EPRI ELECTRIC POWER RESEARCH INSTITUTE

Grid Integration of Micro CHP Distributed Generation

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ARPA-E

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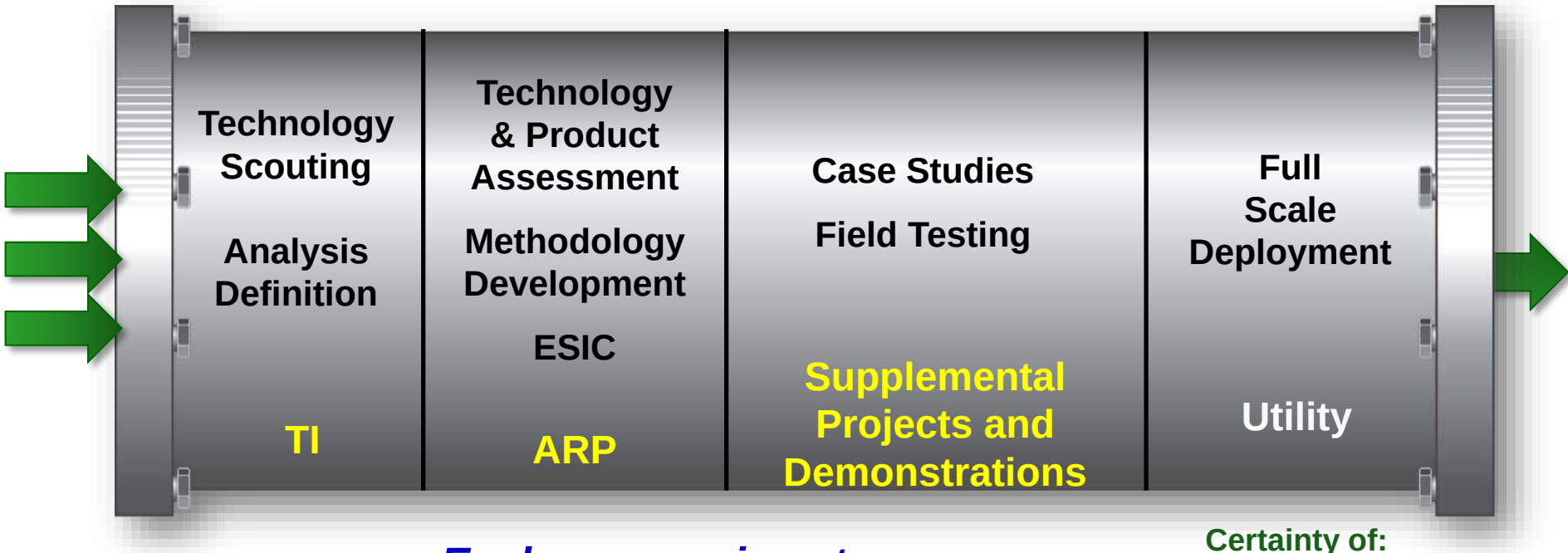
Together…Shaping the Future of Electricity

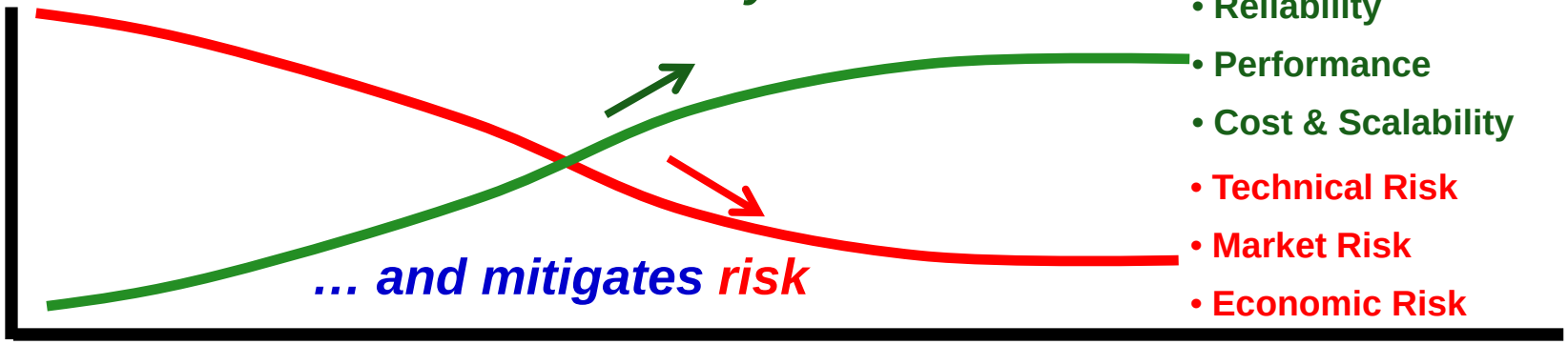
EPRI's Mission

Advancing safe, reliable, affordable, and environmentally responsible electricity for society through global collaboration, thought leadership and science & technology innovation.

