Energy+Environmental Economics

Moving towards transactive energy: E3's experience

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Energy + Environmental Economics (E3)

- E3 has operated at the nexus of energy, environment, and economics since it was founded in 1989
- E3 believes in analytical driven recommendations and solutions, while maintaining the highest levels of integrity and trust
- E3 is involved in rate design and tariff issues in a number of different jurisdictions:
  - California Net Energy Metering Successor Tariff Development, a.k.a. NEM 2.0
  - NY REV
- E3 also works with a number of technology companies like Google along with storage and electric vehicle (EV) companies to value flexible or controllable loads along with making the business cases for storage and vehicle to grid integration

Transactive energy: where are we now and where are we going

- **Transactive energy systems are seen as the end goal for current reform efforts across the energy industry**
  - Will describe different implementations in different regions
- **States are at different stages of technological and policy reform**
  - Early days in defining precisely what the end goal is
- **E3 is working at the forefront of policy reform in three of the key reform efforts:**
  - New York, California, and Hawaii

Bellweather states for new regulatory paradigms

+ New York

- Reforming the Energy Vision proceeding is top-down
- Emphasis on getting price signals right: tariff driven approach

+ California

- Driven by GHG goals: 40% below 1990 by 2030
- Promote DERs and empower consumers to realize bold efficiency, renewable and clean transport goals.
- Emphasis on market transformation

+ Hawaii

- High DG penetration on isolated islands: real risk of unserved load
- Cautionary tale: adoption ahead of planning and policy

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NEW YORK

New York

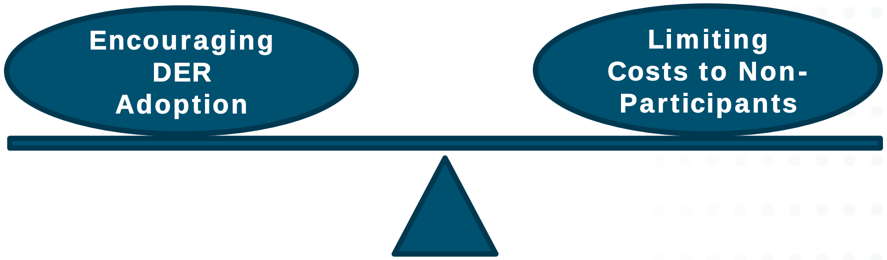
- **New York is evolving the distributed system platform (DSP) through the Reforming the Energy Vision (REV) proceeding**
  - Looking for a successor tariff for DER resources
  - Technology-agnostic tariff design to compensate for value of DERs to the grid (alternative to NEM)
  - Investigating a move away from old style volumetric charges
- **Very high value investment deferrals available through DER**
- **No smart metering infrastructure**
- **Fully restructured: ConEd is a wires company**

Menu of DER Successor Tariffs

+ **E3 in collaboration with DPS and NYSERDA will develop a menu of potential successor tariff design options to develop a framework for utility tariff offerings such as the following:**
  - Compensation based on rates (e.g. NEM) under various rate structures and bill adders
  - Compensation independent of rates
    - E.g. Value of Resource Tariff (VORT), Feed-in Tariff (FiT), Value-Based Credit (VBC)
    - May be value based (i.e. monetized utility avoided costs, societal externalities, etc.) or DER system cost based
    - Value-based compensation may include an adder on top of monetized values to meet certain DER adoption targets or goals (“Outcome” or “Missing Money”)
    - Could be differentiated by time and geographic area
  - Hybrids of the above

Ratepayer Impacts of DER

- DER successor rates and tariffs that reduce the costs to non-participants may also reduce DER adoption, at least in the near term
  - There is no silver-bullet design that accomplishes both
- A DER successor tariff that eliminates costs to non-participants may stop new economic DER adoption
- Rate structures and DER successor tariffs affect the ‘balance’ of future DER adoption and non-participant costs

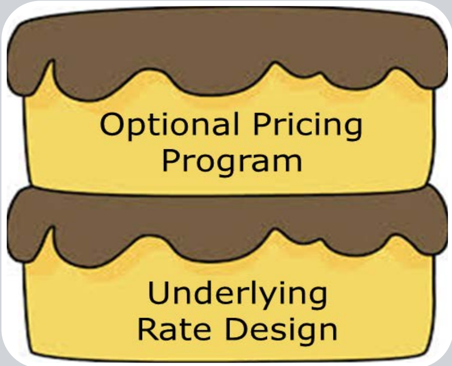


- Some cross-subsidization may be advisable
  - Non-participants benefit from DER adoption in ways not captured by utility system costs
    - E.g. market transformation (reduced future PV costs) and other societal impacts (health, GHG, etc.)

NY REV: Options for retail rate and net energy metering successor tariff design

"Layer Cake"	Surge Pricing	Subscription Model

"Layer Cake"



Surge Pricing

Subscription Model

"Layer Cake"

- NEM reform and optional "DR-type" program with area-specific pricing 'layered' on top of underlying rate design
- Relatively easy to implement and builds upon existing opt-in demand response type of programs
- On-site consumption and production of opt-in customers can be compensated through mechanisms and at levels <u>different</u> than the general population
- Can be difficult to calculate the "baseline" or counterfactual data to calculate changes in consumption for routine load shifting

Surge Pricing

- Area and time-specific pricing with prices varying by time and location (like Uber)
- This is an approach that reforms the underlying tariffs to create hourly area-differentiated charges by time and location
- e.g. local avoided distribution capacity or system wide capacity and time-of-use or hourly energy pricing

Subscription Model

- With contract demand, a cost-based hourly energy and generation capacity price is the signal
- The contract demand would include a higher peak congestion price in constrained areas
- This approach most closely matches customer costs to the actual underlying costs of the system

E3 Believes there are 3 Crux Issues

- **Crux issue #1: Collecting embedded costs**
  - How best to send marginal avoided cost signals to customers, while prudently recovering fixed or embedded costs and encouraging adoption of the highest value DER in a technology agnostic manner
- **Crux issue #2: Deciding on an end state**
  - How to balance the pros and cons of the various possible REV end state(s) with regards to efficient retail rate design and NEM successor tariffs to develop a long-term roadmap for implementation
- **Crux issue #3: Deciding on a transition path**
  - How to determine the transition mechanism(s) or ‘glide path’ to the REV end state(s) which depend on a variety of factors like technology limitations, costs, policy/political concerns, etc.

