LA100

The Los Angeles 100% Renewable Energy Study

# Advisory Group #7

LA DWP Los Angeles Department of Water & Power

NREL Transforming ENERGY

# Today's Focus

- SB 100 and the LA 100 Scenarios
- Jobs and Economic Development Analysis
- Accounting for Costs in Power Systems Planning

# Agenda

- Call to Order
- Welcome and Introductions
- Update Exchange
- Senate Bill 100 Overview
- Scenario Updates
- Jobs and Economic Development Analysis **
- Lunch
- Accounting for Costs in Power Systems Planning **
- Wrap-up and Next Steps

***Q&A and Discussion*

# Welcome and Introductions

# Update Exchange

# Advisory Group Meeting Plan

■ COMPLETED MEETINGS/TASKS
■ PLANNED MEETINGS/TASKS

| QUARTER | Phase 1 \| 2017<br>LAUNCH AND ORGANIZATION | Phase 2 \| 2018<br>SCENARIOS | Phase 3 \| 2019<br>ANALYSIS AND MODELING | Phase 4 \| 2020<br>FINAL REPORT |
|---|---|---|---|---|
| Q1 | | FEBRUARY 15<br>• Advisory Group Meeting Plan<br>• Preliminary Scenarios and Sensitivities<br>• Field Trip Itinerary<br>• Power Strategic Long-Term Power Resources Plan<br>• Once-Through Cooling Study Update | MARCH 28<br>• Preliminary Scenario Tests<br>• Environmental Analysis II<br>• LADWP Financial Office | MARCH 5<br>• Final Results |
| Q2 | JUNE 23<br>• Advisory Group Launch<br>• City Council Motion: 100% Renewable Energy Study | JUNE 7<br>FIELD TRIP April 26<br>• Draft 100% Papers: Framing, Data, Methods<br>• Final Scenarios and Sensitivities<br>• Once-Through Cooling Study Update | JUNE 27<br>• Load Analysis<br>• Jobs & Economic Analysis II<br>• Advanced Engineering Concepts | JUNE 25<br>• Final Report<br>• Final Presentation |
| Q3 | AUGUST 3<br>• Advisory Group Charge and Operating Protocols<br>• Introduction to NREL and 100% Renewable Energy Study | AUGUST 16<br>• 100% Data<br>• 100% Methods<br>• Environmental Analysis I<br>• Once-Through Cooling Study Update | SEPTEMBER 19<br>• Preliminary Electric System Results<br>• Preliminary Visualizations | |
| Q4 | NOVEMBER 16<br>• Defining Clean Energy and Renewable Energy<br>• Considerations for Study<br>• Once-Through Cooling Study Overview<br>• Public Outreach Overview | NOVEMBER 15<br>• Methods for Calculating Investment & Operating Cost<br>• Jobs & Economic Analysis I | DECEMBER 5<br>• Preliminary Economy & Jobs Results<br>• Preliminary GHG & Air Pollution Results | |

LA DWP Los Angeles Department of Water & Power

NREL NATIONAL RENEWABLE ENERGY LABORATORY

# Tips for Productive Discussions

- Let one person speak at a time
- Help to make sure everyone gets equal time to give input
- Keep input concise so others have time to participate
- Actively listen to others, seek to understand perspectives
- Offer ideas to address questions and concerns raised by others
- Hold questions until after presentations

# Senate Bill 100

## 100 Percent Clean Energy Act of 2018

Governor Brown signed into law September 10, 2018

LeiLani Johnson Kowal

Legislative & Intergovernmental Affairs

November 15, 2018

# California Legislative History: Statewide RPS

- Senate Bill 1078 (Sher) (2002)
  - 20% by 2017
- Senate Bill 107 (Simitian) (2006)
  - 20% renewables by 2010
- Senate Bill 2 x1 (Simitian) (2011)
  - 20% renewables by 12/31/2013
  - 25% renewables by 12/31/2016
  - 33% renewables by 12/31/2020
- SB 350 (De León) (2015)
  - 40% renewables by 12/31/2024
  - 45% renewables by 12/31/2027
  - 50% renewables by 12/31/2030

