Conservation Voltage Reduction

Midwest Energy Efficiency Association

January 16, 2013

Ameren ILLINOIS

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ICC Docket No. 13-0498
CUB Ex. 1.4 Revised

What is Conservation Voltage Reduction?

Conservation Voltage Reduction (CVR)

- is an existing technology concept that can increase grid efficiency.
- is the general term for the changes to distribution equipment and operations that can reduce line losses, peak loads and reactive power needs, and save (or defer) consumption by some types of consumer equipment.

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What is CVR?

- CVR is the intentional and routine reduction of system voltage, typically on distribution circuits, to reduce line losses and energy use by some types of end-use equipment while maintaining customer service voltage within applicable national standards (e.g., ±5 percent of nominal).

- Conservation voltage reduction or “voltage optimization” – a term sometimes used to refer to advanced forms of CVR that include VAR control – is designed to reduce capacity needs overall, to reduce energy use, or both.

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CVR Operations

- According to studies, operating a utility distribution system in the lower half of the acceptable voltage range (120-114 volts) saves energy, reduces demand, and reduces reactive power requirements without negatively impacting the customer.
- The distribution lines that deliver energy to homes and businesses typically lose 3 percent to 7 percent of the electricity they carry.

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CVR Operations

- Reducing electric service voltage also reduces energy consumption of some consumer equipment. In fact, much of the savings potential may be on the customer side.
- A study found that when voltage reduction is coupled with major system improvements, 10 percent to 40 percent of the savings accrue on the utility distribution system; the remaining savings are the result of reduced consumption by equipment in homes and businesses operating at lower voltage

(R.W. Beck 2007)

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CVR Savings

- 1-3% reduction in energy use
- 1-4% peak load reduction
- Most energy savings: *end-use* equipment at lower voltage
- Cost is low
- *Incremental* impact of smart grid for CVR estimated at 2%; studies needed to confirm

Estimates from Electric Power Research Institute, Northwest Energy Efficiency Alliance, Northwest Power and Conservation Council

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Existing Technology

- In the past, voltage improvements to the distribution grid have been initiated in the form of installing fixed capacitors (in all three phases) connected along the distribution lines.

- One feeder line of certain length might have one or two capacitor banks installed at 40% and 80% of the line length. These capacitors act as the VAr generators to boost the voltage of the feeder line around them as well as lowering the current that the line would have to carry to support the same loads.

- In addition, both voltage regulators and load tap changers (LTC) are often used at the feeder and substation level respectively to help maintain a consistent voltage profile.

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Challenges for Existing Technology

- Loads and the resulting line currents are extremely dynamic. Changes and fluctuations occur daily (day versus night loads) as well as weekly (workdays versus weekends) and seasonally (winter versus summer).

- With the integration of distributed energy sources such as wind and solar along with the increase in use of electric vehicles, distribution grid complexity continues to increase substantially.

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Challenges for Existing Technology

While system operators may be used to considerable slack above minimum voltage standards, more precise controls and communications allow for margins to be smaller without compromising service quality or damaging consumer equipment.

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Communications Technologies

- Today, with the advancement of sensor, controller, communications technology, utilities can have the distribution grid between the substation and consumer at their fingertips.

- Sensor technology such as transformer controllers and line post sensors integrate accurate, reliable measurement of the primary current and voltage to allow precise switching from the controller at voltage, current, and/or VAR flow magnitudes.

- Coupled with communications back to the operations center, CVR is equipped to take advantage real-time visibility and control to address the increasing complexity of the grid and allow utilities and consumers to experience the benefits of efficiency improvement.

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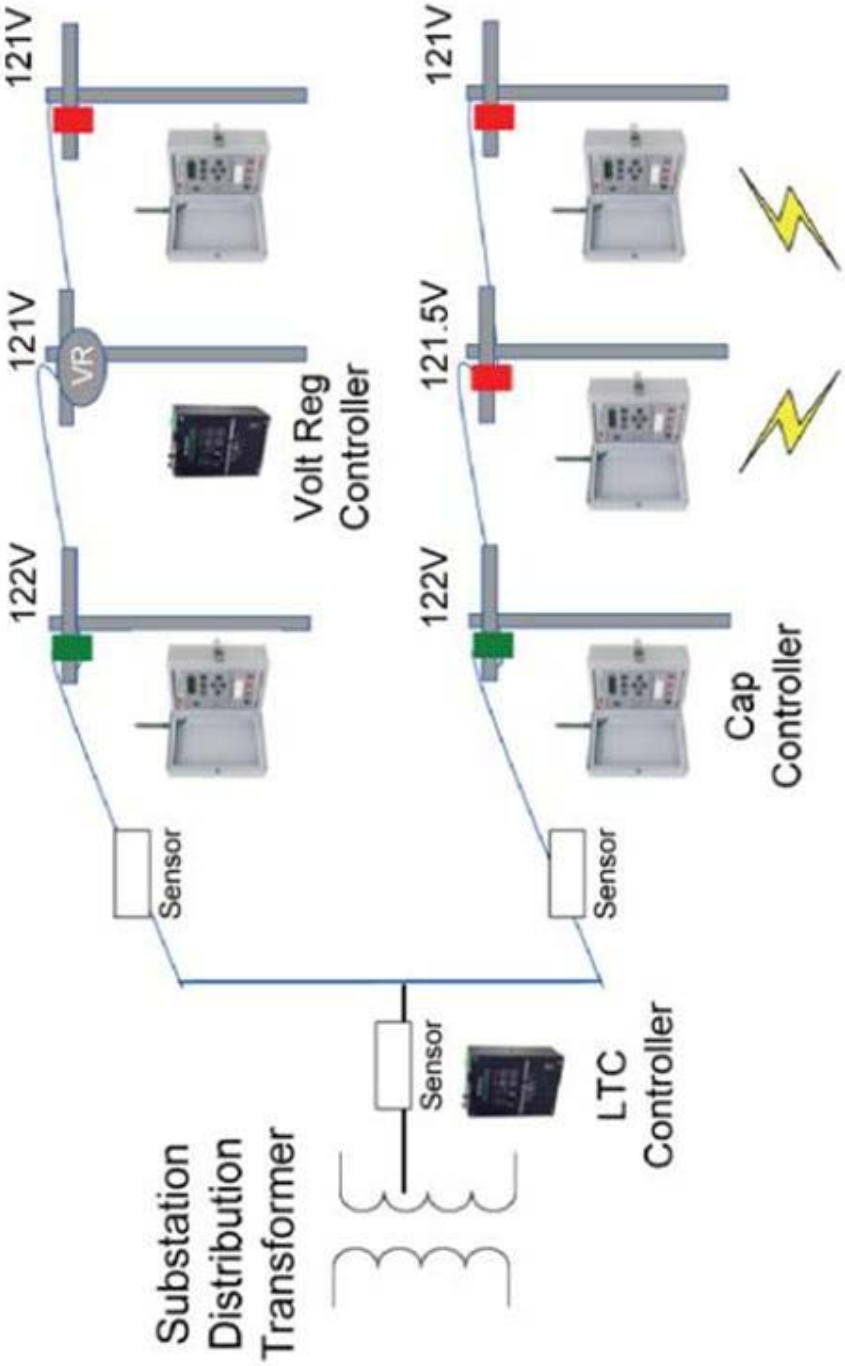

