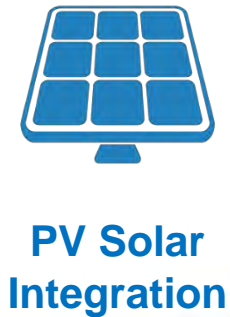


Varentec – Next Generation of Volt/VAr Optimization

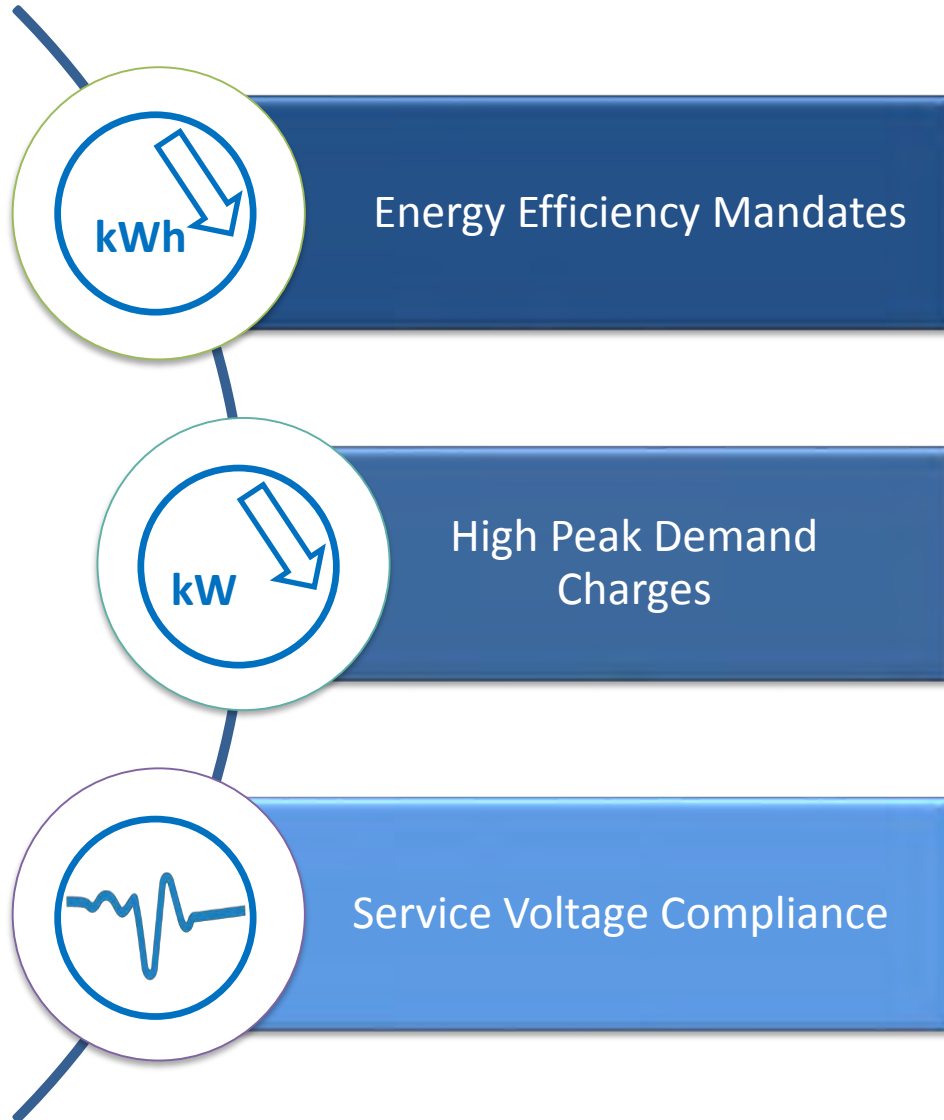


“Grid Edge Voltage Control”

Damien M Tholomier

Nov 31st, 2017

Challenges Facing Electric Distribution Utilities



Investor Owned Utilities are mandated by regulators and/or legislation to achieve efficiency targets through demand-side and supply-side programs.

Utilities in the public power market have a mandate to minimize rates for their members. Purchase power during peak periods creates a significant cost burden.

Over-voltages introduced by PV affects power quality and limits the amount of PV installations possible on a given circuit.

Under-voltage conditions affect quality of supply at the customer end and limit peak demand and energy reduction performance.

Traditional Approach (Medium Voltage VVC equipment)

Volts



LTC



LVR

VARs



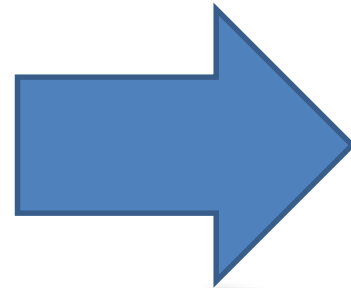
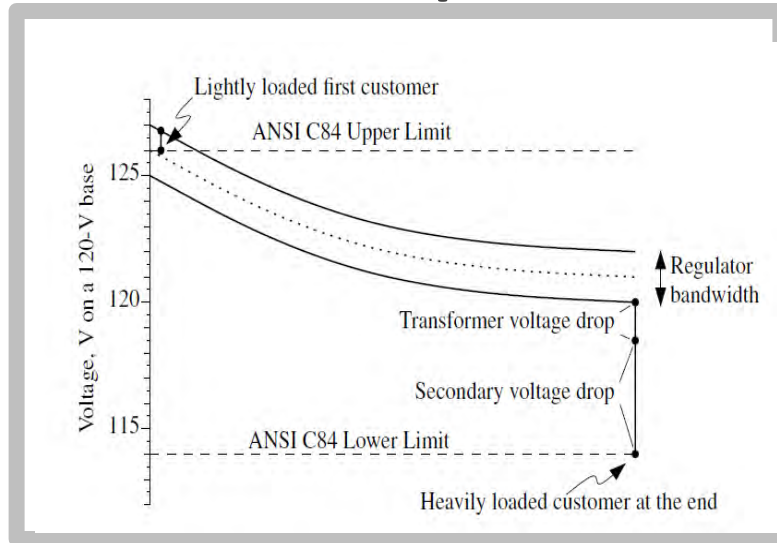
Fixed / Switched Cap Banks