# Senate Bill 100 (De León) 100 Percent Clean Energy Act of 2018

## Two Parts

- Accelerated RPS Targets under California RPS Program (to 60%)
- Zero Carbon Policy (for the remaining 40%)

## Part 1: RPS Targets (regulatory)

- Accelerates the RPS obligations for retail sellers - IOUs, CCAs, ESPs, and POUs as follows:
  - 40% increased to 44% by 2024
  - 45% increased to 52% by 2027
  - 50% increased to 60% by 2030

## Part 2: Zero Carbon Policy (non-regulatory/planning goal)

- 100% retail sales of electricity by December 31, 2045 = renewables + zero carbon resources.
  - No increase in carbon emissions in the western grid
  - No resource shuffling

# Senate Bill 100 (De León)
# 100 Percent Clean Energy Act of 2018

## Zero Carbon Policy

- CPUC/CEC/CARB shall ensure actions related to 100% goal:
  - Maintain and protect the safety, reliable operation, and balancing of the electric system
  - Prevent unreasonable impacts to electric, gas, water customer rates and bills, taking into consideration economic and environmental costs and benefits of renewables and zero carbon resources
  - Lead to adoption of policies and actions in other sectors to obtain GHG reductions that ensure equity between other sectors and electricity sector
  - Not affect rules, requirements for oversight of and enforcement of the California RPS Program

# Senator De León: Letter to the Senate Daily Journal on SB 100

- Resource Shuffling Prohibition
  - Should be implemented in a manner that does not run afoul of the Dormant Commerce Clause
- SB 100 has two separate provisions:
  - 1) Accelerated RPS, and 2) Zero-Carbon Policy
- Zero-Carbon Policy:
  - Includes all zero-carbon resources
    - RPS-eligible resources and existing zero-carbon resources serving California customers
  - Technology neutral
    - If a resource does not produce GHG emissions it is eligible to meet the 100% target
  - Existing obligations
    - Does not seek to require retail sellers to default on existing contractual obligations to deliver electricity to California customers from existing zero-carbon generation facilities

# Senate Bill 100: Zero Carbon Policy Next Steps?

- CPUC/CEC/CARB
  - Utilize programs authorized under existing statutes to achieve policy
  - In consultation with all California Balancing Authorities, in a public process, issue joint report to Legislature by 1/01/2021, and every 4 years thereafter:
    1. Review policy focused on technologies, forecasts, transmission, safety, environmental and public safety protection, affordability, system and local reliability
    2. Evaluate potential benefits and impacts on system and local reliability
    3. Evaluate anticipated financial costs and benefits to electric, gas, and water utilities, including customer rate impacts and benefits
    4. Barriers to, and benefits of, achieving the policy
    5. Alternative scenarios in which the policy can be achieved and estimated costs and benefits of each scenario

LA100

The Los Angeles 100% Renewable Energy Study

# The Los Angeles 100% Renewable Energy Study

Aaron Bloom, NREL

Los Angeles Department of Water & Power

NREL Transforming ENERGY

# California aims to be entirely green powered by 2045, as Gov. Jerry Brown signs SB 100

Climate change is "a real and present danger to California and to the people of the world," Brown said.