Utility perspective: planning under different tariffs

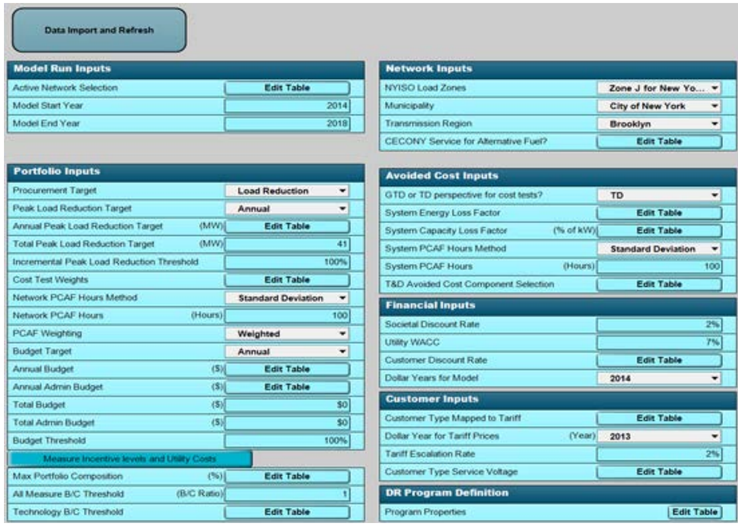
- **The utility has to plan system upgrades to maintain reliability**
  - Applies to future DSPs as well
- **For example, value of capacity resources like DR can be primarily local deferrals**
  - Deferral values have to be identified, and contribution of DER towards deferring them analyzed
- **How to assess DER impacts under different tariff designs?**
  - Need to assess DER technical capabilities, incentivized behavior under tariff design, market potential under tariff design, and dependability during peak load events

Least cost distribution resource planning

- E3 developed the Integrated Demand Side Management Model (IDSM) for Consolidated Edison (ConEdison) to facilitate least cost targeted distribution resource planning

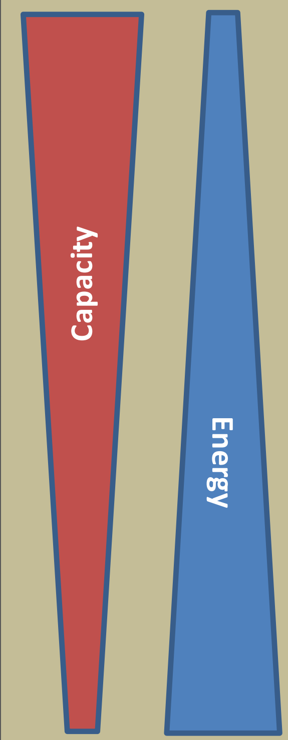
- The IDSM model assesses the market potential and economics of all DER technologies, including their associated use cases and their market interactions.

- Allows geographic targeting of least cost portfolios of DER to defer investments on the distribution system considering all DER value streams.



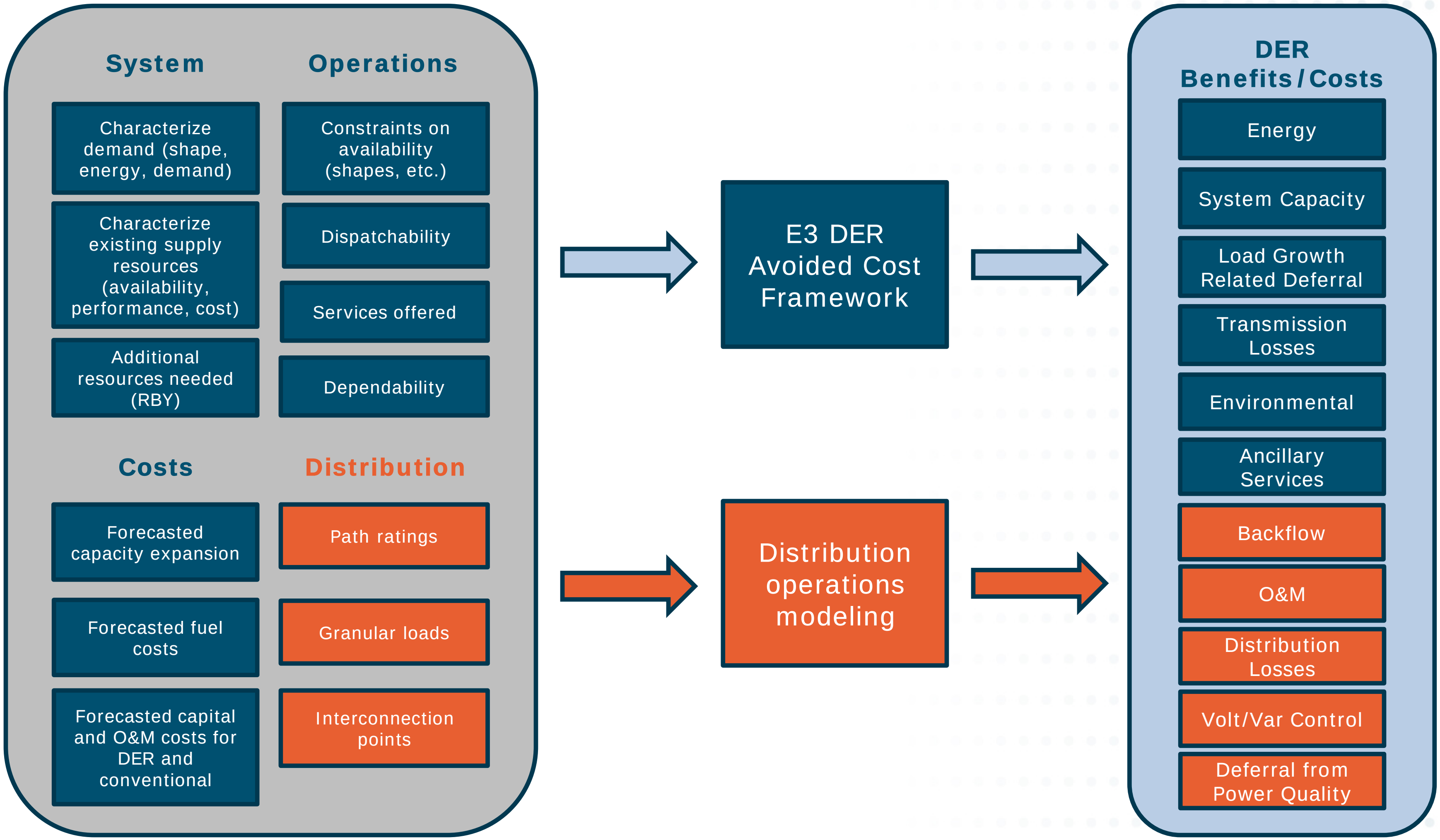
DER Technologies Are Diverse in Terms of Benefits Provided