Normal operation: Voltage out of the substation is kept high (e.g. 126 V) to ensure minimum service Voltage (at least 114 V) to customers closer to the end of the feeder

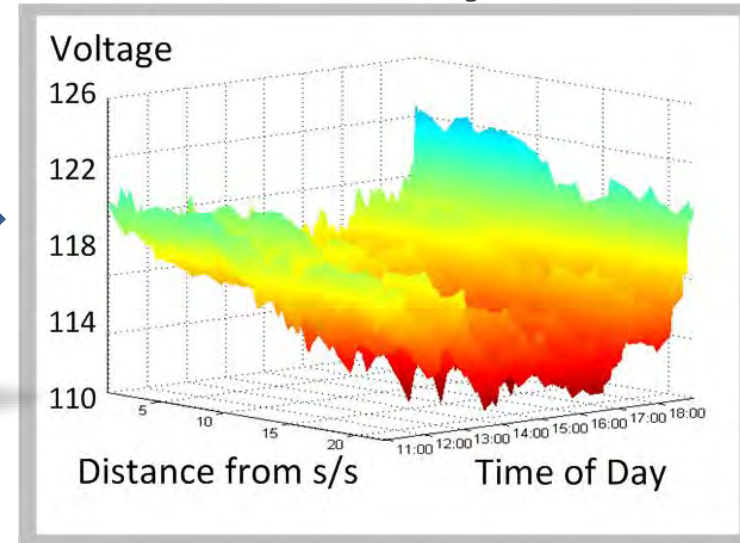
Energy Savings or Peak Demand Reduction: With feeder voltage visibility, CVR can at times reduce upstream voltage to provide overall Energy (kWh) or Peak Demand (kW) savings

So, what's wrong?

