Distributed PV + Behind-the-meter Storage Modeling Overview using dGen™

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Importance of Including Distributed Energy Resources in Load Forecasts

Context:

- Analysts project that distributed solar photovoltaics (DPV) will continue growing rapidly.
- 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.

Importance:

- 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).

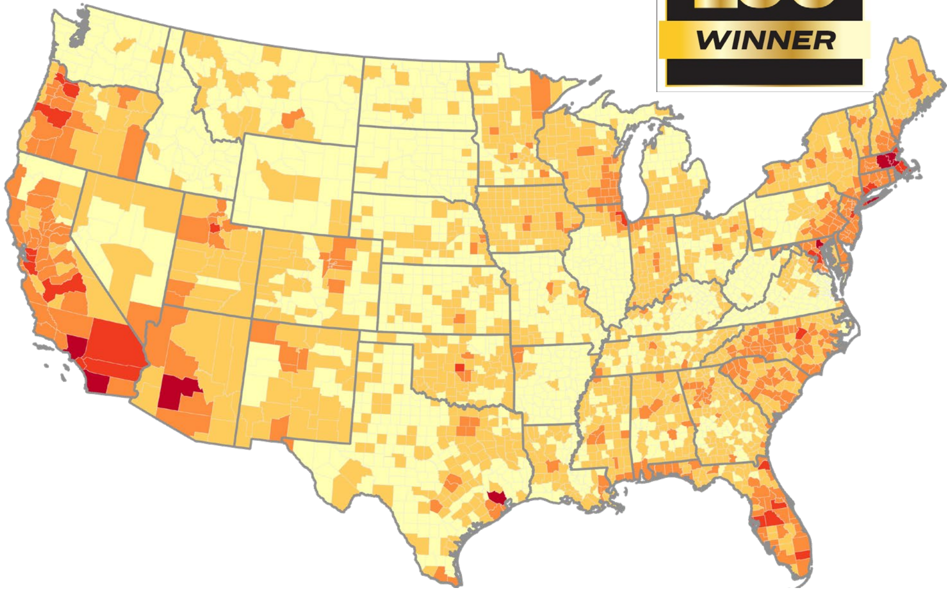
Motivations for DER Adoption

- Most consumers are primarily motivated by savings on utility bills
  - Modeling prices and policies is important
- Consumers are influenced by spatial and social "peer effects"
  - Motivates spatially-granular modeling
- Many of the variables that predict adoption decisions are non-demographic, e.g. pro-environmental norms, innovativeness, social support

Forecasting Distributed Energy Resources: NREL's dGen™ Model

2021 R&D 100 WINNER

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



Source: Cole, Wesley, Will Frazier, Paul Donohoo-Vallett, Trieu Mai, and Paritosh Das. 2018 Standard Scenarios Report: A U.S. Electricity Sector Outlook https://www.nrel.gov/docs/fy19osti/71913.pdf

