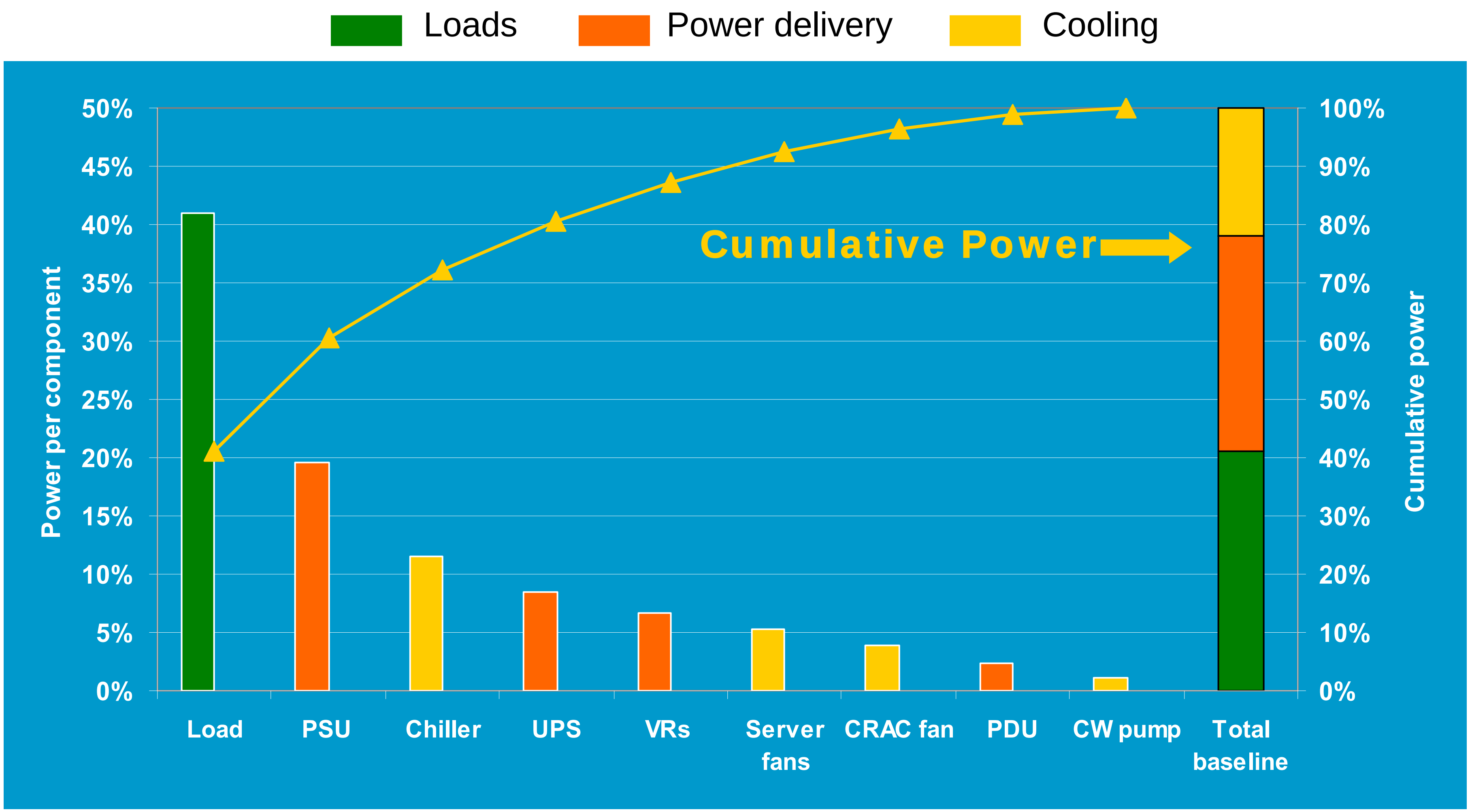
Data Center Power Use

Data center power use nationally is large and growing. Two studies estimated data center energy use:

- 2004 EPRI/Ecos estimated 14.8 TWh
- 2000 Arthur D. Little estimated 10.1 TWh

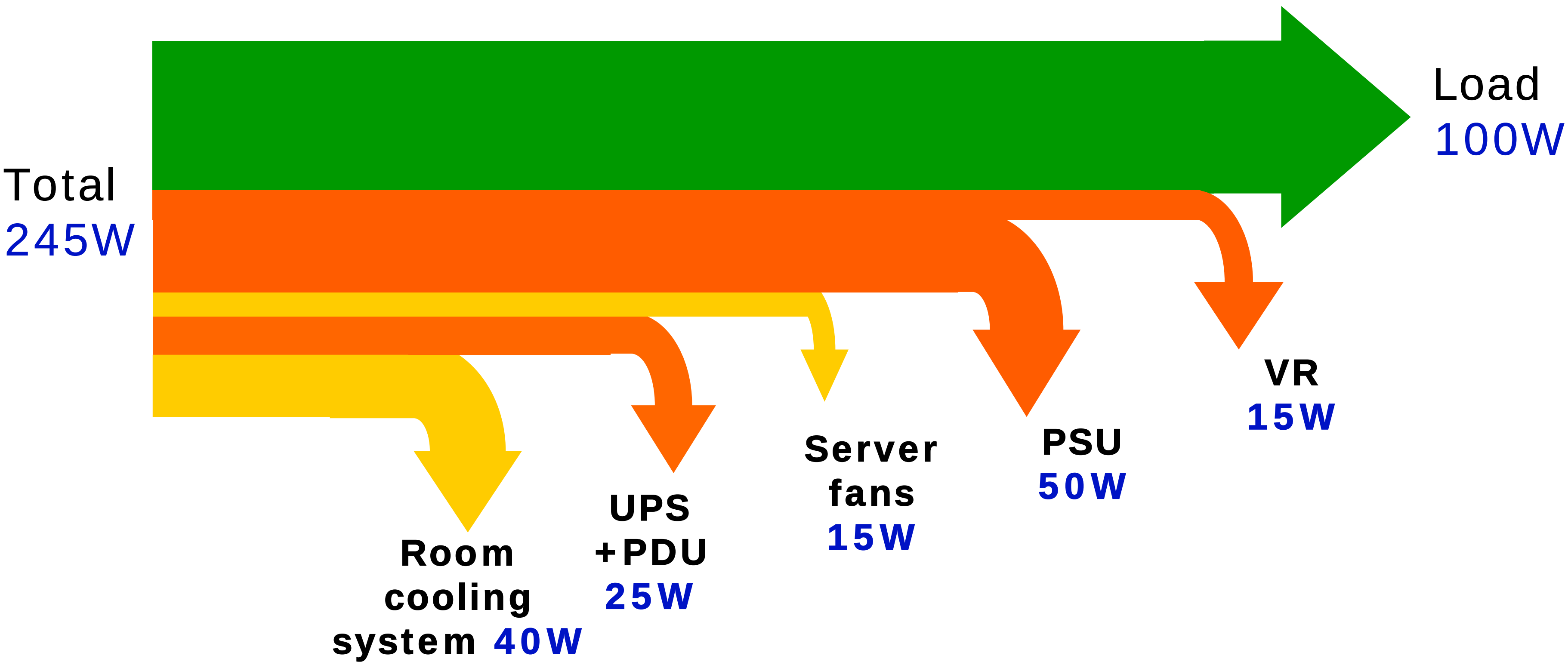
Saving a fraction of this energy is substantial

Typical Data Center Power Use



Source: Intel Corp.