Assumption

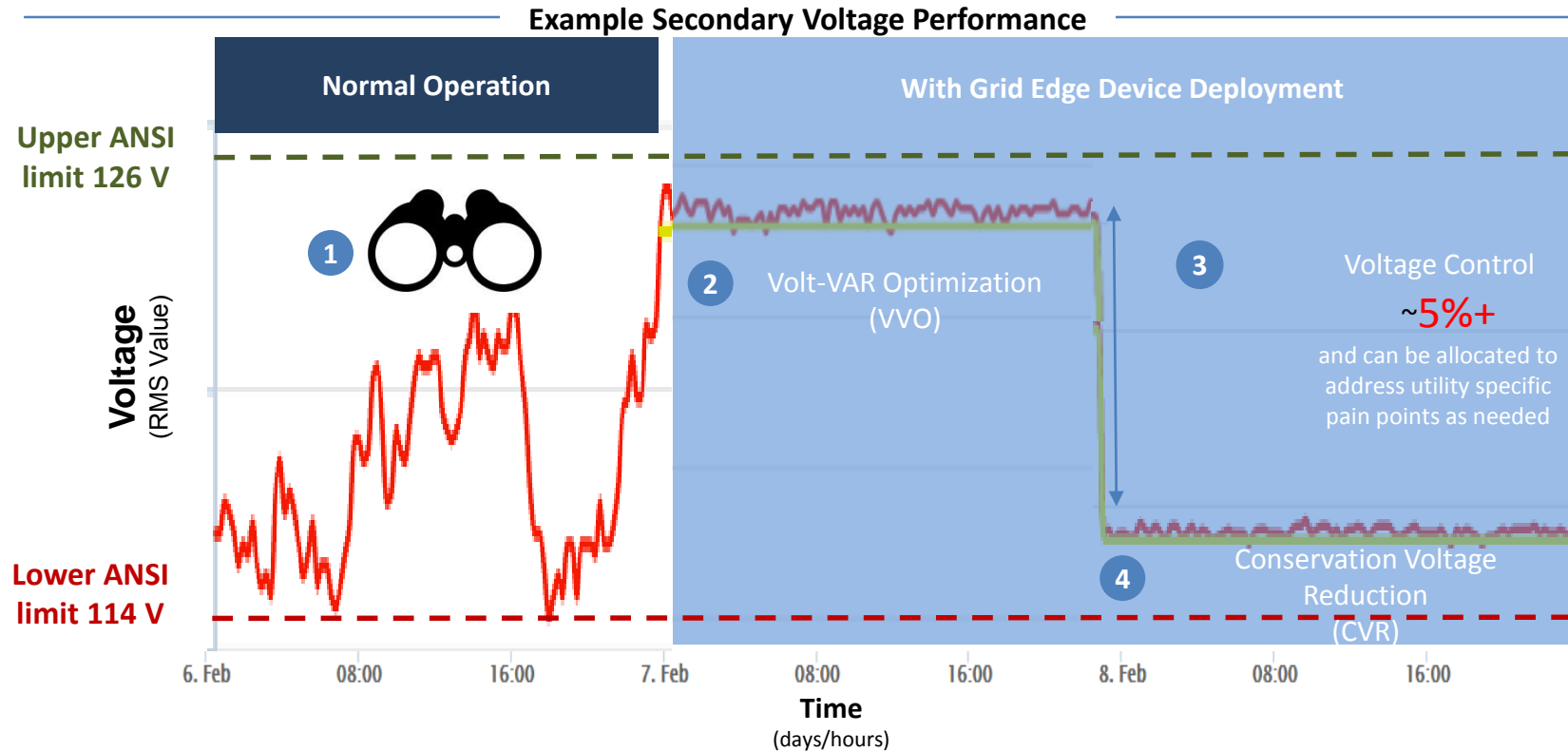


Reality



- **Traditional MV VVC equipment cannot always address Non-clustered Low Voltage Locations:** Voltage drop is not uniform as power travels down a feeder and is distributed to individual customers
- **MV VVC equipment cannot fix service transformer drops and technical losses** – as Traditional VVC equipment is located upstream of the service transformers
- **Visibility Required:** Need AMI or End of Line sensing to know what's happening on the system

Varentec's unparalleled Volt/VAr control performance



- 1 Monitoring of the voltage outliers
- 2 Precise voltage regulation at the grid edge
- 3 Creation of significant voltage margin
- 4 Enabling enhanced Conservation Voltage Reduction (i.e supply-side energy MWh savings or MW demand reduction)