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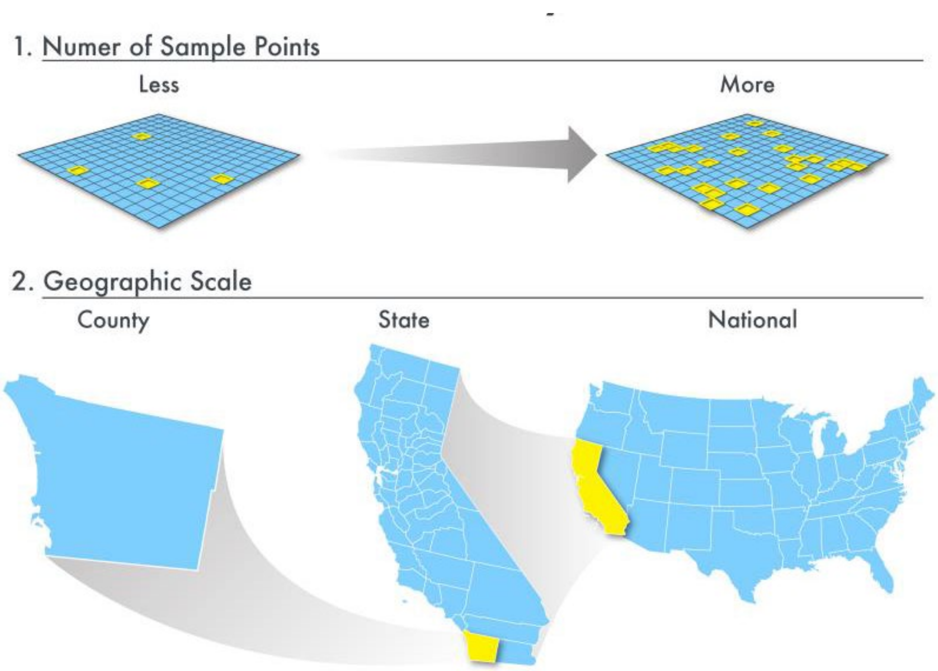
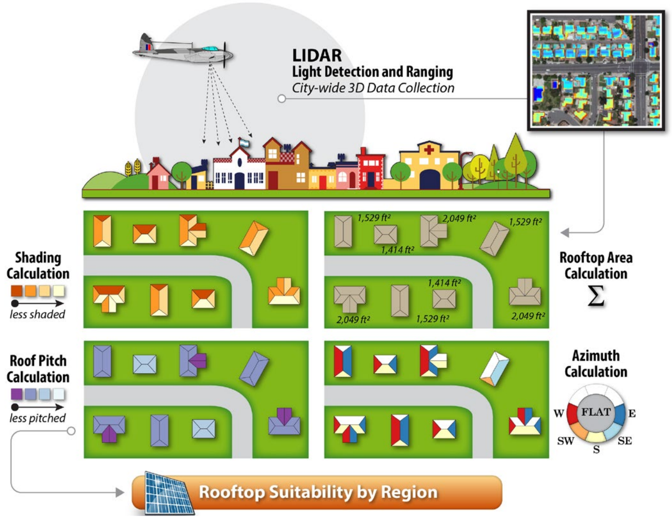
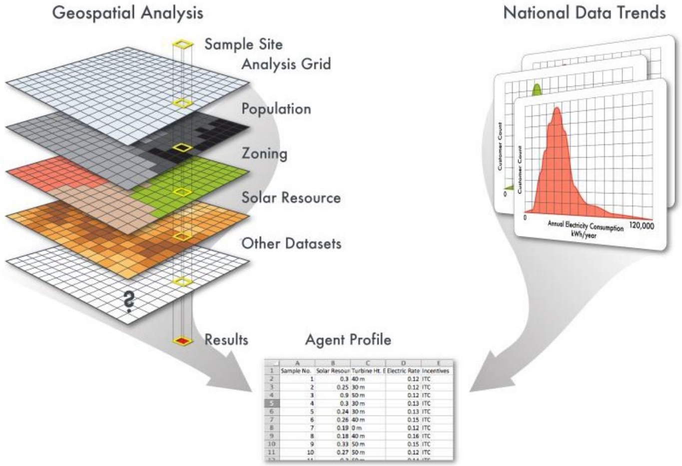
Used in several key analysis: Solar Futures Study, Storage Futures Study, Distributed Wind Energy Futures Study, LA100, PR100, LA100-Equity Strategies.