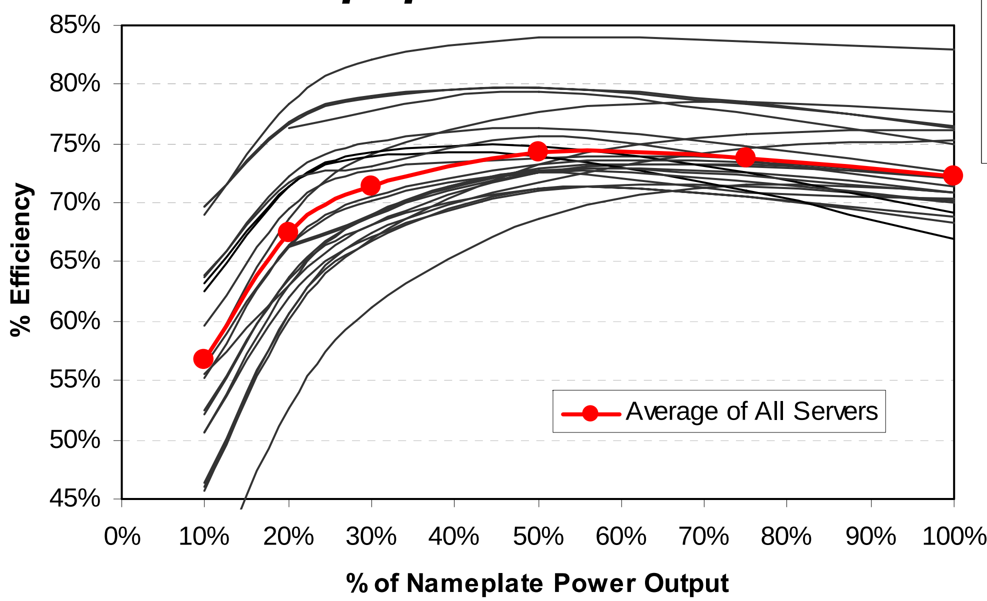
Power Consumption: 100 W System Load

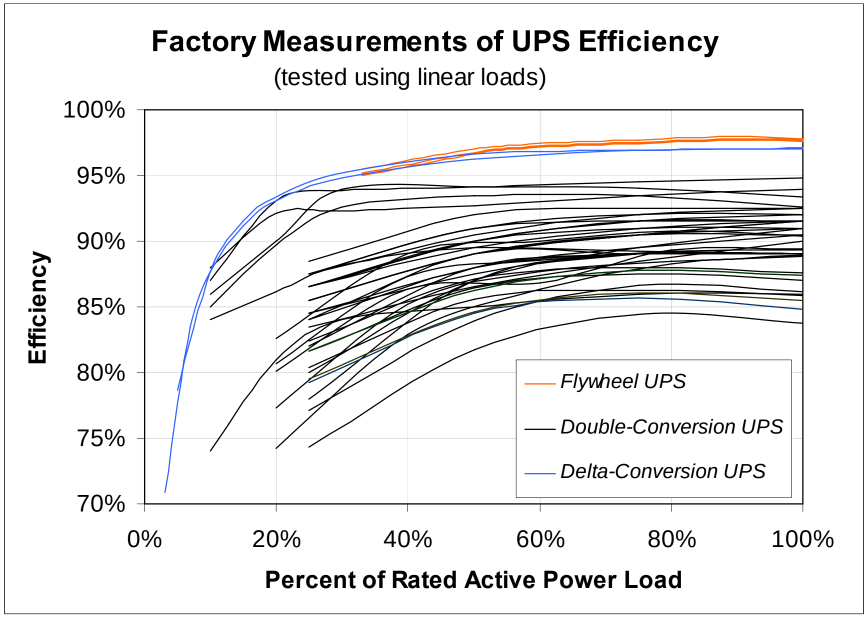


Source: Intel Corp.

This demonstration focuses on reducing power delivery and conversion losses:

Power Supplies in IT equipment

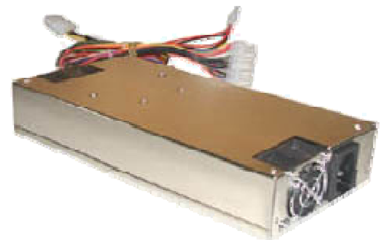




Uninterruptible Power Supplies (UPS)

