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Rooftop Solar Forecast and Model Validation:

Preliminary Results

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August 15th, 2019

California Energy Commission

Introduction

NREL has performed work for the California Energy Commission to adapt its DER adoption forecast model (dGen) for California. Today we present two aspects of the project:

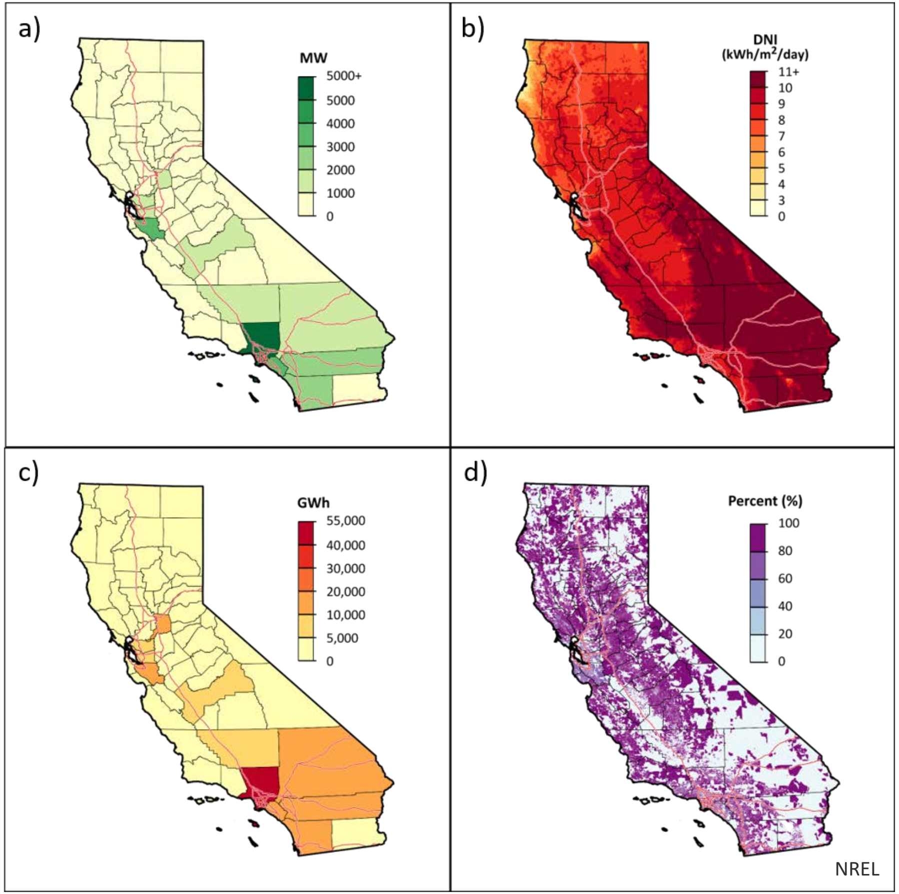
- A new methodology to calibrate and validate the model's predictive performance using a "backcasted" method of simulating adoption from 2008 – 2016
- A preliminary forecast of distributed solar generation:
  - Increased spatial resolution
  - Improved resolution of emerging segments, e.g. multi-family buildings
  - Incorporation of new TOU tariffs and other NEM 2.0 features

dGen Model Overview

Forecasts adoption of distributed solar, storage, wind, and geothermal by region and sector through 2050

Agent-Based Model simulating consumer decision-making

Incorporates spatial data to understand regional adoption trends



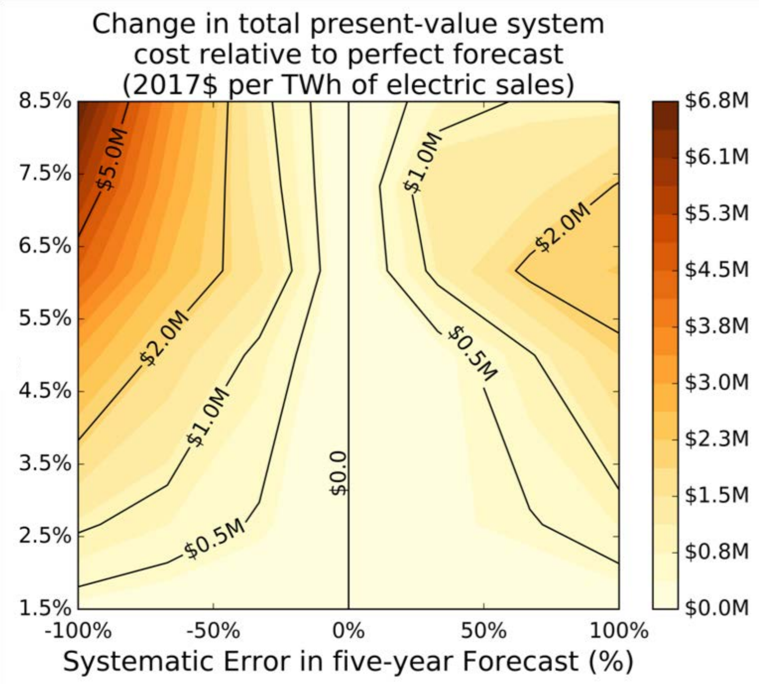
(a) Distributed solar economic potential (MW) in 2030 for the TOU Baseline scenario
(b) Solar resource;
(c) Annual electricity consumption
(d) Distributed solar siting availability.
Ramdas et al 2019

Learn More: https://www.nrel.gov/analysis/dgen/

How accurate are adoption forecast models?

Motivation

Increase in Energy Penetration of DPV by Year 15 (% of total generation)



The cost of misforecasting distributed generation resource varies greatly with the amount of error and actual DPV penetration level, but can be high.

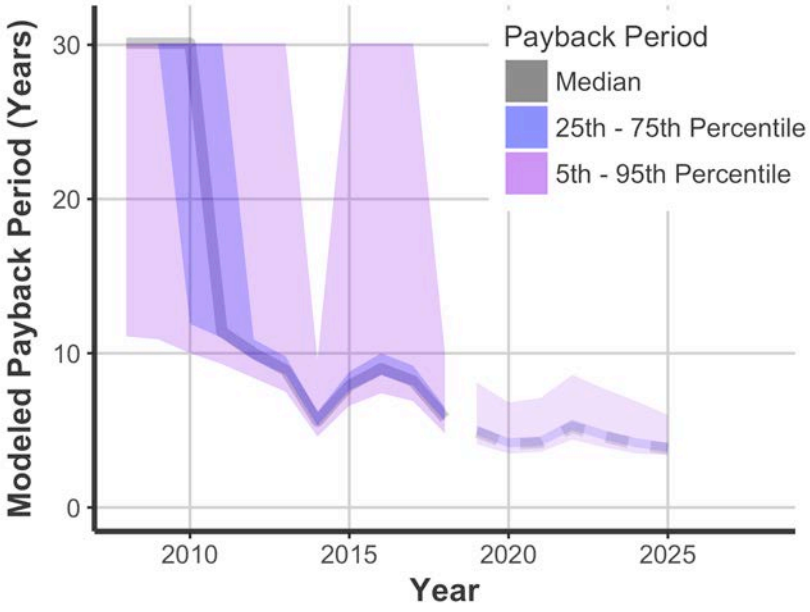
Extensive literature exists documenting *motivations and drivers* of DER adoption.

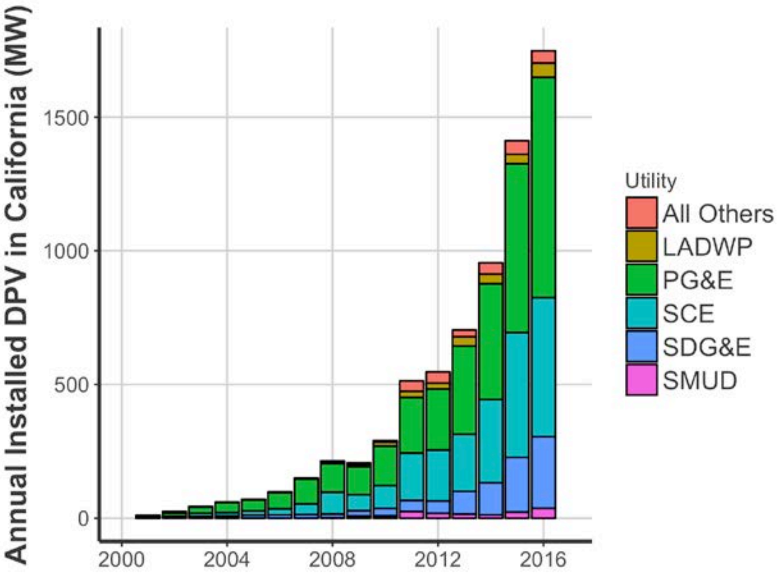
However these are largely oriented around explanation, not prediction. Of the prediction-based literature, most are not intended for large-area forecasts.