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Is SmartGrid Necessary To Implement CVR?

- No – while voltage must be measured at one or more points on the feeder and communicated back to the utility to go beyond the line drop compensation approach, SCADA and strategic placement of a small number of voltage transducers on each circuit are sufficient.

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Ameren Illinois Pilot

- ICC order to pilot a Voltage Optimization project in 2010
- Include testing of demand response and energy efficiency capabilities
- Design a number of tests using industry best practices

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Ameren Illinois Pilot Expectations

- Demonstrate ability to control and levelize voltage
- Test and verify amount of demand reduction
- Test and verify amount of energy efficiency (24/7)
- Determine applicability to remainder of system & develop implementation plan

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Pilot Status

- Equipment installed at two substations on four selected feeders in 1Q 2012
- On-going monitoring of urban and rural feeders for 1 year period
- EPRI assisting with pilot design and analysis including methodology, circuit modeling, testing criteria, test data analysis

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Questions?

CVR as an Energy Efficiency Resource

Prepared for:

IL Stakeholder Advisory Group

Prepared by:

Applied Energy Group

Kelly Warner

April, 30th, 2013

The AEG CVR Team

About AEG

Applied Energy Group (AEG) is a multi-disciplined, technical, economic and management consulting firm serving electric and gas utilities across North America. Founded in 1982, the company is headquartered in Islandia, NY and is a wholly-owned subsidiary of Ameresco (NYSE:AMRC).
www.appliedenergygroup.com

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CVR Leadership Team

Kelly Warner – Executive Vice President

30+ years experience (15 as CEO of major consulting and energy services firms) spanning the value chain of the electric and gas utility industry

CEO of Deerpath Energy, Inc., KEMA Inc. and XENERGY Inc.

Ron Willoughby – Executive Consultant

38+ years experience in electric power systems planning and operation.

VP at KEMA; Director of technical services at Cooper Power Systems; Manager for Westinghouse's Advanced Systems Technology Group.

Agenda

CVR Technology Overview

- How it works
- Voltage reduction and end use load impacts

CVR as an EE Resource

- CVR Potential
- Economics
- Industry results

Knowledge Gaps and Issues to Consider

CVR - a technology whose time has come

- Proven technology used on a limited scale by utilities over the past 3 decades.
- Lowering voltages improves the efficiency of many end-use appliance
  - Most customers receive voltage at the high-end of the ANSI range.
- The intersection of interest in Smart Grid and Energy Efficiency are increasing awareness of CVR.
  - Low-cost, scalable, controllable
- Utility business case and regulatory constructs are holding back CVR's potential
  - Utilities incur the cost while customers receive the benefit
- When viewed as an EE resource, CVR has huge potential.

1. CVR is also referred to as Conservation Voltage Regulation, Conservation Voltage Optimization (CVO), or Volt/VAR Optimization (VVO).

