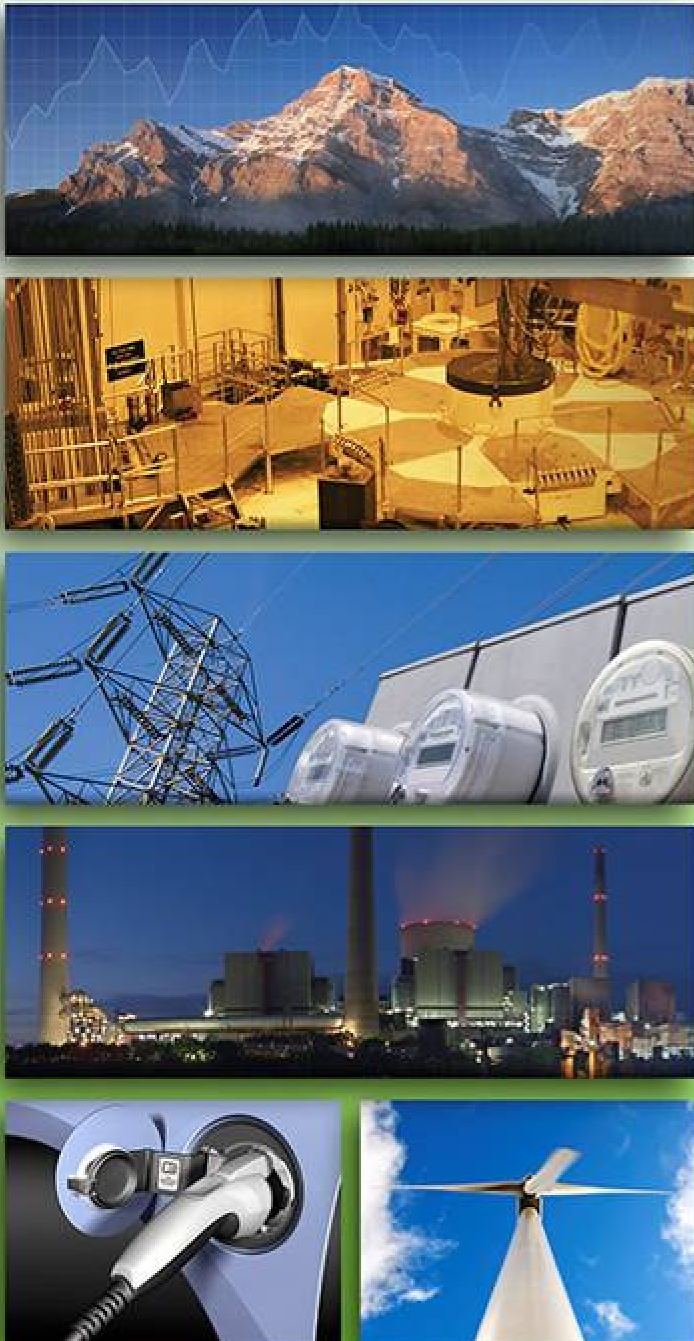


ELECTRIC POWER RESEARCH INSTITUTE

Applications and Requirements for Grid-Scale Energy Storage

Haresh Kamath

16 September 2010

The Electric Power Research Institute (EPRI)

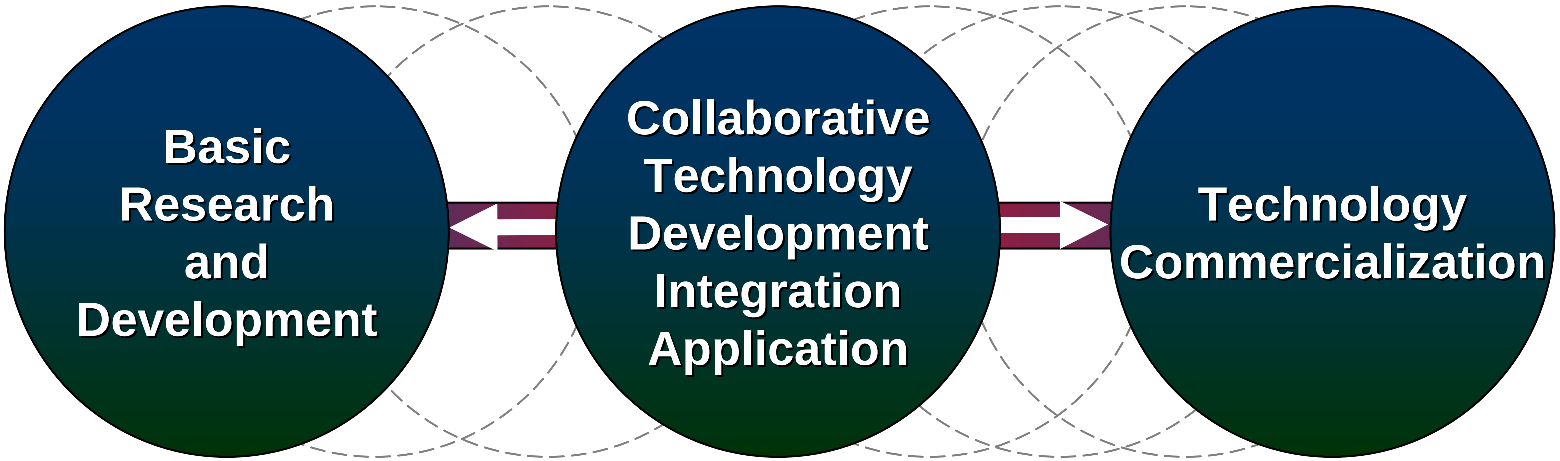
- Independent, non-profit, **collaborative** research institute, with full spectrum industry coverage
  - *Nuclear*
  - *Generation*
  - *Power Delivery & Utilization*
  - *Environment*
  - *Technology Innovation*
- Major offices in Palo Alto, CA; Charlotte, NC; and Knoxville, TN