Source: Gagnon et al. (2018)

Methodology

We adapted dGen to simulate 2008 – 2030 using a bottoms-up modeling of historic PV costs, retail rates, incentives, number of consumers, and other factors. We use 2008 – 2014 as the calibration phase and 2015 – 2016 as the validation phase.

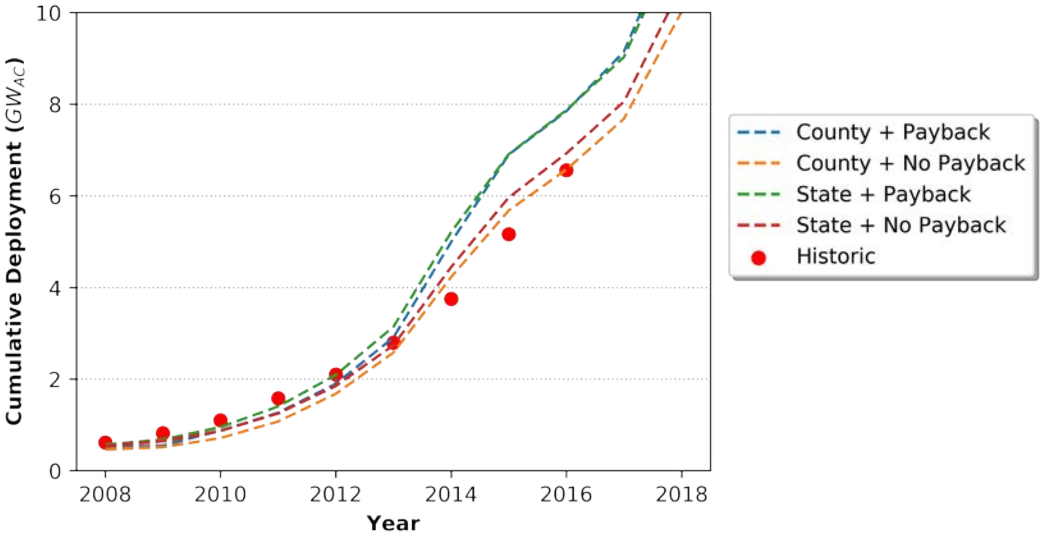




Calibration and Validation Results

dGen was calibrated with a suite of scenarios to better understand the effect of the geospatial resolution (county vs. state) and the influence of payback periods on the goodness of fit.

In general, the fit to historic adoption data is better when the influence of historic payback periods is ignored. The effect of geospatial resolution is minimal, though the best fit (by RMSE) is the "**County** + No Payback Influence" scenario.



	Normalized Root Mean Square Error
County + No Payback Influence	13.7%
State + No Payback Influence	15.2%
County + Payback Influence	31.2%
State + Payback Influence	32.7%

Adoption forecast

Scenarios Modeled

Suite of scenarios developed to show sensitivity of projected adoption to specific variables/conditions, including differing PV cost schedules, load and electricity rate growth scenarios, and Bass parameter calibration methods.

High and Low Demand scenarios developed to align with CEC scenarios.

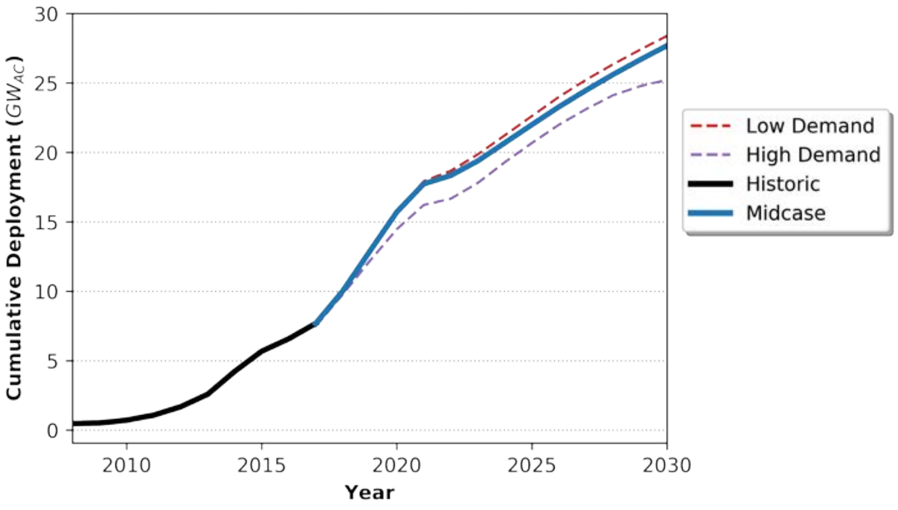
Scenario Name	Technology Costs	Economic/Demographic Growth	Retail/Wholesale Electricity Rates	Bass Calibration
Mid Case	ATB19[1] Mid Case	Mid growth case	ATB19 Mid Case	By county-sector
High Demand	ATB19 Mid Case	High growth case → high growth in building stock	ATB19 Low PV	By county-sector
Low Demand	ATB19 Mid Case	Low growth case → low growth in building stock	ATB19 High PV	By county-sector
High PV	ATB19 High PV Costs	Mid growth case	ATB19 High PV	By county-sector
Low PV	ATB19 Low PV Costs	Mid growth case	ATB19 Low PV	By county-sector

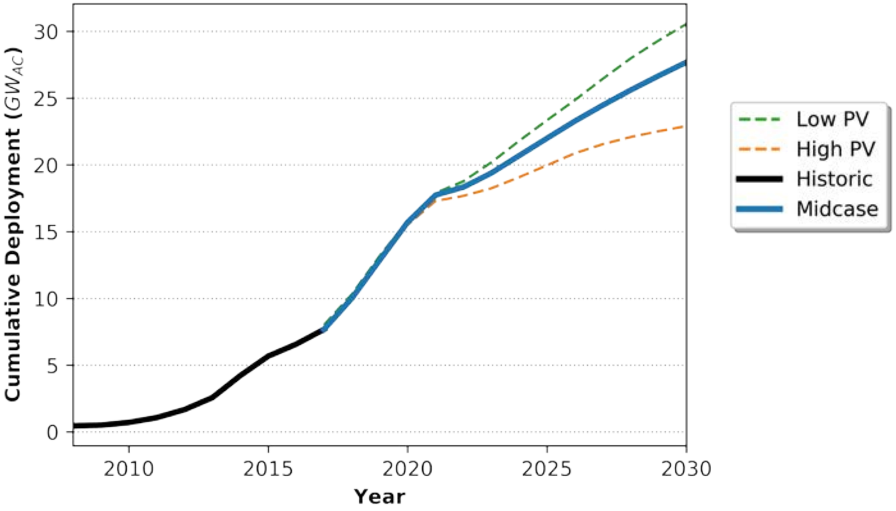
[1]Annual Technology Baseline (ATB): https://atb.nrel.gov/

Adoption Forecast
Sensitivity to Demand and PV Prices

The sensitivity of adoption projection to demand scenario is modest. The range between High and Low Demand adoption totals is only 3.1 GW_{AC} (2030). The influence of electricity rate growth is greater than that of the load growth in each Demand scenario.

Despite a relatively mature solar market in California, PV prices still have a demonstrable effect on projected adoption, with a range between the High and Low PV scenarios of 7.6 GW_{AC} (2030). Though the PV installation costs are quite different in the High PV scenario ($3/$W_{DC}$ in 2030) compared to the Low PV scenario ($0.5/$W_{DC}$ in 2030).