Standard Voltage Regulation Using Substation LTC

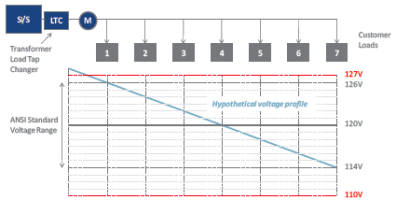


Figure 1. Hypothetical Feeder Voltage Profile with an LTC

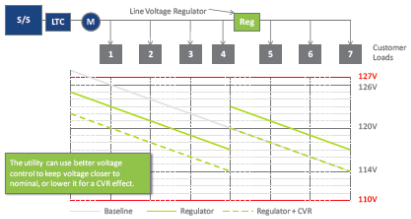


Figure 2. Hypothetical Feeder Voltage Profile with an LTC and Voltage Regulator

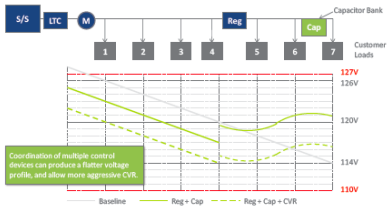


Figure 3. Feeder Voltage Profile with LTC, Voltage Regulator and Capacitor Bank

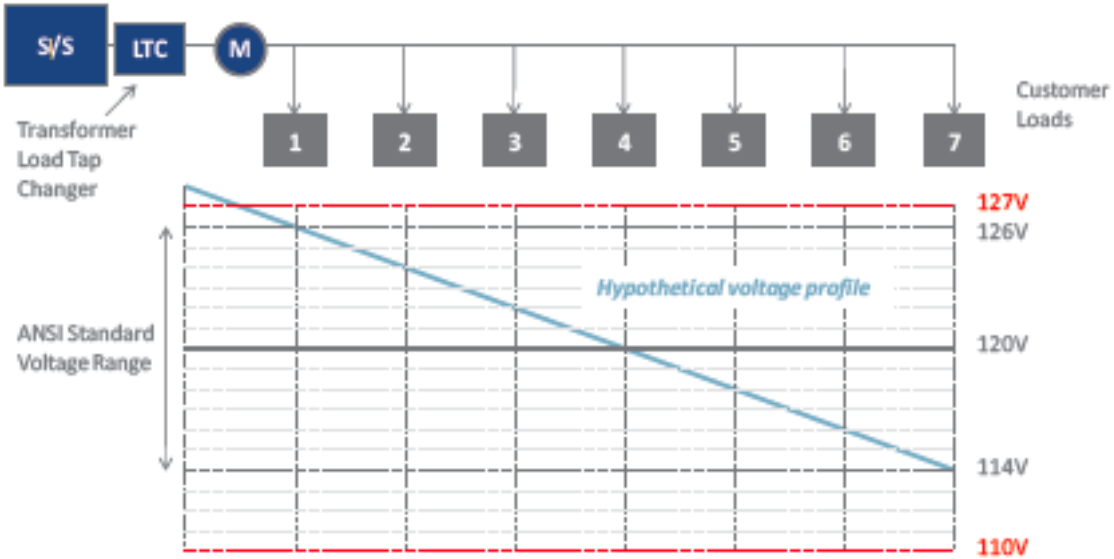
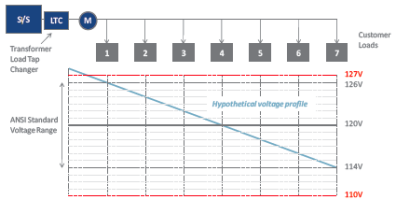


Figure 1. Hypothetical Feeder Voltage Profile with an LTC

Source: Application of Automated Controls for Voltage and Reactive Power Management – Initial Results. DOE – Smart Grid Investment Grant Program, December 2012

Enhanced Voltage Regulation Using Downstream Voltage Regulators



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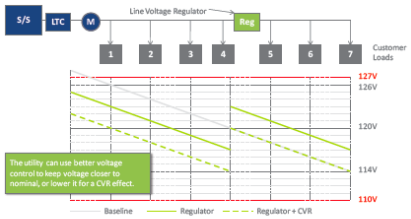

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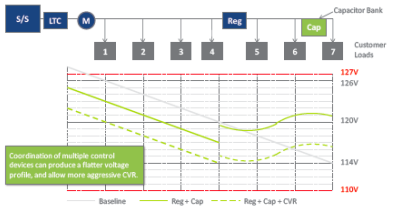

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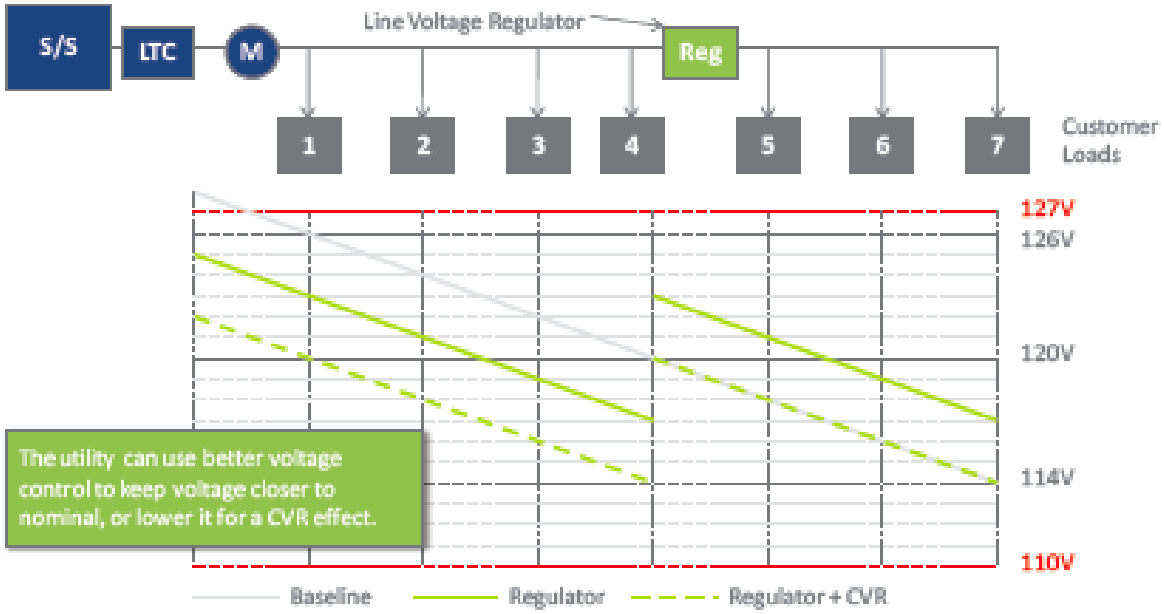

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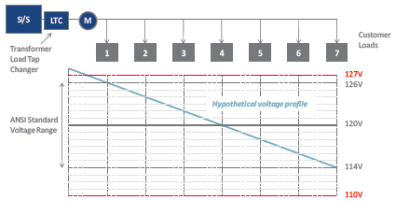
Source: Application of Automated Controls for Voltage and Reactive Power Management – Initial Results. DOE – Smart Grid Investment Grant Program, December 2012

