Forecasting load on the distribution and transmission system with distributed energy resources

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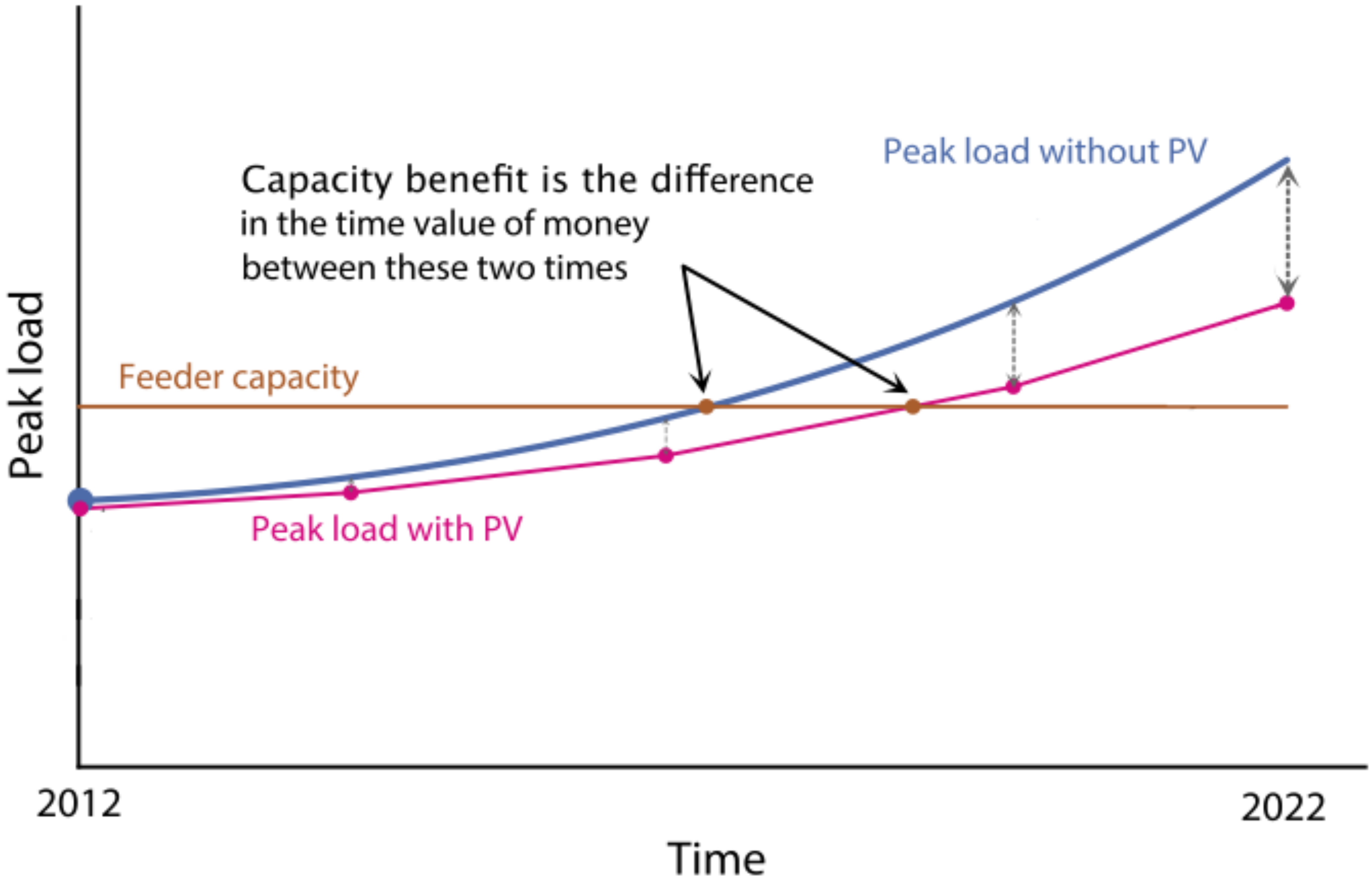
Importance of Including Distributed Energy Resources in Load Forecasts

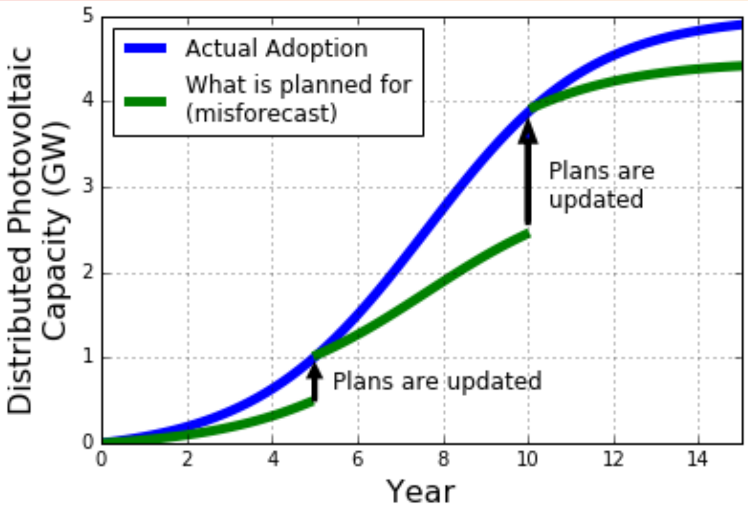
- Distribution system investments: replacing aging infrastructure and distribution expansion
- Procurement of generating capacity to meet peak demand
- Proactive investments to increase hosting capacity
- Evaluating the costs and benefits of incentives or policies to promote distributed energy resources (DER)