Field data shows > 2 x Voltage Control Range vs Traditional solutions

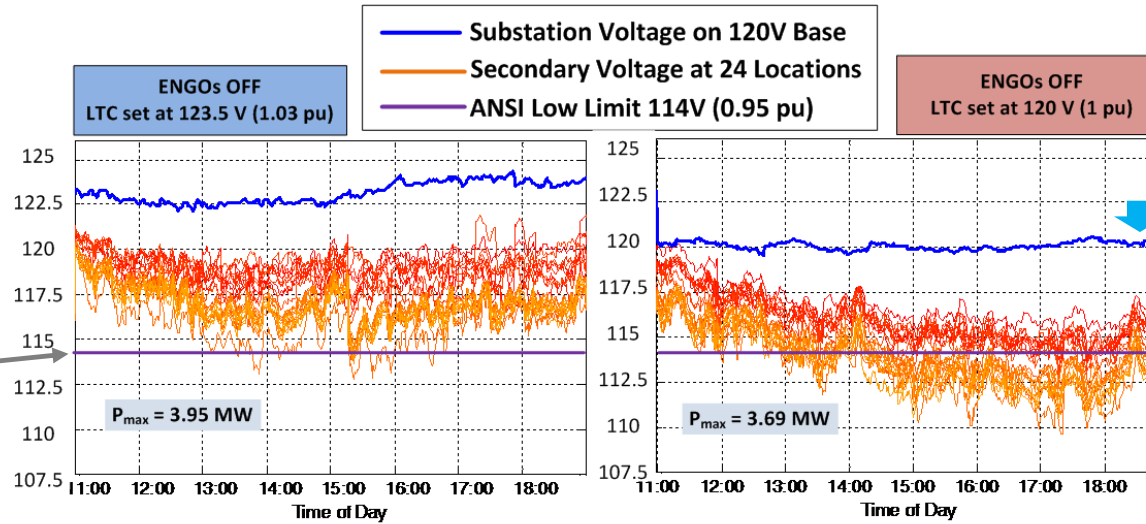


1

No voltage reduction

Varentec solution: OFF

Minimal ANSI violations



2

3% voltage reduction

Varentec solution: OFF

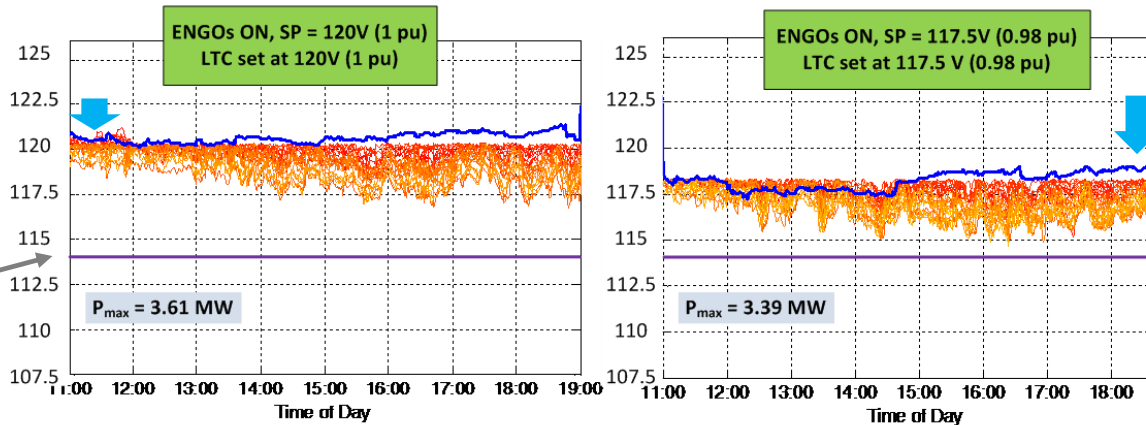
ANSI violations

3

3% voltage reduction

Varentec solution: ON

No ANSI violations



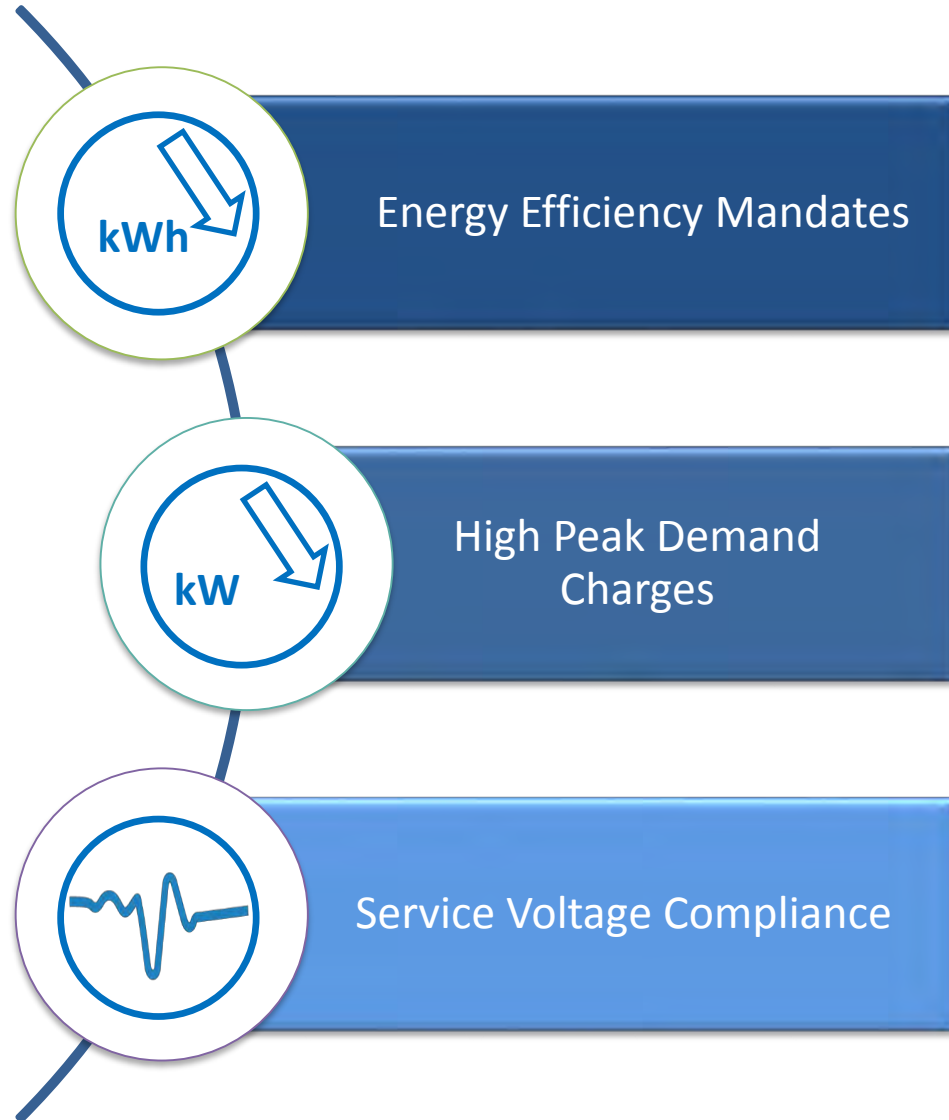
4

5% voltage reduction

Varentec solution: ON

No ANSI violations

5% voltage reduction ≈ 5% energy saved*



Use Case: Energy Savings for Investor Owned Utilities

Key Metrics: % Energy Savings & Levelized Cost of Energy Saved (LCoE)

- **System Performance:** ~ 5% energy savings
- **Utility Economics:** LCoE of ~ 18.5 \$/MWh saved, 10% IRR

Use Case: Peak Demand Reduction for Public Power (Coops & Munis)

Key Metrics: Annual Demand Charge Reduction | Payback

- **System Performance:** ~ 6% demand reduction
- **Utility Economics:** \$90/MW shaved, Payback ~ 3 years

Use Case: PV Hosting for Investor Owned Utilities

Key Metrics: Voltage fluctuation reduction & PV capacity increase

- **System Performance:** PV Capacity increase from 5 MW to 7 MW (+40%)
- **Utility Compliance:** Contributes to 100% renewable by 2040

Varentec's approach yields better results

- 1 Enabling ~1% to 3% **additional** voltage reduction compared to traditional CVR solutions
- 2 Sub-cycle control: dynamic and targeted regulation vs traditional minutes or even hours to react
- 3 Proven results in enabling additional PV capacity and supporting DER integration to the Grid
- 4 Power Quality Support including reducing voltage fluctuation without the need to upgrade existing assets
- 5 Distributed and local decision making, with a centralized platform; resilient to communications or system failures
- 6 Fast deployment with immediate savings and no dependency on other operational or enterprise systems
- 7 Does not require prior implementation of AMI, remote sensors, or DMS/GIS systems



Technology is getting great traction as utilities are moving to full scale projects:

Xcel - Low Voltage VAR Compensators technology has been approved by the Colorado PUC as part of Xcel Energy's Advanced Grid Intelligence and Security Initiative (AGIS).