EPRI Advances Technology through Development Pipeline



Each successive stage increases certainty…



Certainty of:

- Safety
- Reliability
- Performance
- Cost & Scalability

Risk:

- Technical Risk
- Market Risk
- Economic Risk

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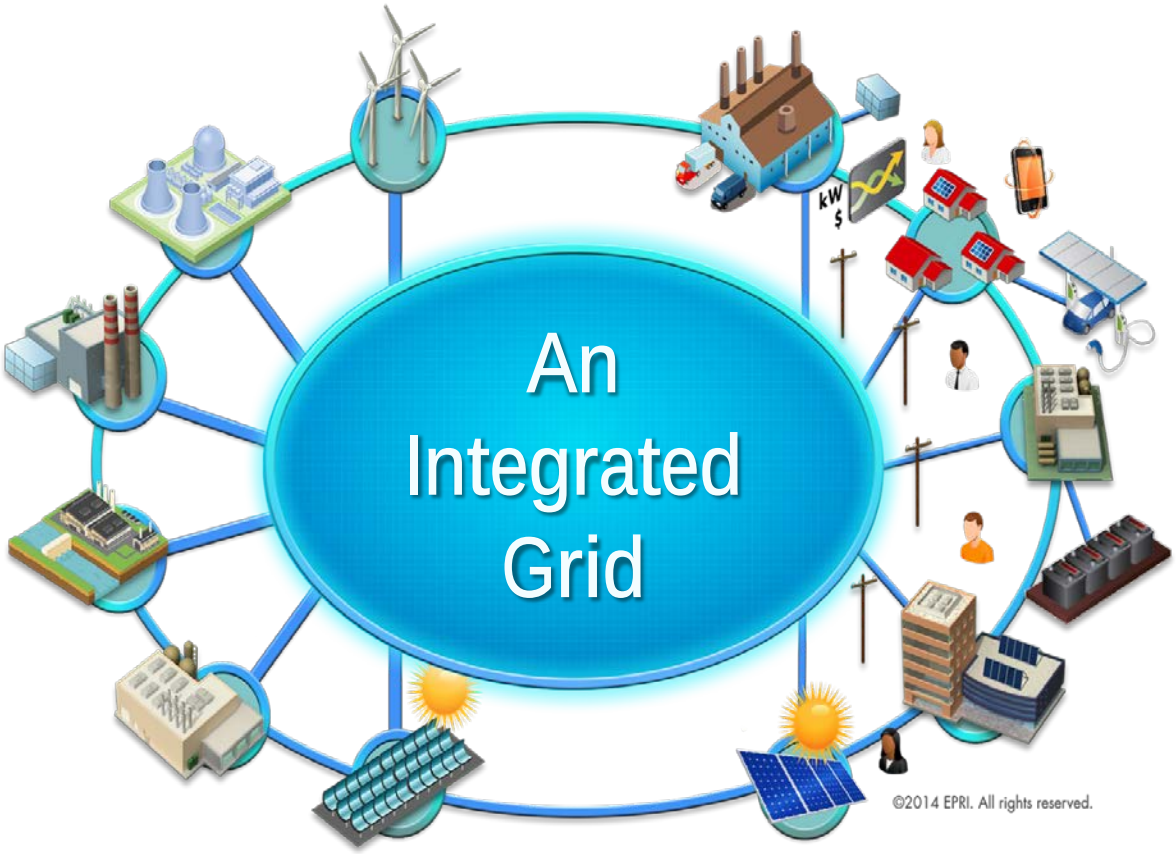
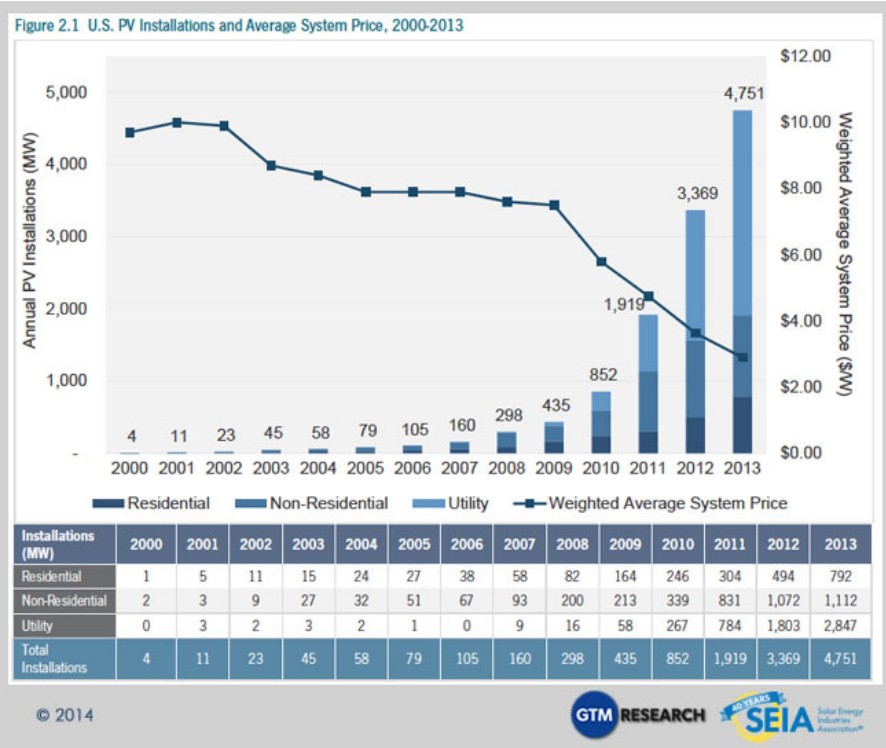
Integrated Grid Methodology