Data Center Power Delivery System

UPS	Power Dist	Power Supply	DC/DC
85 - 92%	98 - 99%	68 - 72%	78 - 85%

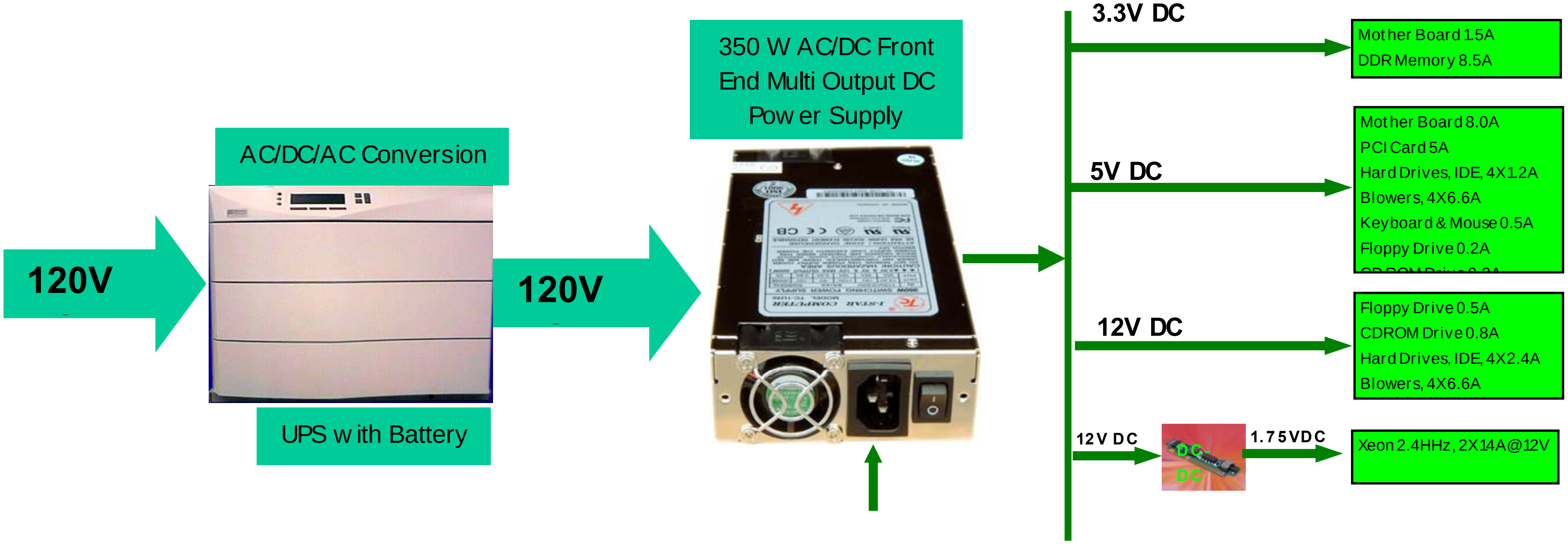


The heat generated from the losses at each step of power conversion requires additional cooling power

HVAC: Additional 35% to 76% of Power Loss for Cooling

Thinking “Beyond the Silver Box”

Can we eliminate some of the conversion steps and measure reduction in losses?



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DC Demonstration - Objectives

The demonstration's objectives are to show the following:

1. DC powered server equipment exists in the same form factor or can readily be built from existing components
2. DC powered server equipment can provide the same level of functionality and computing performance when compared to similarly configured and operating AC server equipment
3. Efficiency gains from the elimination of multiple conversion steps can be measured by comparing traditional AC delivery to a DC architecture
4. DC system reliability is as good or better than AC system reliability

Industry Partners Made it Happen

Equipment and Services Contributors:

- Alindeska Electrical Contractors
- Baldwin Technologies
- Cisco Systems
- Cupertino Electric
- Dranetz-BMI
- Emerson Network Power
- Industrial Network Manufacturing (IEM)
- Intel
- Nextek Power Systems
- Pentadyne
- Rosendin Electric
- SatCon Power Systems
- Square D/Schneider Electric
- Sun Microsystems
- UNIVERSAL Electric Corp.

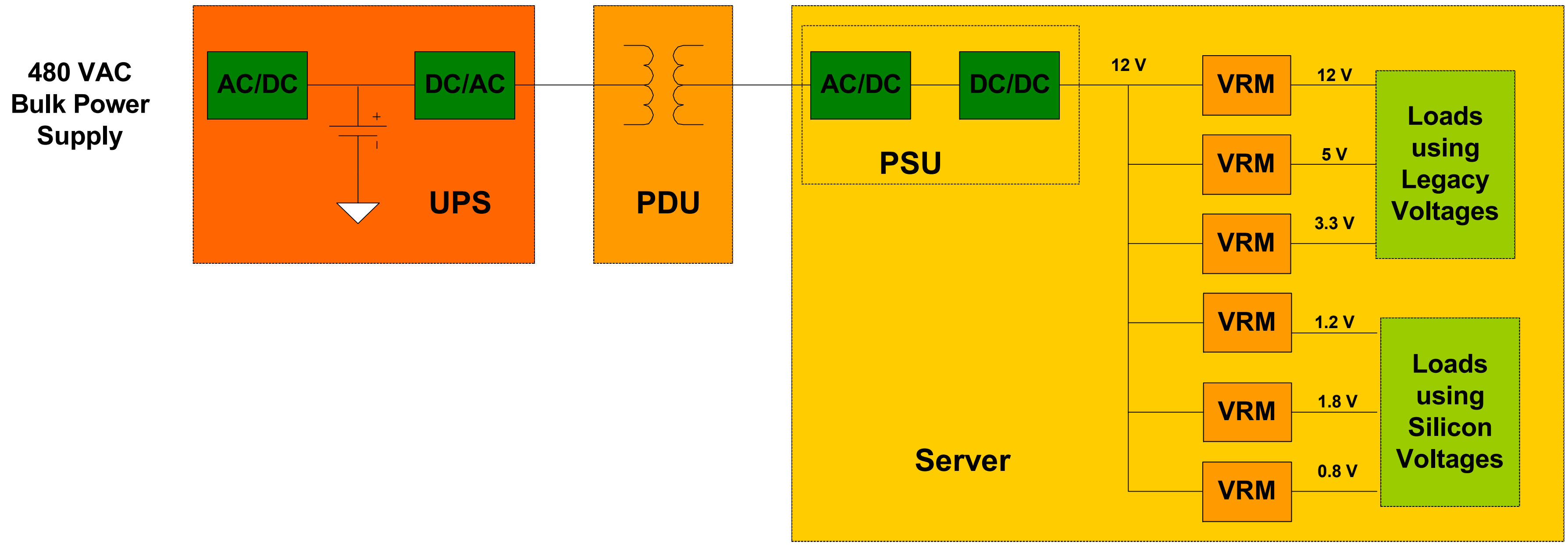
Opportunities for IT equipment participation remain