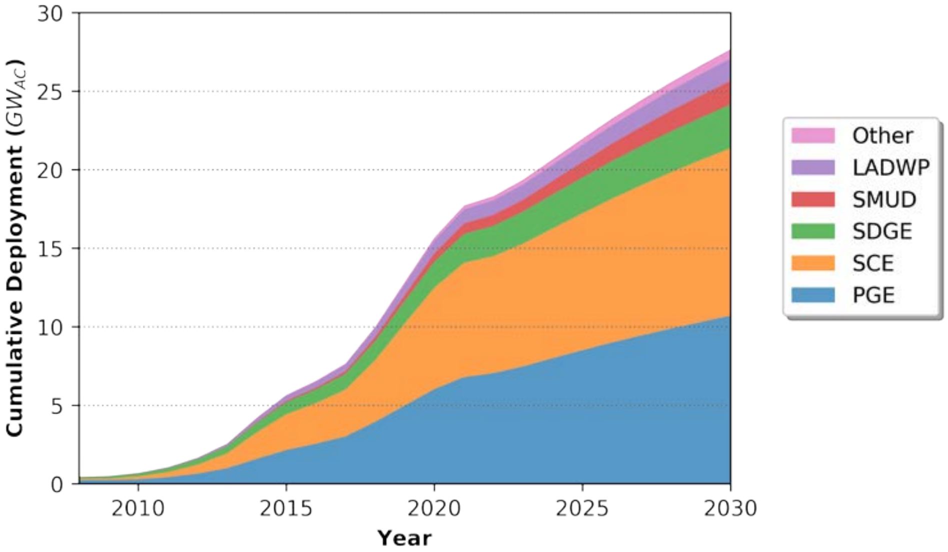




Adoption Forecast by Planning Area

The adoption total estimates demonstrate that the major IOUs will continue to lead the way, with the PG&E and SCE planning areas each projected to see approximately 10.7 GW_{AC} of cumulative adoption by 2030.

The discrepancies by planning area are reflective of the number of customers in each region, though economics at the granular level are favorable for full-retail NEM utilities.



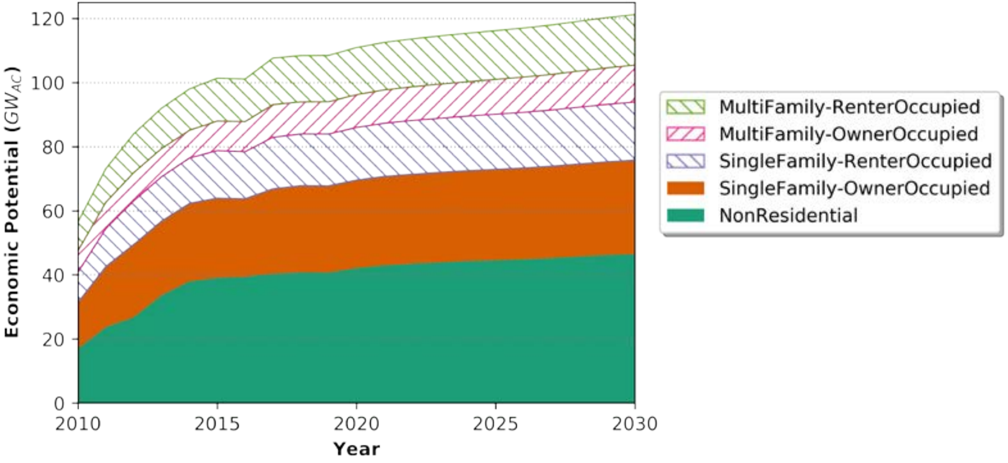
	PGE	SCE	SDGE	SMUD	LADWP	Other
Midcase	10.7	10.7	2.8	1.5	1.4	0.6
Low Demand	11.0	10.9	2.8	1.6	1.4	0.6
High Demand	9.9	9.7	2.6	1.3	1.3	0.5

Units: GW_{AC}
All estimates for 2030

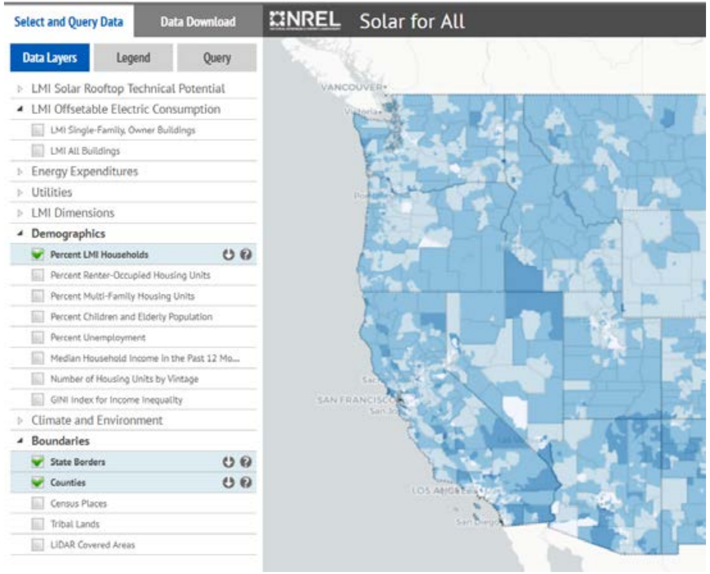
Adoption Forecast in Emerging Markets

New datasets have enabled preliminary analysis of emerging markets in California. The non-single-family/owner-occupied market demonstrates strong potential, though analysis limitations still exist in accurately evaluating the nuances of multi-family and/or renter-adopted systems.

Economic potential is defined as the amount of PV capacity that exceeds a given rate of return (i.e., positive net present value). The non-traditional market segments add an estimated **45 GW** of potential statewide in 2030.



Rooftop Energy Potential of Low Income Communities in America (REPLICA) – Tract-level solar technical potential by income, tenure, and building type, joined with 10 additional datasets to provide socio-demographic and market context (e.g. energy expenditures, demographics, etc.). https://data.nrel.gov/submissions/81



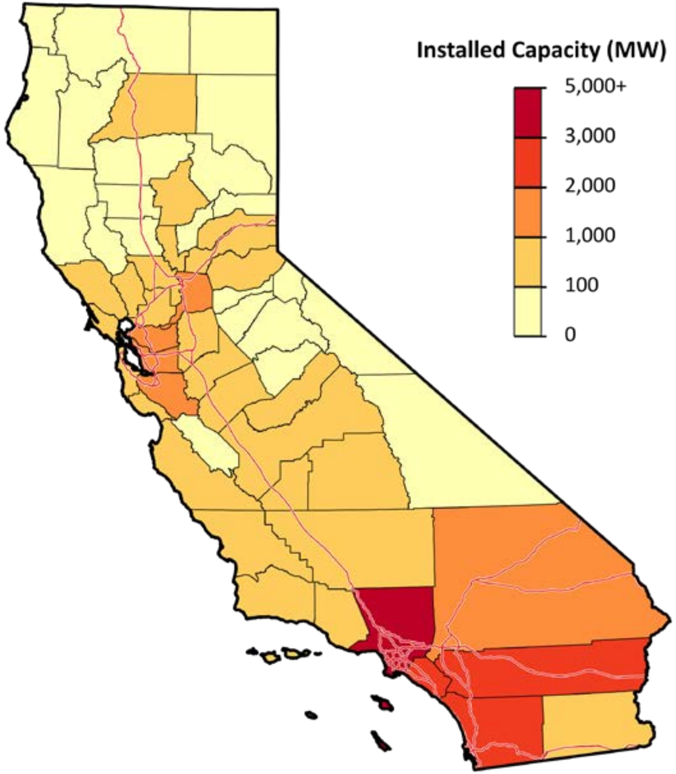
Source: Sigrin and Mooney (2018)

Geospatial Trends of Adoption

Geographical trends in the **Midcase** scenario (2030) demonstrate trends that follow strong solar resource and areas of high load.

Top 5 counties by installed capacity:

Los Angeles – 5.3 GW
San Diego – 2.8 GW
Riverside – 2.4 GW
Orange – 2.4 GW
San Bernardino – 1.5 GW



Conclusions

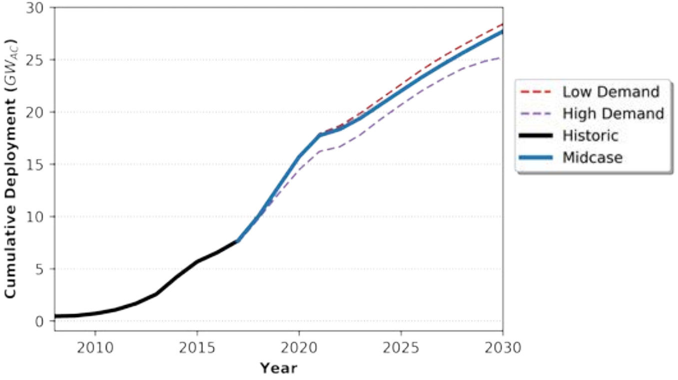
New effort to **calibrate and validate** the dGen model has elucidated the major influences on the goodness of fit to historic data.