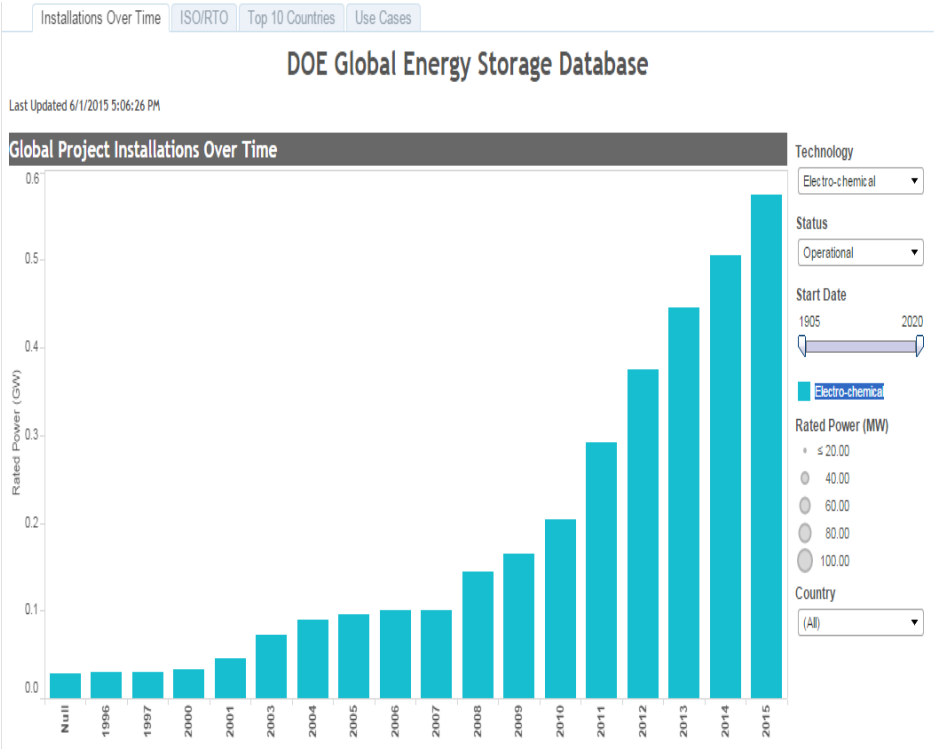
- The electric power system is changing—rapidly in some areas—with the rise of distributed energy resources (DER) such as solar PV.
- To fully realize the value of these distributed resources, and to provide power quality and reliability, a deliberate and beneficial integration is needed.
- Widespread deployment of PV needs to be incorporated into both grid planning and operational processes.
- This in mind, EPRI has developed a comprehensive benefit-cost framework aimed at better informing strategic decision-making by all power system stakeholders.



Why focus on Distributed Generation? Quick look at trends



Installations (MW)	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Residential	1	5	11	15	24	27	38	58	82	164	246	304	494	792
Non-Residential	2	3	9	27	32	51	67	93	200	213	339	831	1,072	1,112
Utility	0	3	2	3	2	1	0	9	16	58	267	784	1,803	2,847
Total Installations	4	11	23	45	58	79	105	160	298	435	852	1,919	3,369	4,751



11% CAGR Battery B to B

Source: Panasonic

Source: DOE Global Energy Storage Database

Compare to smart phone forecast of CAGR of 7.1-13%

Sources: CCS Insight, PRN Newswire, Forrester

EPRI Energy Storage and Distributed Generation

Through the EPRI Energy Storage and Distributed Generation Program, member utilities:

- Follow the rapidly developing worlds of energy storage, distributed generation, and microgrids
- Learn from the experiences and practices of other utilities and investigators
- Guide the way that storage and DG are used, as well as the tools used to design and apply them

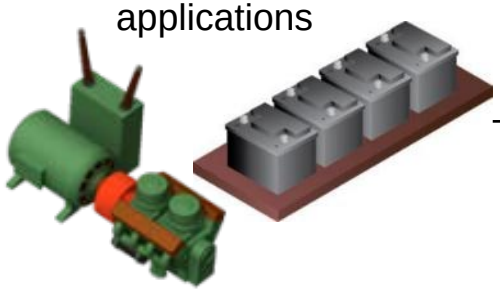
Approach:

- Investigate customer-side storage products and DG products for performance and grid compatibility
- Analyze the effects of customer side storage and DG on the power distribution network

Key EPRI Research Initiatives in ES/DG: Facilitating Grid-Ready DER Systems

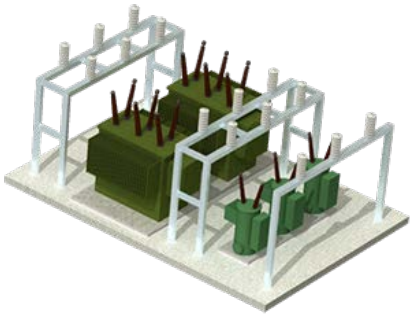
Underlying Technologies

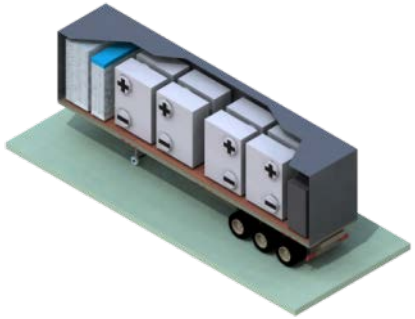
- Exploring technology tradeoffs
- Optimizing technology for utility applications