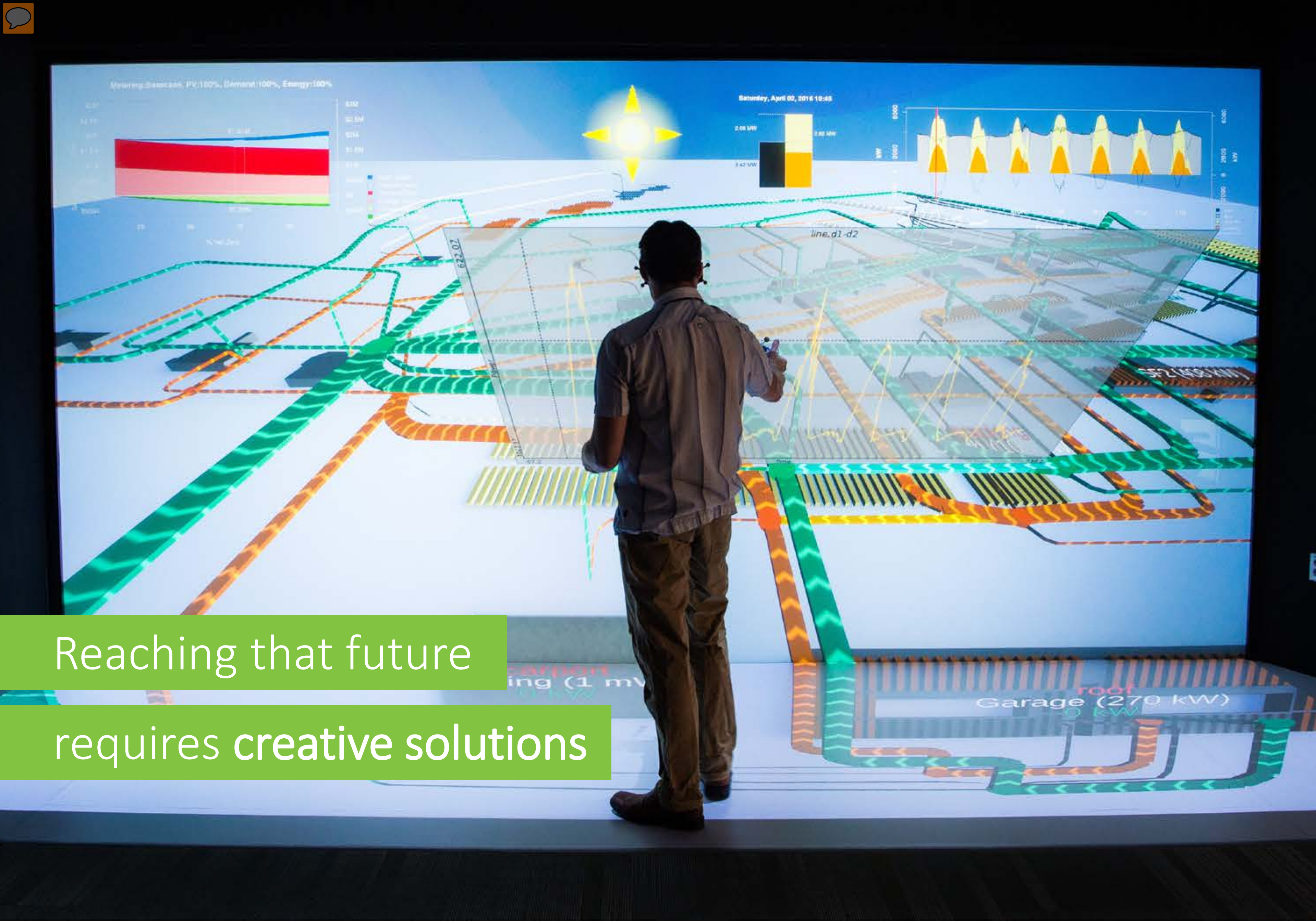
by James Rainey / Sep.10.2018 / 1:39 PM ET / Updated Sep.10.2018 / 5:51 PM ET

California is **moving fast**

toward a clean energy future.