Impact of DPV on T&D Investments: Potential Deferral Value

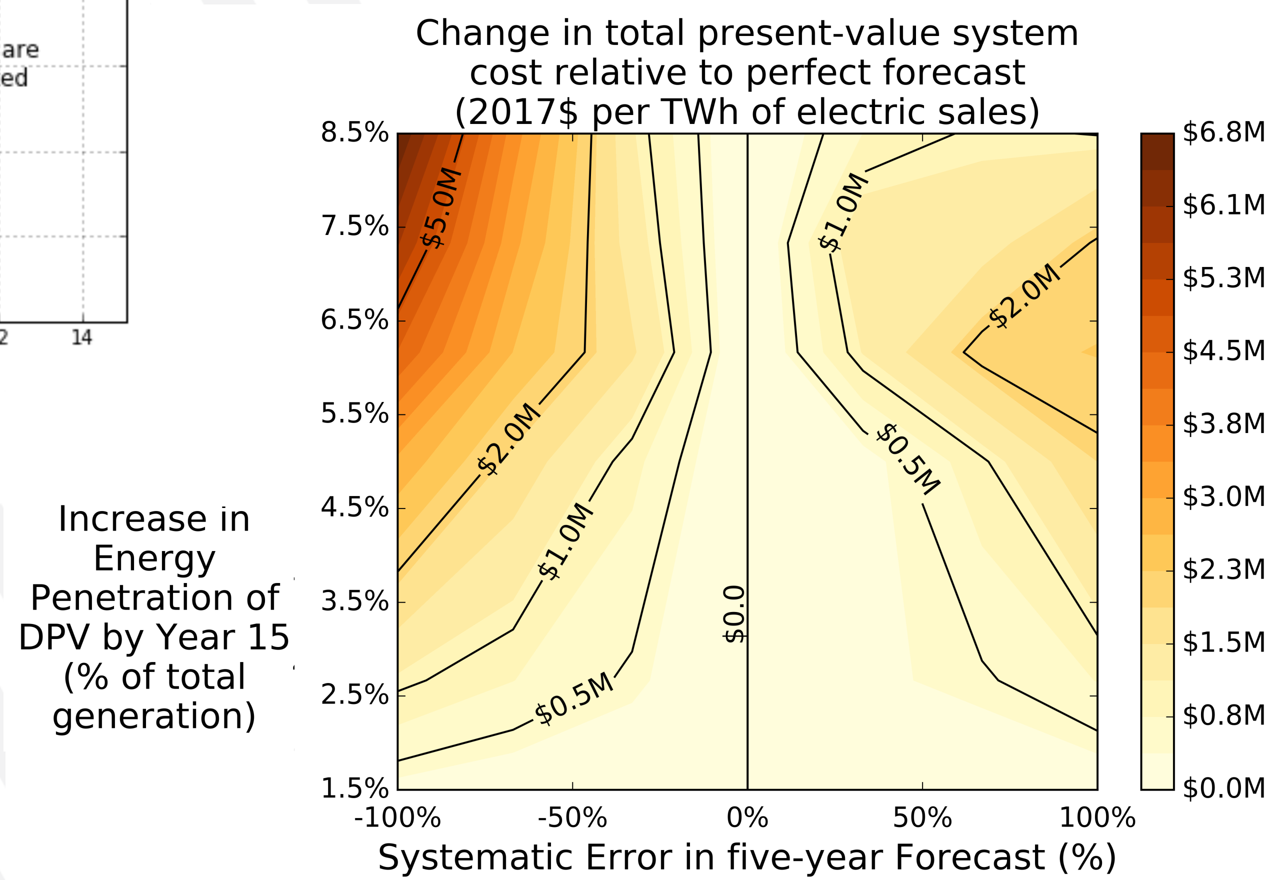


Source: Adapted from Cohen et al. 2016

Increasing Adoption of DER Increases the Importance of Accurate Forecasts in Planning



Costs of roughly **$70 million from severe underforecasting** and **$20 million from severe overforecasting** for a utility with sales >10TWh/yr and with up to 8.5% of sales from DPV by the end of a 15-year period



Source: Gagnon et al. (forthcoming)

Planning for a Distributed Disruption: Innovative Practices for Incorporating Distributed Solar into Utility Planning

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Context

- Analysts project that distributed solar photovoltaics (DPV) will continue growing rapidly across the United States.
- Growth in DPV has critical implications for utility planning processes, potentially affecting future infrastructure needs.
- Appropriate techniques to incorporate DPV into utility planning are essential to ensuring reliable operation of the electric system and realizing the full value of DPV.

Approach

- Comparative analysis and evaluation of roughly 30 recent planning studies, identifying innovative practices, lessons learned, and state-of-the-art tools.

Scope

- Electric infrastructure planning (IRPs, transmission, distribution).
- Focus on the treatment of DPV, with emphasis on how DPV growth is accounted for within planning studies.

Key Findings

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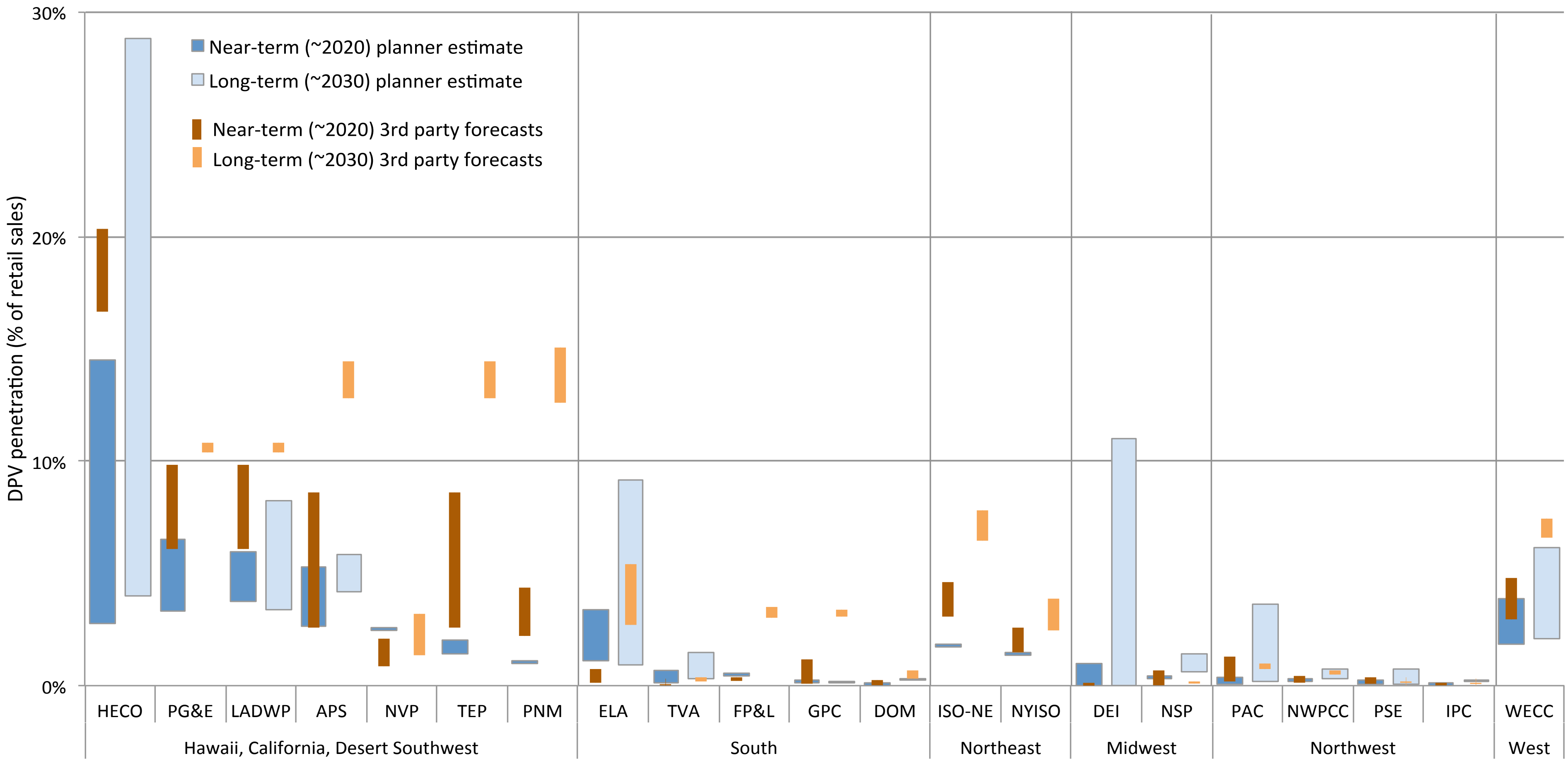
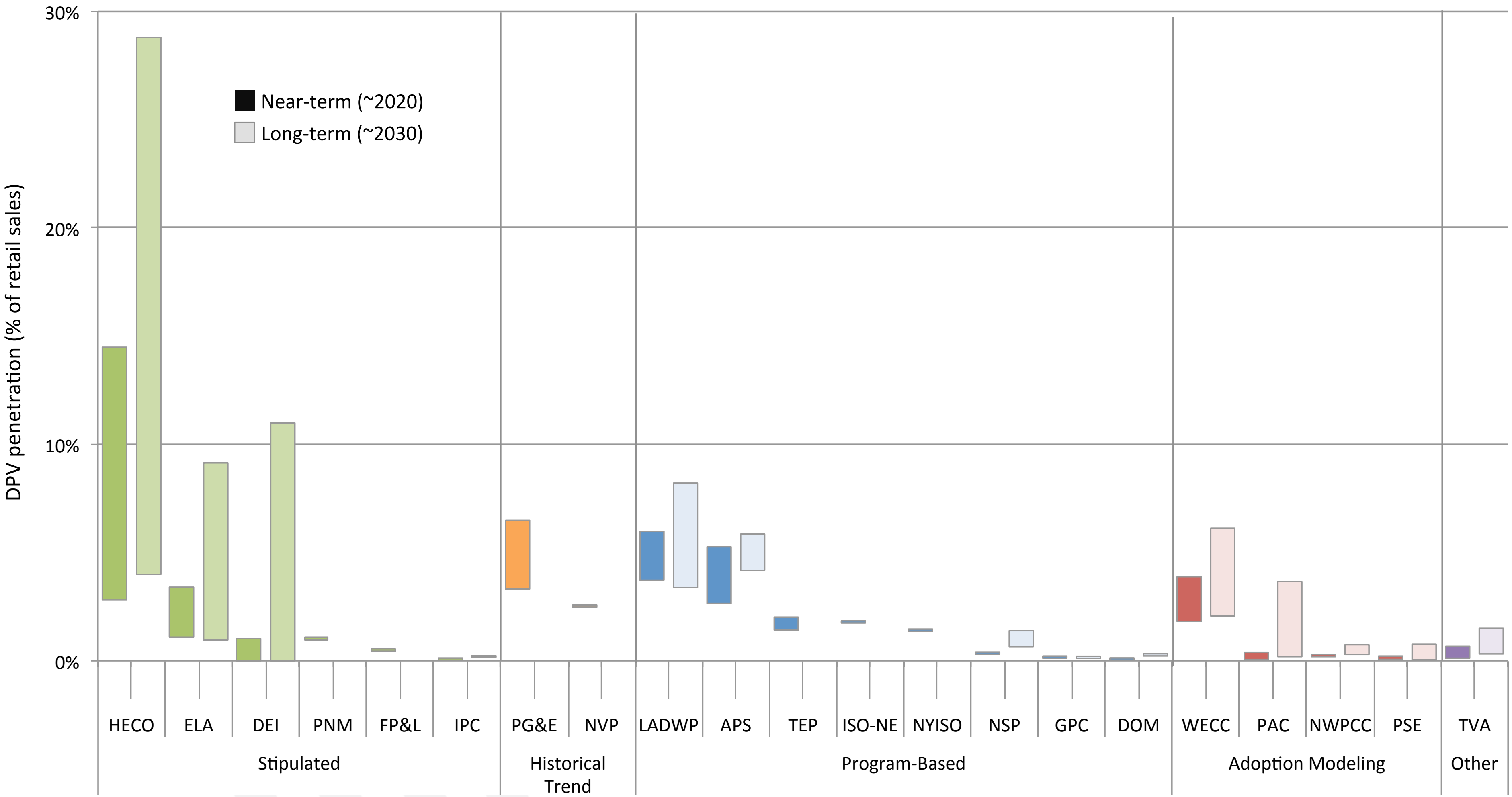
- Forecasting load with DER is often “top-down”: separately forecast load and quantity of DER at the system level, allocate that system forecast down to more granular levels.
- Many factors affect customer decisions to adopt DER, including the cost and performance of DER, incentives, customer retail rates, peer-effects, and customer demographics. Customer-adoption models can help account for many of these factors.
- Forecasts are uncertain: It may be valuable to combine various approaches and to benchmark against third-party forecasts.