Our Members…

- 450+ participants in more than 40 countries
- EPRI members generate more than 90% of the electricity in the United States
- International funding of more than 18% of EPRI's research, development and demonstrations
- Programs funded by more than 1,000 energy organizations

Our Role…

Help Move Technologies to the Commercialization Stage…



National Laboratories

Universities

EPRI

Suppliers

Vendors

Technology Accelerator!

Grid Energy Storage:
Taking electricity into the fourth dimension!

- Storage moves electricity in time, just as transmission moves it through distance

- Storage enhances the flexibility of the bulk grid, accommodating more variable renewable energy

- Storage increases reliability and asset utilization of the power delivery system

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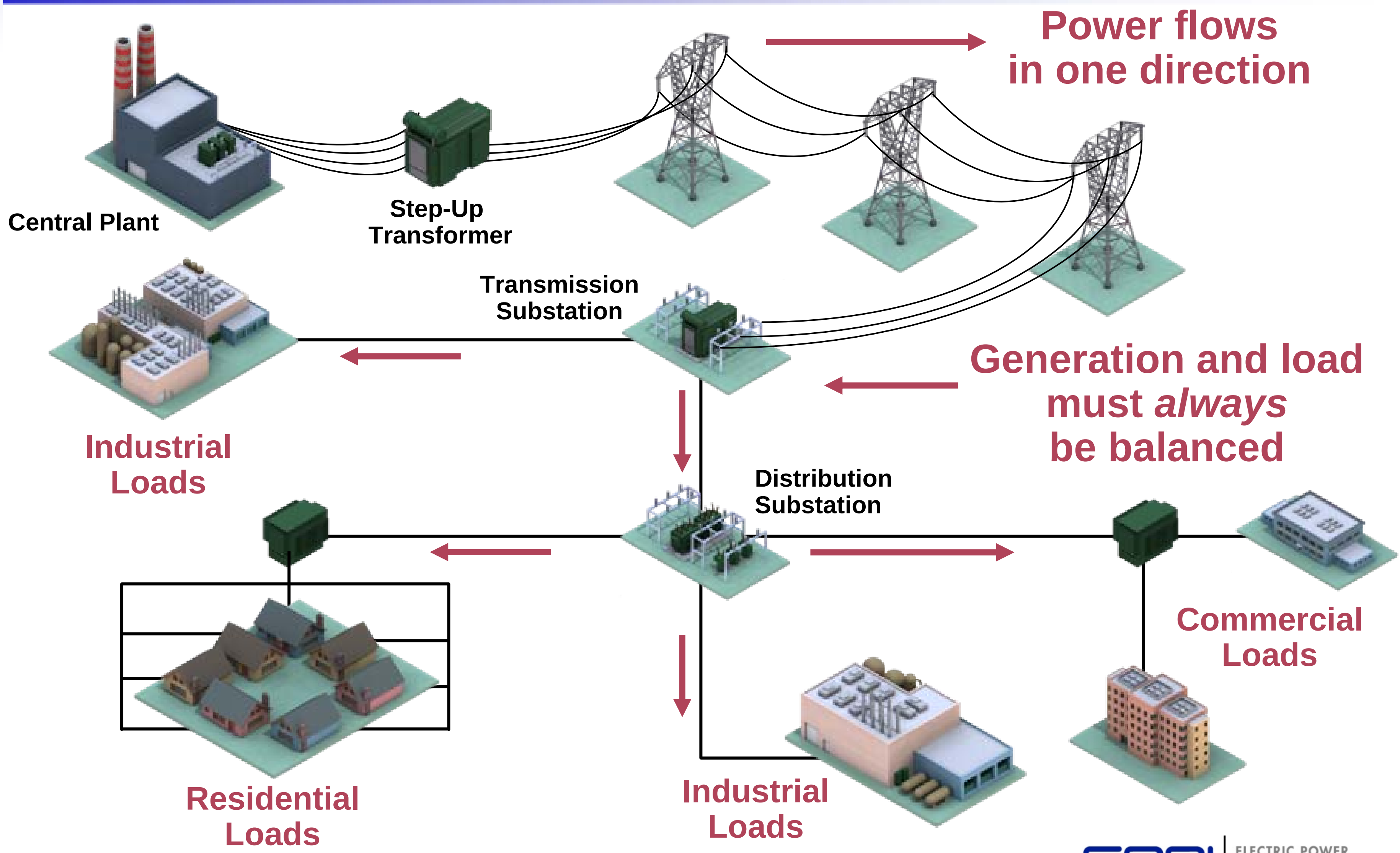
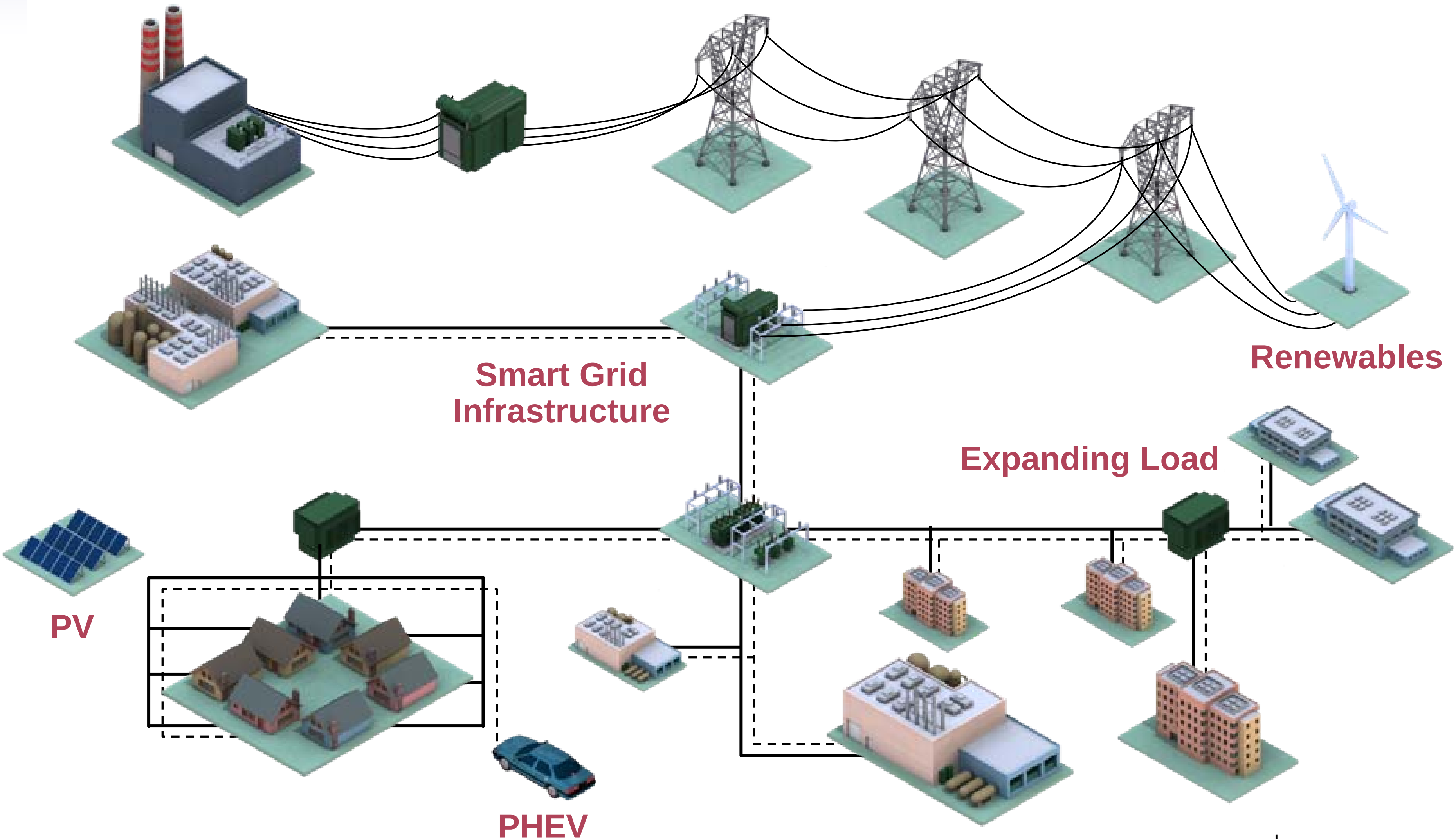
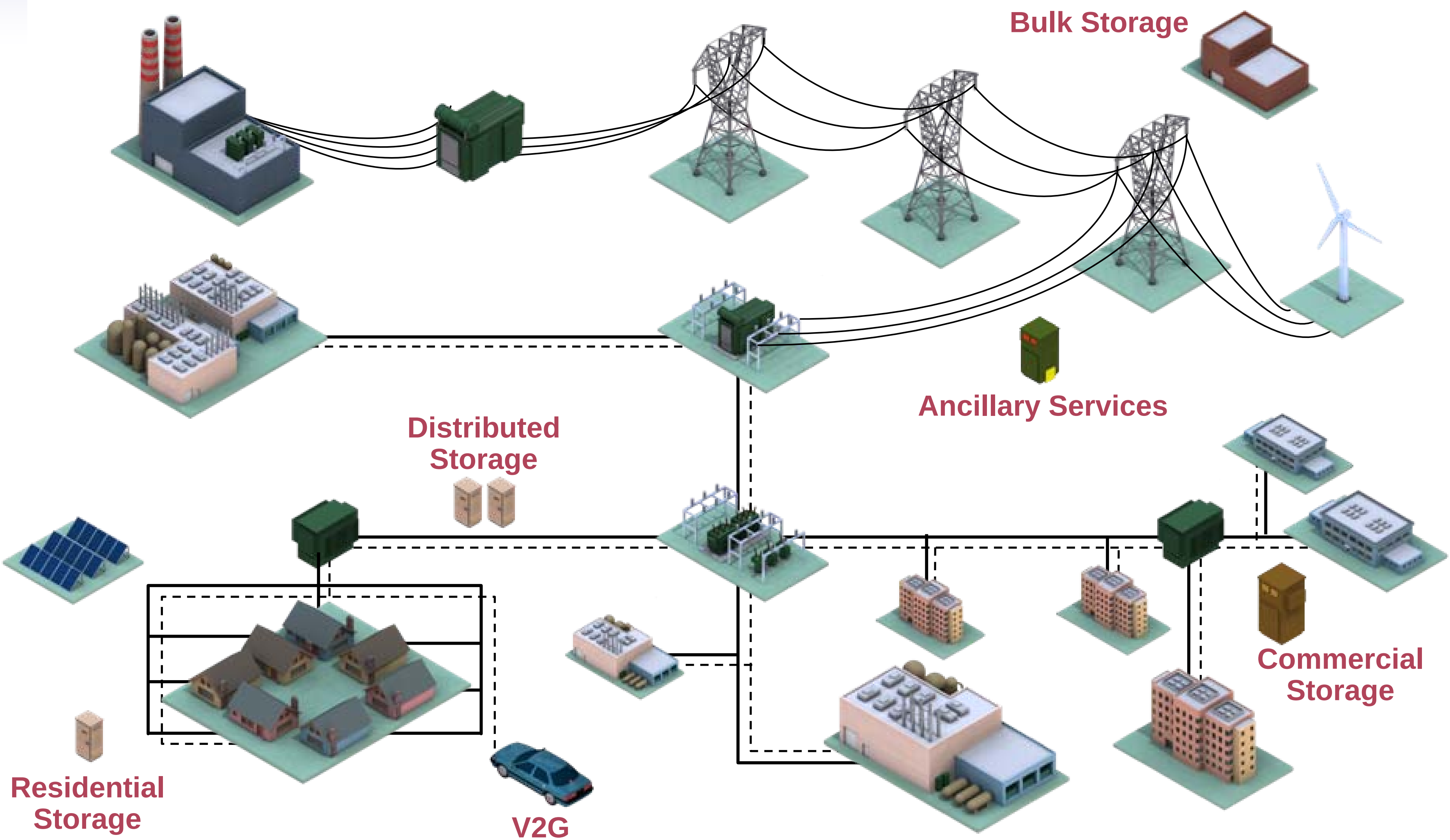
How the Electricity Grid Works Today