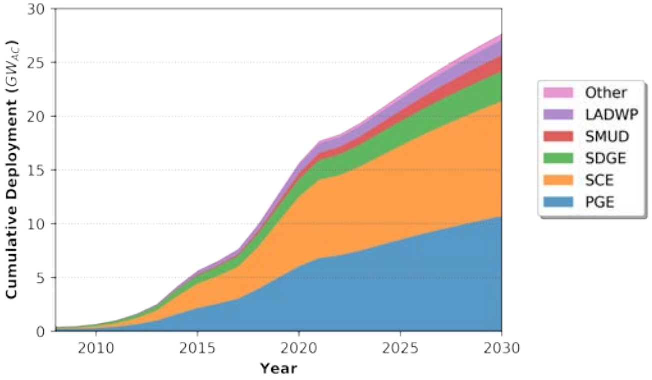
- **Historic payback periods** do not aid the current calibration process in improving the fit.
- Adoption totals at the **county-level** (without payback period influence) resulted in a marginally more accurate fit than using **state-level** data.

The various forecast scenarios demonstrate a **modest sensitivity of adoption to demand** (i.e., load and electricity rate growth) and a **more acute sensitivity to PV prices**.

By planning area, the **major IOUs are projected to lead adoption** through 2030.

Emerging markets (e.g., non-single-family/owner-occupied residential buildings) **show promise**, though further data and analysis tools are necessary for more accurate modeling.





Questions?

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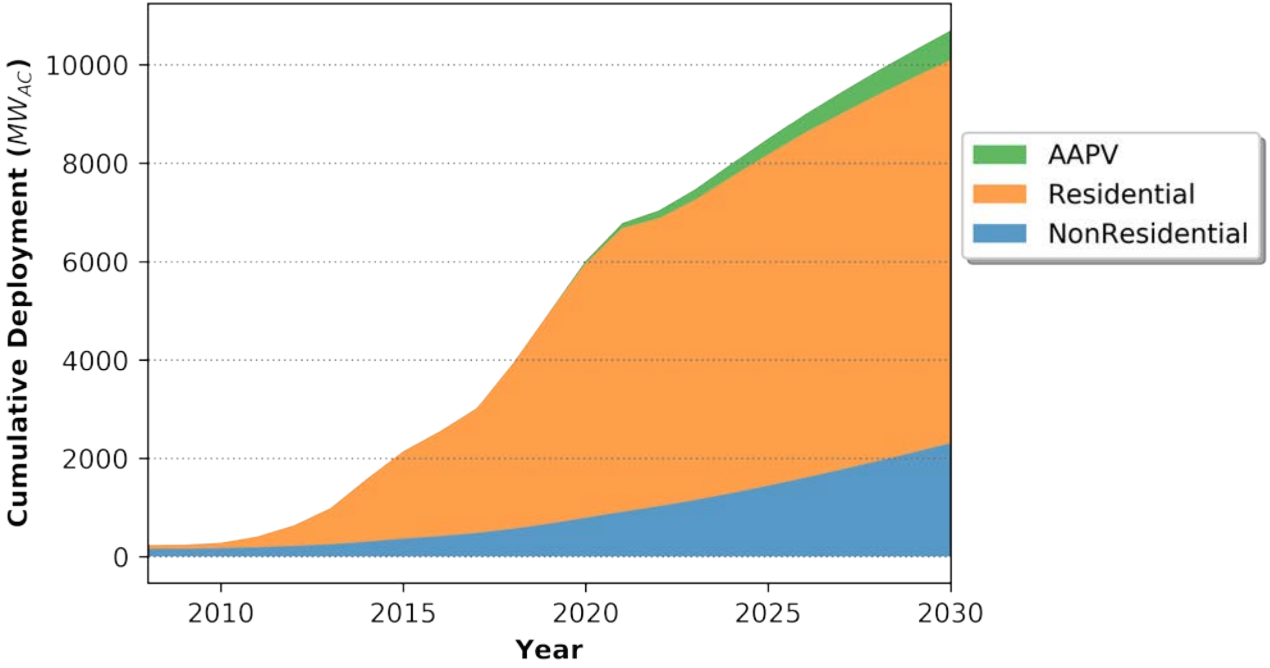
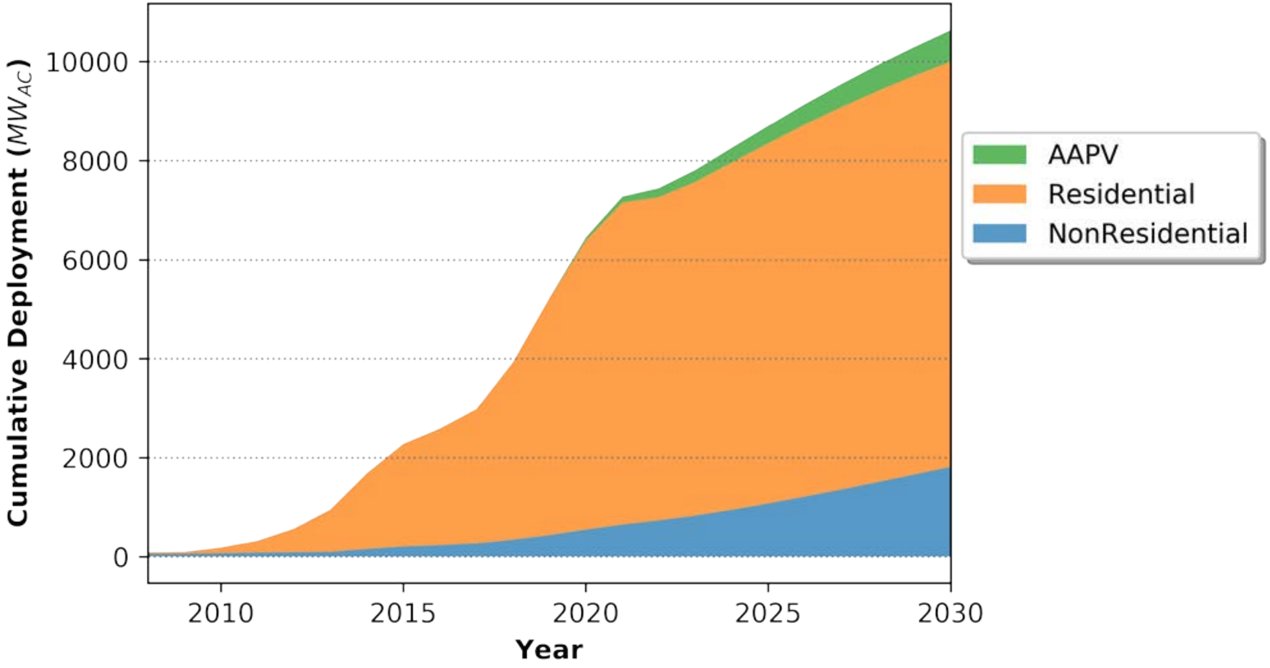
Appendix