Agent-Based Consumer Level Understanding of DERs







Spatial Data Matters In Forecasting Technology Adoption

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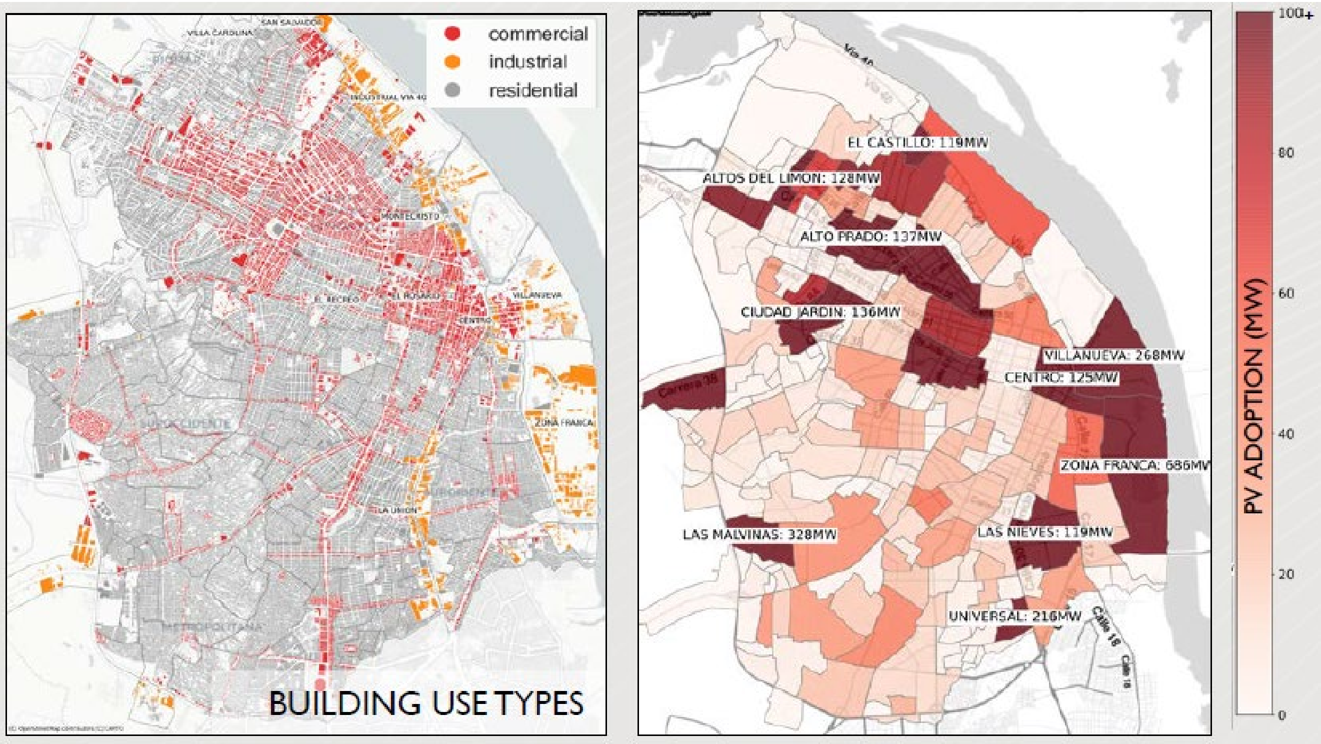
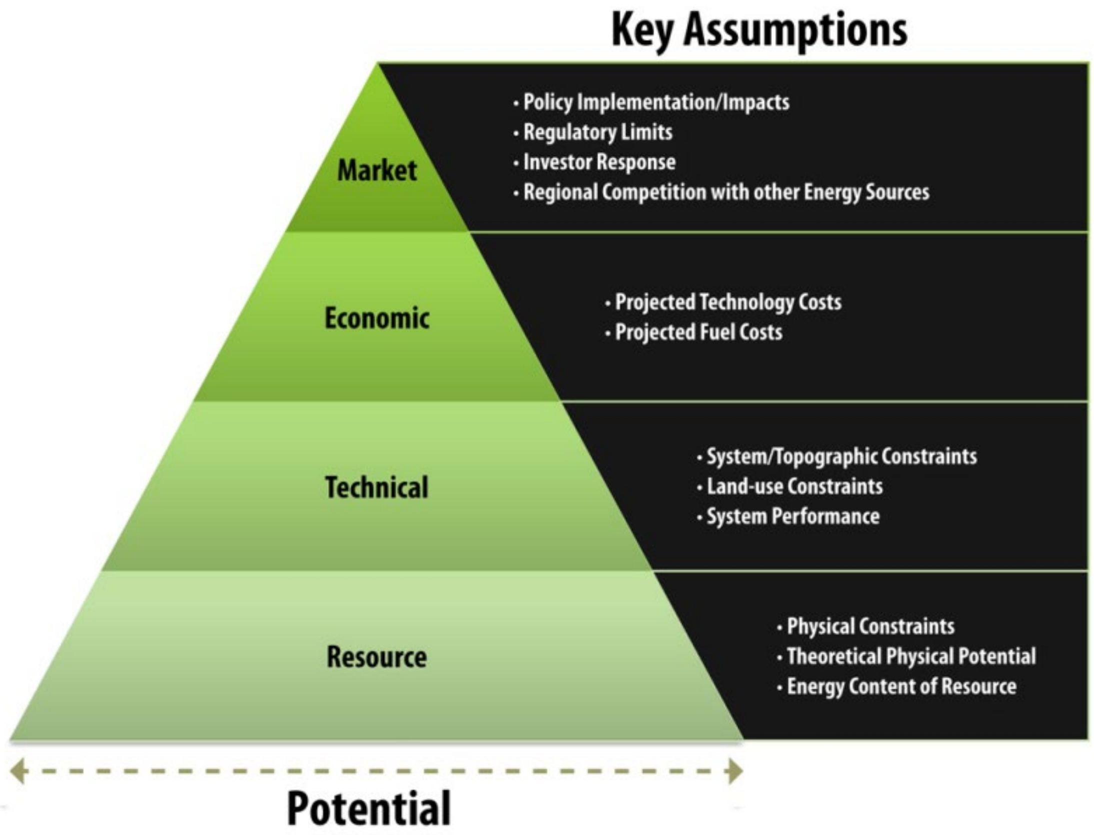
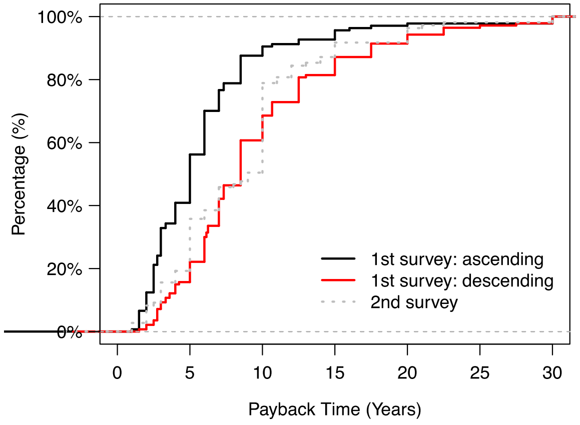
- dGen™ uses **household-level data** to instantiate consumers (agents)
- Attributes can include **building suitability** or **location** on the distribution system
- **Agents** can be **individual or statistical**
- This level of spatial resolution is crucial for **distribution system modeling**



