Developing a Roadmap for Energy System Modernization & "Prosumer" Integration

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Modernization Roadmap: Setting Strategic Direction

Why: Set Strategic Direction

What's Needed: Identify Likely Requirements

What's Missing: Define Gaps

How: Assess Options & Potential Innovations

Act: Develop & Update Plans

Modern Energy Systems should be Simultaneously:

- Affordable
- Reliable, Resilient, & Secure
- Environmentally Sustainable

Achieved in an Equitable and Socially Acceptable manner

"If you don't know where you are going any road can take you there." – Lewis Carroll, Alice in Wonderland

Likely Requirements

- **Affordable:**
  - Engage Underutilized Capabilities: Use Grid Flexibility & Co-Optimize Buildings, Transport, DER, Fuel Supply
  - Invest Efficiently for Reliable, Resilient, Secure Service and in Environmental Sustainability
- **Reliable and Resilient:**
  - Deliver Customer Value: Value of Uninterrupted Service (or Any Service During an Extended Service Disruption) varies among different Customers, End Uses, and Conditions
  - Flexible as well as Hardened: Rapidly Adapt and Reconfigure Available Resources when Disruptions Occur
- **Secure:**
  - Defend against and Deter: Malicious, Sustained, Multi-Sector Cyber – Physical Attacks
  - Extended Cyber Defense: At a minimum to the Interfaces between Power & Interrelated Domains
- **Environmentally Sustainable:**
  - Integrate Significant Increases in Variable Renewable Generation
  - Electrify Most Transport, Heating, and Other Uses of Fossil Fuels
  - Optimize End Use Efficiency relative to System and Environmental Costs

Defining Key Gaps

- Integrate Intelligent Devices, Vehicles, & Distributed Resources
  - Smart Technology will Anticipate Demand Response Events, Increasing Baseline Usage
  - Smart Technology will respond to Time-Varying Rates with Large, Instantaneous, Discrete Shifts in Net Demand
- Address Fast System Dynamics
  - Multi-GW System Ramps from Variability in Solar and Wind Generation
  - Rapid Variations in Voltage & Net Load from Rooftop Solar
- Manage Complexity
  - Single Distribution Utility may soon include Millions of Smart End Use Devices, Hundreds of Thousands of EVs, and Thousands of MW of Distributed Resources
  - Co-optimize increasingly dynamic systems (topology & flow control) across multiple: layers (home to circuit to region), time scales (sub-cycle to multi-hour receding time horizons), & domains (buildings, transport, DER, pipelines)

Smart Devices & Electric Vehicles

As many as 40 million homes, over 1/3 US households, forecast to have smart thermostats by 2020 [1]

US EV Sales in 1st 10 Months of 2018: 72% Higher than Same Period in 2017 [2]

Bridging the Gaps: Near-term Innovations

Incremental Reforms

- Time-Varying Rates: Time-of-Use, Critical Peak Rebate, Critical Peak Price
- Specify Smart Inverters to Keep PV within ANSI Voltage Standards
- “Prosumer” PV & Storage: Integrated through Hosting Capacity Studies

Foundation for Modern Energy System

- Dynamic Market-based / Marginal Cost Pricing + Smart Technology
- Deploy Advanced Power Electronics to Compress Variability & Control Voltage
- Community Microgrid: Optimizing Energy Systems for Customer Value