High End of 3rd Party Forecasts Suggests More DPV Than Considered By Utilities



A Variety of Methods are Used to Develop DPV Forecasts



DPV Deployment Drivers

- DPV economics:
  - DPV technology cost and performance
  - Federal and State incentives
  - New business models (e.g., third party ownership)
  - Electricity prices
  - Rate design (including the availability of Net Energy Metering)
- Public policy:
  - Renewables Portfolio Standards and environmental requirements
  - CO_2 regulation
- Customer preferences:
  - DPV deployment may be shaped by interest in increased customer choice
- Macro factors:
  - Economic growth, load growth, oil prices, and cost and availability of complementary technologies (e.g. storage and electric vehicles)

Customer-adoption Modeling Brings Customer Decisions Into DPV Forecast

Method	Description	Predictive Factors Used				
		Recent installation rates	Incentive program targets	Technical potential	PV economics	End-user behaviors
Stipulated Forecast	Assumes end-point DPV deployment					
Historical Trend	Extrapolates future deployment from historical data	X				
Program-Based Approach	Assumes program deployment targets reached		X			
Customer-Adoption Modeling	Uses adoption models that represent end-user decision making	X		X	X	X

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Some Planners Use Customer-adoption Models for DPV Forecasting

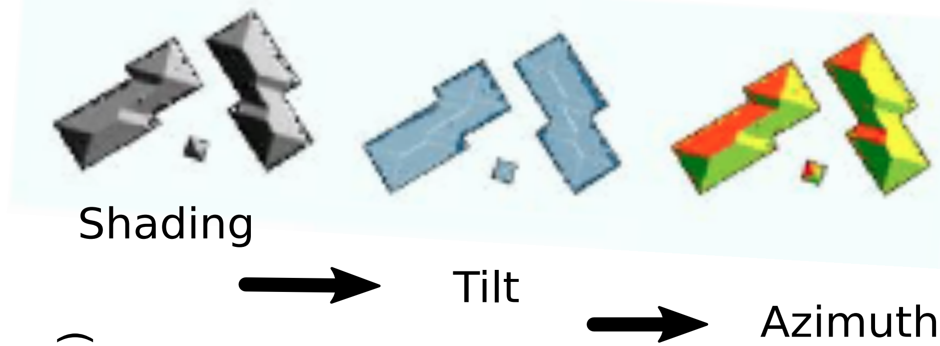
Technical Potential

↓

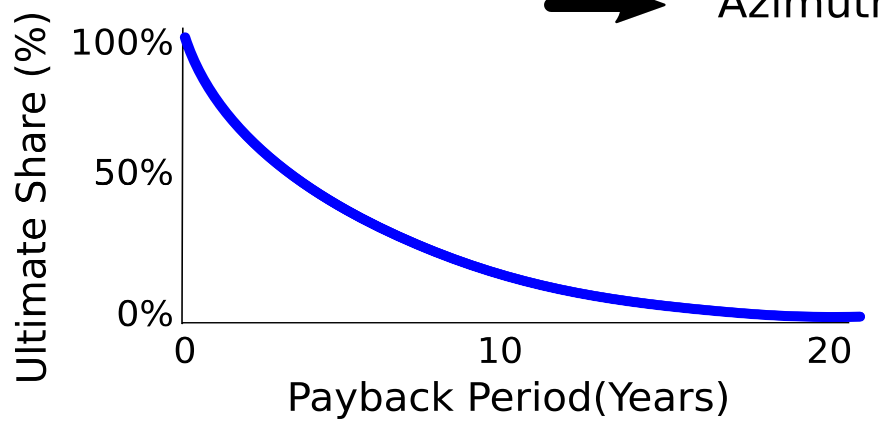
Willingness-to-adopt

↓

Diffusion



Adapted from: Gagnon et al. 2016



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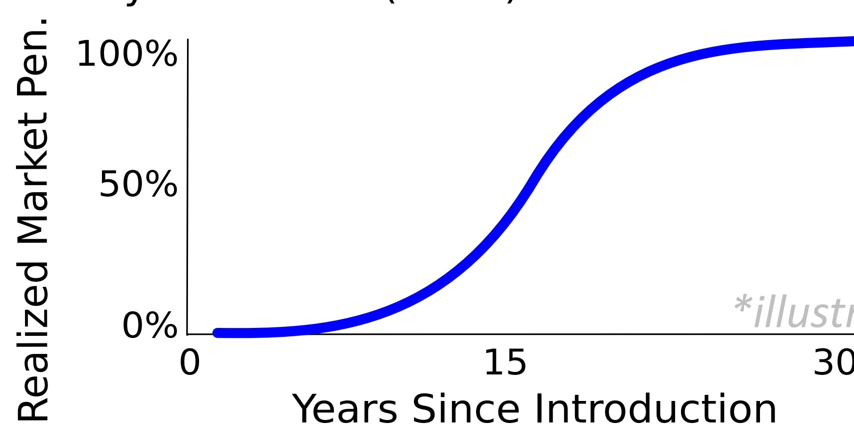