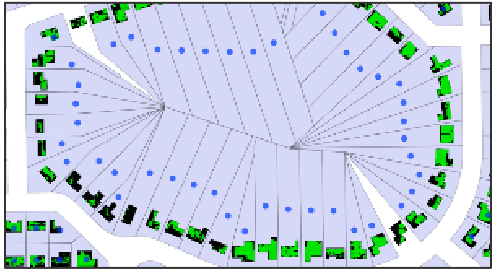
Framework for Modeling DER Adoption



Behavior and Decision-Making



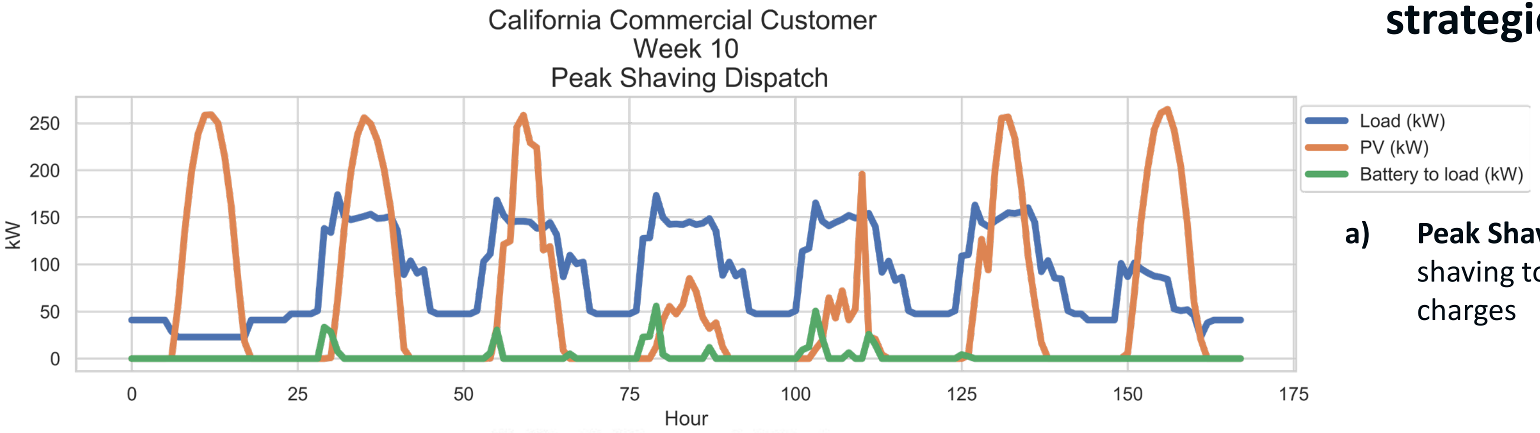
	Yes	Maybe	No	I don't know
I would seriously consider solar if the payback time was 1 year or less	○	○	○	○
I would seriously consider solar if the payback time was 2 years	○	○	○	○
I would seriously consider solar if the payback time was 3 years	○	○	○	○
I would seriously consider solar if the payback time was 5 years	○	○	○	○
I would seriously consider solar if the payback time was 7 years	○	○	○	○
I would seriously consider solar if the payback time was 10 years	○	○	○	○
I would seriously consider solar if the payback time was 15 year	○	○	○	○
I would seriously consider solar if the payback time was 20 years	○	○	○	○
I would seriously consider solar if the payback time was 25 years	○	○	○	○
I would seriously consider solar if the payback time was 30 years	○	○	○	○