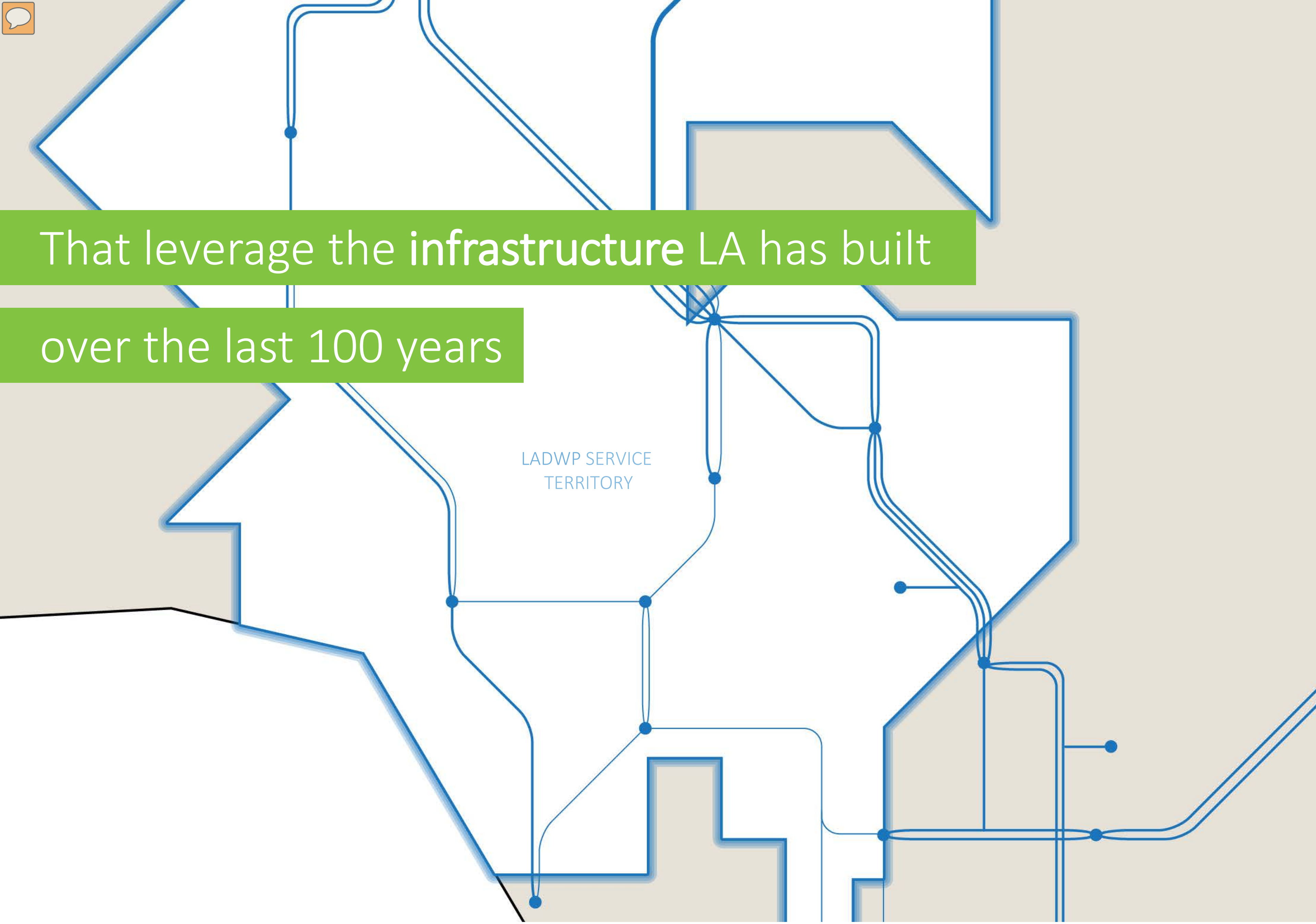
# And LA is leading the charge


Toward 100% renewable energy to benefit 100% of LA.




# Reaching that future requires **creative solutions**

That leverage the **infrastructure** LA has built over the last 100 years



# To harness the **resources** it will need


to power the **next 100**.

The Los Angeles 100% Renewable Energy Study

will give LA the information it needs to get there.

# Here’s our approach.

# The energy system used to be all about the **grid**.


# Today, it’s about the **people**, too.

We are **impacting** and **contributing to** the grid in ways we never have before.