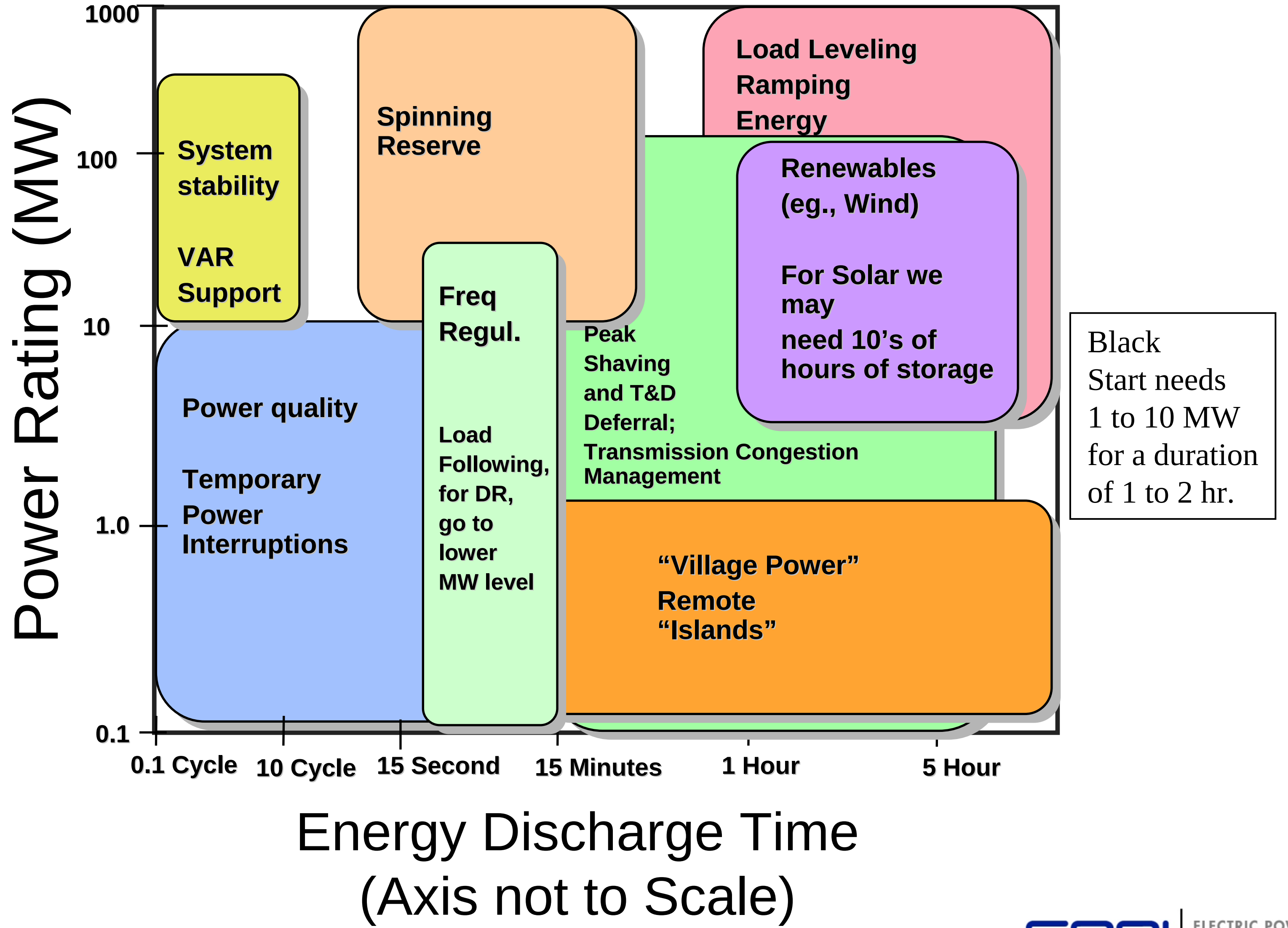
How the Grid is Changing



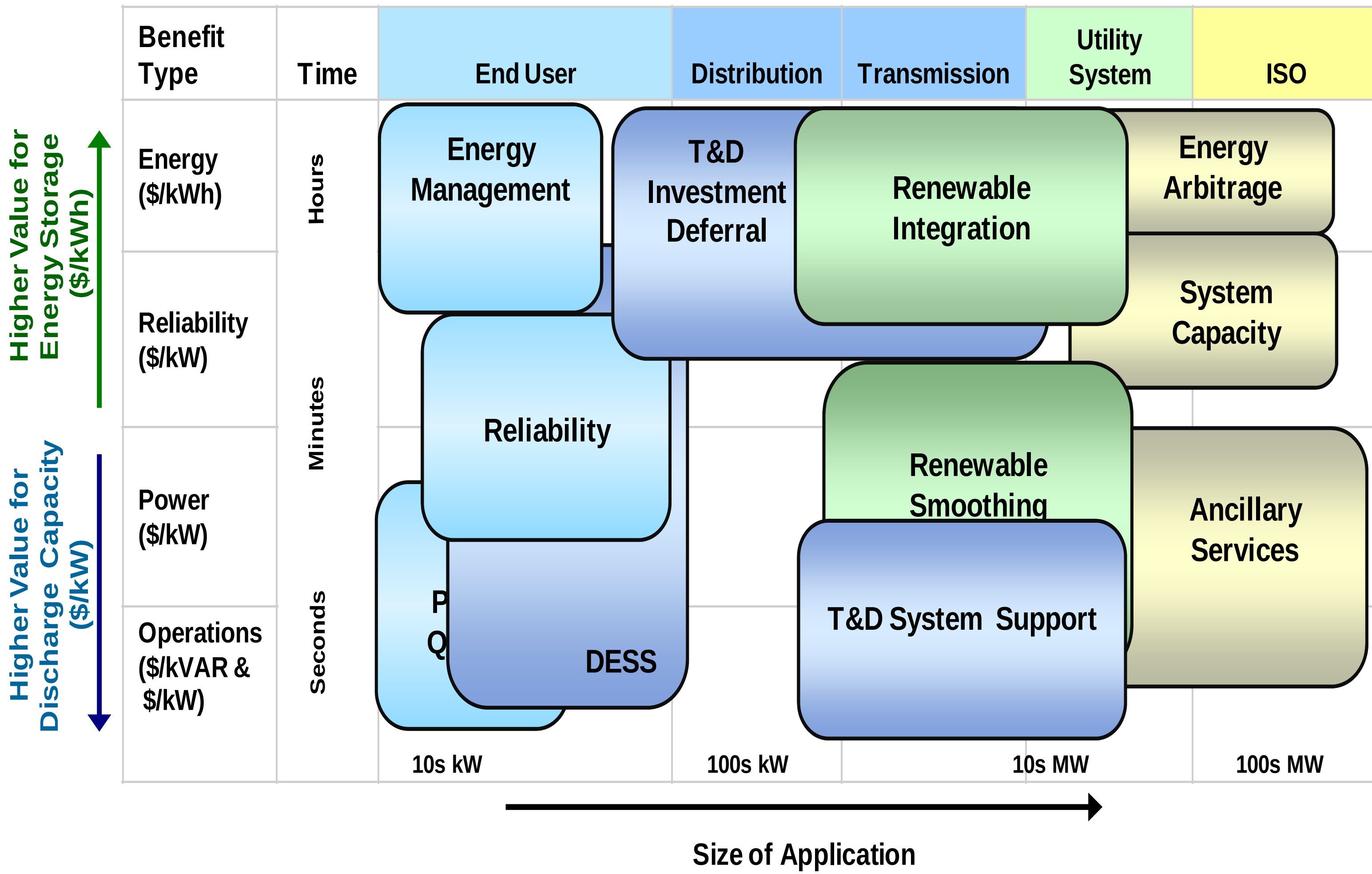
The Role of Storage



Storage Applications

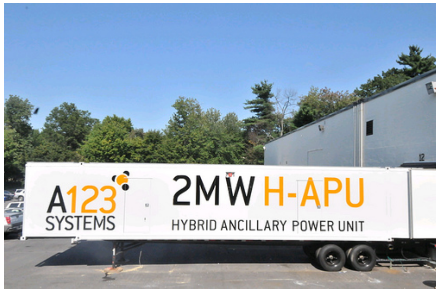


Overlapping applications



Enabling Grid-Ready Storage

Technology Capabilities



Grid-Ready Storage Solutions

Industry Requirements

<u>Grid-Ready Storage</u>

Safe and Reliable

Cost-effective

Ready for Integration

Established Track Record

Critical Parameters for Grid-Ready Storage

Technical Specifications	Economic Considerations	Other Factors
Power rating	Initial Cost	Safety
Energy rating (duration)	Lifetime Cost	Environmental Effects
Operating Voltage	Operating Costs	Recyclability
Temperature Range	Maintenance Costs	Regulatory Status
Footprint	Disposal Costs	Public Perception
Reliability	Costs of Alternatives	
Efficiency	Possibility of Multiple Value Streams	
Lifetime		
Required Maintenance		

The customer must know what he is getting!

Storage must interface with all aspects of grid

Grid Operations

- Regulatory Framework
- Market Framework
- Operational algorithms

Smart Grid

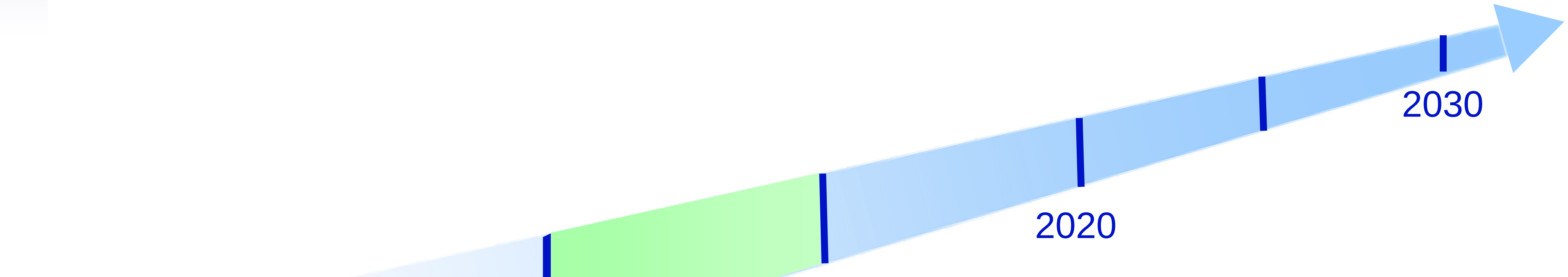
- Communications and control protocols
- Object Models
- Cybersecurity

Energy Storage

Distribution Infrastructure

- Protection schemes
- Understanding capacity implications
- Islanding
- Interface with public and local agencies

Energy Storage at EPRI



**Near Term:
Enable Grid-Ready
Storage Solutions
by 2015**

Near-term Focus: Grid-Ready Storage Solutions

- EPRI goal: Reliable, cost-effective storage solutions in three areas:
  - Large-scale bulk storage as a balancing resource for renewables (> 50 MW for several hours)
  - Substation storage for transmission and distribution asset upgrade deferral (1 – 10 MW for 2 – 6 hours)
  - Distributed energy storage systems at neighborhood level (15 – 25 kW for 2 – 4 hours)

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Functional Requirements for Energy Storage Systems

Project Goals

The overarching goal of project is to develop functional requirements for energy storage systems connected to the electric grid to be used in specific ways (use cases/operational modes). From such functional requirements, vendors will be able to develop energy storage system products that meet utility needs.