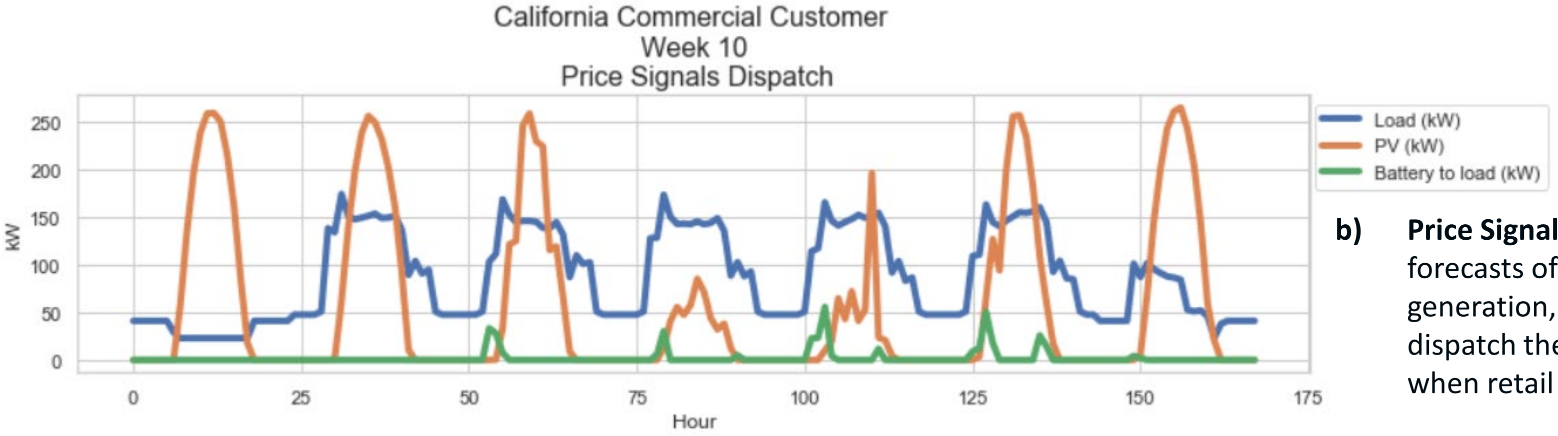


Agent decision-making (e.g., price needed to adopt) is calibrated through surveys and program data (top). It uses location-based attributes (e.g., building size, proximity to other adopters) to represent population heterogeneity (left)

- The dGen model simulates bottoms-up consumer decision-making, allowing a rich representation of
  - ➢ heterogenous population
  - ➢ behavioral drivers of energy actions
- The simulated decisions are calibrated to many data sources, but are also designed to be flexible as needed by the consumer