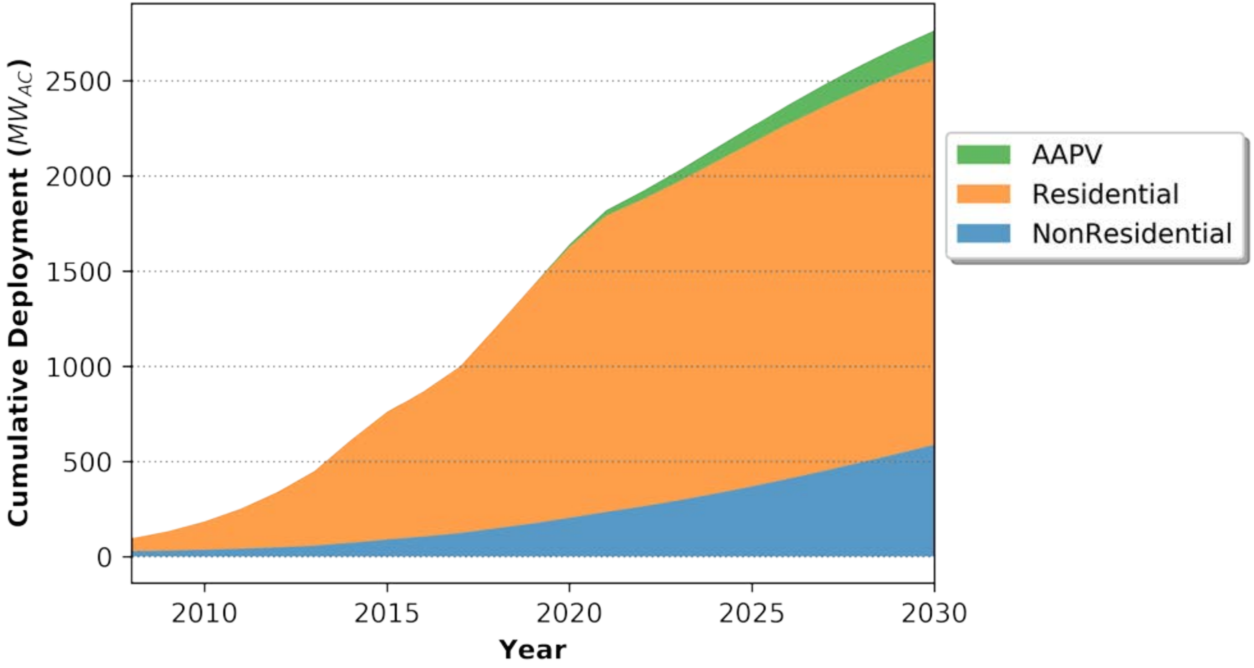
PGE Forecast by Sector – Midcase



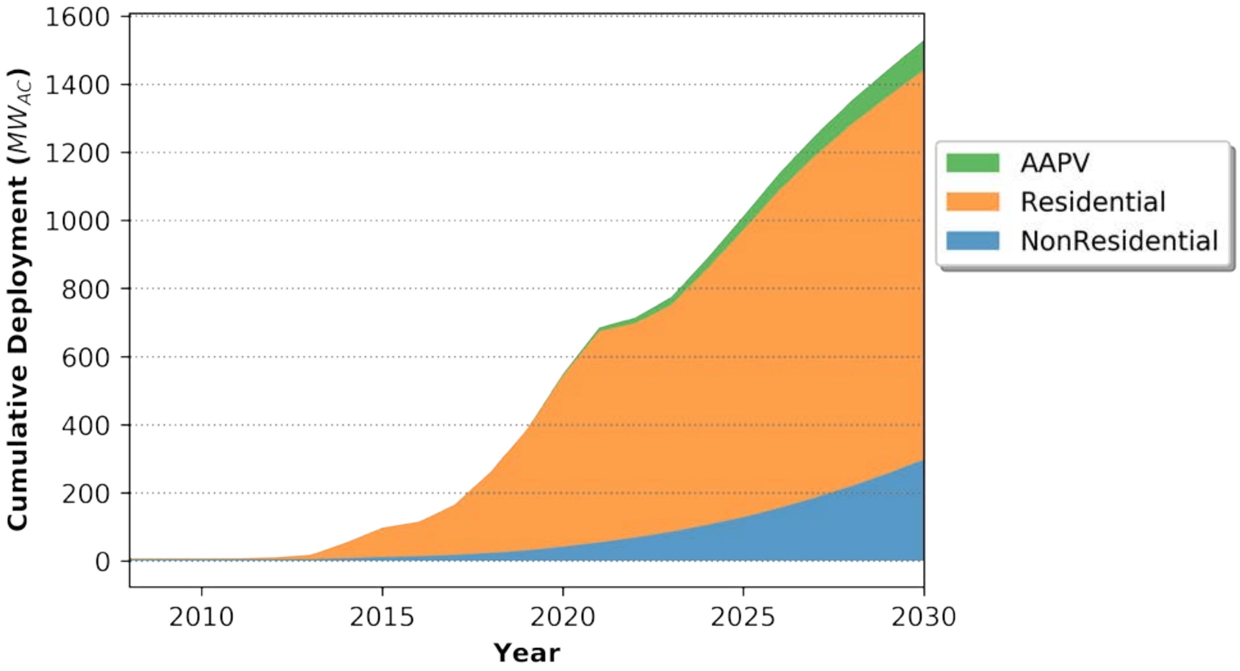
SCE Forecast by Sector – Midcase



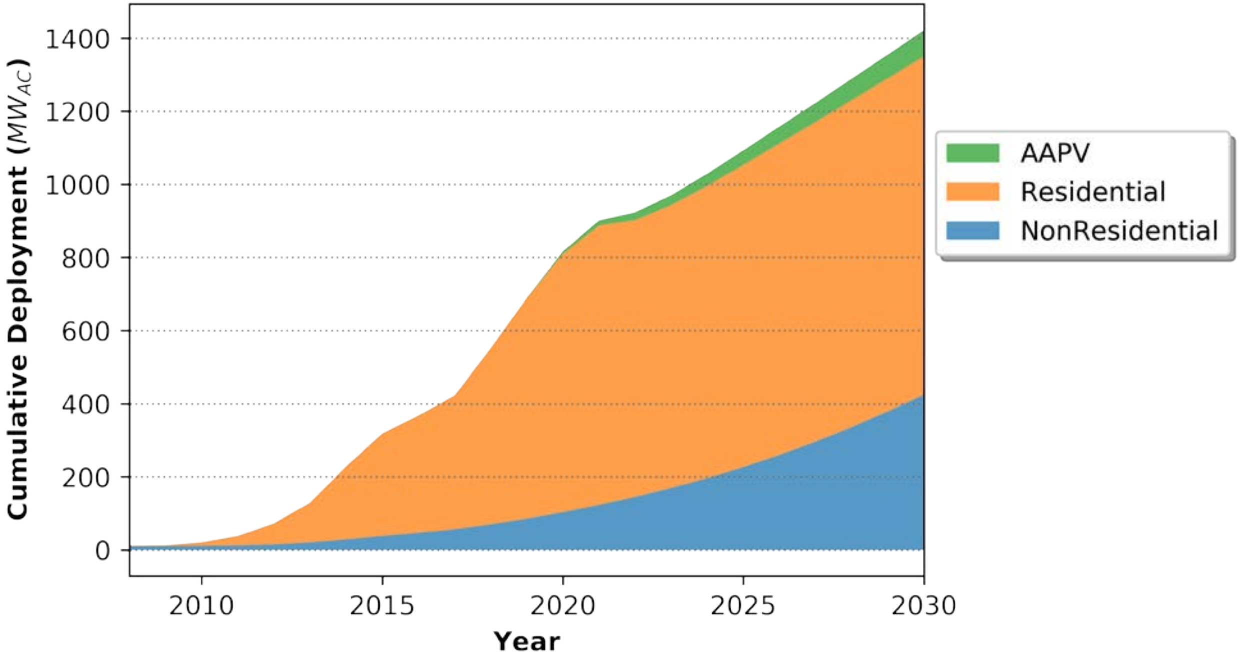
SDGE Forecast by Sector – Midcase



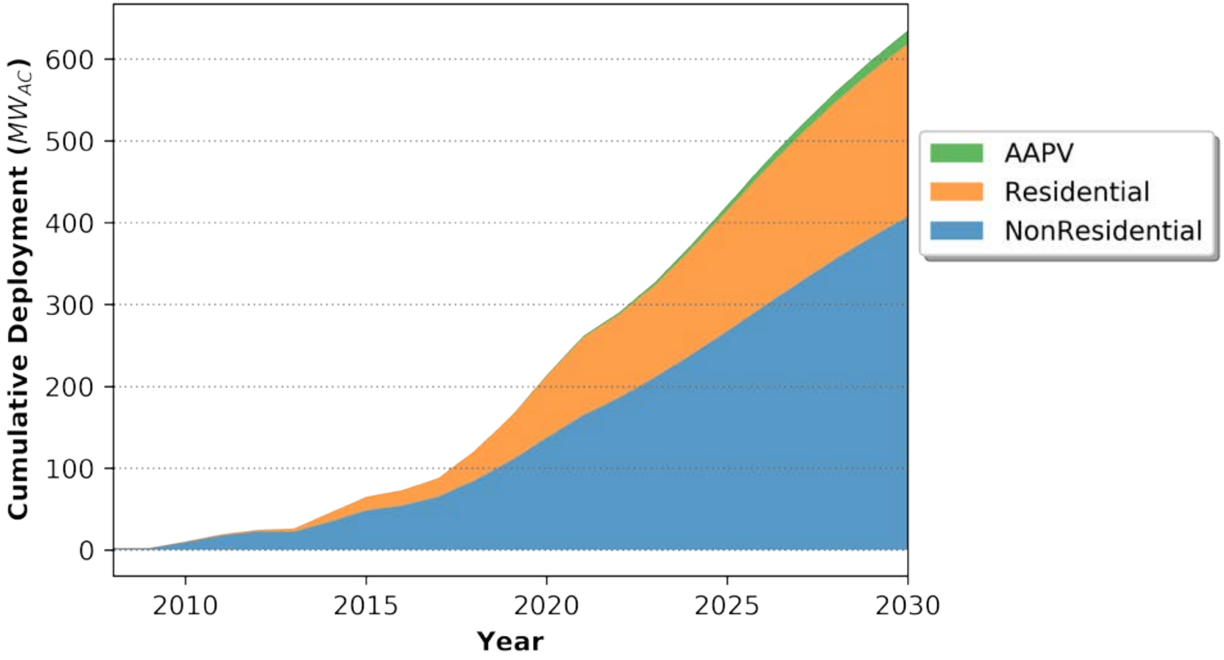
SMUD Forecast by Sector – Midcase



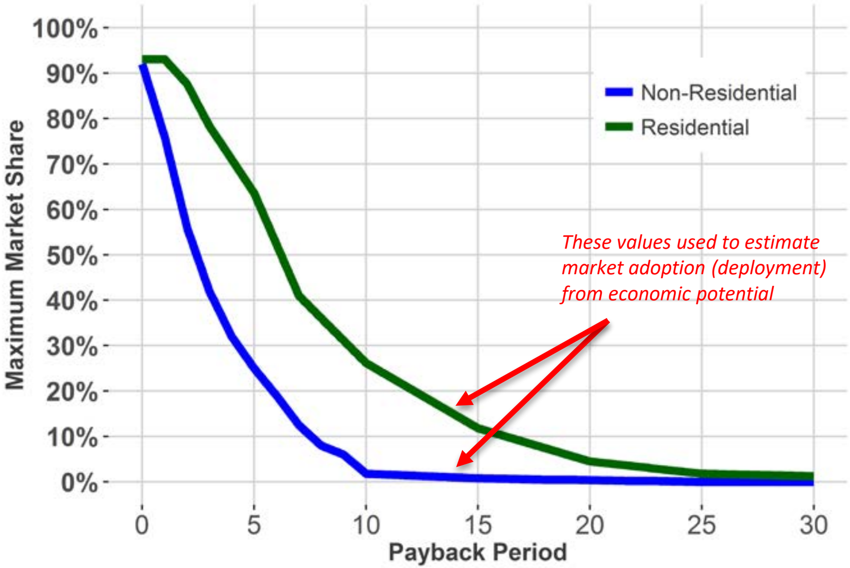
LADWP Forecast by Sector – Midcase