+ **Different DER technologies vary in terms of the capacity, energy, and other benefits they offer**

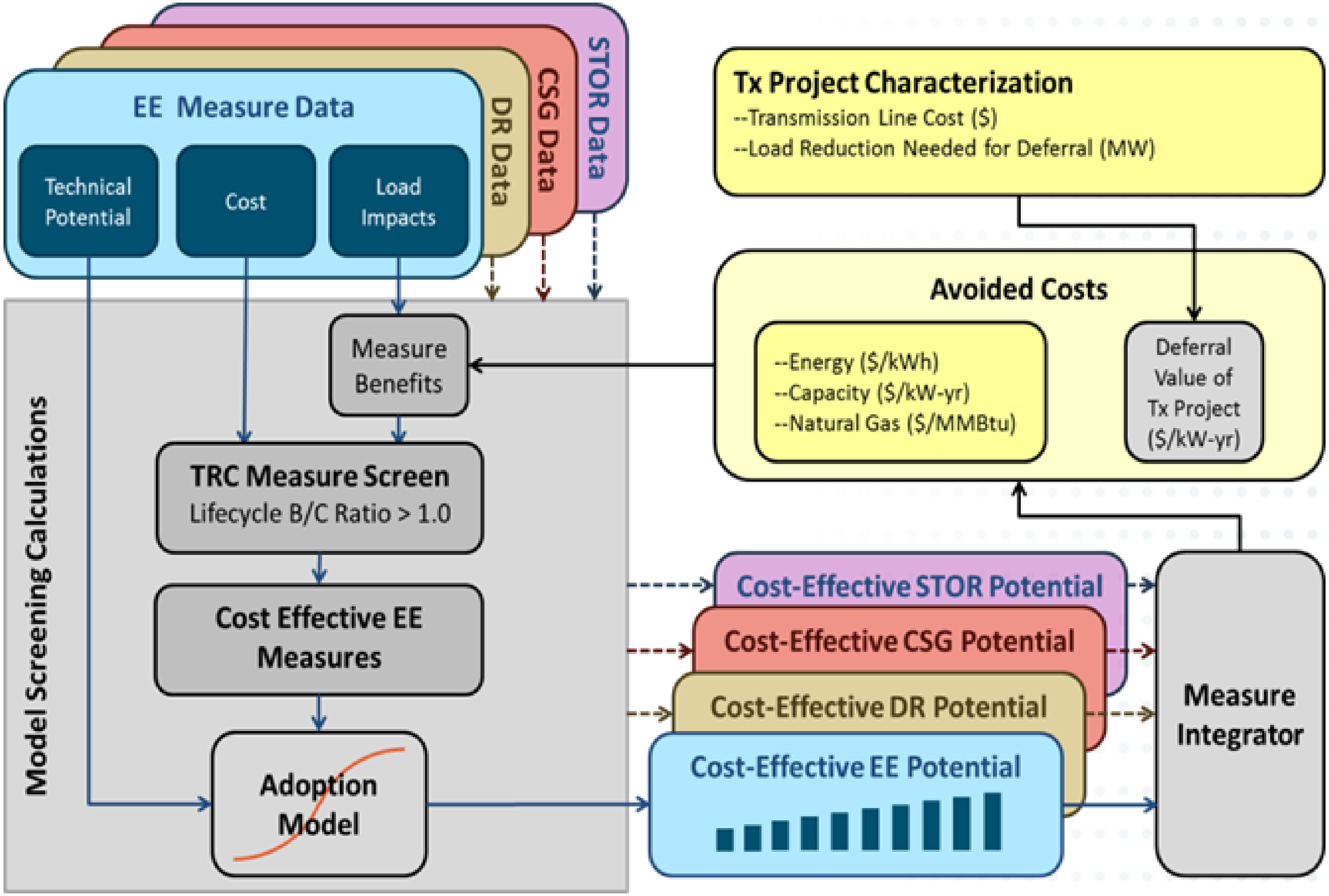
Category	Primary purpose	Timeframe	Value stream
Emergency demand response	Improve reliability	Seldom, during contingency	
Demand response	Reduce powerplant construction	<100 hours per year	
Permanent load shifting	Improve load factor	Daily, all year, or by season	
Renewable distributed generation	Reduce fuel consumption and emissions, avoid new powerplant construction	Year round with seasonal, diurnal trends	
Energy efficiency	Reduce fuel consumption and emissions, avoid new powerplant construction	During device operation (e.g., seasonal, or daily)	

+ **"Fair" compensation should capture all relevant value streams**

E3 Avoided Cost Framework



IDSM: Model overview



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CALIFORNIA

California: technology driven approach planning and deployment of DERs

+ Goal is to create a "plug and play" grid

- CPUC ordered the large utilities to develop Distribution Resource Plans that identify high value locations for DERs to interconnect (filed July 1, 2015)
- Ongoing efforts to liberalize interconnection rules

+ Emphasis on market transformation for efficiency, renewables, storage and clean transportation

- Many technology-forcing performance mandates: RPS, Storage mandate, EE targets, ZEV mandate
- Pending legislation would raise RPS to 50% by 2030
- EE, DR and clean DG are considered "preferred resources" in electricity system planning favored over grid-scale generation and transmission investments

+ Regulators striving to maintain safe, reliable, affordable service while driving aggressive clean energy agenda

E3 engaged in developing tariff designs and cost-effectiveness tools for DERs

+ CPUC: Net Energy Metering Reform

- Initial E3 study showed that combination of NEM and steeply tiered residential rate design led to transfers to solar rooftops owners from other res customers
- Current docket developing compensation scheme that supports continued solar adoption while reducing transfers and maintaining utility revenue model.
- E3 developed a model to test impact of alternative compensation approaches on solar adoption and rates for non-solar customers. CPUC using tool to support public stakeholder process.