Project Management and Staff

EPRI

Bill Steeley | Project Manager

Ben Norris | Technical Content

TTC

Jeff Serfass | Facilitation of collaboration

Emanuel Wagner | Project Coordinator

Project Timeframe

- April 1st – Commencement of Project
- May - August – Webinar Reviews
- August 31st – Draft Report
- September 30th – Project Completion

P94.002 Energy Storage and Distributed Generation Options for Grid Support and Reliability

Report Outline – Overview

1. **Executive Summary**
   – Project description and goals, Methodology and participants, Results, Conclusions

2. **Introduction**
   – Need for Energy Storage, Defining functional requirements, This project

3. **Substation Grid Support Functional Requirements - Eva Gardow**
   – storage at the substation or distribution feeder

4. **Distributed Energy Storage System (DESS) Functional Requirements - Tom Walker**
   – storage at the transformer serving several customers

5. **Energy Storage to Support Renewable Energy Integration Functional Requirements for**
   A. Wind Smoothing (Ramping) in Power System Operations – Dale Bradshaw
   B. PV Transient Support in Power System Operations - Mike Grant
   C. Load Shifting to Integrate Wind and Solar in Power System Operations - George Gurlaskie

6. **Recommendations for Future Work**

7. **Appendices - List of Organizations that Participated and other Resource Materials**

P94.002 Energy Storage and Distributed Generation Options for Grid Support and Reliability

Functional Requirement – Overview 1/2

Functional Requirements	Use Cases / Operation Modes	Interconnection	Notes
Substation Grid Support • 1 – 20 MW • 2 – 6 hours - Minutes only for frequency regulation • Includes - Stationary - Transportable - Modular	• Peak load management • Frequency regulation • Capacity market (RTO/ISO) • Reactive Support • Support for critical loads during outage (Islanding)	• Distribution voltage • Substation or feeder	• Use cases are listed in order of priority • Products do not need to meet all use cases • Peak load management is controlled based on substation/feeder real time loads • Frequency regulation based on signals from ISO • Capacity market based on control from ISO • System may be modular
Distributed Energy Storage System (DESS) • 25 – 1000 kW • 1 – 4 hours	• Peak load management • Increase customer reliability (backup power) • Voltage regulation	• Secondary voltage • Utility side of meter • Can operate as island	• No frequency regulation support • Peak load management is controlled based on substation/feeder real time loads • Reactive power support based on local voltage • No DC ports (as in AEP doc) • Dampens PV variability

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Functional Requirement – Overview 2/2

Energy Storage to Integrate Renewables	Use Cases/ Operating Modes	Inter-connection	Notes
A. PV Transient Support • Power up to several MVA (TBD by utility site) • 1 second to 20 min (TBD by utility)	• Eliminate rapid voltage and power swings (flicker) on distribution systems where high-penetration levels of PV systems are found	• Distribution voltage (4kV - 34kV)	• Better manage the intermittency of solar real power output due to cloud cover (act like an electric shock absorber). • Reactive power controlled based on local voltage
B. Wind Smoothing (Ramping) • 1 – 100 MW • 2 – 15 minutes	• Ensure windfarm ramp-rates (MW/min) are kept to within design limits; • Maintain local transmission and sub-transmission voltage	• Medium or transmission voltage	• Typically windfarm owned and operated
C. Load Shifting • Power defined by size of renewable resource; kW to hundreds of MW • Up to 10 hours	• Shift renewable generation to peak times • Utility demand response resource • Participate in capacity markets as a dispatchable resource • Energy arbitrage • Ancillary services	• Mainly transmission and distribution voltages • Could also apply to secondary distribution voltages	• May be directly coupled and sized to local renewable resource or sized and operated independently • May also serve to smooth windfarm output and/or dampen PV transients

Chapter Outline for Each Functional Requirement

Description of Application
- Block Diagram
- Scope

Use Cases/Operating Modes
Performance Ratings
- System Definition
- Auxiliary Loads
- System Ratings

System Effectiveness
- System Efficiency
- Performance Curve

Physical Characteristics
- Size
- Transportation Standards
- Harnessing
- Status Lights and Alarms
- Environmental Conditions