Voltage Regulation Using V-Regs and Capacitors



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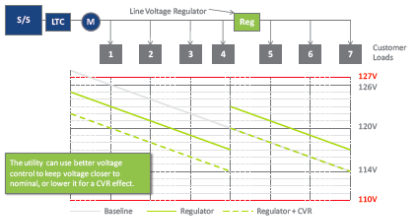

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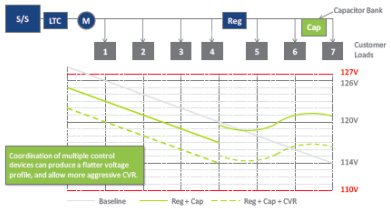

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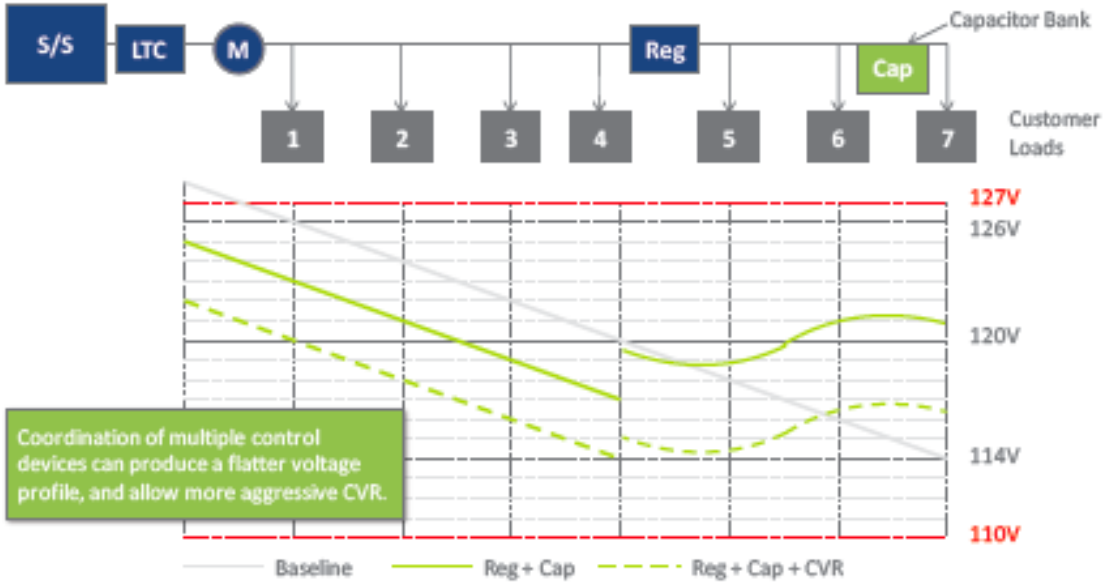

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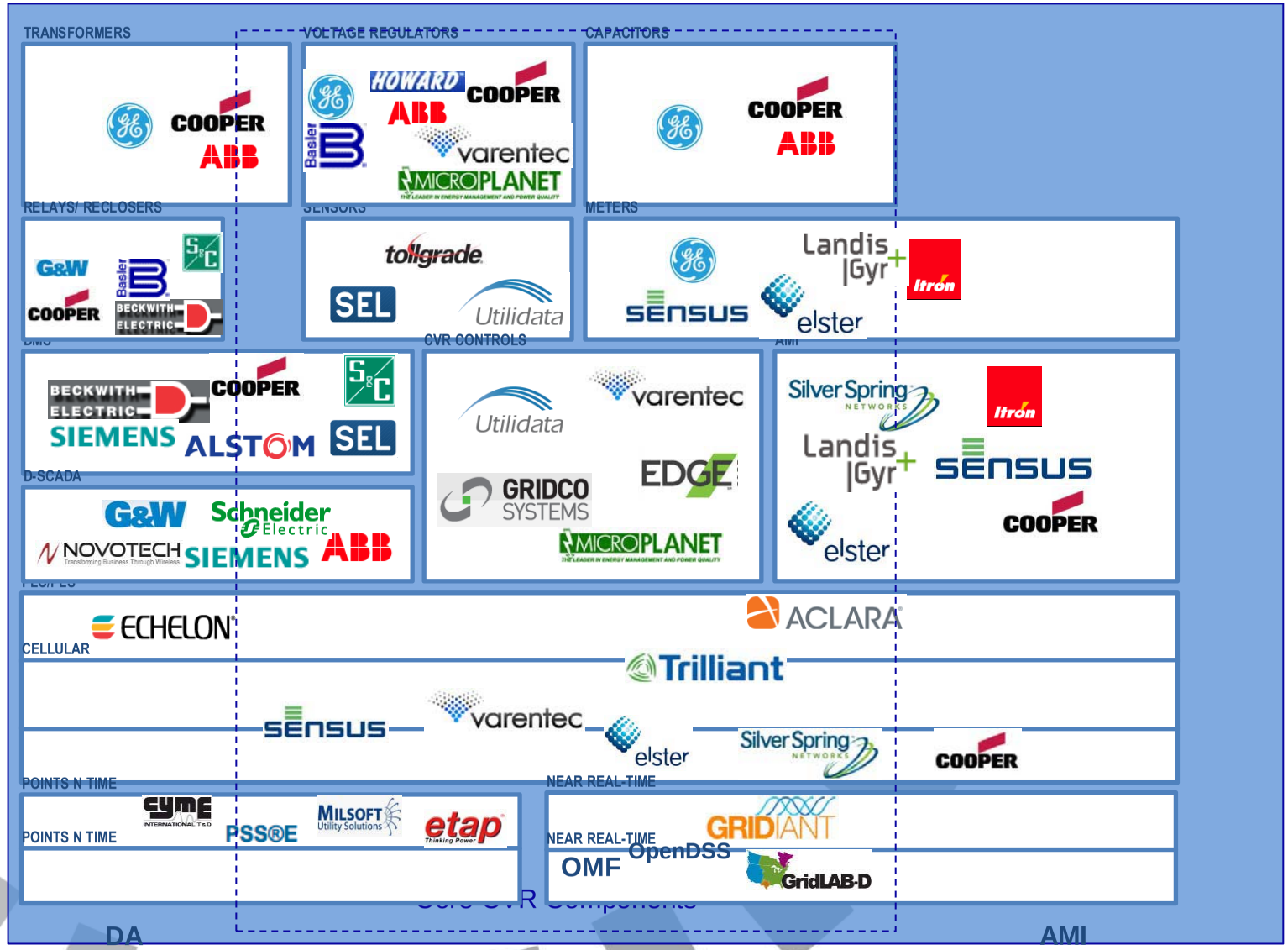
CVR Market Taxonomy