Where to in the future?

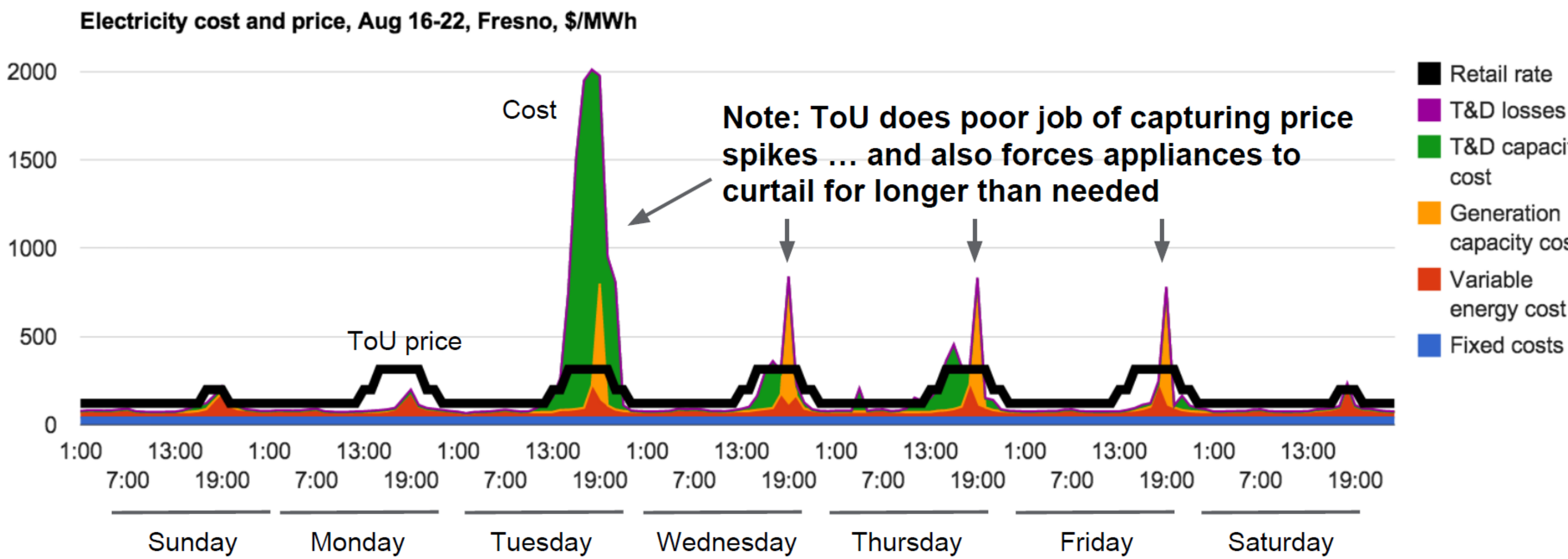
- **Many different tariff and market design options that will be shaped by the Californian context**
- **What if the end point were residential real time pricing (RTP)?**
  - Residential smart-meters have been rapidly deployed, enabling RTP in many locations, but Illinois is the only state today with residential RTP programs
- **Next slides present an E3 RTP case study done for Google in California**

Why is residential RTP compelling?

- The real-time cost of electricity is volatile and volatility will increase with higher renewable penetrations
- The technology for home energy optimization has arrived through cheap integrated circuits and internet access
- The service degradation cost is lowest in the residential market
- RTP incents efficient customer behavior but keeps control in the customer's hands

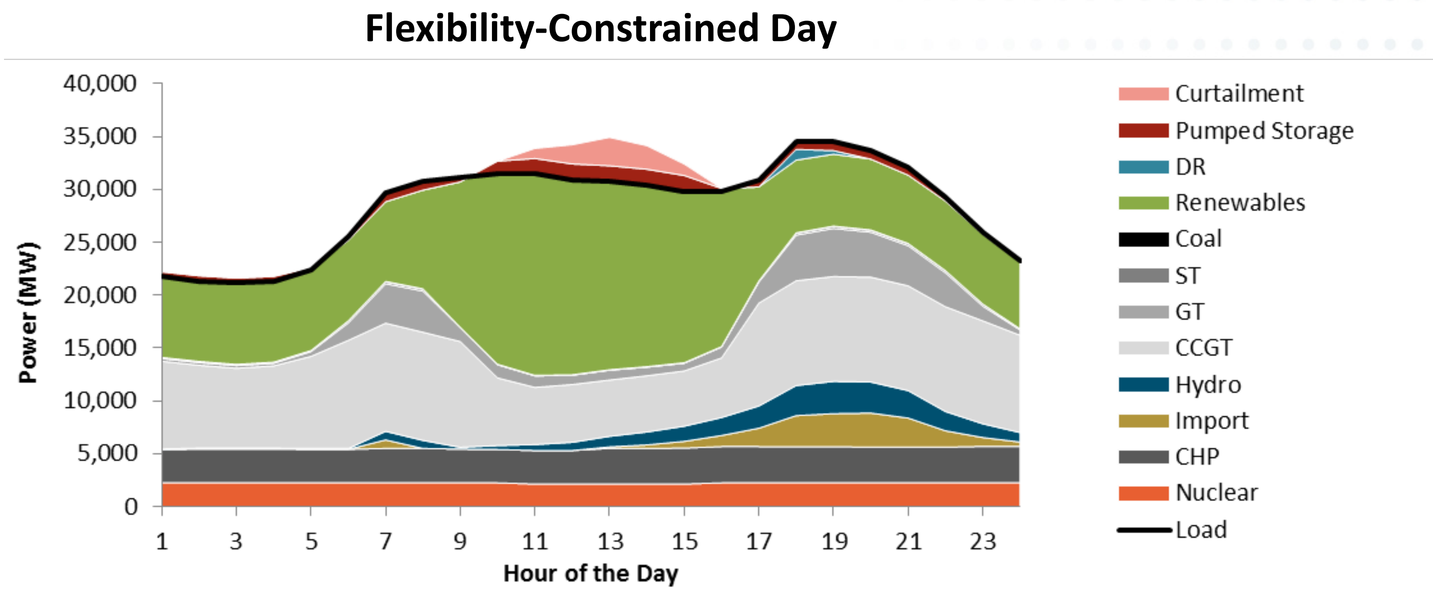
Contrasting existing TOU rates with RTP based on avoided cost