Storage Dispatch Strategies

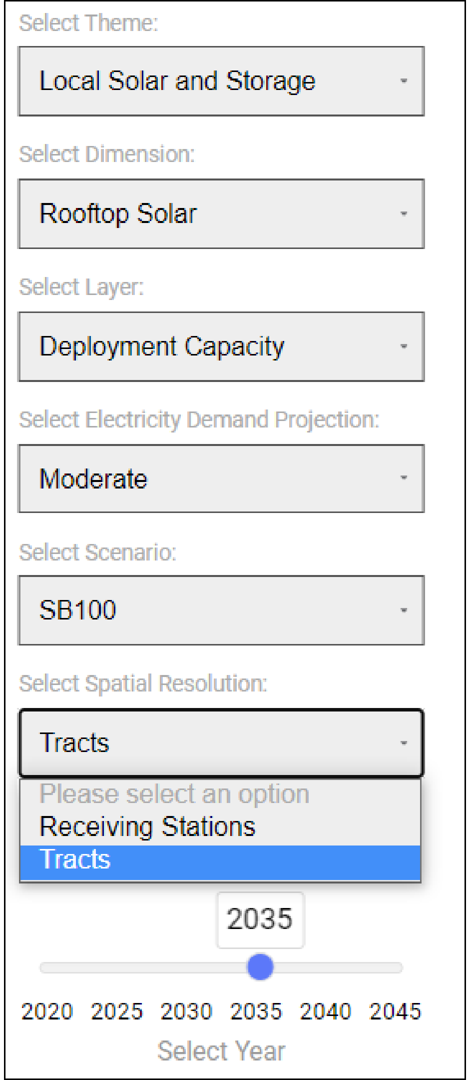




Model uses the following storage dispatch strategies:

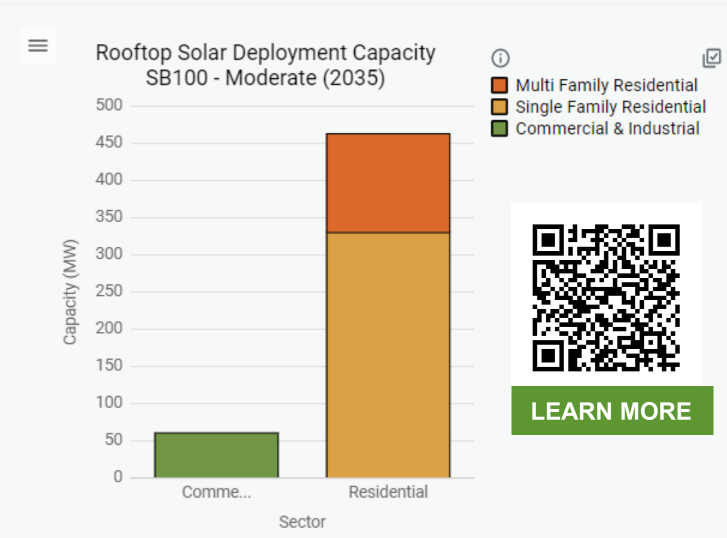
a) **Peak Shaving Strategy**: Peak shaving to reduce demand charges

b) **Price Signals Strategy:** Combines forecasts of day-ahead load generation, and the utility rates to dispatch the battery in the hours when retail rates are high