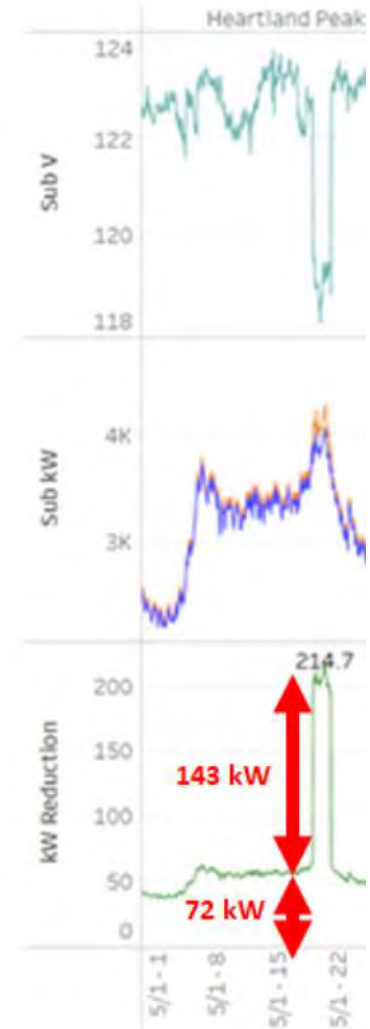
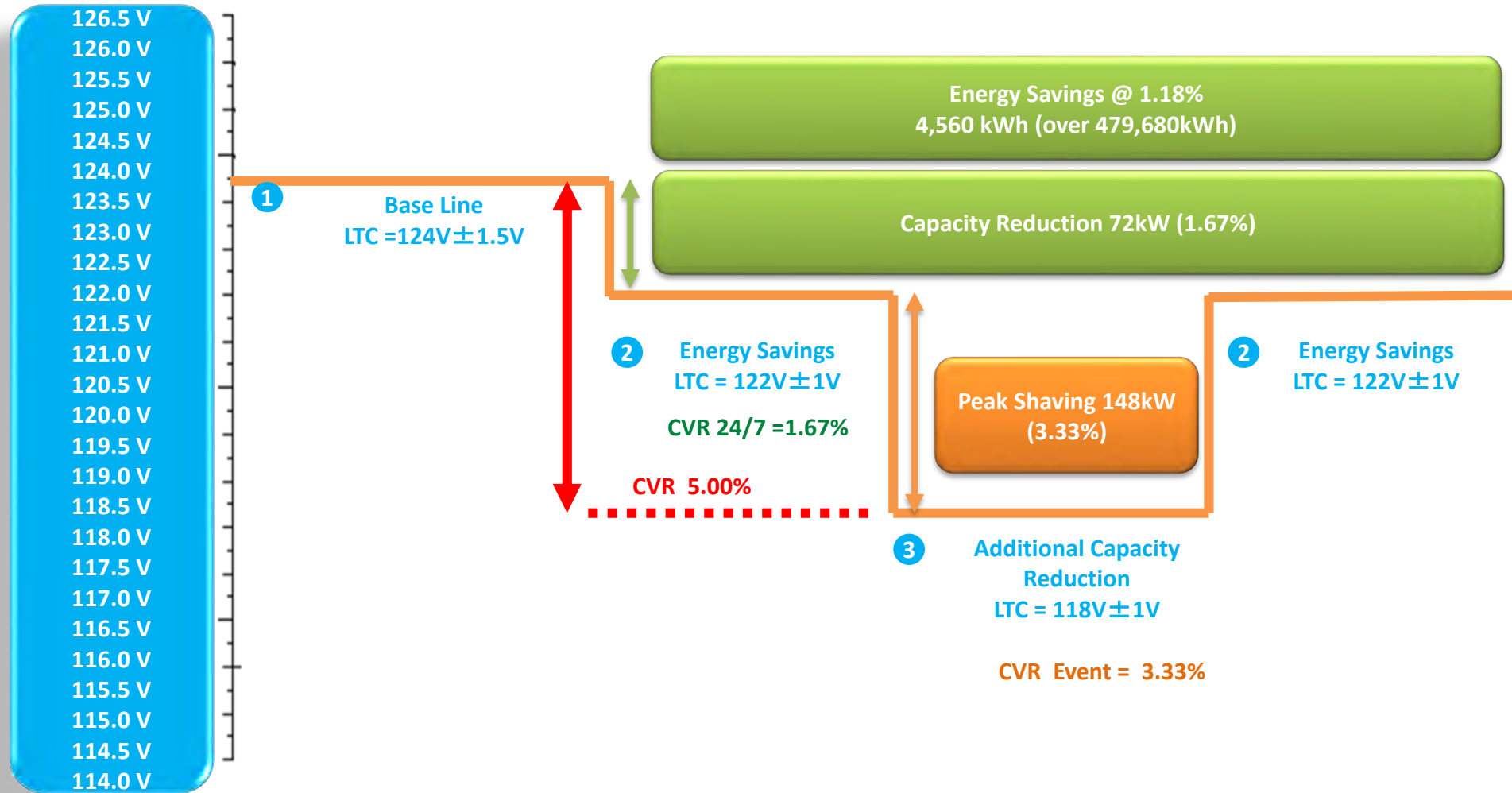
"In the filing, Public Service estimates that the average energy savings that will be achieved upon deployment of IVVO with SVCs will be 2.06% (expected voltage reduction level of 2.86%) by deploying 4,350 units in 472 feeders (Denver Metro Area). However It is anticipated that the deployment of SVCs would increase the energy savings up to 3% and in some instances even higher."

