The Prices We Need:

What pricing will be needed to realize an affordable clean energy future?

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Climate Impacts

Domestic Impacts Are No Longer Distant and Uncertain

Top Mkt Cap Utilities	GHG Reduction Goal	Year
NextEra Energy	#2 Zero CO_2 Gen - Reduce 40%	2025
Dominion Energy	Net Zero	2050
Duke Energy	Net Zero	2050
Southern Company	Net Zero	2050
AEP	⇩ by 80%, Aspiration Net Zero	2050
Exelon Corp.	#1 Zero CO_2 Gen - Reduce 15%	2022
Sempra Energy	100% Renewable Electric	2045
Xcel Energy	100% carbon free	2050
Eversource Energy	Carbon Neutral	2030
WEC Energy Group	Net Carbon Neutral	2050
PSEG	Net Zero	2050
ConEd	100% Clean Energy	2040

S&P Global July 2020

Changing Power System

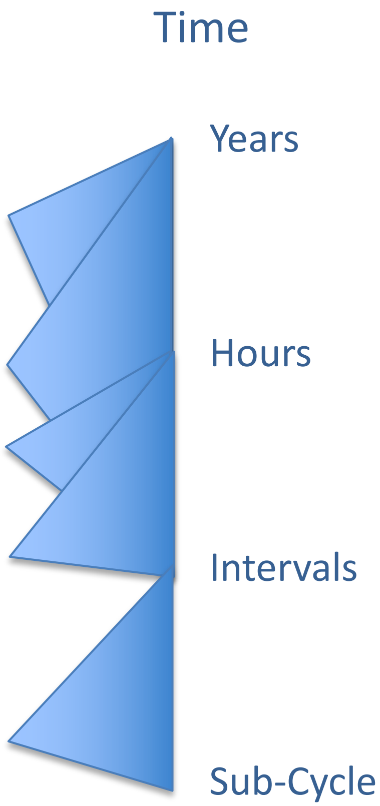
- Increase in Number and Severity of Disruptive Events
- Reliance on Renewable Resources with Variable, Intermittent, and Correlated Availability
- Distributed Intelligent Devices: Inexpensive embedded processors and sensors, near ubiquitous connectivity, advances in data analytics, machine learning, and intelligent control systems
  - Flexible Demand & other DER can continuously shape, shift, & modulate net demand
    - Thermal inertia becomes energy storage: 37% of electricity is used in heating, cooling, ventilation, & refrigeration[1]
    - Flexibility in timing of industrial process, agricultural pumping, water supply & treatment, & data center operations
  - EEI 2018 consensus forecast: 18.7 million EVs expected on US roads by 2030 [2] – requires coordination:
    - Fast charging: Today ranges from 35 kW to Tesla V3 at 250 kW / vehicle; expected power levels of 400 kW+ [3]
    - Electrification reduces potential cooling for a distribution transformer which "drastically decreases its life" [4]
  - Intelligent devices will change system operations, demand response, and pricing:
    - Centralized dispatch becomes computationally intractable as one distribution utility may have millions of intelligent end use devices, hundreds of thousands of EVs, and hundreds of megawatts of distributed generation and storage
    - Intelligent systems will reduce the effectiveness of conventional demand response & peak time rebates by anticipating events and increasing usage during the expected baseline period to maximize incentive payments
    - Smart devices will respond to changes in Time-of-Use prices with rapid discrete changes in demand [5]

How Pricing Might Enable an Affordable, Clean Future

Prices = Communication: *“We must look at the price system as … a mechanism for communicating information if we want to understand its real function – a function which, of course, it fulfills less perfectly as prices grow more rigid.”* – Friedrich Hayek, Recipient of the 1974 Nobel Prize for Economics

Communication Functions:

- Environmental Value
  - Corporate Net Zero Emissions: Time & Location specific Marginal Emission Rates [6]
  - Society: Economy wide price at emission sources – Second bests require B/C analysis
- Resource Adequacy
  - Scarcity: Continuous, stochastic, time- & location-specific risk [7]
- **Value of Flexible Demand & Distributed Resources**
  - **Matching Demand to Available Resources: Wholesale settlements & retail pricing**
- Coordination within and with Distribution Operations
  - DER valuation: Value of DER to distribution system [8]
  - Multiple parties’ Demand, EVs, & DER in a constrained grid: Distributed LMP [9]
  - ISO/RTO with DSO given High DER: Managing seam between LMP – DLMP markets
- Autonomous Systems
  - Locally generated real-time prices [10]