Dynamic Pricing + Smart Technology: Efficient Pricing

- Can Have More Accurate Price Signals for integrating Smart Technology by starting with Market-Based Pricing – e.g. Real-Time Prices (RTP), RTP + Capacity Adder (RTP+), Block & Index (Hedged RTP)
  - Idealized TOU Rates (set with perfect foresight) have been found to capture Less than 30% of the actual variation in PJM prices and only 6% to 13% of the actual variation in CA ISO prices [3]
- Time Varying Rates + Enabling Technology produces Significant Peak Demand Reductions [4]
- Smart Buildings & Vehicles can Shift Significant Demand both for Short Periods and with Model Predictive Control over Multi-hour Time Horizons
- Efficiency Objective: Communicate Time-, Location-, & Product-specific Marginal Cost & DER Value [5]
  - Not "avoided" or "long-run marginal" costs, non-specific planning terms often conflated with economic Marginal Costs: the Cost of a Very Small Additional Unit of Short-run Output
  - Distribution Level: May include Pricing Scarcity at times and locations where circuits are Approaching Distribution Constraints and Pricing Marginal Distribution Losses
- Near Term Limitations:
  - PJM Zonal & Hourly Demand Settlements & Peak Load Forecasts Socialize Costs [6]
  - Failure to Price Carbon complicates Rate Design Generally

Dynamic Pricing + Smart Technology: Engaging Customers

- Provide Opportunities for Customers to Hedge Volatility in Monthly Bills: Multiple Options
  - Block & Index Pricing (common in C&I market) offers Predictable Bills for Typical Use & Efficient Prices
    - Customers Pre-purchase Blocks of Energy covering a Representative Hourly Load Shape
    - Receive a Rebate equal to Real-Time Price any time they use less Energy than they Pre-purchased
    - Pay Real-Time Price for any Energy used in excess of their Pre-purchased Hourly Load Shape
  - Budget Billing (common for residential gas customers) pro-rates expected bills subject to periodic adjustments or rebates
  - Bills can be Discounted for Customers installing technology that manages demand and mitigates risk
- Develop Platform Markets for Smart Products and Services: Can Build on Existing Marketplaces that Connect Consumers to Smart Technologies
  - Most large EDUs, many Public & Cooperative EDUs, & some States have online Energy Marketplaces
  - Most integrate Energy Efficiency program rebates or financing
  - Several Curate Options based on Customer Data and Can Highlight Choices Valuable to Specific Customers
  - Several offer 1000s of Products, each with Energy Efficiency and Consumer Product Ratings
  - Some support shopping for Electric Vehicles or offer Home Maintenance Services

Dynamic Pricing + Smart Technology: Residual Cost Recovery

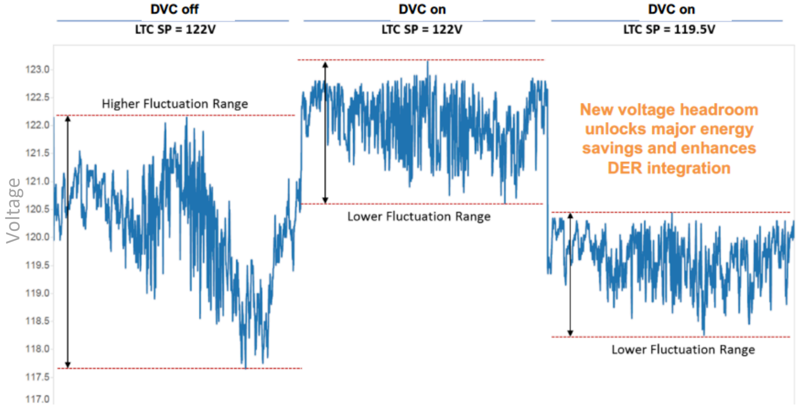
- Natural Monopoly: T&D Costs Rarely Fully Recovered at Marginal Cost Rates
- Objective: Minimize Changes in Efficient Patterns created by Marginal Cost Pricing
- Typical Options Conflict with this Objective or Raise Equity Concerns

- Fixed Access Charges based on Customer's Installed Service Level May Provide a More Equitable and Efficient Approach to Recovering Residual T&D Costs
  - Fixed Access Charges that Vary with the Size of Installed Service at the Breaker Box: Objectively Recognize Differences in Potential Use Within a Customer Class without Distorting Actual Usage
  - Comparable Approaches Used by European Electric Utilities, in Network Industries (cable, mobile phone), and for Products with High Fixed / Low Marginal Costs (software subscriptions)
  - May be Efficient to Discount Fixed Charges for Low Income Customers, recognizing Income Elasticity and their Potential to be Unable to Afford Service [7]