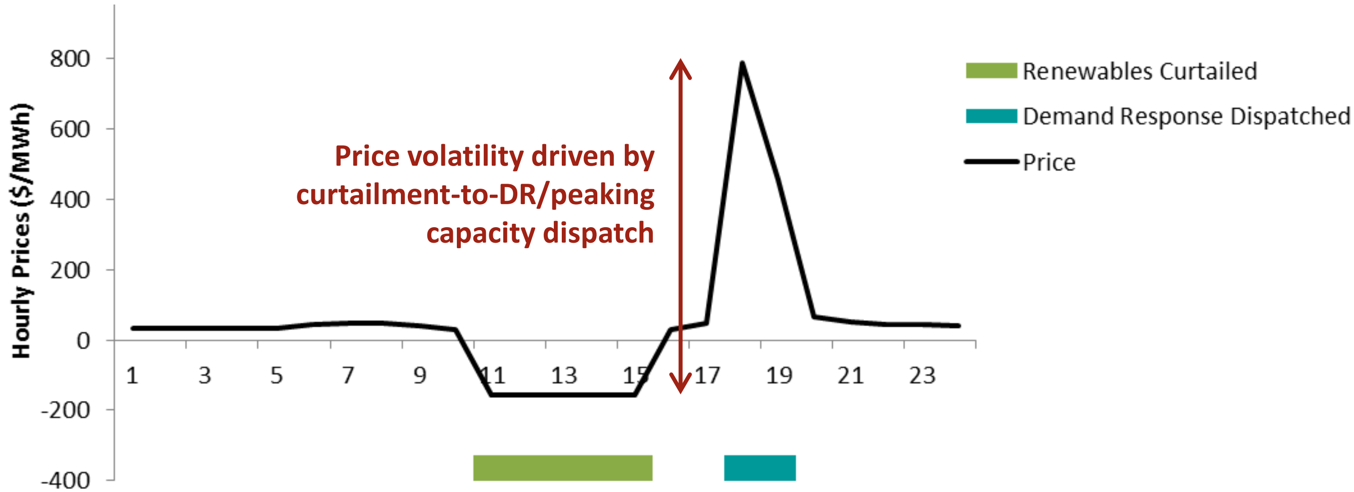
- **TOU rates may reflect the average cost of service but it misses the peaks and valleys of actual utility avoided costs**
- **The more volatile the real-time cost of electricity the more value comes from distributed control strategies**