Other Partners Collaborated

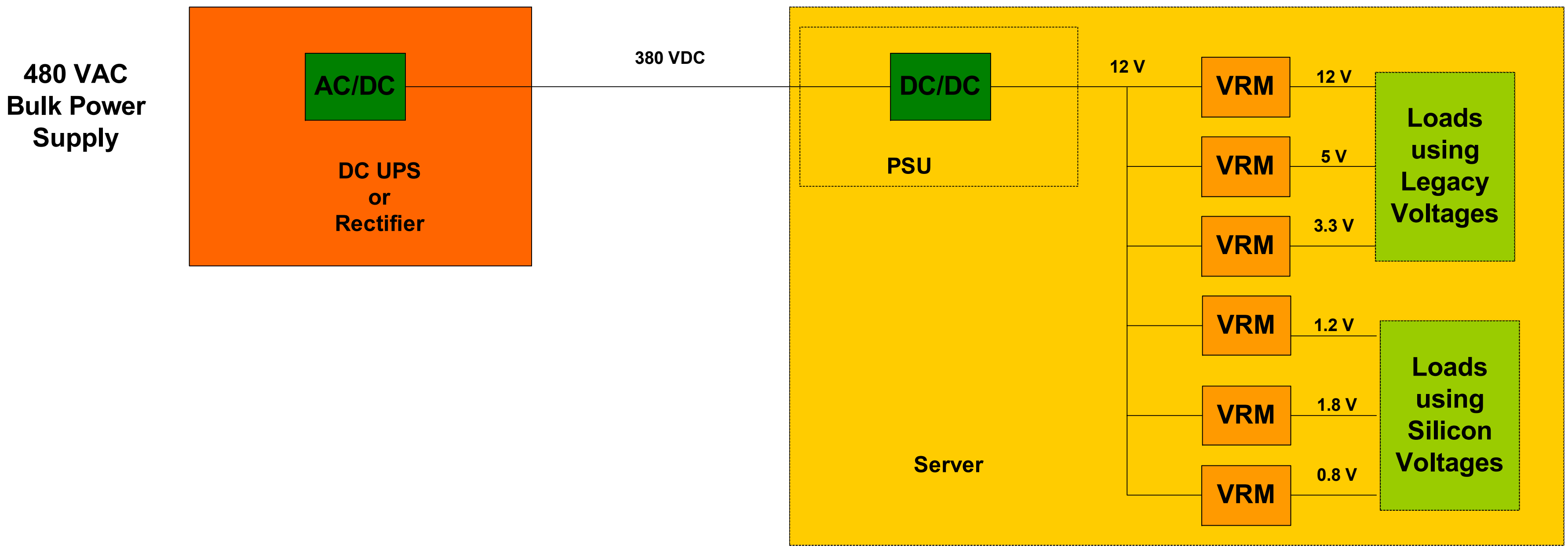
Stakeholders:

- 380voltsdc.com
- CCG Facility Integration
- Cingular Wireless
- Dupont Fabros
- EDG2, Inc.
- EYP Mission Critical
- Gannett
- Hewlett Packard
- Morrison Hershfield Corporation
- NTT Facilities
- RTKL
- SBC Global
- TDI Power
- Verizon Wireless

Today: AC Distribution



Facility-Level DC Distribution



Data Center Power Delivery

	UPS	XFMR	Power Supply	Total Efficiency	
Efficiency Measured - UPS 1	89.6%	98.0%	90.0%	79.03%	
Efficiency Measured - UPS 2	89.9%	98.0%	90.0%	79.29%	
Efficiency Measured - DC	94.2%	100.0%	92.0%	86.66%	
	Output Load (kWh)		Input Load (kWh)		
Power Measured - UPS 1	23.3		26.0		
Power Measured - UPS 2	23.3		25.91		
Power Measured - DC	22.7		24.1		
Power Improvement - 1					7.31%
Power Improvement - 2					6.99%