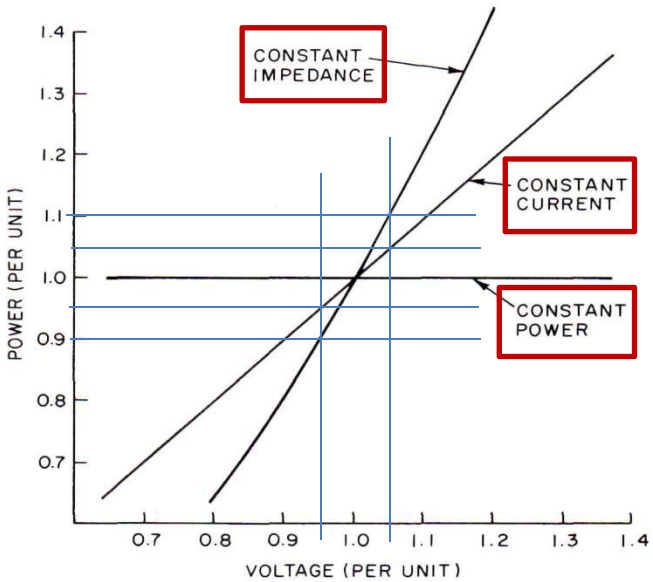


CVR Operating Models

CVR Strategy	Operating Model	Benefits
Emergency Load Relief	Short-term event-specific voltage reduction	System protection during emergency events
Substation Voltage Reduction	Continuous substation voltage optimization	Distribution systems energy savings at the sub-station
Peak Load Management	Economic dispatch model during high avoided-cost periods	Avoided high margin supply costs during peak periods
Customer End-use Efficiency	Continuous dynamic voltage control across an entire feeder	Customer energy and demand savings

Understanding how CVR affects customer loads is a critical step to using CVR as an EE resource

Load Types



Reference: IEEE Brown Book, ANSI/IEEE Std 399-1980

- Voltage reductions affect end use loads differently.
  - Circuits w/ more constant impedance loads will show more savings than constant power loads.
- Assessing CVR potential is a function of knowing what types of loads are on each circuit.
- Targeting “high value” feeders is important. PNNL estimates that 40% of the feeders account for 80% of the CVR potential.

PNNL, PG&E, ConEd, and others have validated end-use impacts of voltage reduction.

Pacific Northwest National Labs has conducted significant lab tests and computer simulations of CVR affects on end-use power consumption