Source: E3 California Avoided Costs and PG&E TOU Rates

CAISO price phenomena
40% RPS in 2022

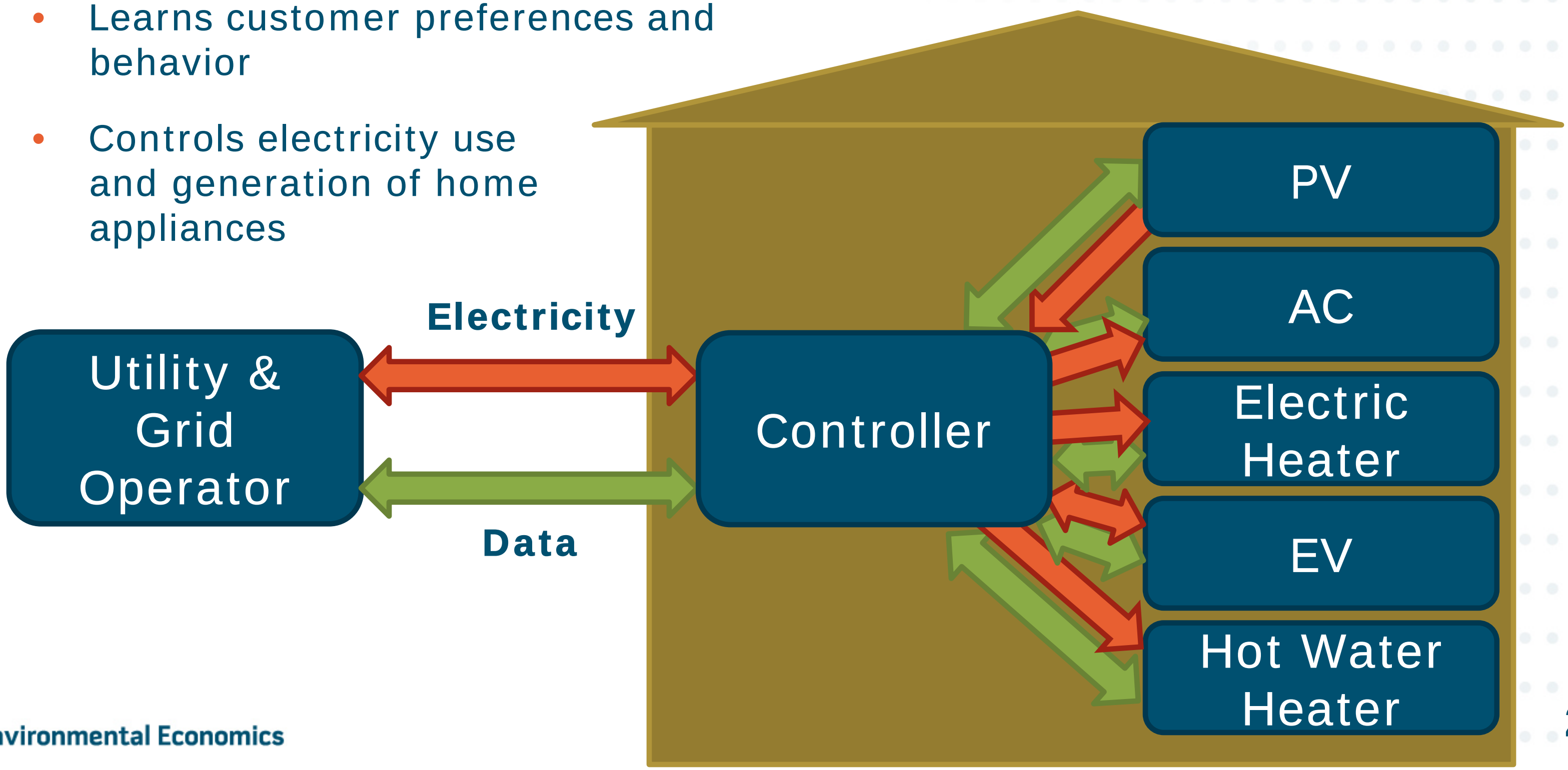




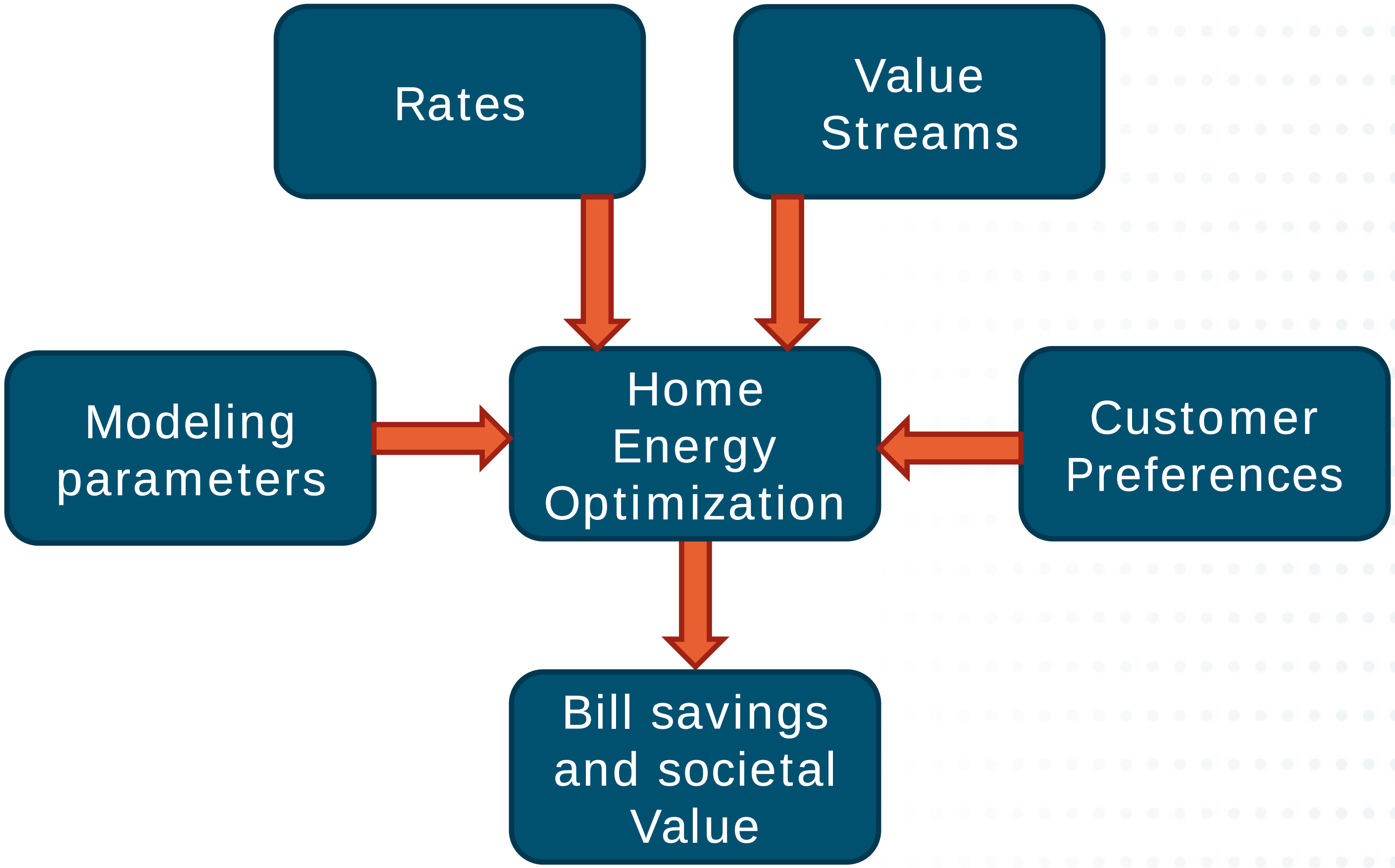
E3 Google Model: Overview

+ **Models the participant and utility system benefits of controllable flexible loads under any user defined retail rate price schemes including TOU, tiers, demand charges, and real-time pricing (RTP)**

+ **A generic home energy control device is modeled that:**
  - Sends and receives data signals to/from the electricity grid
  - Learns customer preferences and behavior
  - Controls electricity use and generation of home appliances