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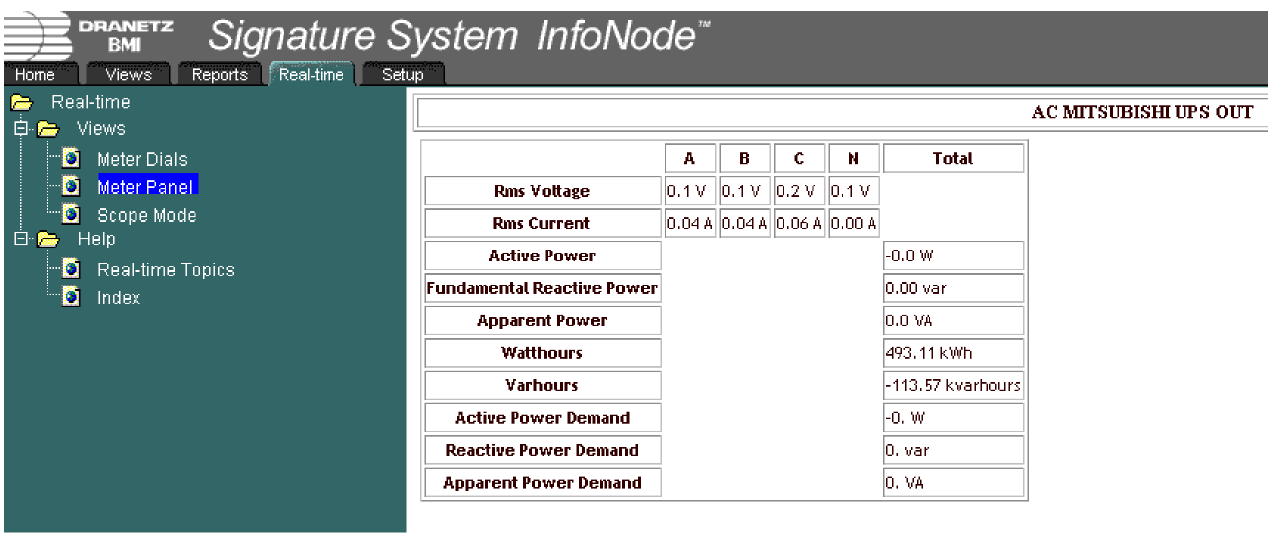
Measured Performance was Viewable On-line

Lawrence Berkeley National Laboratory websites for more information

- http://hightech.lbl.gov/
- http://hightech.lbl.gov/dc-powering/



A Typical Data Center Would See Even Greater Benefits

- Redundant UPS and server power supplies operate at reduced efficiencies
- Cooling loads would be reduced in the equipment and overall in the center.
- Both UPS systems used in the AC base case were “best in class” systems and performed better than typical benchmarked systems – efficiency gains compared to typical systems would be higher.
- Power supply efficiency in the demonstration was much better than typical.

Data Center Power Delivery

For a typical center energy savings could exceed 20%

	UPS	XFMR	PS	Total Efficiency	
Typical Efficiency	85.00%	98.00%	73.00%	60.81%	
DC Option	92.00%	100.00%	92.00%	84.64%	
	Compute Load (W)		Input Load (W)		Difference
Typical Efficiency	10,000		16444.93		
Optimized DC Option	10,000		11814.74		28.16%

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Installation

Vendor Activity

390V Input VRM for High Efficiency Server Power Architecture

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*Center for Power Electronics Systems
Virginia Polytechnic Institute and State University
Blacksburg, VA 24061 USA

**Intel Corporation
2111 NE 25th Avenue
Hillsboro, OR 97124

***Abstract*-This paper describes a highly efficient, high power density converter generating 3.3VDC from a 390VDC input, for use in a proposed power distribution architecture with a reduced number of conversion stages, which increases system efficiency. Key design considerations, theoretical and experimental results are presented for the LLC resonant converter.**

I. Introduction

Performance per watt requirements are driving higher energy efficiency in datacom equipment designs for both idle and active power states. Hence there is a strong incentive to increase the overall efficiency of power delivery systems. Figure 1 shows two common power delivery architectures for

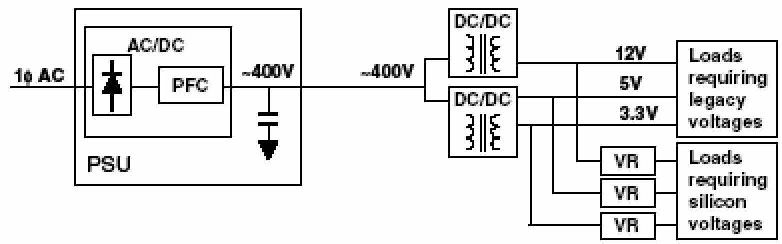

Figure 2. Proposed power delivery architecture

II. Design of 390V to 3.3V Converter

Key design goals for the proposed 390V input VRM is high power density with >90% efficiency over a load range from 10% to 100%. The converter with a 3.3V/25A output is

DC Power - next steps:

- DC power pilot installation(s)
- Standardize distribution voltage
- Standardize DC connector and power strip design
- Server manufacturers develop power supply specifications (including disturbances)
- Power supply manufacturers develop prototypes
- UL and communications certification
- Address other types of IT equipment (storage, switches, etc.)