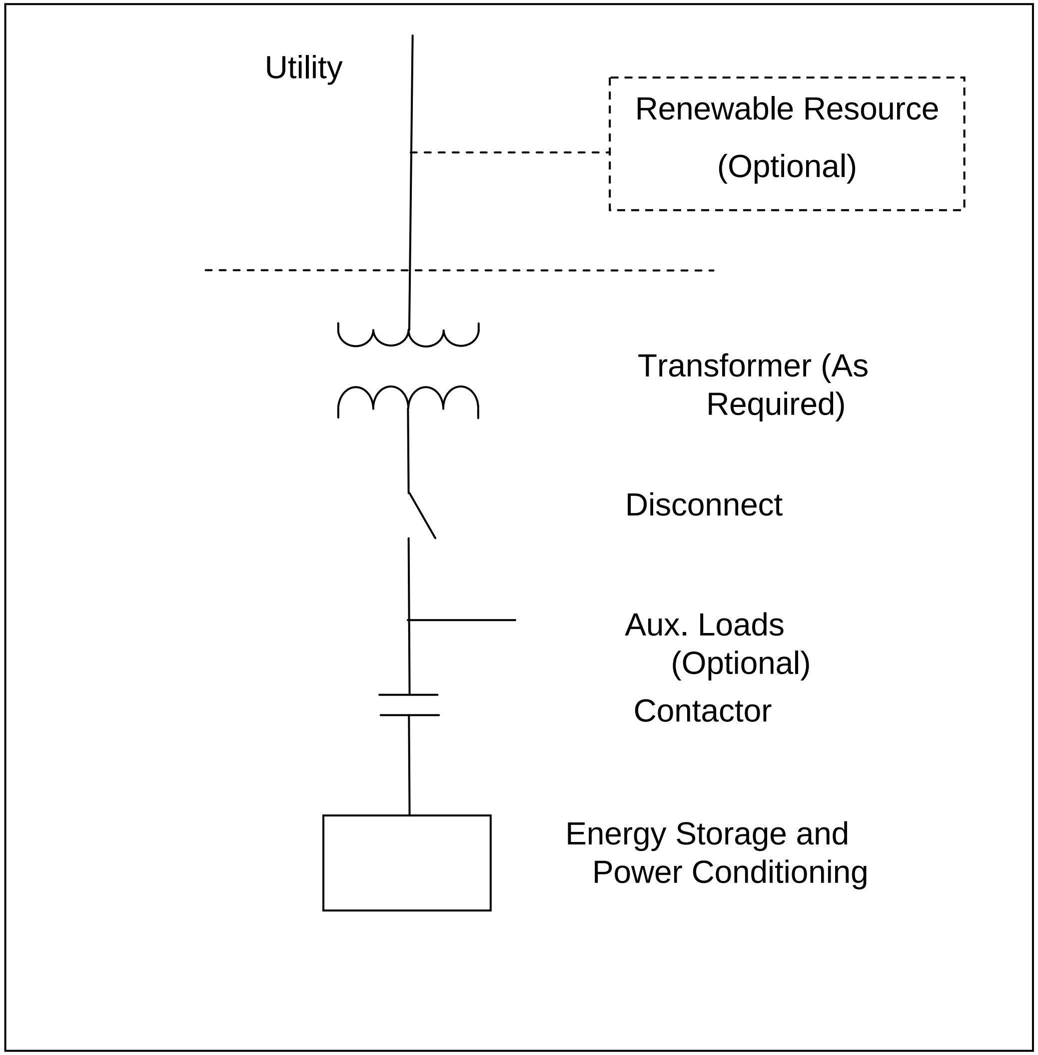
Electrical Interface
- Standards
- Disconnect Breaker
- Contactor

Communications, Control and Data Management
- Communications Method
- Communications Protocol
- Integrated Interface
- Operational Data
- Event-triggered Data
- Data Access

Installation and Maintenance
- Installation
- Operation and Maintenance
- DC Maintenance

Safety

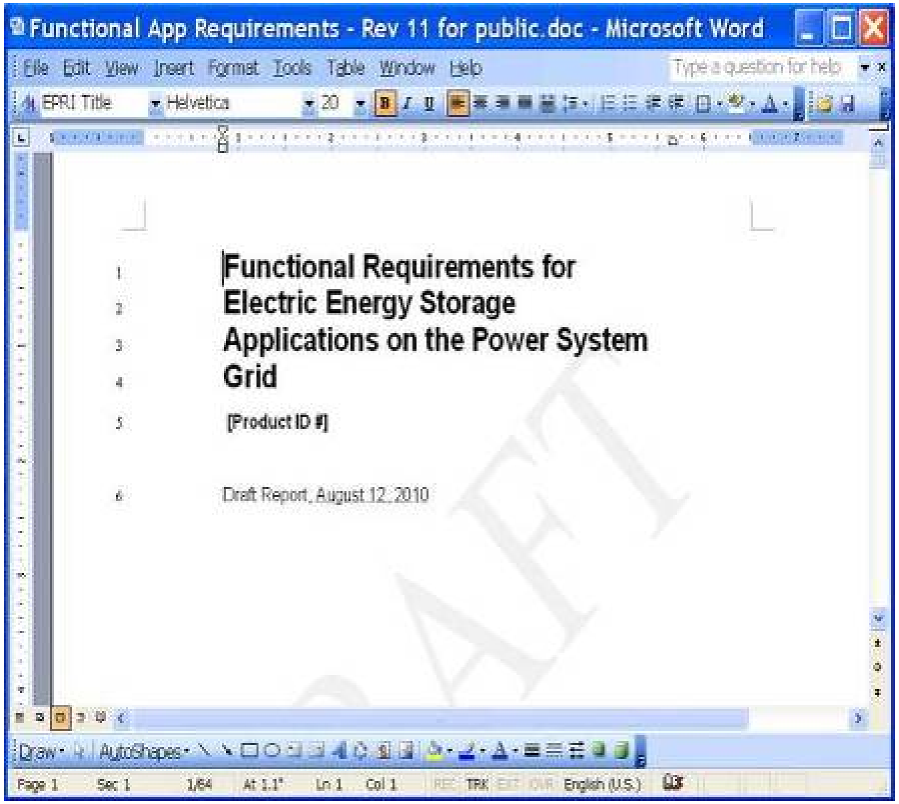
Sample Block Diagram for Load Shifting



P94.002 Functional Requirements for Electric Energy Storage Applications on the Power Grid

Project Manager: William Steeley
Product ID: 1020075

- Plans and Next Steps
  - Currently obtaining input from stakeholders to incorporate into the next version of draft report
  - Working Groups will then review and revise as necessary
- Schedule
  - Finish draft report
  - Complete Project in 4th QTR



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Together…Shaping the Future of Electricity