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Technical Potential Estimates Are Typically Based on Customer Count and Rooftops

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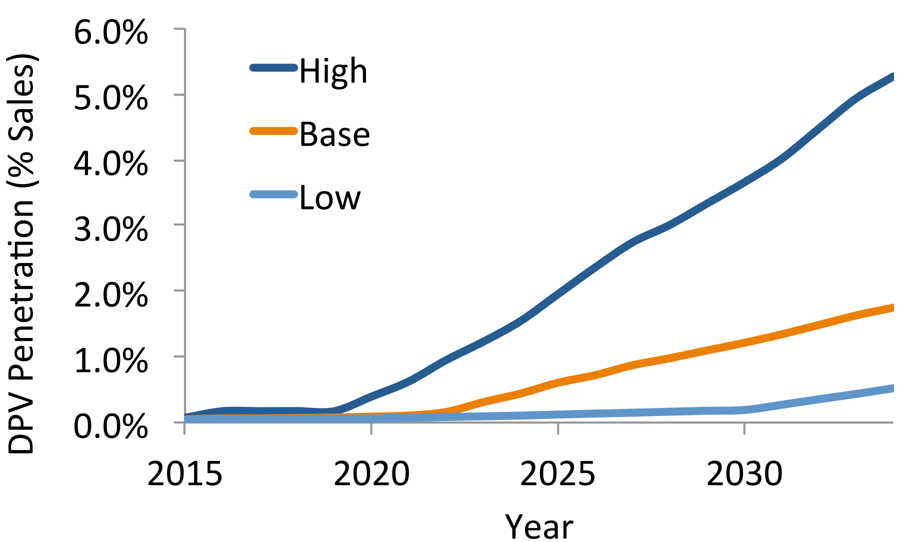
- Technical potential studies used by utilities in our sample of studies were based primarily on customer counts and floor space surveys
  - Rooftop space is based on average number of floors and assumptions about the density of PV arrays
- New emerging tools like Light Detection and Ranging (LiDAR) imaging can refine technical potential estimates:
  - Infer shading, tilt, and azimuth from rooftop images
  - Apply availability constraints to exclude unsuitable orientations or insufficiently large contiguous areas
- Can also refine with permitting and zoning restrictions, if applicable

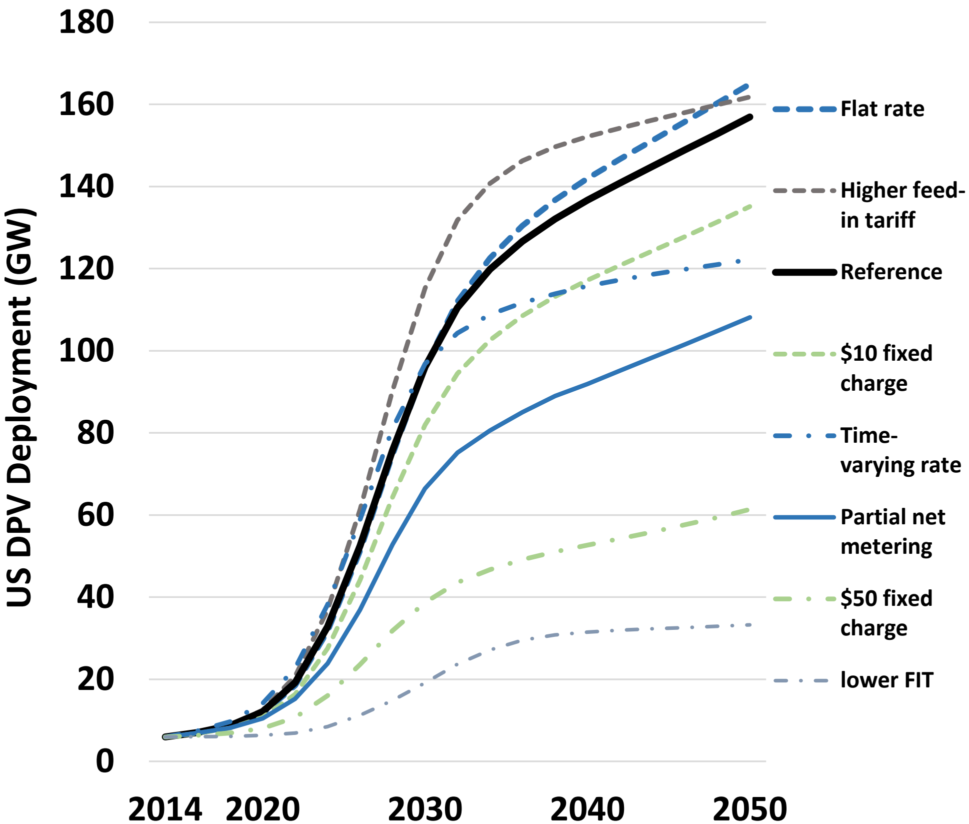
Factors Affecting Customer Economics of DPV Can Significantly Affect Forecasts

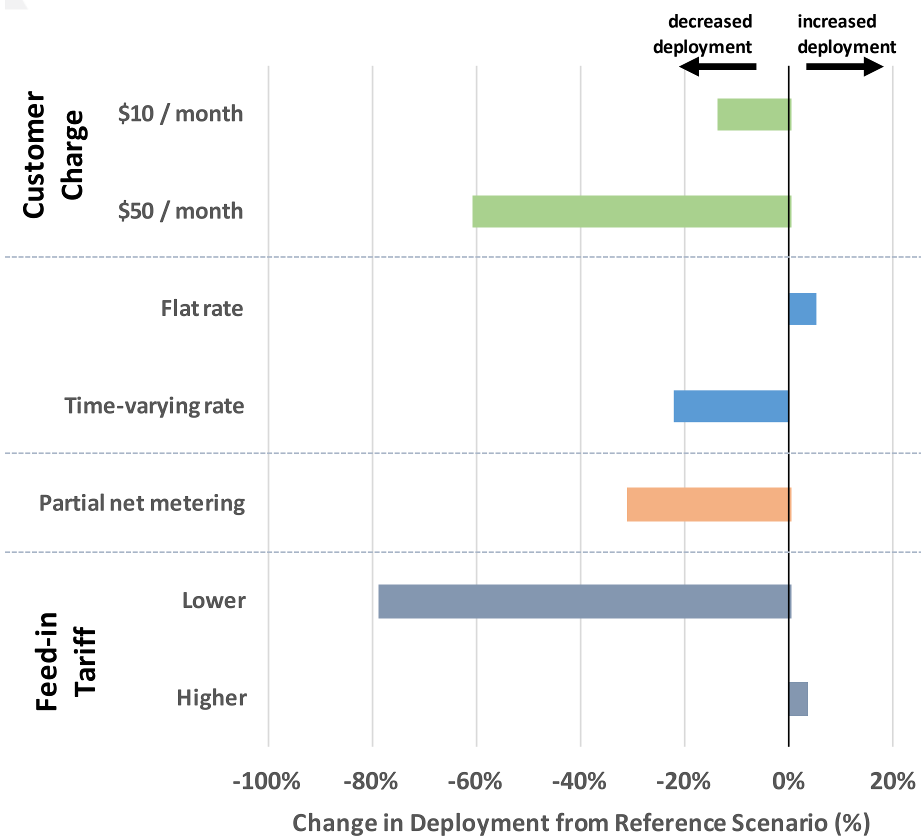
- PacifiCorp forecast of DPV created a High and Low forecast by varying factors impacting customer economics:
  - DPV cost, DPV performance, and electricity retail rate escalation