Additional Information

Project Coordination & Contacts:

Lawrence Berkeley National Laboratory

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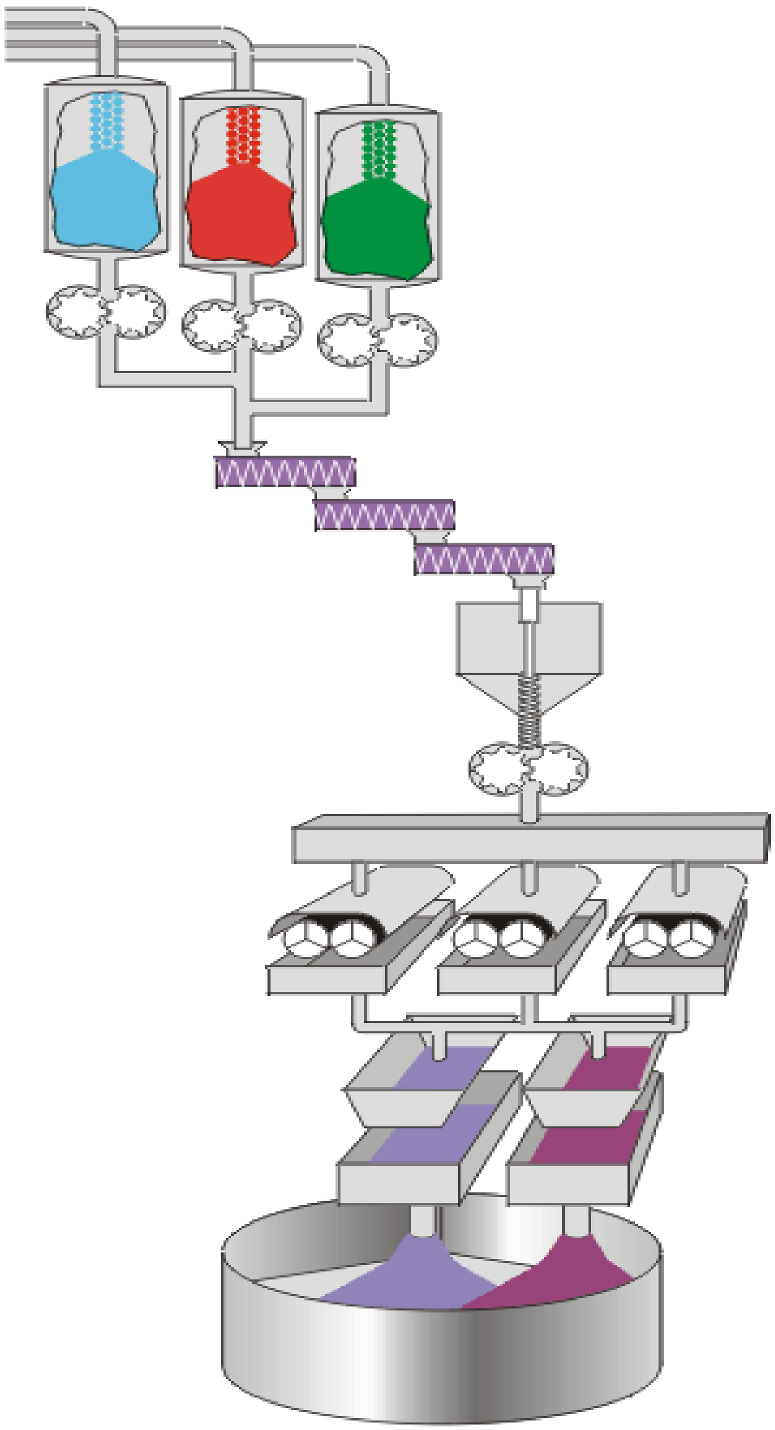

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Program 1
Project Set C
Achieving Cost-Effective PQ Compatibility between the Electrical System and Loads