Foundations: Efficient Price Signals

Objective: Efficient & Equitable Pricing and Rate Design

- Efficient Pricing in Power Markets: Locational Marginal Prices (LMP) including Scarcity Pricing
  - "It is short-run marginal cost to which price should at any given time - *hence always* - be equated, because it is short-run marginal cost that reflects the social opportunity cost of providing the additional unit that buyers are at any given time trying to decide whether to buy." – Alfred Kahn, *Economics of Regulation* [11]
- Standard retail rate designs, together with zonal & hourly wholesale demand settlements, prevent LMP prices from reaching most consumers
  - Counterfactual demand response programs are limited to discrete events
- To fully engage flexible demand, LMP would become a default component within a larger system of choices that enhance customer control
  - Intelligent technologies will forecast and continuously adjust to expected prices & based on diverse and changing user requirements
- Transmission & distribution are natural monopolies: Average costs generally exceed marginal costs
- Recovery of residual transmission & distribution costs should avoid distorting efficient price signals
  - Language: Marginal and Residual Costs ≠ Fixed and Variable Costs

Foundations: Equitable Rates

Residual Costs: Most residual T&D costs are "common costs" not directly caused by specific customers

Residual common costs can be allocated based primarily on equity, tempered by concern for the income elasticity impacts of total bills on low income consumers & other risks of grid defection

- Allocative Equity including Aristotle and Bonbright [12]
  - Equals should be treated equally & unequals unequally, in proportion to relevant similarities & differences
  - Anonymous Equity: No ratepayer's demand can be uneconomically diverted away from an incumbent
  - Allocative Equity: Residual costs should be allocated on characteristics <u>not</u> impacted by short-term usage or production decisions, one customer's behavior should not cause another to pay more or less
- Distributional Equity: Allocation of residual costs should not unduly burden disadvantaged customers
- Transitional Equity: Planning and addressing customer expectations during a transition to new rates
  - Community Standards of Fairness based on a Principle of Dual Entitlement: Customer & supplier expectations of a *reference transaction* and the firm's entitlement to a *reference profit* [13]
    - Information, ability to prepare, and potential benefits increase acceptance of price changes
  - Unanticipated changes in T&D prices or service quality could discourage complementary investments [14]

Customer Impacts

- Flat Rates and Basic Generation Service (Default Supply) Procurements
  - Basic Generation Service rates are higher than average wholesale prices: Suppliers face correlated price & quantity risks, which increases supply costs compared to hourly pricing [15]
  - Uniform kWh rates are often regressive: Low income customers generally have less peak oriented load shapes and cross–subsidize higher income customers [16]
- Client Study: Electric Distribution Utility Rate Analysis
  - Analyzed AMI data from over 450,000 customers for a two-year period ending in 2019, statistically associated usage patterns with income categories based on customers' 9-digit zip codes
  - Separately analyzed AMI data for customers in income qualified programs
  - Identified natural beneficiaries of Real-Time Pricing with no change in level or timing of customer demand
  - Most consumers benefit from hourly pricing without changing demand:
    - Over 60% of single-family non-heating customers with estimated incomes <$40,000/year in the larger sample and, in the low-income sample, 69% of single-family non-heating customers could have reduced their average bills
    - Over 80% of multi-family non-heating and 97% of heating customers in all income categories could have lowered their average bills

2-Part Rate Design: LMP Experiments

- Defaults matter: Real-time LMP would become a component in a default retail rate
  - Default is a more cost-effective way to access flexible demand: Most customers will stay on default time-varying or RTP rate [17]
  - Competitive LSEs gain incentive to help customers manage demand & index competitive prices to LMP [18]
- System of choices that both are cost-effective and enhance customer control:
  - Smart Technology: Access & financing for LMP interoperable demand management technology & apps
  - Payment Options: Budget billing with a bill tracking app, High bill payment plans, Pre-pay
  - Hedging Options: Block & index pricing, Max price guarantee (call option)
  - Combo Products: "Fixed Bill +" – Outsourced demand management & Energy @ specified Service Quality[19]
- Introduce DLMP as feasible & needed for:
  - Multi-party coordination in constrained segments, e.g. EV clusters, Islanded / fractal circuits, Microgrids
  - Visibility and management of bulk power – distribution seams
- DLMP reflects marginal distribution costs: Constraints, Reactive power, Equipment degradation, Marginal losses

2-Part Rate Design: Differentiated Access Charges

- Multiple options: Residual ”common costs” should be allocated primarily based on equity
  - Allocative equity: Allocate costs in proportion to a relevant customer characteristic
  - Distributional equity: Don’t unduly burden vulnerable customers
- Fixed access charges are a more efficient & equitable way to recover such costs
  - Efficiency: Recovery of residual costs should not distort efficient Part 1 prices
  - Allocative Equity: Given an initially equitable allocation of residual common costs, recovery should not allow one customer to shift costs to others based on short-term changes in energy usage or production
- Differentiated Access Charges:
  - Fixed monthly charge for a specified period: May be contractual, based on a customer subscription
  - Familiar model for most consumers: Common in network industries (Mobile phone, internet data, cable TV) & products with high fixed, low marginal costs (software)
  - Many European electric distribution utilities use demand-based access charges
    - Demand is often more highly correlated with income than total usage
    - Demand-based subscription might include overage charges and upgrade options
  - Income- or location-based access charges could address additional equity concerns

What’s needed to realize an affordable clean energy future?

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