- Willingness-to-adopt curve translates the payback period of DPV to ultimate share of the technical potential.
- Payback period depends on both the cost to the consumer and the consumer bill savings
- The cost to the consumer will be affected by declining costs of DPV and availability of incentives (e.g. the investment tax credit).
- The consumer bill savings depend on rate levels, rate design, and availability of Net Metering.

Rate Design Can Significantly Affect Adoption of Distributed PV





Source: Darghouth et al. 2016

Forecasters Tend to Rely on Similar Willingness-to-adopt Curves

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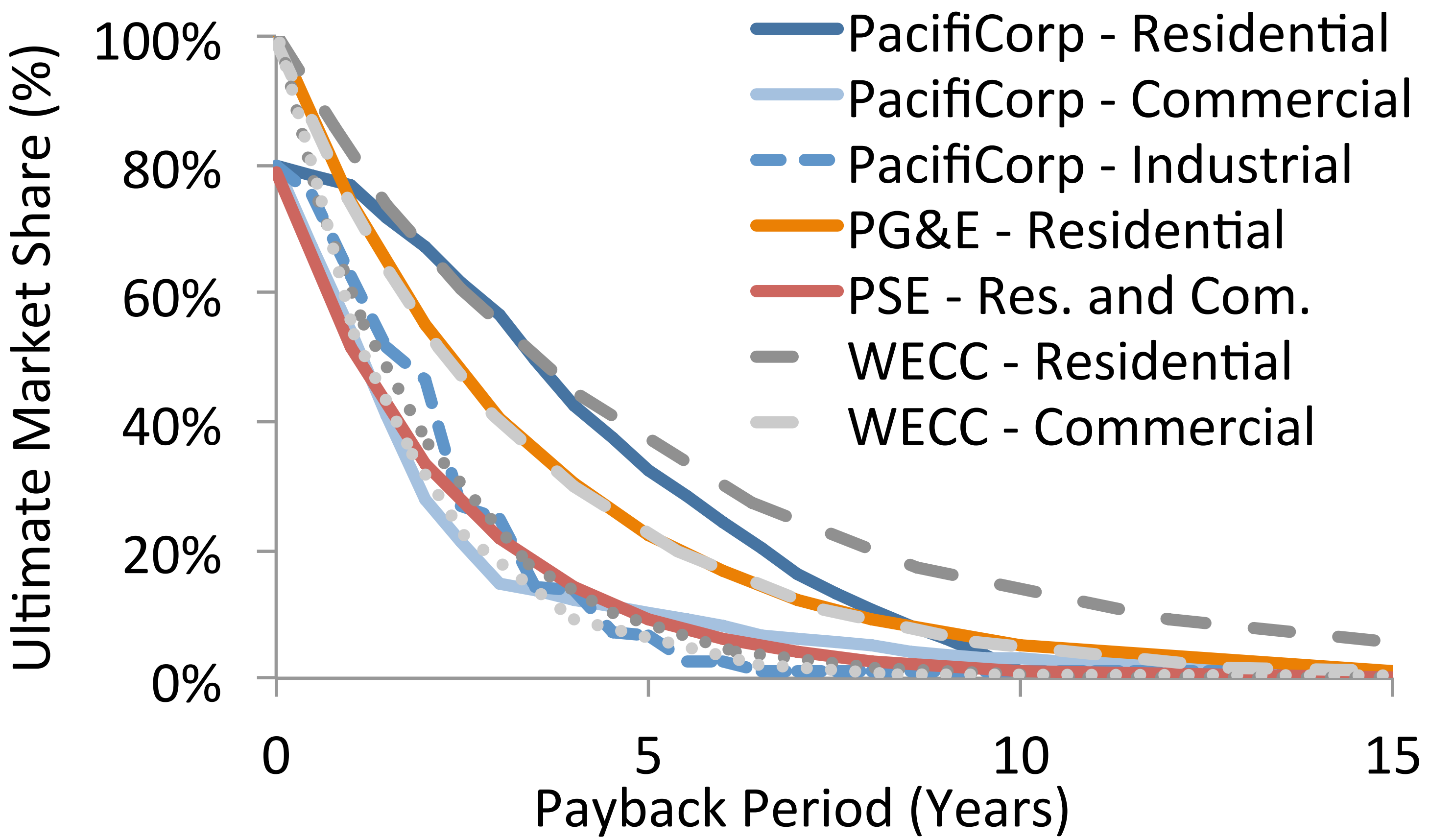
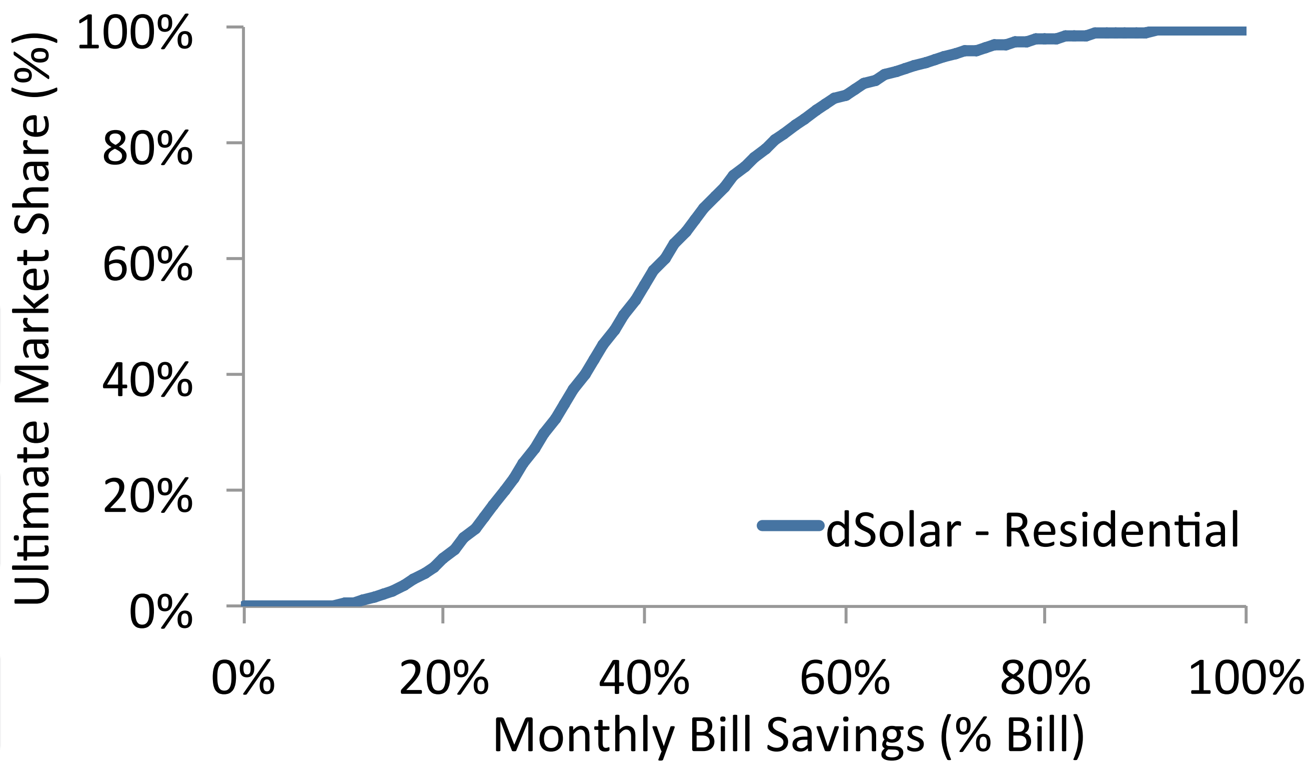