Power Conditioning

- Establishing appropriate operations and control
- Ensuring efficient and reliable operation





Deployable Product

- Ensuring safety and reliability
- Understanding cost and performance
- Simplifying procurement and operation through standardization of specification and interfaces

Grid integration

- Establishing best practices for siting and permitting
- Standardizing the interface with the grid
- Modeling and analyzing the effects on the grid

Communications and Control

- Defining interoperable protocols
- Developing operational and dispatch algorithms

The Utility Challenge: Integration of DG and Microgrids

Technical Challenges:

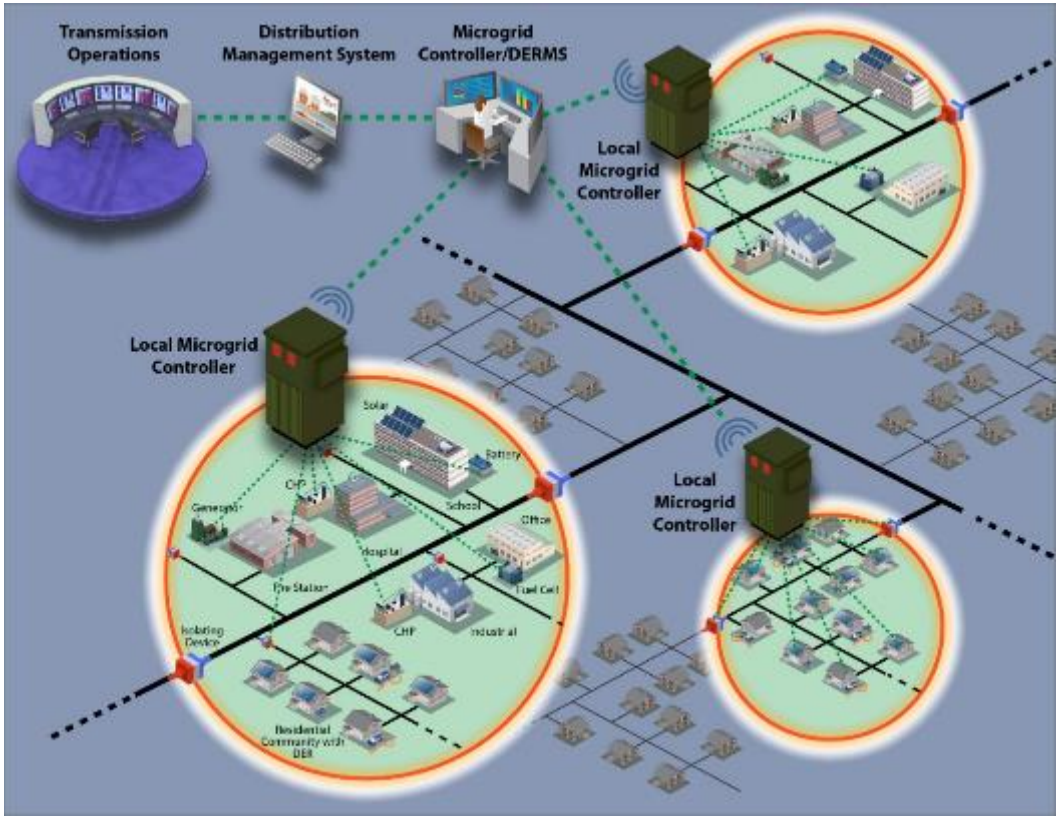
- Bi-directional power flows
- Fault current contribution – protection scheme impacts
- Unit Level Volt/VAR support
- Islanded Operation

Economic Challenges:

- DG technologies still costly and with uncertain lifetimes
- Business model still undeveloped

Typical Applications:

- Demand response
- Voltage/frequency support
- Renewables mandates
- Capacity (offset peakers)
- Upgrade deferrals



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How does EPRI address DG Integration to Utilities?

- System, Feeder and Equipment models -
  - System Portfolio
    - Overall system generation portfolio assessments
    - Environmental impacts
  - Grid integration voltage/protection impacts