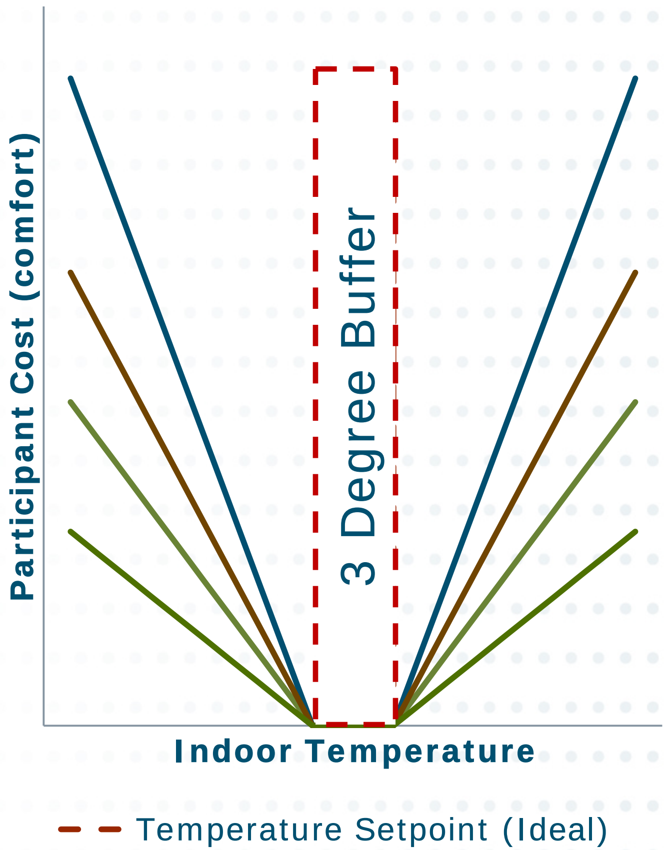


E3 Google Model: Methodology Overview



Customer preference penalties

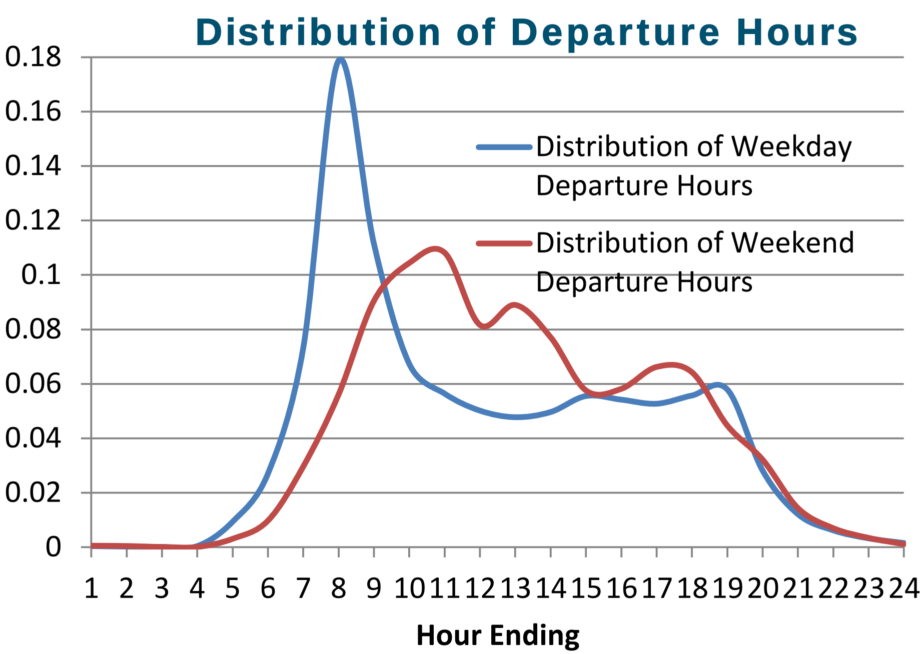
+ **Modeled variations in customer sensitivities to:**
  - Indoor air temperature deviation from set point (allowing 3 degree buffer)
  - Possibility of running out of hot water
  - Possibility of having insufficient charge during a trip (next slide)
+ **Results test nine linear preference functions**
  - Aimed to span the range of potential dispatch behavior due to customer preferences, not to accurately estimate preferences

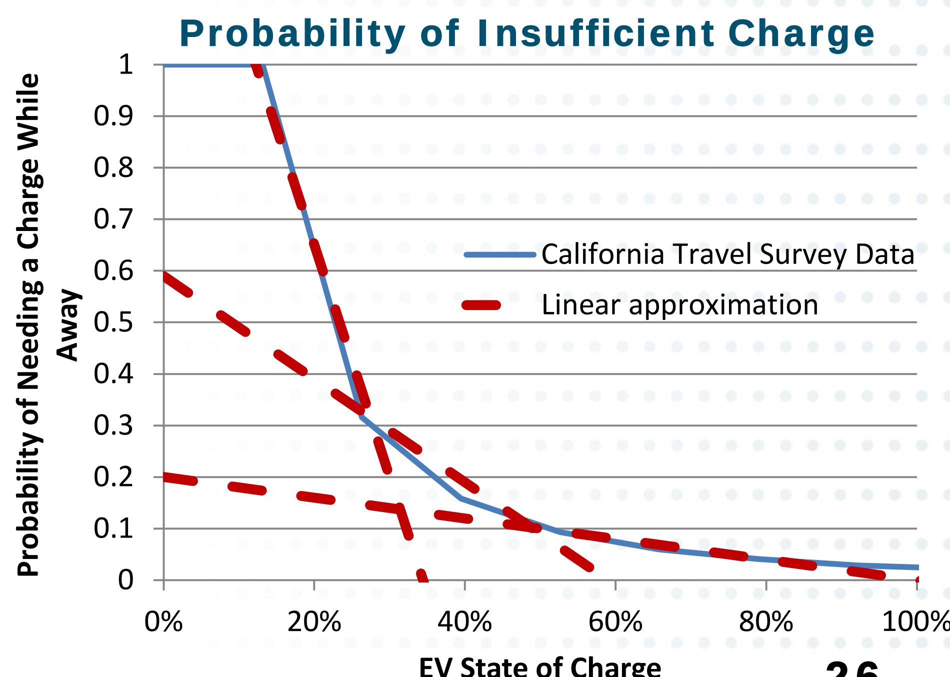


EV penalty functions

- Penalty price in dollars per instance with insufficient range
- EV has flexibility during early hours even at high penalty price

$$Penalty_h = Number\ of\ Daily\ Trips \times P(departure)_h \times P(Needing\ a\ Charge|EV\ Charge) \times Cost\ of\ Insufficient\ Charge$$