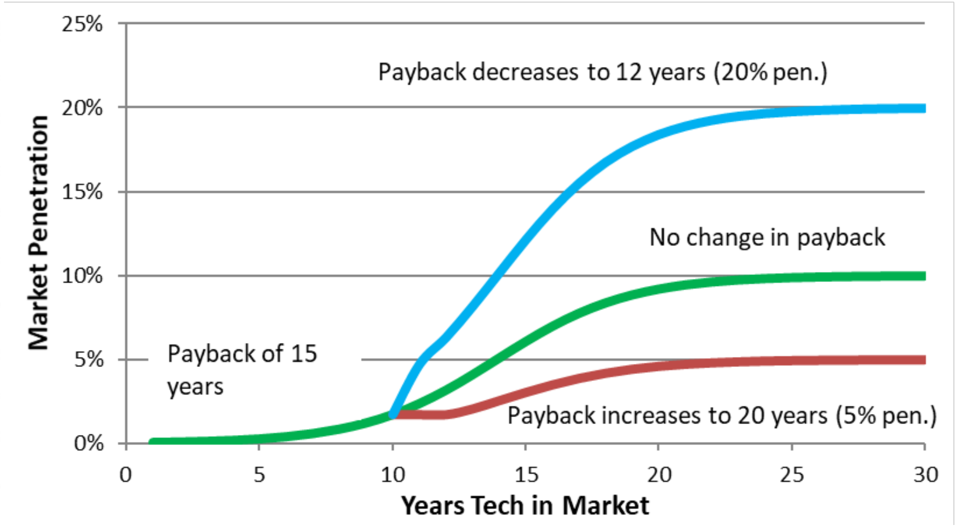


Other Planning Areas Forecast by Sector – Midcase



Modeling Solar Adoption

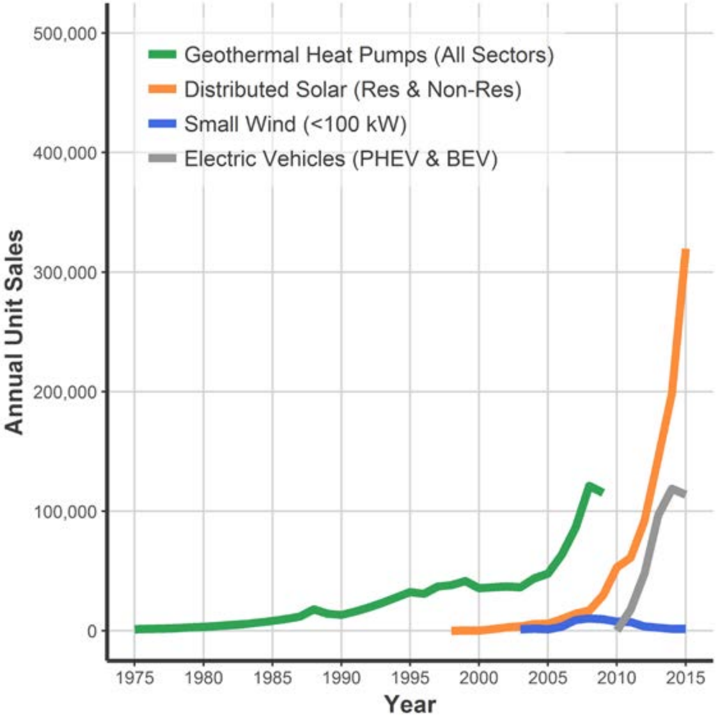


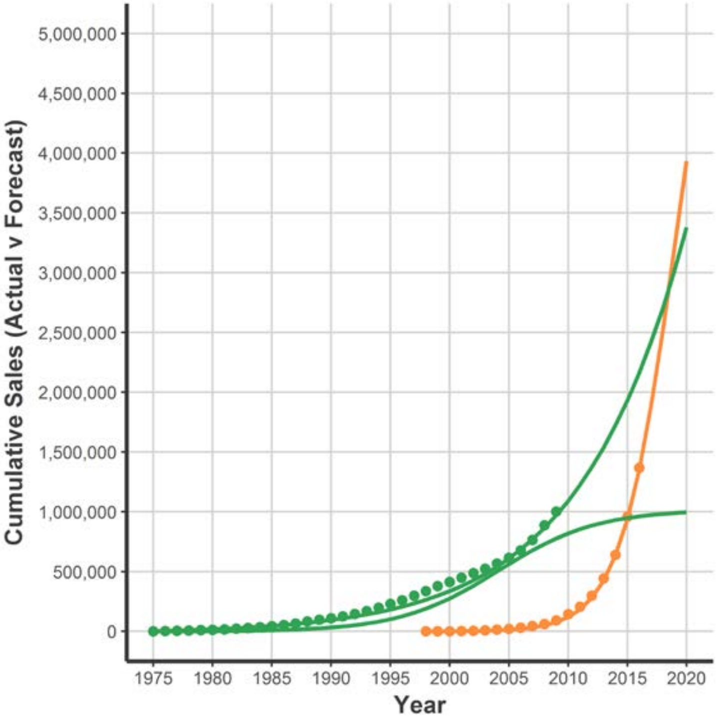


Using consumer surveys, relate the system payback to the fraction of consumers that would adopt solar. Also note that a 5.4% WACC corresponds to a payback of 14 years.