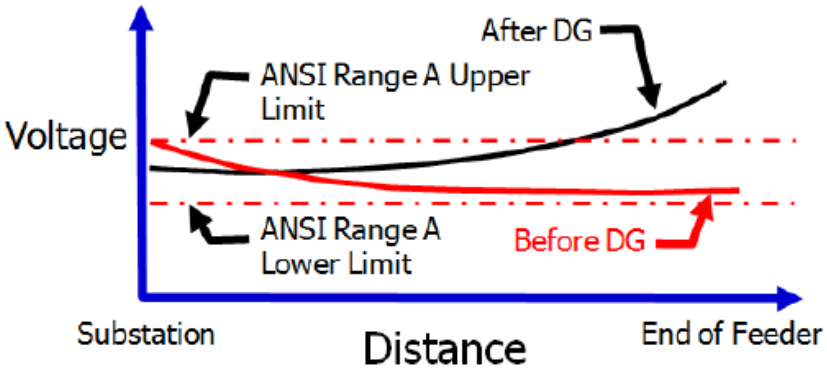
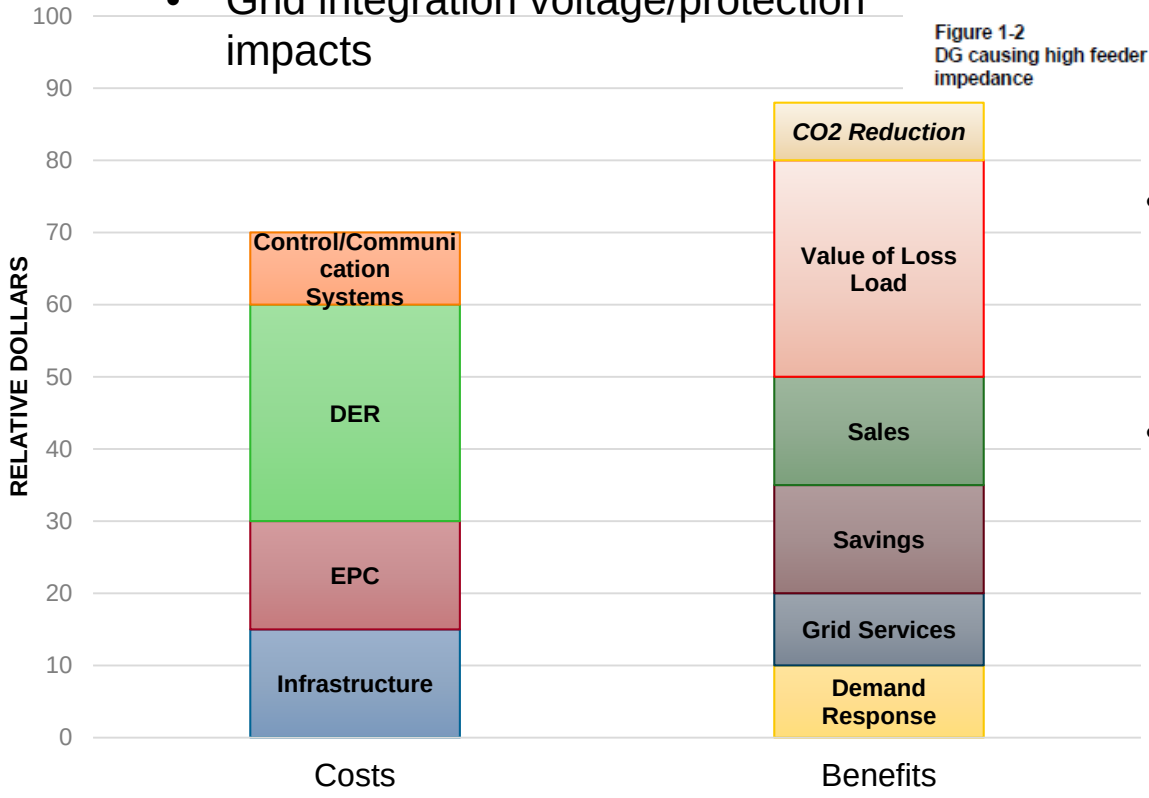


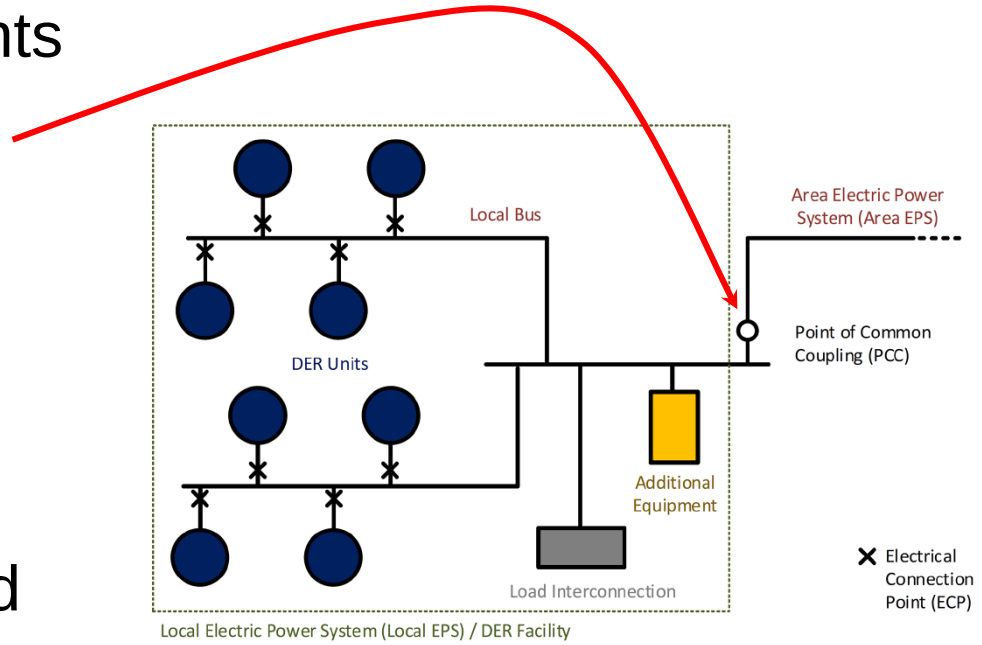
Figure 1-2
DG causing high feeder voltage when exporting large amounts of power relative to circuit impedance