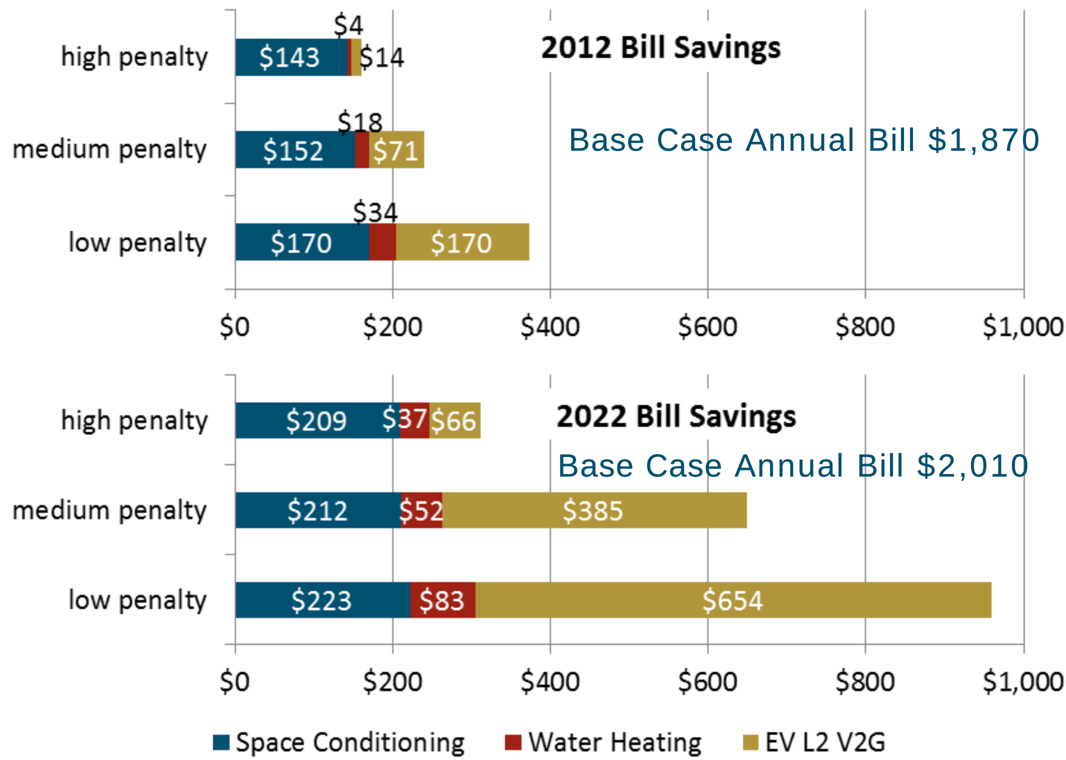




Data source: California Travel Survey http://www.dot.ca.gov/hq/tsip/otfa/tab/chts_travelsurvey.html

Detailed bill savings 2012 & 2022

- Annual bill savings calculated at 13% in 2012 and 32% in 2022 for a medium customer penalty
- Not included are enabled energy savings from smart controls while occupants are away from home
  - These were not our research focus but are likely significant with some estimates as high as 39% [1]



	low penalty	medium penalty	high penalty	units
Space Conditioning	0.05	0.30	1.00	$/°F-hour
Water Heating	0.50	2.00	3.50	$/Shortage
EV	5.00	25.00	100.00	$/Shortage

[1] Meyers, R.J. et al, 2009. Scoping the potential of monitoring and control technologies to reduce energy use in homes

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HAWAII

Hawaii

- **The capability to integrate DG PV is finite, but DG PV is a valued option among utility customers**
  - Rapid DG PV growth increasing cross-subsidy while also reducing potential for other more economic alternative resources
- **Proposed transitional tariff (TDG) to foster a sustainable and more cost effective DG PV market place**
  - Honor rights of existing customers
  - Transition towards a new fixed cost allocation
  - New standard contract incorporating advanced DG PV technical capabilities
  - Increase penetration limits, supported by circuit investments

Technical challenges

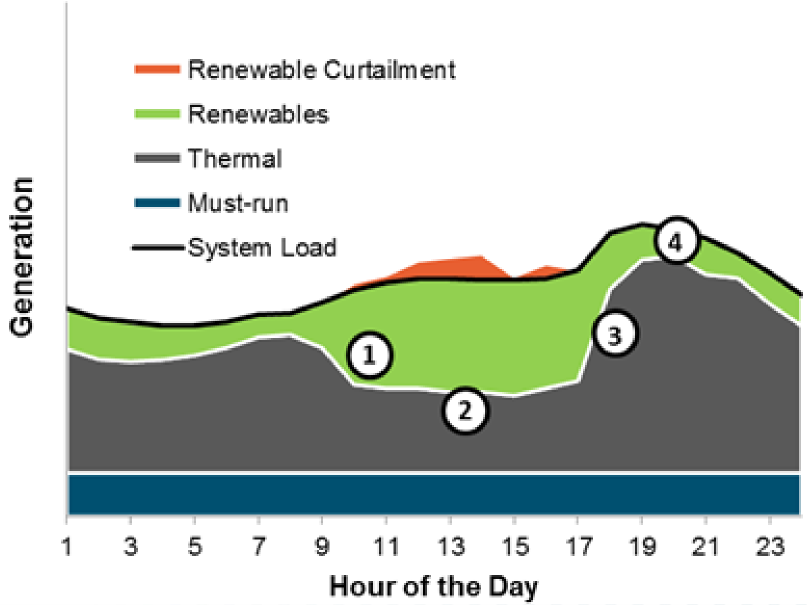
- **Tariff requires technical changes to newly interconnecting DG PV, including:**
  - Increasing circuit penetration threshold from 120% to 250% of gross daytime minimum load
  - Using advanced inverters with voltage and frequency ride through requirements and two way communication
- **Discussion of future control functionality to curtail DG PV, increasing flexibility**
- **Beyond local interconnection thresholds and without DG PV control, interconnection of DG PV is limited by current system constraints**
  - Overgeneration due to conventional fleet minimum generation and reserve requirements
  - Potential ramping constraints

Analysis of limits and beyond

+ **E3 hired to investigate the limits to DG PV interconnection on the current HECO systems**

+ **Characterize expected system imbalance issues caused as DG PV is increased**
  - What are the potential solutions?

+ **Planning and tariff design:**
  - Very high rooftop PV penetrations
  - 65% RPS by 2030
  - DER expected to be a key part of the vision



1. **Downward ramping capability**
2. **Minimum generation flexibility**
3. **Upward ramping capability**
4. **Peaking capability**
5. **Sub-time step flexibility**

Final thoughts

- Historically, we have planned and operated power systems assuming load was, for the most part, inflexible—supply is easier to control and reacts to load
- In a future scenario with high levels of variable generation such as solar PV and cheap distributed controls, this paradigm may reverse—load will dispatch based on fixed supply characteristics
- The transition to transactive energy, including new DER tariff designs, markets and rate structures, is an important step to achieving an efficient, resilient, and clean electricity grid with high levels of variable generation and flexible loads
- The transition will be shaped by the regional goals and challenges

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Thank You!

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