EPRI Webcast

April, 2007

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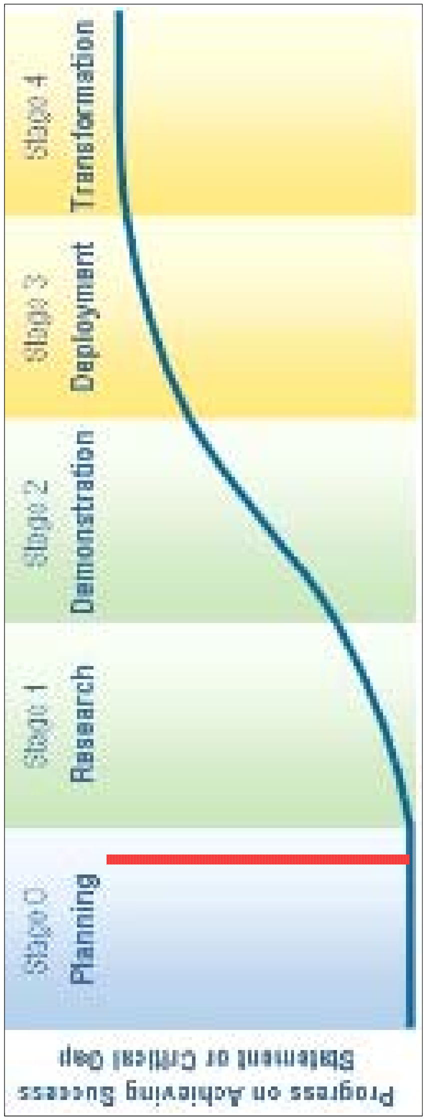
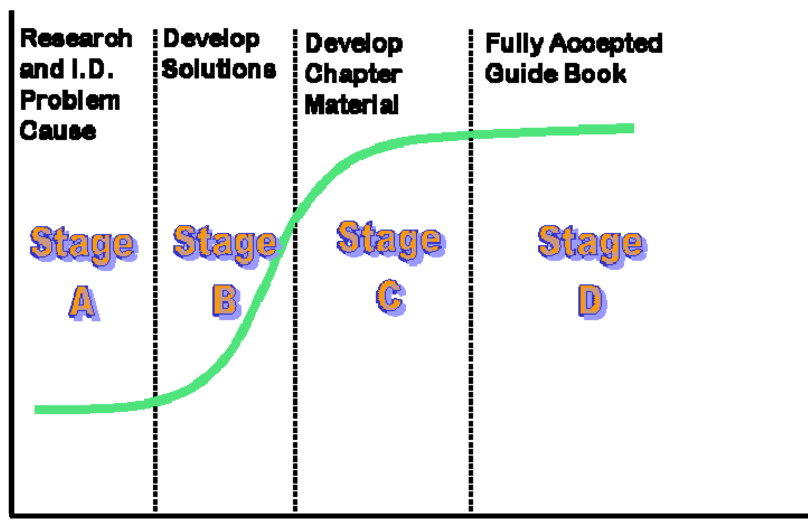
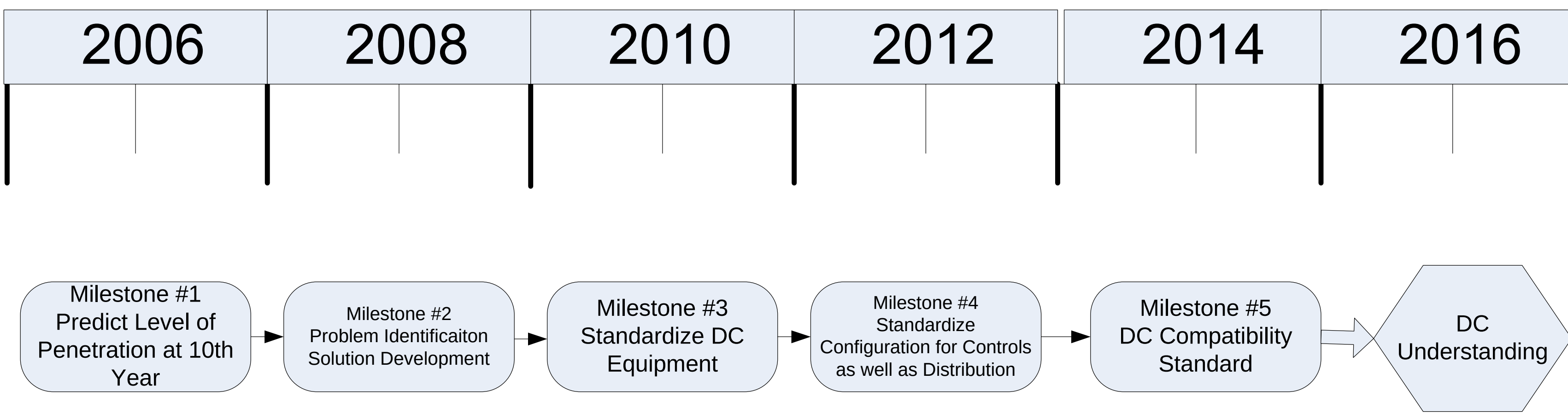
PQ Master Plan Implementation





Master Plan Development PS1C

Success Statement #15
In 10 years, we will have a comparable level of understanding about compatibility and PQ issues for DC as we do for AC



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