- Optimization of DG
  - Location
  - Size
- Cost/Benefit Analysis
  - Technology Surveys
  - Distributed Resource Financial Models

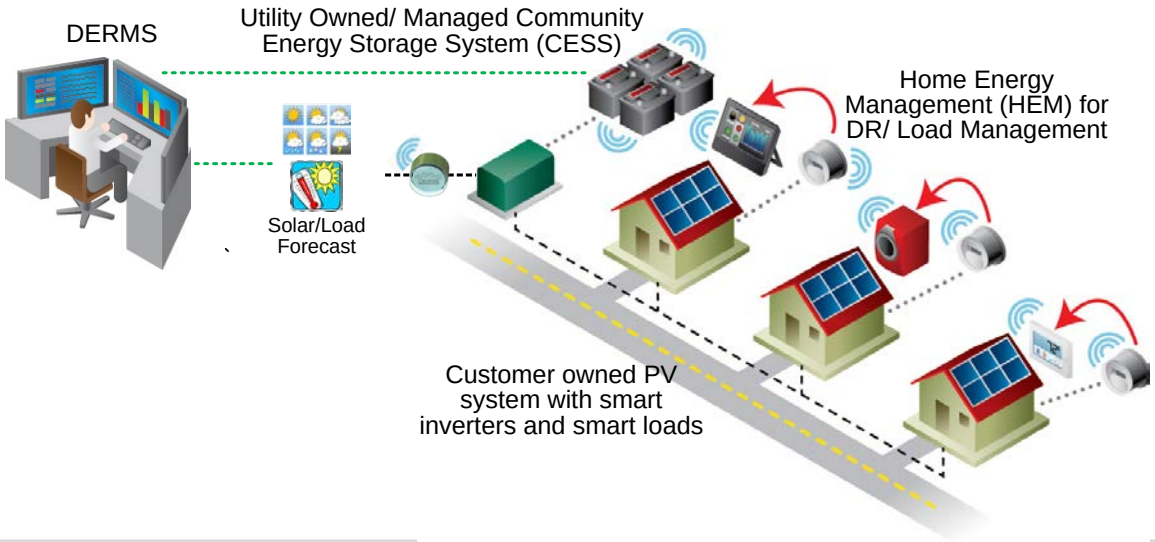
How do these approaches apply to micro CHP?

- Typical residential interconnect requirements
  - Most focus is on Point of Common Coupling
  - Net meter
  - UL rated inverter
  - Disconnects
- If more complicated applications are pursued (voltage regulation/islanding) – more rigorous requirements are applicable



How do these approaches apply to micro CHP?

- Controls - How is benefit extracted?
  - Who owns Micro CHP?
    - Customer – rate based incentives
    - Utility/other – over-arching grid incentives
  - Who controls for given applications?
    - Utility back office control – Smart Grid – Enterprise based systems



- Considerations
  - What Communication Platform?
  - What protocol is used?
  - Cybersecurity issues
  - Latency
  - Data ownership

How do these approaches apply to micro CHP?

- Cost benefits - modeling – customer specific
  - See EPRI 3002004191 – Program on Technology Innovation: Natural Gas Distributed Generation Options: Cost and Market Benchmarking Assessment – Nov 2014

- Microgrid considerations
  - Role of micro CHP in microgrid
    - Can it carry black start or load shift?
    - Complications of thermal load modeling