- End-use specific load impacts
- Efficiency potential
- Load Models

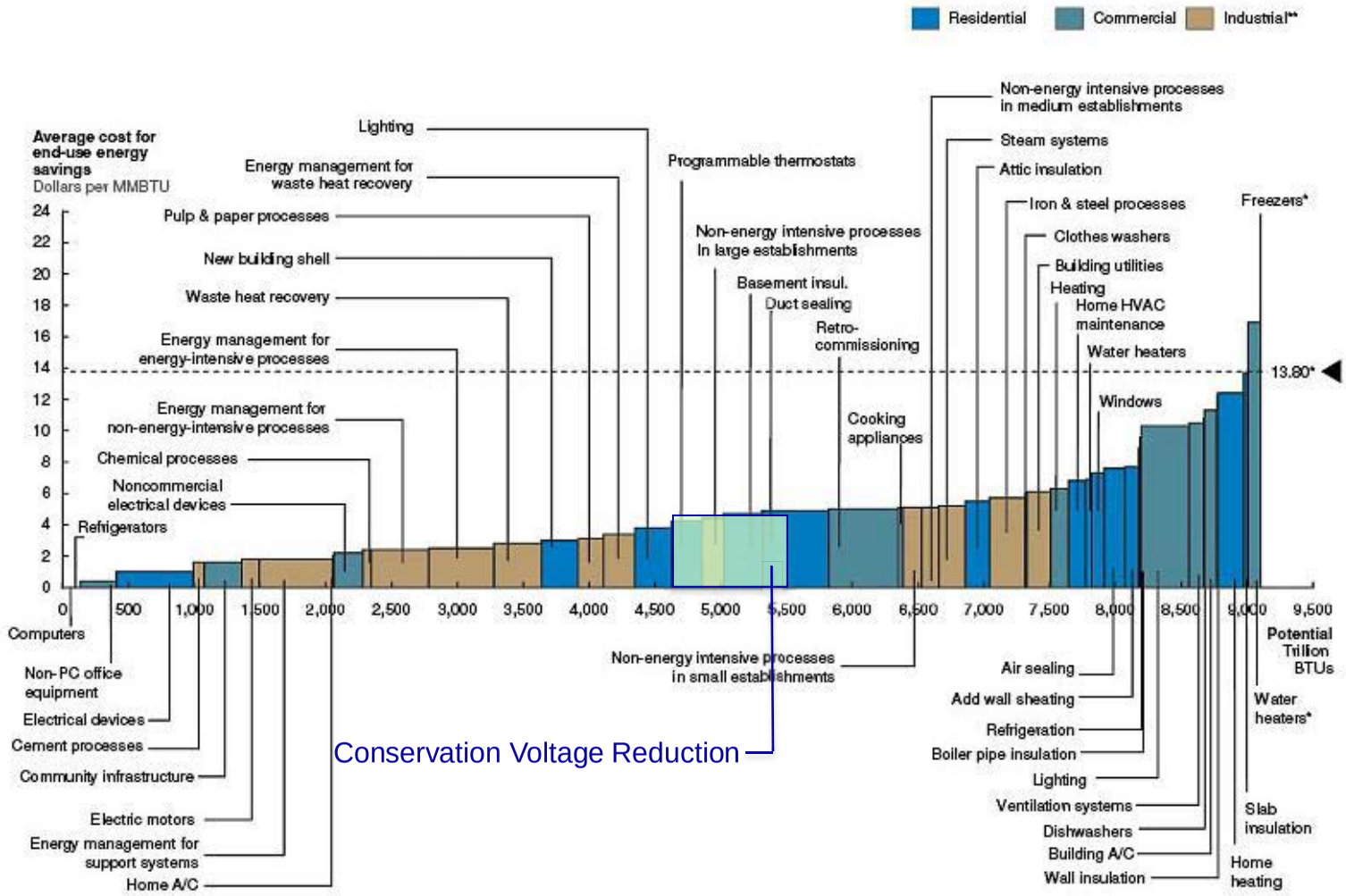
Powered-Down Appliances

118 VOLTS VS. 122 VOLTS

Appliance	Conserved power (watts)	Conserved power (percent)
INDUCTION MOTOR		
Fan	4.2	6%
DISPLAY		
CRT TV	2.1	4%
LCD TV	0	0%
Plasma TV	–2	0%
Desktop LCD	–0.6	–2%
LIGHTING		
13-W compact fluorescent lamp (CFL)	0.9	8%
20-W CFL	1	6%
LED (low quality)	0.2	6%
75-W incandescent	3.4	5%
42-W CFL	0.8	2%
LED (high quality)	0.1	1%
LED (medium quality)	–0.1	–1%

Source: Peter Fairly, IEEE Spectrum, Oct. 2010

CVR adds significantly to cost-effective EE resource potential, with a potential to save 750 Trillion BTU's at $4.40/MMBTU***.



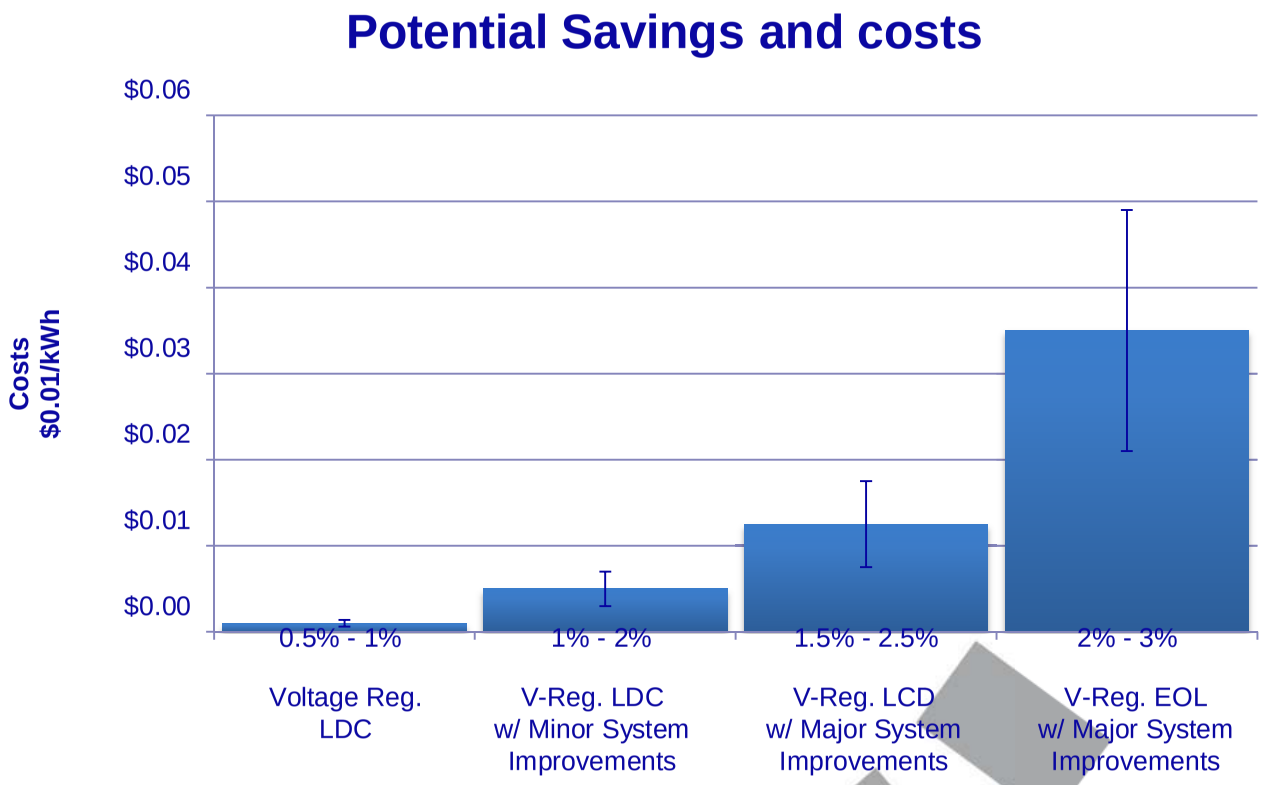
* Average price of avoided energy consumption at the industrial price; $35.60/MMBTU represents the highest regional electricity price used; new build cost based on AEO 2008 future construction costs