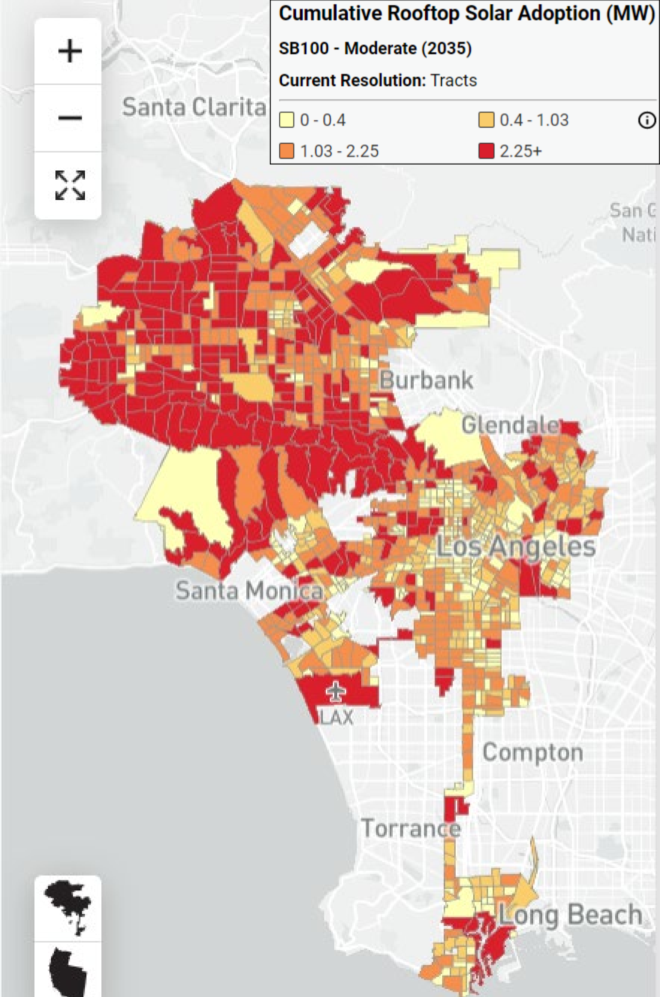


LA100

The Los Angeles 100% Renewable Energy Study

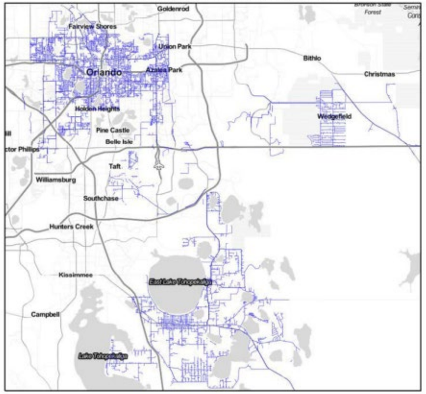


Source: LA100: The Los Angeles 100% Renewable Energy Study.
Data Viewer: https://maps.nrel.gov/la100/data-viewer

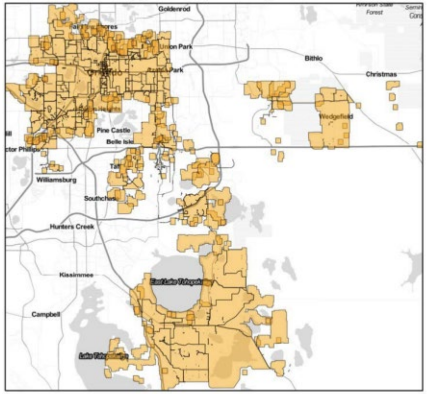


dGen^{TM}: Orlando Utilities Commission (OUC)

Feeder Lines Provided by OUC



Polygons Imputed by NREL



Adoption by Top 20 Feeders (MW)				
Feeder ID[1]	2020	2030	2040	2050
A	1.7	16.5	21.4	23.2
B	1.2	15.7	20.6	22.3
C	0.9	11.7	15.6	17.1
D	0.4	6.2	10.1	16.5
E	0.9	9.4	13.7	15.5
F	0.6	8.7	13	15.3
G	1.4	9.4	12.8	14.5
H	0.8	8	12	12.6
I	0.8	7.7	10.5	12
J	0.7	6.3	8.7	10.8
K	0.6	5.9	8.1	9
L	0.5	5.9	8.2	8.8
M	0.9	5.7	8	8.8
N	0.4	6.4	8.1	8.6
O	0.7	5.6	8.1	8.6
P	0.5	5.9	8	8.3
Q	0.4	5.8	7.6	7.9
R	0.2	4.5	6.6	7.9
S	0.2	4.4	6.5	7.8
T	0.4	4.8	6.8	7.7

Distribution-level DER modeling seeks to understand DER adoption patterns either at the individual or substation-level to inform distribution planning

Animation of DPV adoption by Distribution Feeder for Orlando Utilities Commission (OUC) Service Territory

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Ongoing Research

Modeling Co-adoption of Technologies

Consumers increasingly co-adopt distributed solar with (a) energy storage, b) energy efficiency appliances and (c) electric vehicles.

1. Identify **residential customer** preferences for co-adopting/using solar PV, energy storage, and electric vehicles (EVs)
2. Determine **commercial and industrial (C&I) customer/facilities manager** preferences for adopting/managing workplace PV, energy storage, fleet EVs, and EV charging infrastructure

1. Improve Data Standardization and Access: Publicly available datasets
2. Model and Algorithm Development: Standardized data (agents) and new modules
3. Dissemination and Outreach: **Provide technical assistance** to ISO/RTOs, utilities, state and local energy planners, local governments, policymakers, and regulators.

Drivers of Uncertainty

Techno-Economic Drivers

- Technology Cost
- Technology Performance
- Electricity Prices
- Load Growth -Economic Growth and Electrification

Policy & Market Drivers

- Incentives –Federal and State
- Net Metering, Feed-In Tariff etc.
- Rate Design
- Financing (debt, leasing) and terms of financing (interest rate, debt fraction, WACC, etc.)

Operational Drivers

- Oversimplifications
- Misrepresentations
- Coarsely-resolved forecasts
- Modeling methods or source code are not publicly available

Thank you

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