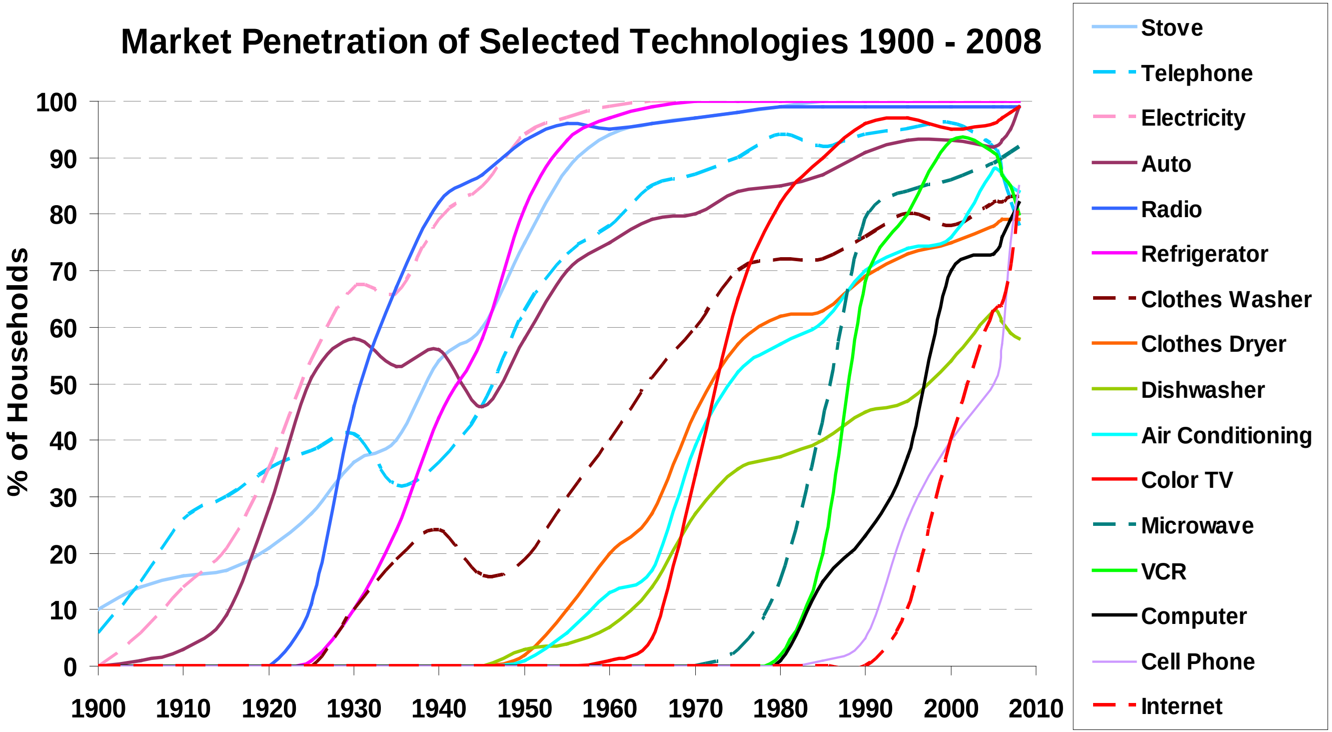
Use the Bass Diffusion model to simulate adoption over time, using the “Maximum Market Share” as the terminal adoption level

Historical Trends of Distributed Generation Technologies

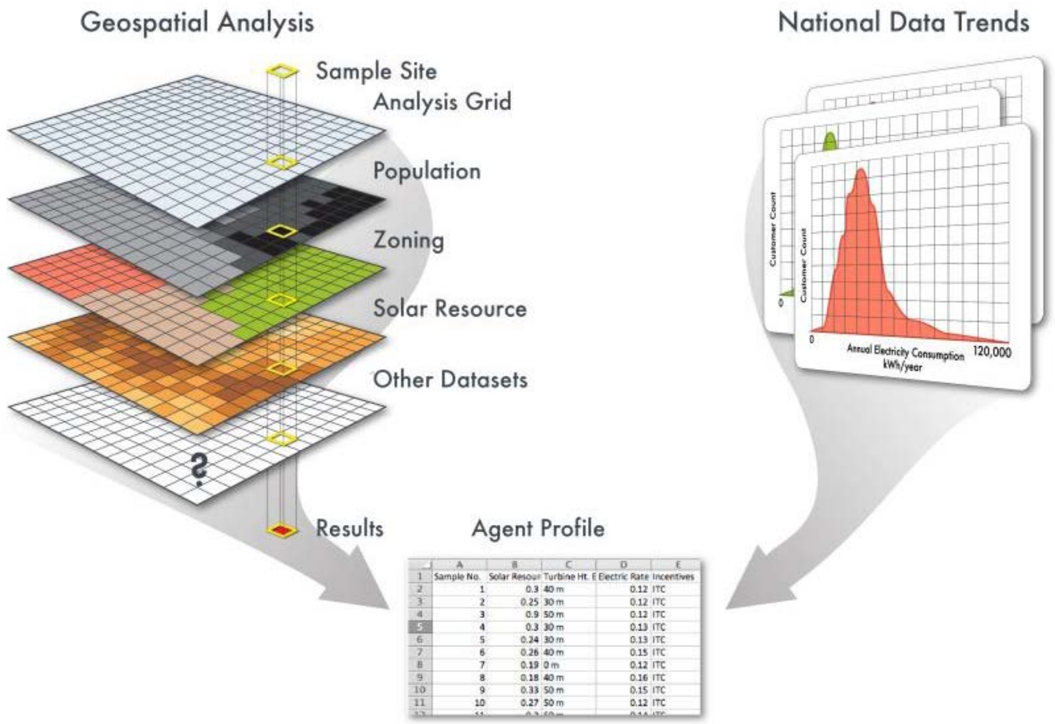




Simulating Technology Adoption/Deployment



dGen Model Overview



	A	B	C	D	E
1	Sample No.	Solar Resour	Turbine Ht. E	Electric Rate	Incentives
2	1	0.3	40 m	0.12	ITC
3	2	0.25	30 m	0.12	ITC
4	3	0.9	50 m	0.12	ITC
5	4	0.3	30 m	0.13	ITC
6	5	0.24	30 m	0.13	ITC
7	6	0.26	40 m	0.15	ITC
8	7	0.19	0 m	0.12	ITC
9	8	0.18	40 m	0.16	ITC
10	9	0.33	50 m	0.15	ITC
11	10	0.27	50 m	0.12	ITC

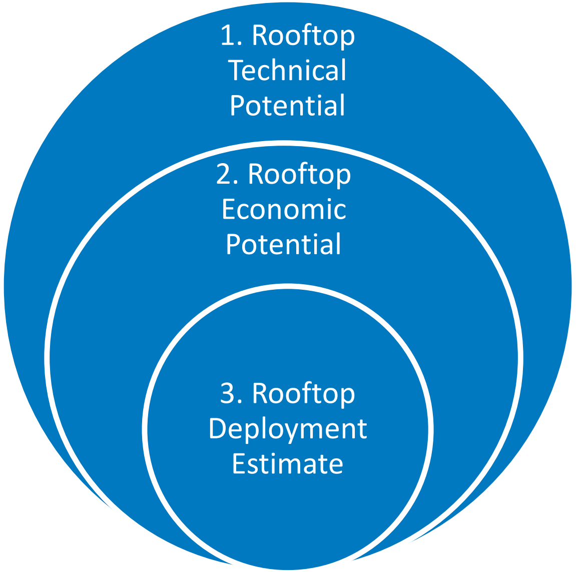
Agent characteristics derived from population-weighted sampling to create a comprehensive and representative database of the analysis population

- Forecasts adoption of distributed solar, storage, wind, and geothermal by sector and county through 2050
- Agent-Based Model simulating consumer decision-making
- Incorporates detailed spatial data to understand geographic variation

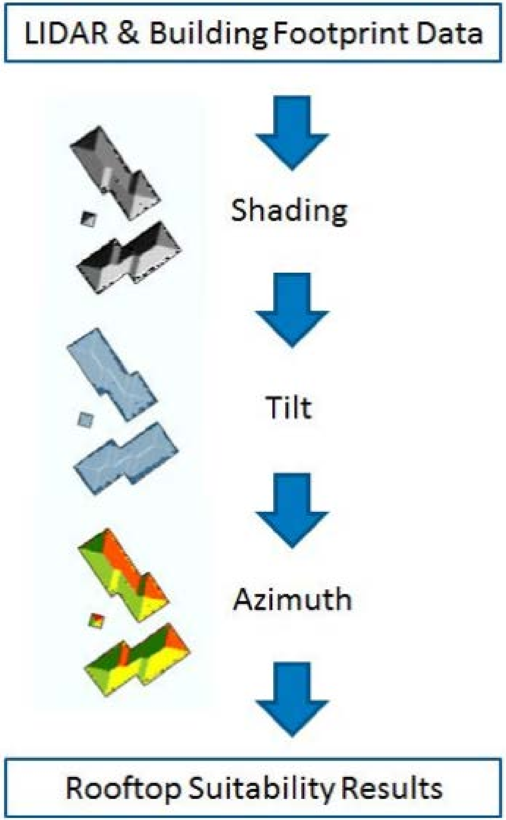
Methodological Steps

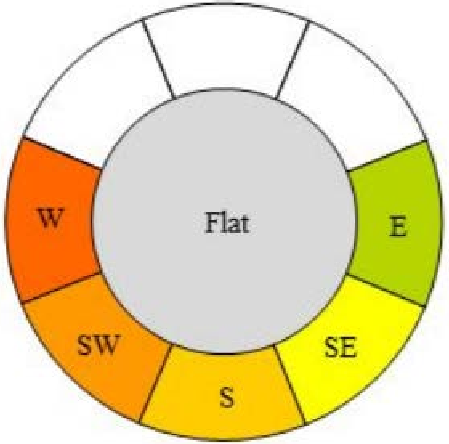
Three primary steps to estimate Florida distributed energy resource solar deployment