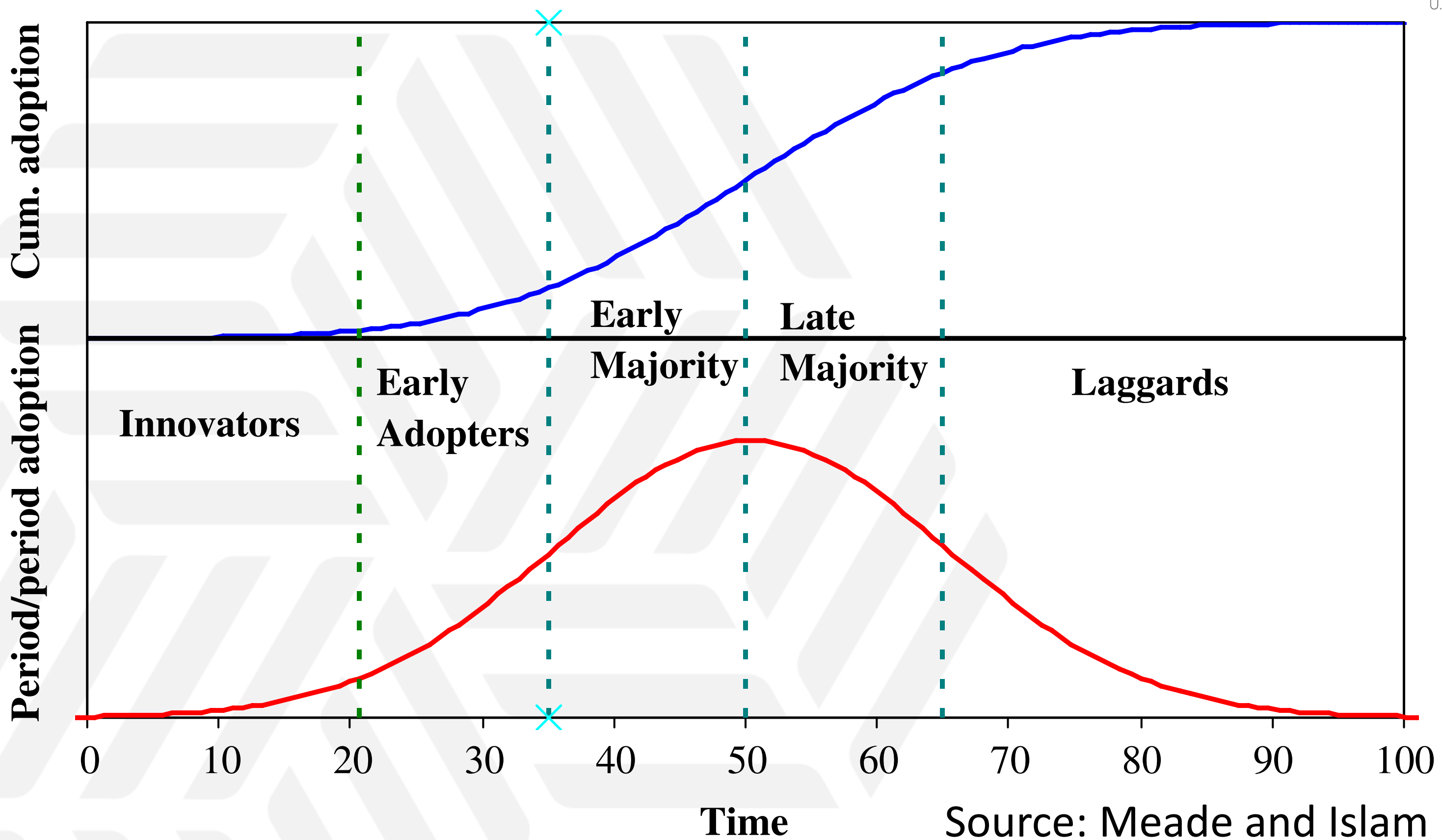
Note: Dashed gray lines (WECC) are for existing buildings, and dotted gray lines are for new buildings.

Innovative Business Models Shift Focus from Payback to Monthly Bill Savings



- Payback period is not a useful metric for systems that are leased from a third party
- Willingness-to-adopt curves can also be defined in terms of monthly bill savings

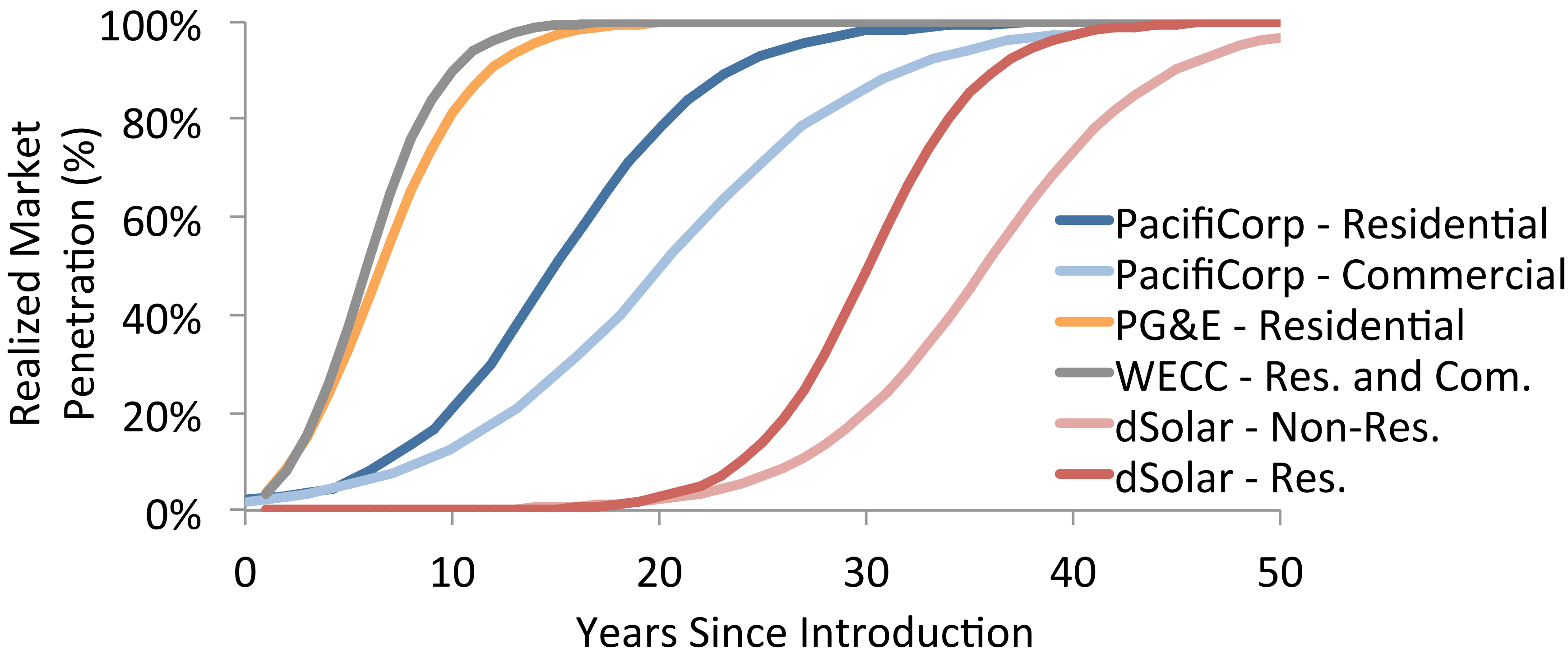
Diffusion of Technology Impacts Time to Achieve Ultimate Market Share