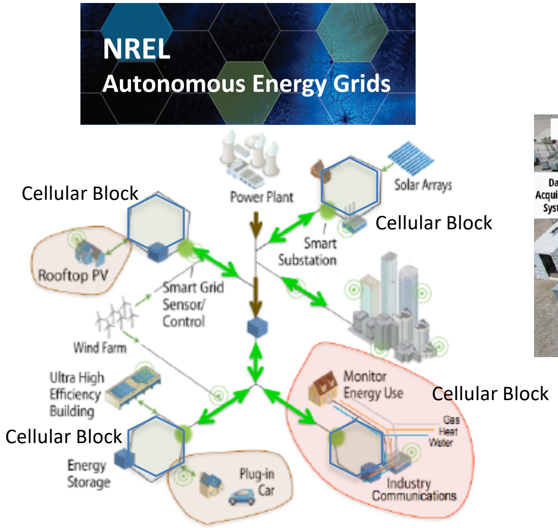
System Integration of "Prosumer" DER

- Hawaiian Electric (HECO) is installing autonomous distributed Volt-VAr controls using advanced power electronics to compress the voltage variations on sub-cycle basis toward operator provided targets, enabling HECO to double the PV hosting capacity on previously saturated circuits [8]
  - Navigant estimated that integrating this technology into their Volt-VAr Optimization programs California utilities could more than double VVO energy savings at a cost under 1¢/kWh saved [9]

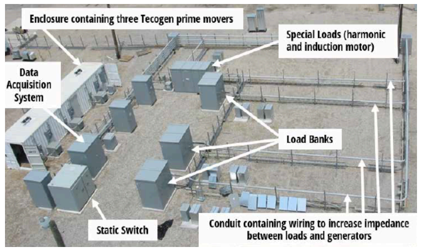
Hawaiian Electric
Maui Electric
Hawaiʻi Electric Light



- Modern Energy Systems, that are highly secure and resilient (self-healing) and ensure economic and reliable performance, may be built in scalable cellular blocks (fractals), which, in real time, self-optimize when isolated from and participate in optimal operation when interconnected to larger grids [10]
  - Community Microgrids offer opportunities explore real-time autonomous control, efficient allocation of available power, and buffering needed to manage the volatility in islanded systems [11]

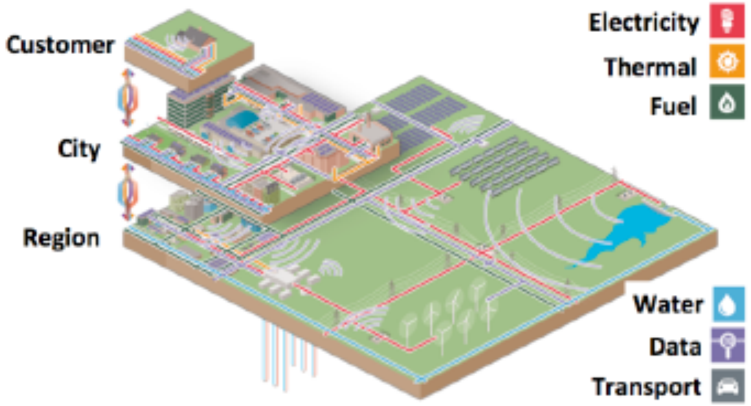


AEP – CERTS Microgrid Testbed



Closing Observations

- Energy Systems that are Affordable, Reliable, Resilient, Secure, and Environmentally Sustainable will be Interconnected Systems:
  - Systems that are flexible, efficient, and engage underutilized resources
  - Built upon physical, data, and multi-sided market platforms, which optimize across domains on a time- and location-specific basis and connect prosumers with other consumers and producers both locally and in larger community and regional energy systems



- The multi-year process of developing such systems will require Significant Innovation
  - Prosumers and Entrepreneurs, and also: Utilities, Regulators, and other Stakeholders will be necessary participants in the innovation eco-system enabling this development

"Skate to where the puck will be." - Wayne Gretsky, Leading scorer in NHL history

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