HECO - Hawai'i Grid Modernization Plan is also adopting Low voltage VAR compensators moving forward:

"The pilot project deployed 61 fast-acting SVC power-electronics devices from Varentec (an ARPA-e grantee) ... The pilot confirmed that this simplified and automated system enables greater penetration of DG-PV and prevents strain on grid infrastructure. Importantly for customers, the pilot demonstration project improved the simulated static hosting capacity from approximately 5 MW to 7 MW on the Keolu substation feeder."

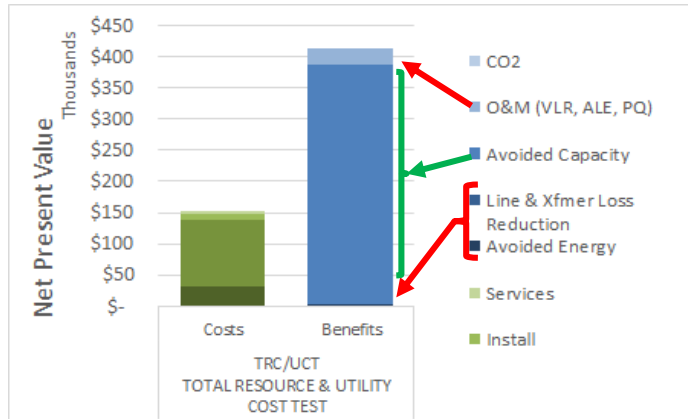
- ENGO Units Deployed on 4 feeders with 37.3 MW Peak and 20.1 MW Average Load
- Based on test results:
 - ENGO provides improvement in voltage margin by a minimum of 1.7% up to 2.4% could
 - CVR factor for power and energy computed (June and July 2017)
 - $\text{CVR}_{\text{f-power}} = 0.84 \pm 0.26$ with 95% confidence
 - $\text{CVR}_{\text{f-energy}} = 0.66 \pm 0.27$ with 95% confidence
 - CVR factor for Energy and Power will vary with seasons (winter vs. summer), type of connected load (constant impedance, constant current, constant power), and the type of feeders (rural, urban, sub-urban)
 - Max. voltage reduction achieved without voltage violation at peak load
 - 68 ENGO provide 4% voltage reduction or 2.64% of energy saving (or 4,679 MWh saved yearly)
 - 87 ENGO provide 5% voltage reduction or 3.30% of energy saving (or 5,849 MWh saved yearly)
 - Energy Savings can be maximized by optimizing the voltage reduction continuously with coordinated control between a Centralized VVO software controlling the primary VVC equipment and the ENGO devices
 - Peak demand reduction benefits:
 - ENGOs provide 1.53 MW of peak demand shaving or 4.2% peak shaving

Optimized VVO/CVR – 1/3 ES and 2/3 PDR



Peak Demand Reduction Use Case

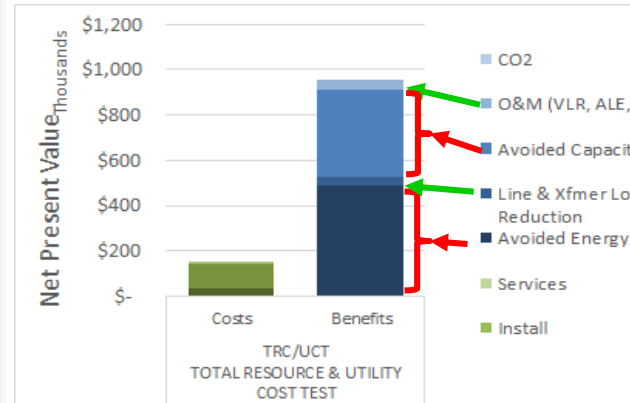
TRC/UCT Tests - NPV Costs/Benefits



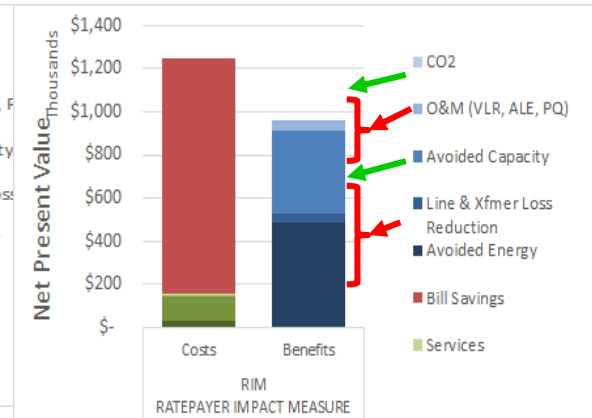
- Peak shaving of **4.91%** causes **annual demand charge reduction** by **~\$39k**
- Payback in 4 years**
- BCR ratio ~3.78** (over 15 years, undiscounted)
- LCoC \$77** per kW-Yr shaved
- Change in Bills by -0.59%** (**\$18.4k** annual bill reduction or **~\$14** per customer per year) with a IRR of 10%