Source: Meade and Islam (2006)

- The Bass diffusion model and Fisher-Pry model are two common choices that produce the characteristic "S-Curve" in adoption.

Diffusion Curves for DPV Forecasts Are Often Based on Fits to Data, and Can Vary Widely

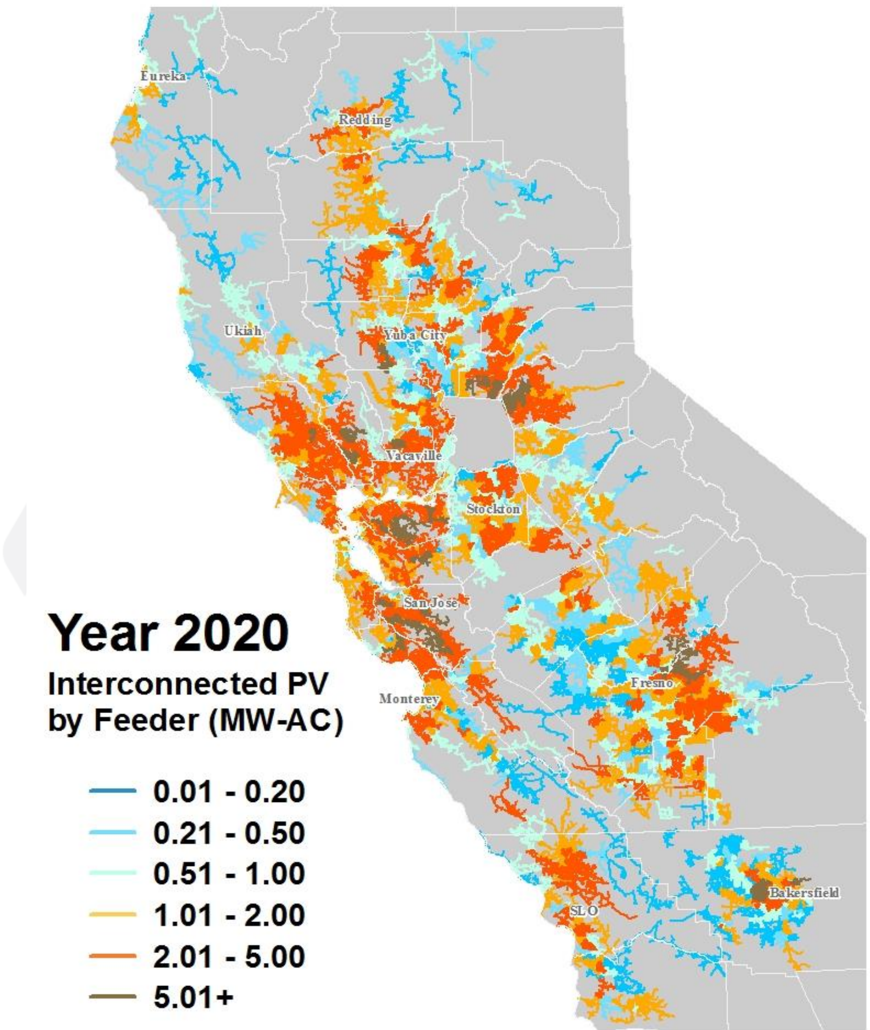


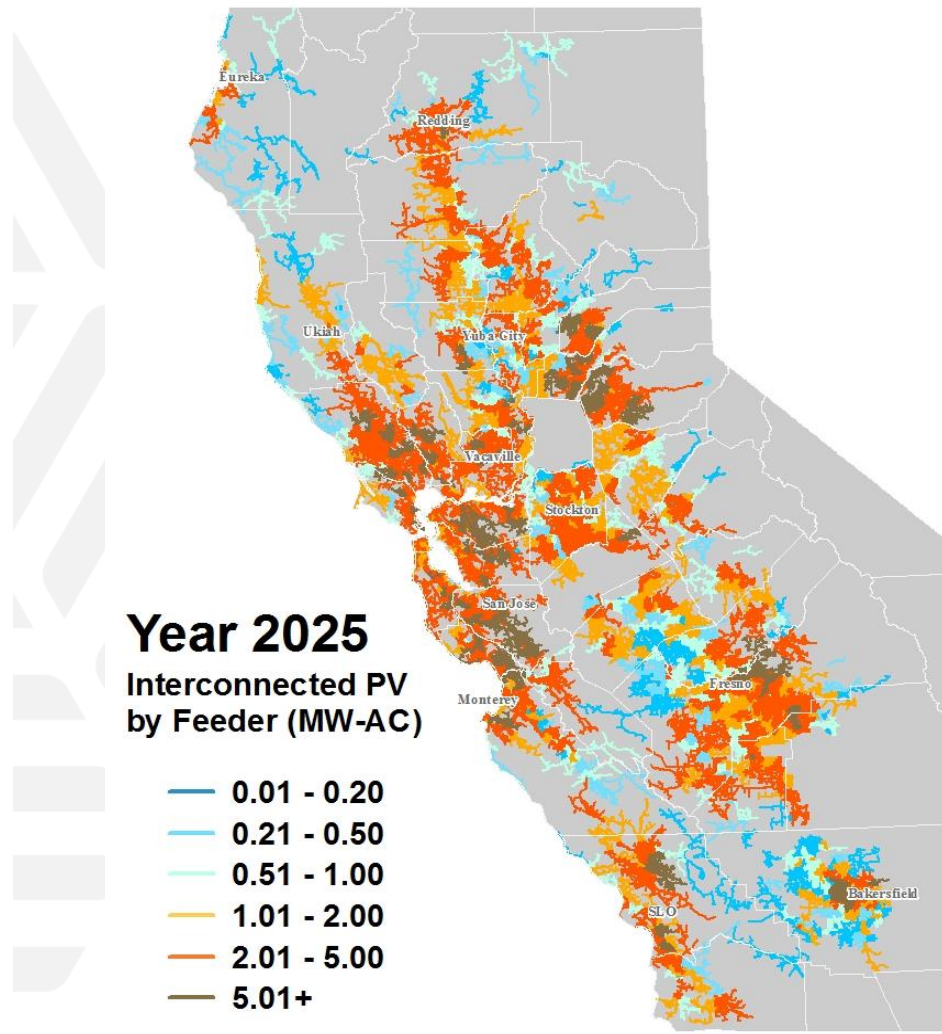
- Important feature of diffusion curves is that period of rapid adoption can follow period with relatively low shares of adoption.
- Similar behavior has been observed for several consumer durable goods including refrigerators, VCRs, internet access, and mobile phones.