** Our 49th source of savings, refining processes, offers no NPV-positive savings

Source: EIA AEO 2008, McKinsey analysis

*** extracted from Pacific Northwest National Labs "Evaluation of CVR on a National Level" July 2010

While low cost CVR options exist, deeper CVR deployments have the potential to generate significant savings at very reasonable costs



Source: Northwest Energy Efficiency Alliance, Distribution Efficiency Initiative Project Final Report. December 2007

CVR pilot project show promising results

R#	Utility	Voltage Reduction (ΔV%) 120V base	ANNUAL SAVINGS from CVR			CVR Metrics			
			Energy Reduction (%)	MW	(MWH)	Total Resource Cost B-C Ratio	$/MHh	$/KW installed	CVRf = ΔE% / ΔV%
Energy Savings from CVR									
118	**Alabama Power (Note 3)**	3.62%	2.71%	0.33	1,705	1.8	$20.35	$487	0.75
118	**Alabama Power (Note 3)**	2.81%	2.47%	0.18	934	1.8	$20.83	$499	0.88
98, 115	**Avista Utilities**	1.40%	3.15%	0.33	1,729	0.8	$31.40	$752	2.25
100, 105	**Clark County PUD**	1.40%	0.82%	0.31	1,600	0.1	$203.93	$4,883	0.59
100, 106	**Cowlitz County PUD**		1.02%	0.30	1,545	0.2	$94.74	$2,269	
118	**Duke Energy (Note 3)**	1.89%	1.64%	0.21	1,087	4.0	$7.46	$179	0.87
118	**Duke Energy (Note 3)**	1.89%	1.73%	0.12	628	2.3	$12.91	$309	0.92
98, 114	**Flathead Electric**	3.33%	7.19%	19.10	99,367	2.5	$8.74	$209	2.16
Demand Response Savings from CVR									
63, 104	**City of Manassas**	2.50%	2.00%	2.72	0	20.1	NA	$55	0.80
R121	**Case Study [CONFIDENTIAL]**	5.00%	3.28%	13.12	0	1.9	NA	$206	0.66

Utility Early Adopters of CVR as an Energy Efficiency Resource

Utility	Program Attributes
PECO	First utility to receive regulatory approval to use CVR to achieve EE targets. 320,000 MWh 1st year savings achieved through CVR-lite (1/3 of 4yr goal). Deeper deployment in planning stages.
BPA	Extensive CVR R&D. Currently offering $0.025/kWh saved over 10 years. Extensive M&V
AEP	35 feeder pilot of advanced CVR. Motivated my Ohio SB 221 allowing distribution efficiencies to count towards EE goals
TVA	Commitment to spend $60M over the next 5 years for CVR EE incentives for member utilities.
SMUD	Large scale deployment of automation equipment targeting improved power factor, peak demand reductions, and EE
DOE - SGIG	26 utility CVR projects; 7 using CVR for EE

Regulatory	
NARUC	November resolution supporting Volt/VAR as an EE resource
OHIO	SB221 mandates EE; includes distribution efficiencies

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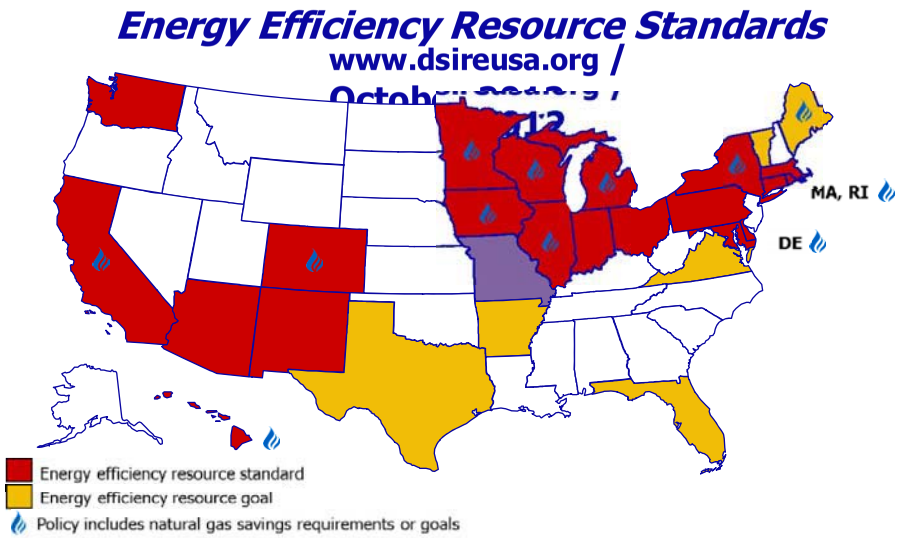
Energy Efficiency Resource Standards and Regulatory Incentive Mechanisms are driving the market for EE. CVR has the potential to benefit from these activities.



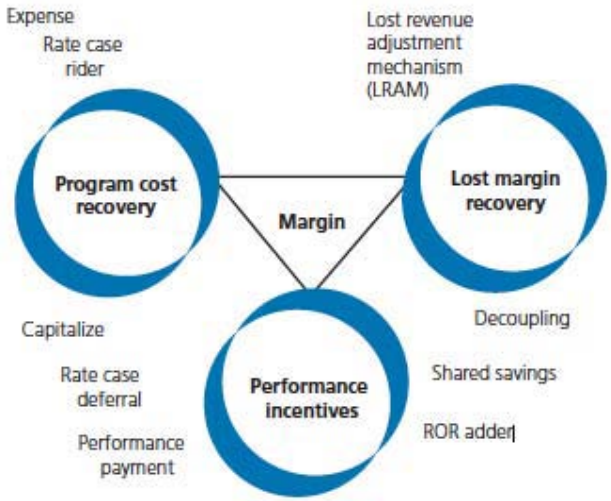
Over half of the States have EERS or EE resource goals.