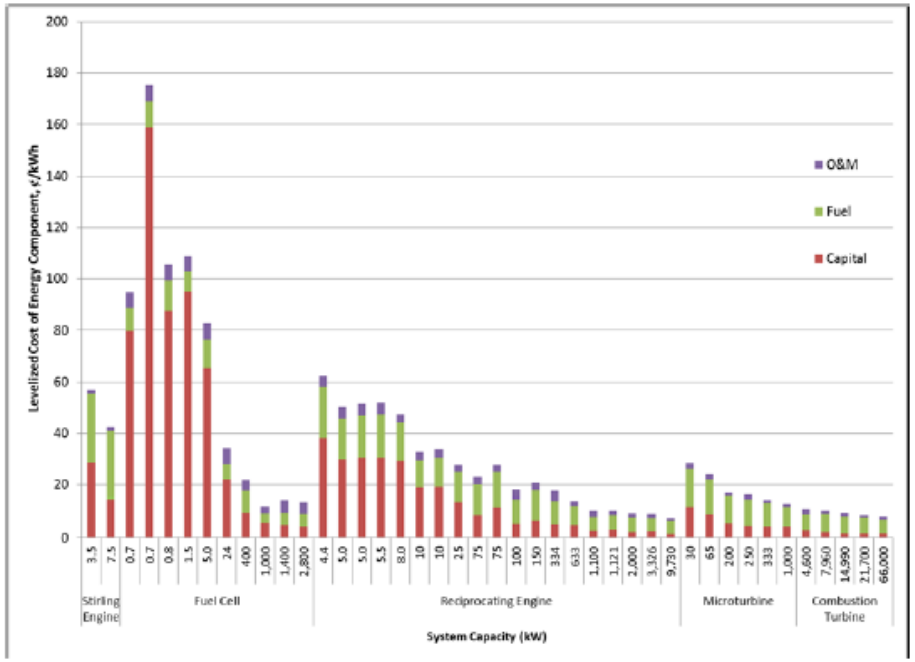
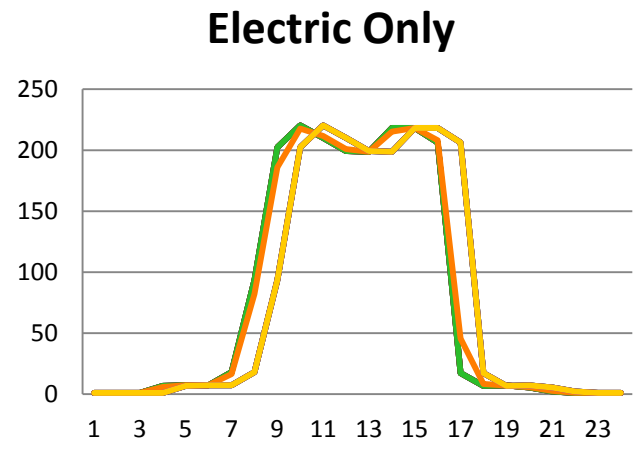
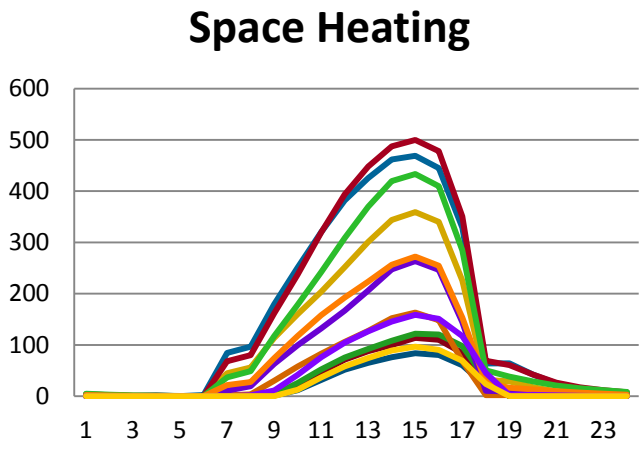
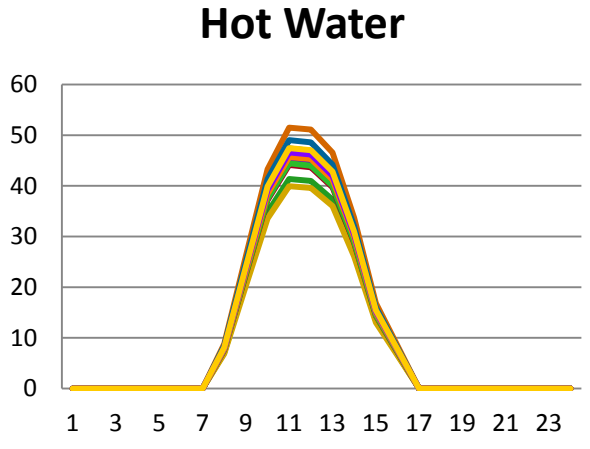


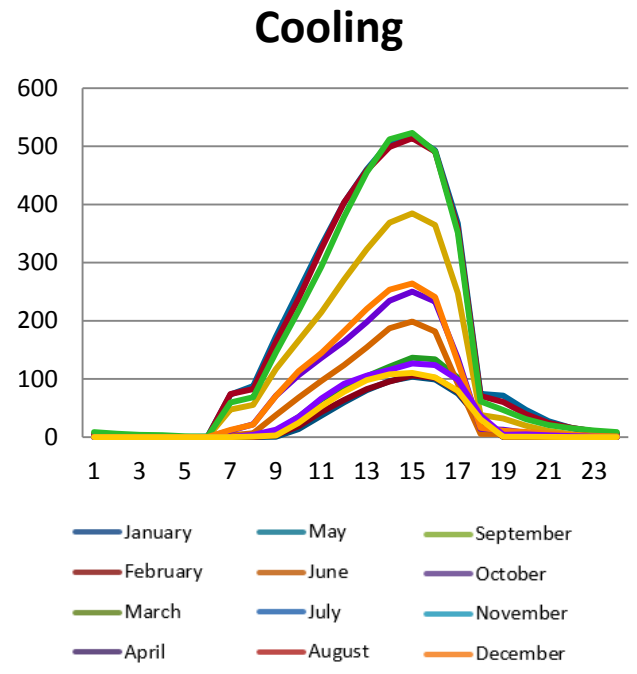
Figure 5-2
Levelized Cost of Energy Results without CHP for Specific Technologies