Energy Savings Use Case

TRC/UCT Test - NPV Costs/Benefits



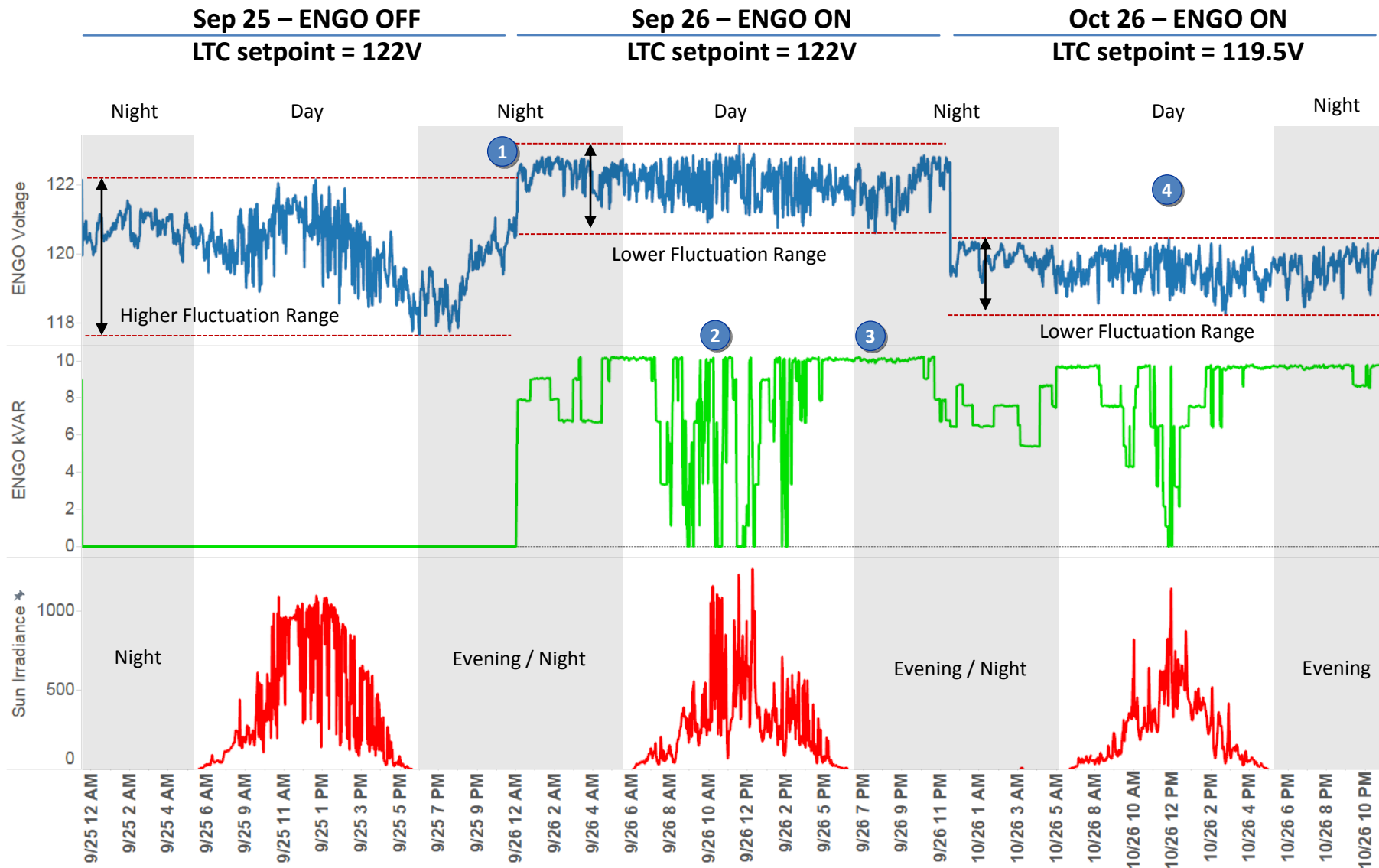
RIM Test - NPV Costs/Benefits



- Energy savings of **3.66%**
- BCR ratio ~0.80** (over 15 years, undiscounted)
- Change in Rates by **+0.82%** (**+0.09 cts/kWh**)
- Reduction** in member **Bills** by **2.00%** (**\$62.5k** annual bill reduction or **~\$47** per customer per year) with a IRR of 10%
- LCoE €1.476** per kWh shaved