1. Estimate total rooftop solar potential for all Florida counties based on analysis of rooftops using LIDAR data
2. Estimate rooftop solar economic potential that meets or exceeds economic return threshold of 5.4% Weighted Average Cost of Capital (WACC)—equivalent to a ~14 year payback
   – Three scenarios tested representing different PV cost projections
3. Estimate total rooftop solar deployment by applying market diffusion estimates (i.e., not all sites with economic potential will be deployed)



Assessing Rooftop Solar Technical Potential





Clockwise:

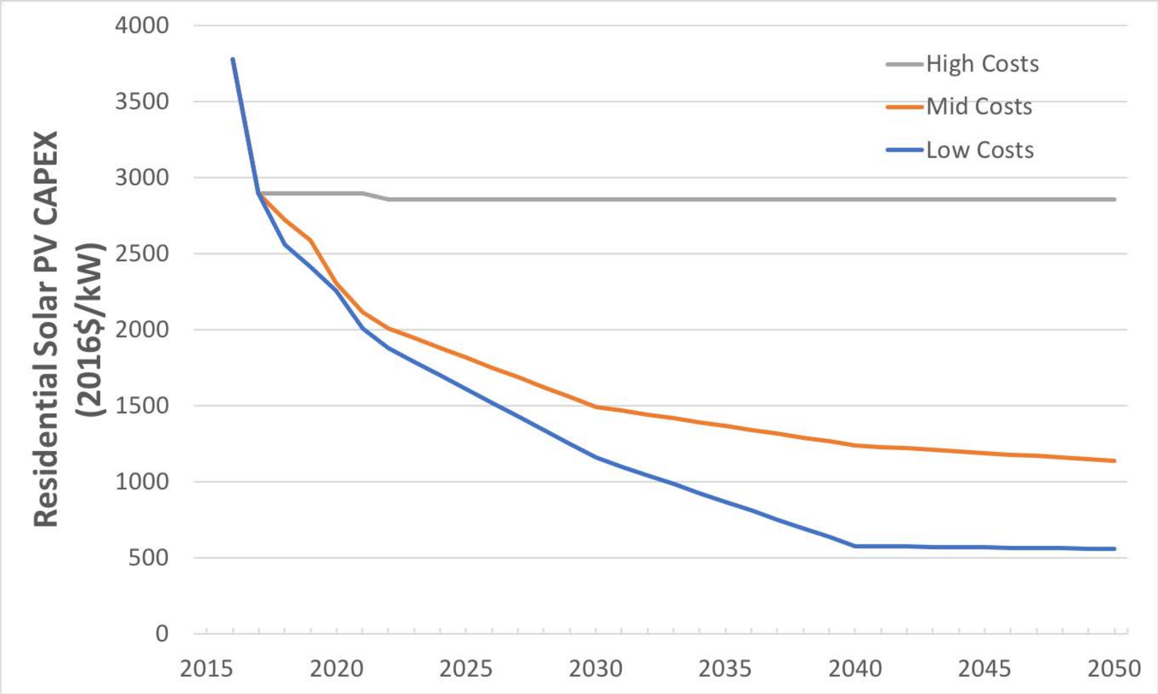
(1) Raw LIDAR imagery of buildings

(2) Developable area estimated for each building in dataset, then aggregated at regional level

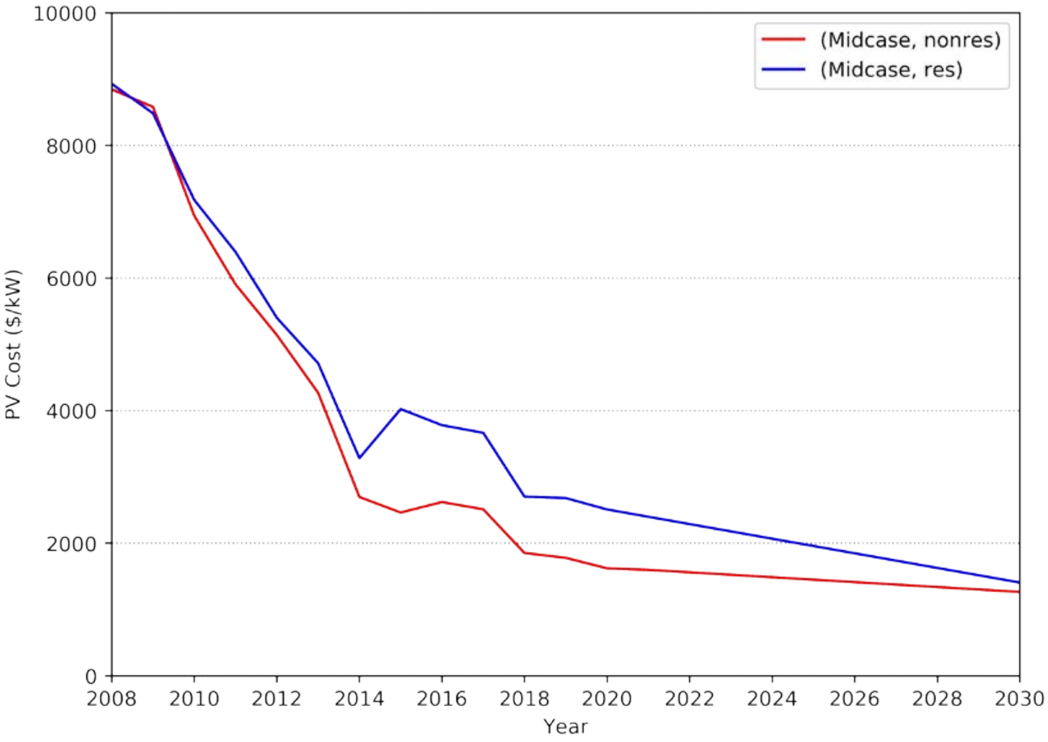
(3) Suitability based on roof plane orientations, tilt, size, and shading

Gagnon, P. et al. (2016). *Rooftop Solar Photovoltaic Technical Potential in the United States. A Detailed Assessment.* NREL/TP--6A20-65298.

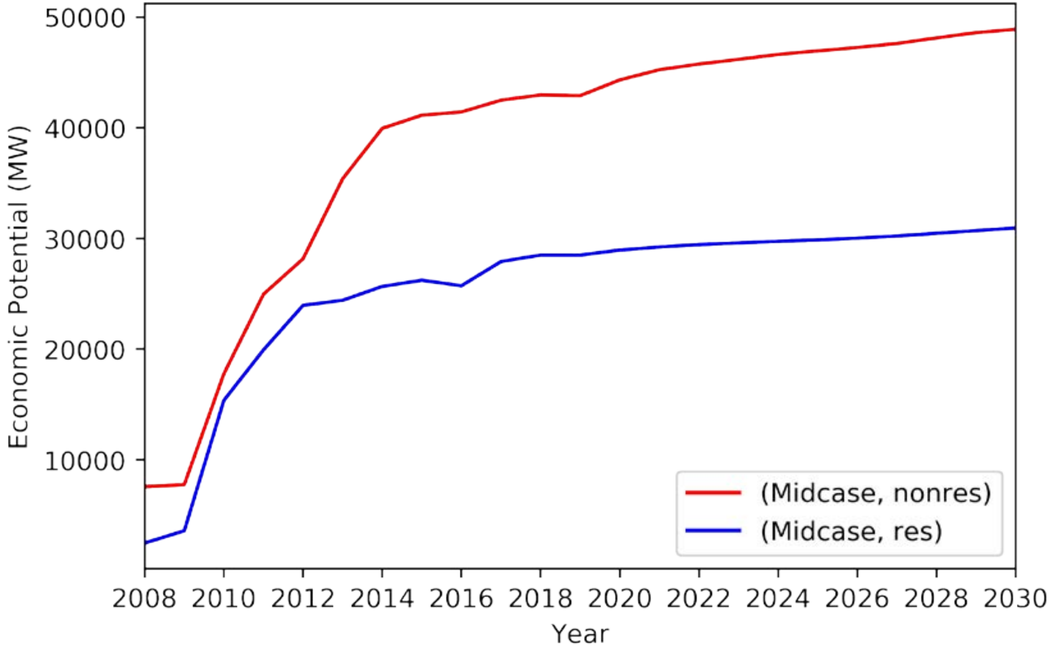
PV Cost Schedules



PV Cost Schedules – With Historic Values



Midcase Economic Potential



Economic Potential by Scenario