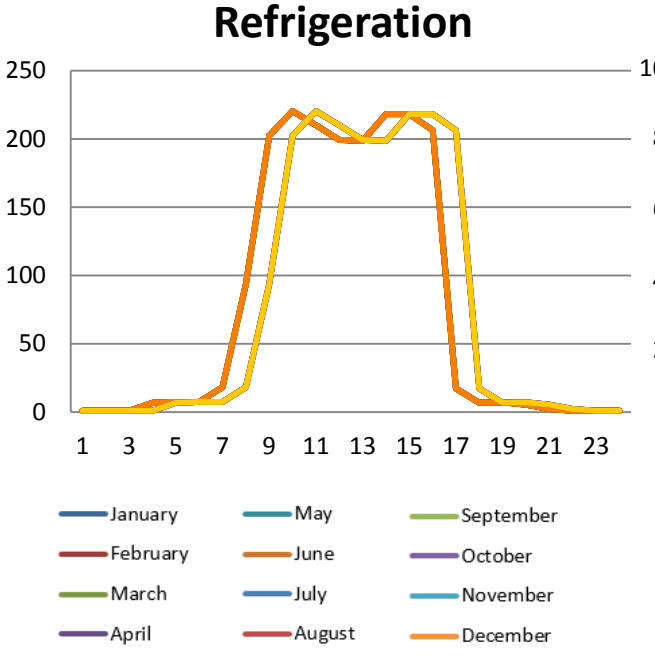
Load (Electrical, Thermal) Characterization – numerous load profiles need to be addressed

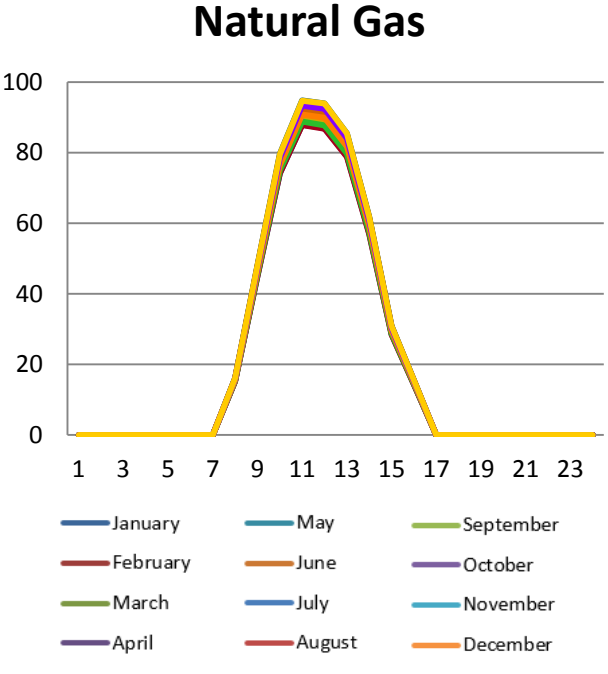








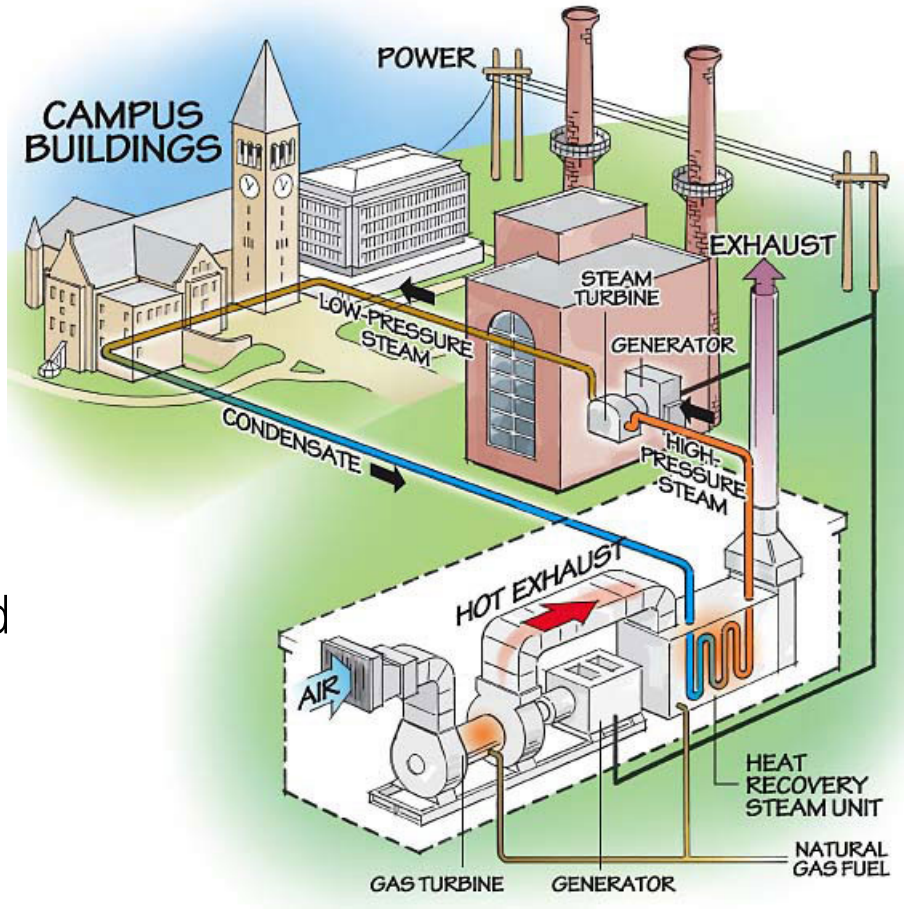




How do these approaches apply to micro CHP?

- Environmental Considerations
  - Small capacity, but non-zero air emissions
  - Sources close to people
  - Short stacks and cooler flue gas alters plume rise & buoyancy
  - Impact of building topology

  - Therefore, air quality impacts (outdoor or indoor) should be tested
    - Assess emissions
    - Fine scale modeling
    - Inform siting considerations



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