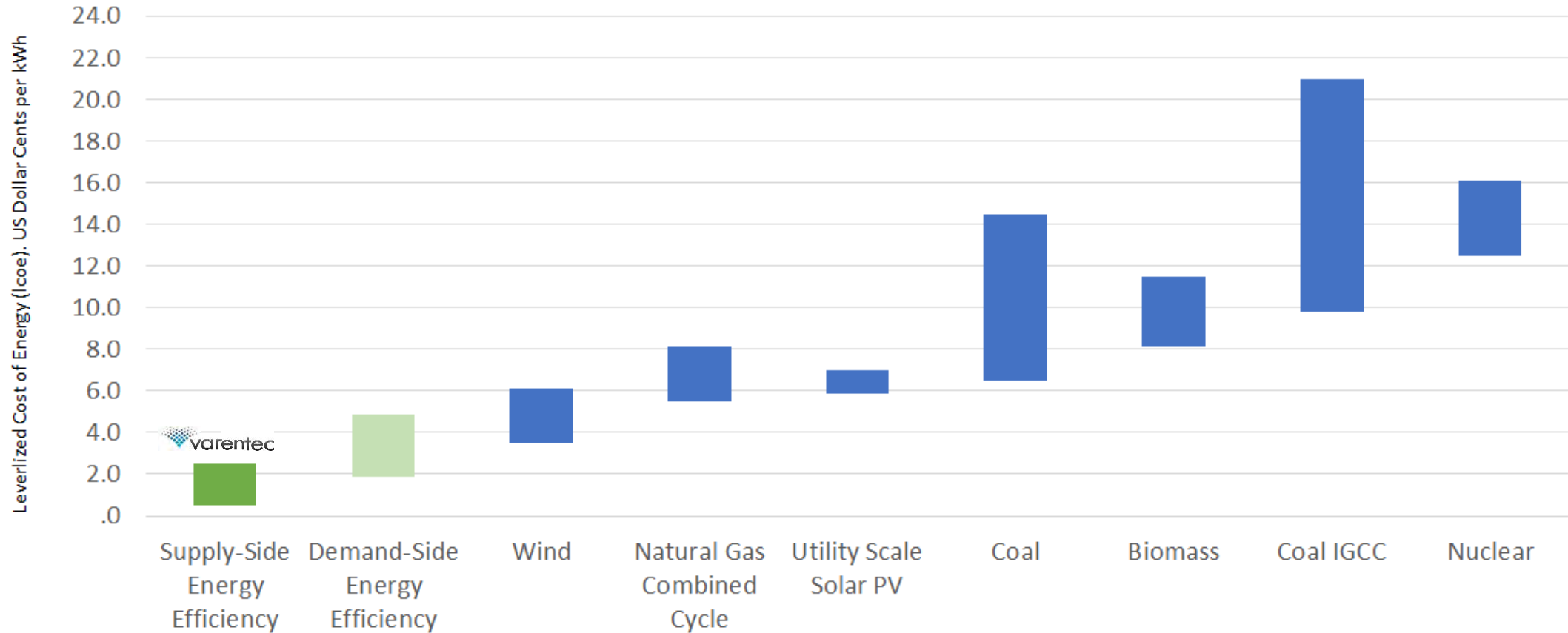
A Win – Win Situation for Coops, Members and G&T

Beyond Energy Savings – DER Support



- 1 **Fluctuation Reduction:** ENGO voltage fluctuation range reduces when ENGO units are active
- 2 **Daytime Operations:** During the day time, ENGO units provide dynamic VAR support to compensate for PV generation volatility (e.g. cloud cover)
- 3 **Night Time Operations:** During the night time, ENGO units provide full kVAR support during peak-load times when PV generation is not available
- 4 **Tap Down LTC to Enable Energy Savings or Extra PV Penetration:** ENGO provides voltage support that allows operation at lower voltage and the opportunity for extra PV.

Varentec Is Competitive to Any Next Generation Plant or Demand-Side EE Initiative



Notes: Demand Side EE program portfolio data from Molina 2014. All other data from Lazard 2016. High-end range of coal includes 90% carbon capture and compression

Varentec provides a unique market offering with multiple potential benefits (most notably, energy efficiency & increased capacity for DER integration). As a result, the policy strategy must look for areas where there is a favorable policy environment, including:

- **Demand-Side Energy Efficiency:** Traditional utility cost recovery is designed for energy efficiency measures implemented on the “demand side” (or “consumer side”) of the utility meter, often asking the consumer to change its consumption pattern or behavior
- **Grid-Side (or Supply-Side) Energy Efficiency:** While there are many states that support energy efficiency measures deployed on the “grid side” (or “supply side”), it is less common
- **DER Penetration:** Many regulatory policies support increased levels of distributed energy resources where an integrated voltage solution can enhance the hosting capacity of the distribution network

What are the relevant Policy Limitations?

Many states have implemented mandates and policies to support energy efficiency and demand-side programs. However, these policies often are insufficient to provide a strong motivation for utility deployment of advanced technology, because:

- **Decoupling is revenue-neutral:** As one of the pillars of energy efficiency policy, decoupling allows for revenue loss recovery and removes a barrier to utility deployment, but does not create a positive incentive.
- **Mandates are fixed targets:** Once the utility has reached its required target, there is typically no incentive to go beyond the requirement.
- **Investment Opportunity:** Most utilities are primarily motivated by the opportunity to earn a rate of return on invested capital in system infrastructure (rate base). Energy efficiency and advanced technologies often reduce the overall investment requirement, creating a lost opportunity for the typical utility business model.

With Varentec's Solution Everybody Wins



Utilities Win



- Authorized Equity Rate of Return with loss revenue adjustment mechanism
- Deferred CAPEX Investment in Asset Upgrades
- Improved Network Reliability and Efficiency
- Enabling DER Integration

Consumers Win



- Lower Electricity Bills - lower energy usage without changing behavior (3-5% net kWh energy usage reduction and 2-4% net electricity bill reduction)
- Power quality improvement and rooftop PV hosting



Society Wins

- LCOE Saved: 10 – 25 \$/MWh; compared to:
National Average of EE: 46 \$/MWh
New power generation: 30 -160 \$/MWh
- Reduced environmental impacts, and lower carbon footprint

**Berkeley Lab – Policy & Electricity Markets – April 2015*



Thank You