Propensity to Adopt Accounts for Factors Like Customer Demographics

Method	Description	Predictive Factors Used		
		Location of existing load or population	Location of existing DPV	Detailed customer characteristics
Proportional to Load	Assumes DPV is distributed in proportion to load or population	X		
Proportional to Existing DPV	Assumes DPV grows in proportion to existing DPV		X	
Propensity to Adopt	Predicts customer adoption based on factors like customer demographics or customer load	X	X	X

Predicting the Location of DPV Adoption Using Propensity to Adopt





Source: PG&E 2015 DRP

Factors Considered in PG&E's Propensity to Adopt Metric

- Residential Customers:
  - Home ownership
  - Electricity usage
  - Income
  - Credit
  - Building characteristics (area, number of stories)
- Non-Residential Customers:
  - Property Ownership
  - Electricity usage
  - Retail Rate
  - Business type (NAICS)
  - Building characteristics (area, number of stories)

- Propensity to adopt metric is then used to allocate system forecast down to customers.

Source: PG&E presentation to DRPWG (4/2017)

Advances in Customer Adoption Modeling

- Agent based models simulate actions and interactions of agents to assess their individual effects on a larger system.
  - Allows for better representation of heterogeneity of customers and more complex decision-making criteria
- Discrete choice models have a well defined methodology for soliciting customer preferences and can model competition between several options
  - Provides framework for empirically derived forecasts

- Some open questions:
  - How might consumption change after adoption of DPV: is there a rebound effect?
  - How does the willingness-to-adopt curve vary across customer segments?
  - How does customer adoption of DPV compare to customer demand for community solar? Do these two options compete directly for market share or are they complementary?

Additional Challenges: Removing DER from Historical Load to Create Accurate Load Forecasts

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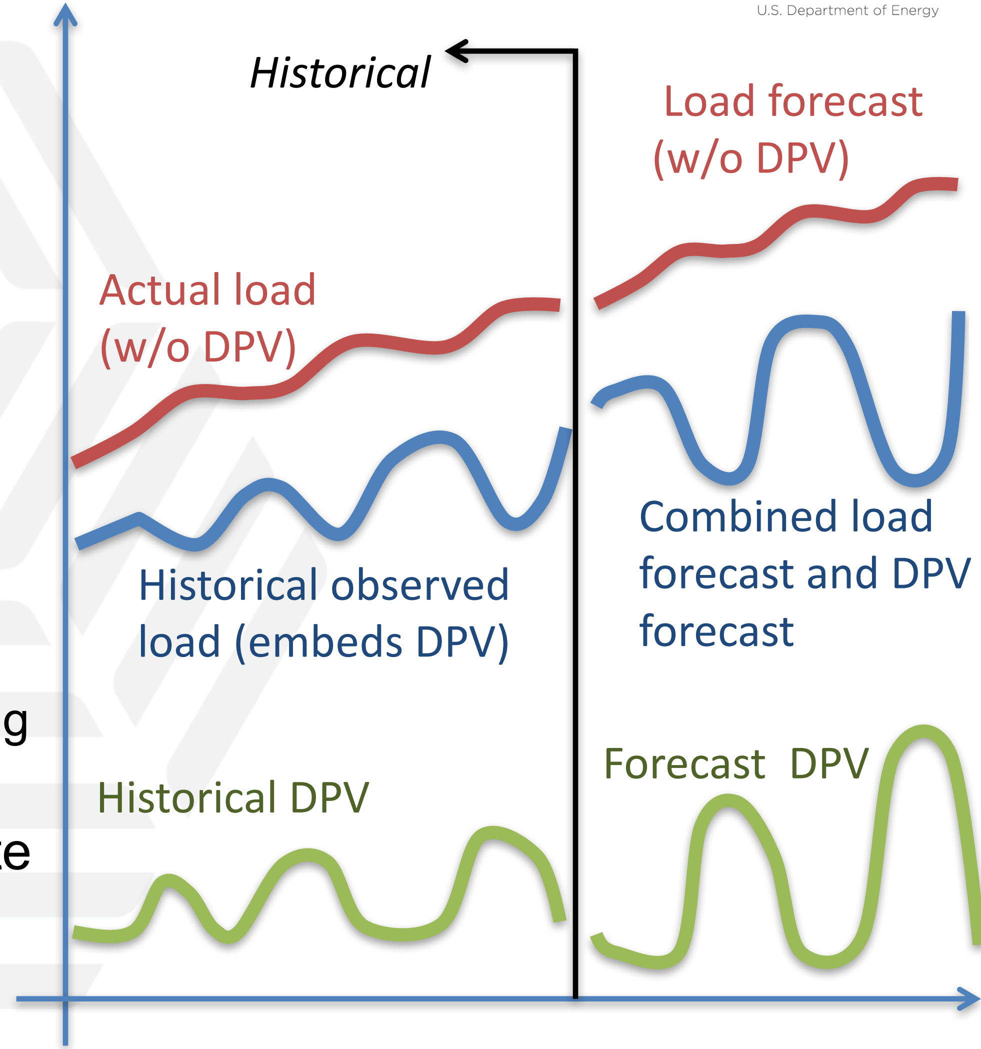
- PJM recently adjusted load forecasting methodology to better account for behind-the-meter PV
- Original approach used the observed load to forecast future load, without adjusting for effect of behind-the-meter DPV on the observed load
  - Load reductions from behind-the-meter DPV were being attributed to new end uses in the load forecasting model
- Revised approach removes estimate of historical PV before forecasting load, then adds back in forecast of DPV to new net load forecast



Additional detail: Falin (2015)

More Examples of DER in Transmission Plans

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- Evaluating DPV as a resource option:
  - CAISO transmission planning process identifies transmission needs to meet reliability criteria, then examines feasibility of meeting needs with DPV.
  - If CAISO finds it is feasible to meet needs with increased DPV, information is passed onto CPUC and utilities to determine if programs to encourage additional DPV would be cost-effective.
- Locating DPV within the system:
  - ISO-NE and NYISO use the load-zone-level DPV forecast in their capacity markets and transmission planning. PJM adjusts the load-zone peak demand by the on-peak contribution of DPV for its capacity market and transmission planning.
- Peak demand reduction (i.e. transmission level capacity credit):
  - ISO-NE and PJM use a stricter definition of peaks in transmission planning than for the capacity market.
- Consistent scenarios across planning forums:
  - CAISO/CPUC/CEC coordination, NYISO Gold Book, ISO-NE 10-year regional planning process to coordinate assumptions

Forecasting Other Distributed Energy Resources

- Some DER are similar to DPV :
  - Systems can be installed either in-front-of- or behind-the-meter
  - Adoption can occur for residential, commercial, or industrial customers
- These technologies have yet to see significant adoption due to higher cost or other barriers, but adoption might increase in the future. Similar forecasting tools and models can be used for these emerging technologies.
- Other DER systems are different in that the system cost, performance, and design are specific to individual customers and systems tend to be larger (e.g., CHP units)
- In these cases, local knowledge from distribution planners might be more useful than the top-down methods described here.

Key Questions for Regulators About DER Forecasts

- What are the primary factors that drive your forecast of DER adoption? How do you consider customer economics and factors that might affect customer economics within the forecasting horizon?
- How do you account for the tendency for adoption of technologies to follow an S-shaped curve?
- How does your forecast compare to forecasts from third parties for the same region?
- How do you account for factors that might be uncertain such as availability of future incentives, technology cost, or customer choice?
- Do you use a top-down method to forecast DER adoption at the system level? If so, how do you allocate that forecast down to the distribution level? Do you account for differences in customer demographics?

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