In States with long-established EE programs, escalating goals and the impact of codes and standards are creating a need for new, innovative sources of cost-effective EE. CVR could be a very attractive option for highly-saturated EE markets.

The EE industry has developed a wide range of performance incentives and cost recover mechanisms that reward utilities for achieving EE goals.

Ohio SB221 specifically defines grid activities such as CVR as EE measures that count towards a utilities EE goals.

NARUC recently passed a resolution to allow CVR to be included in EERS.



Source: Aligning Utility Incentives with Investment in Energy Efficiency. November 2007. National Action Plan for Energy Efficiency

CVR has similar benefits to DSM when viewed across multiple stakeholder perspectives

Utility	Participating Customer	Rate Payers	Society
• Lower generation costs and carbon emissions • Better utilization of T&D assets • Deferred T&D capital investments • Cost-effective EE goal attainment	• High percentage of customers are participants • Energy savings and bill reductions • Equipment life extension • No action or investment required	• Average bills are lower • Potential negative impact on rates (based on marginal avoided cost structure). • Low cost EE goal attainment	• Carbon reductions • Positive environmental impacts • Positive societal economic impacts

CONSERVATION VOLTAGE REDUCTION CONSORTIUM

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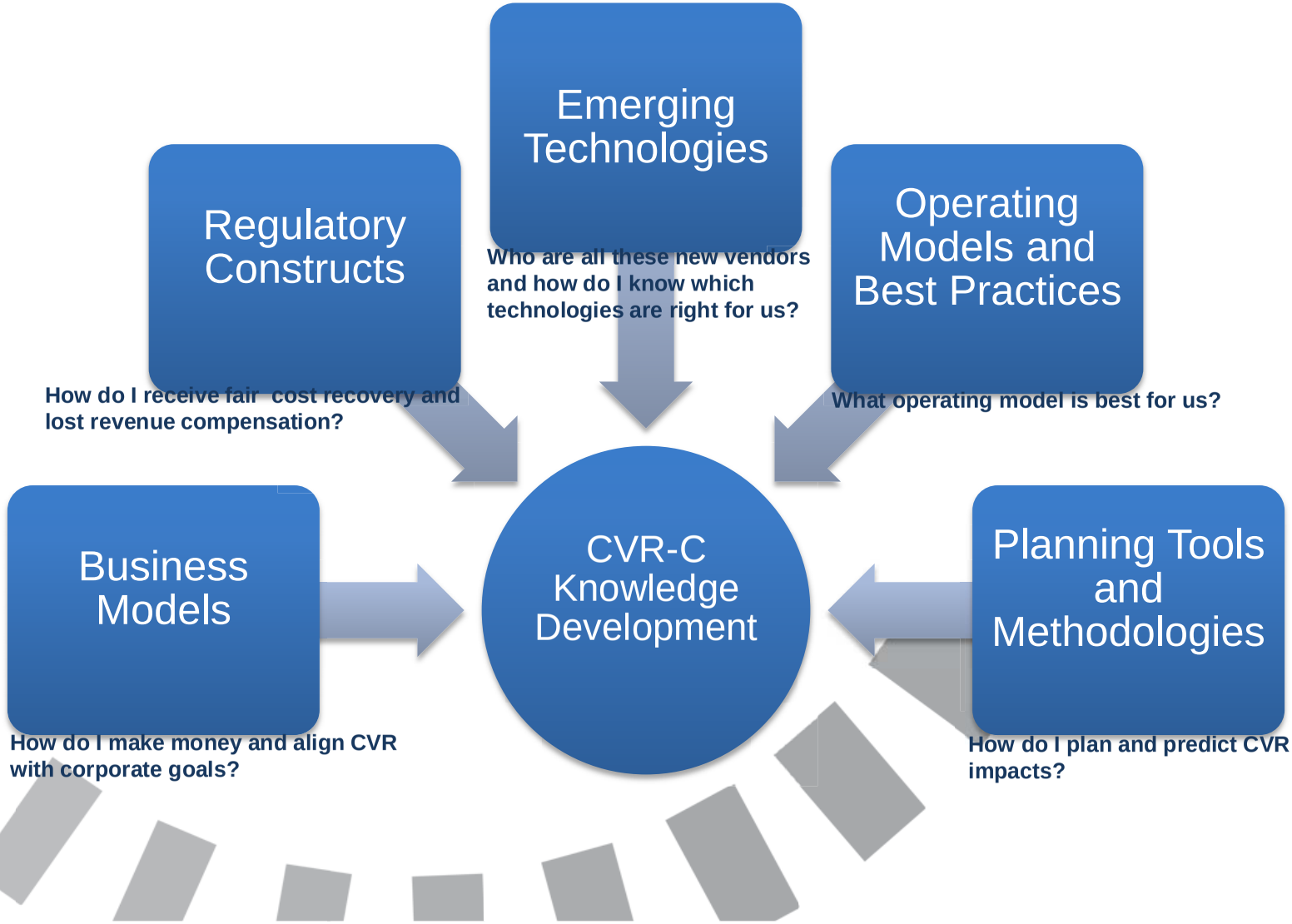
CVR-C Consortium: much to learn, much more to gain



Issues to Consider when addressing CVR as an EE Resource

Defining costs and benefits

- Costs – incremental, overlap w/ other SmartGrid investments, etc.
- Benefits – energy, peak, power quality, line losses, etc.

Incentive mechanisms to capture maximum savings potential

- Deep penetration per circuit
- Persistence of savings.

Funding mechanisms

- SBC, Ratebase, other?

M&V

- There are no formally established M&V protocols.
- Ensuring persistence of savings

Interaction with DG

- Voltage regulation on high penetration DG circuits