# How will people **interact** with the grid as it evolves?

# How do we make sure the system is **reliable**?

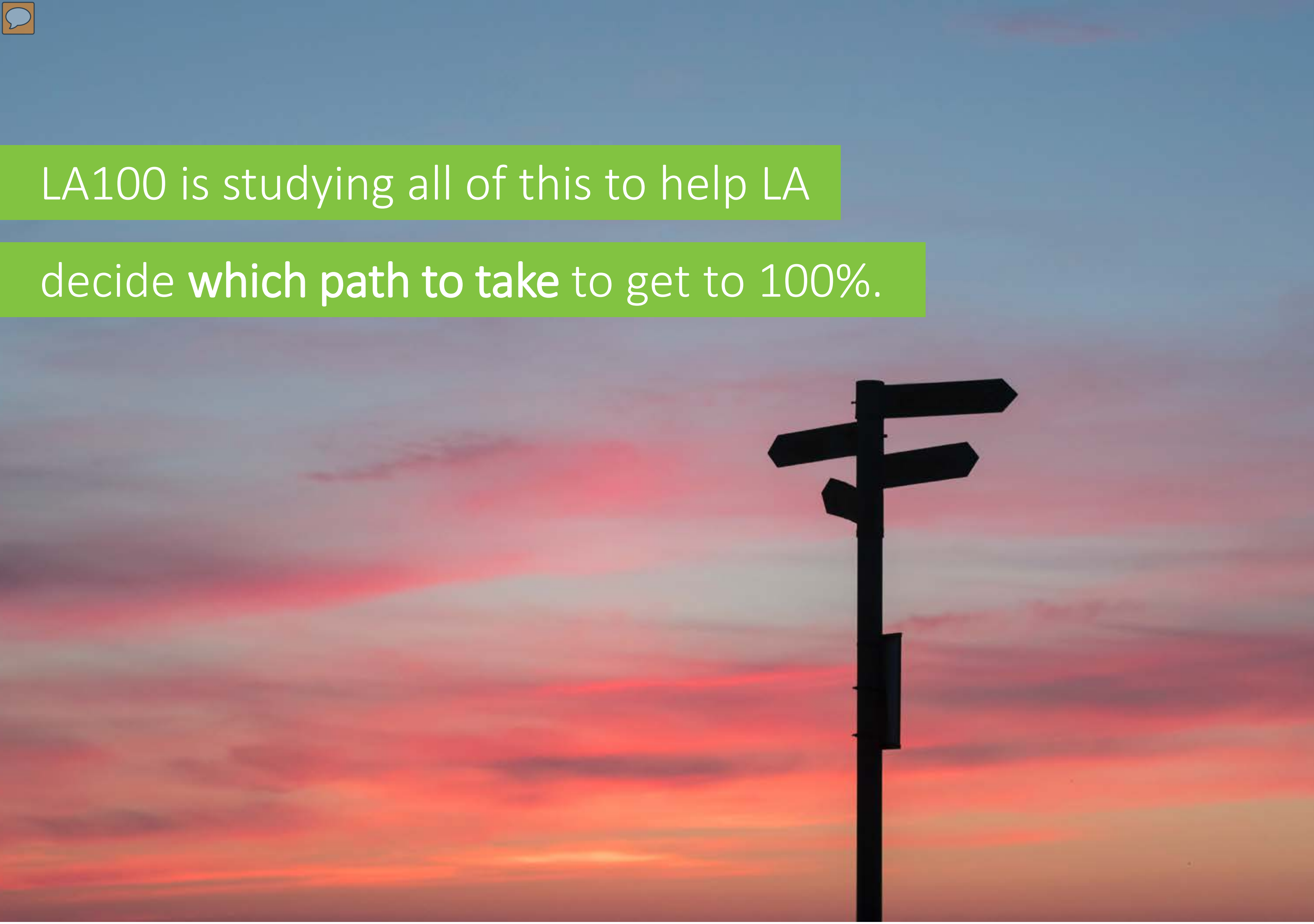
# And **affordable** for all of LA?

# What are the potential **economic** and **environmental** impacts?


LA's future power system needs to work **with** its people, **for** its people

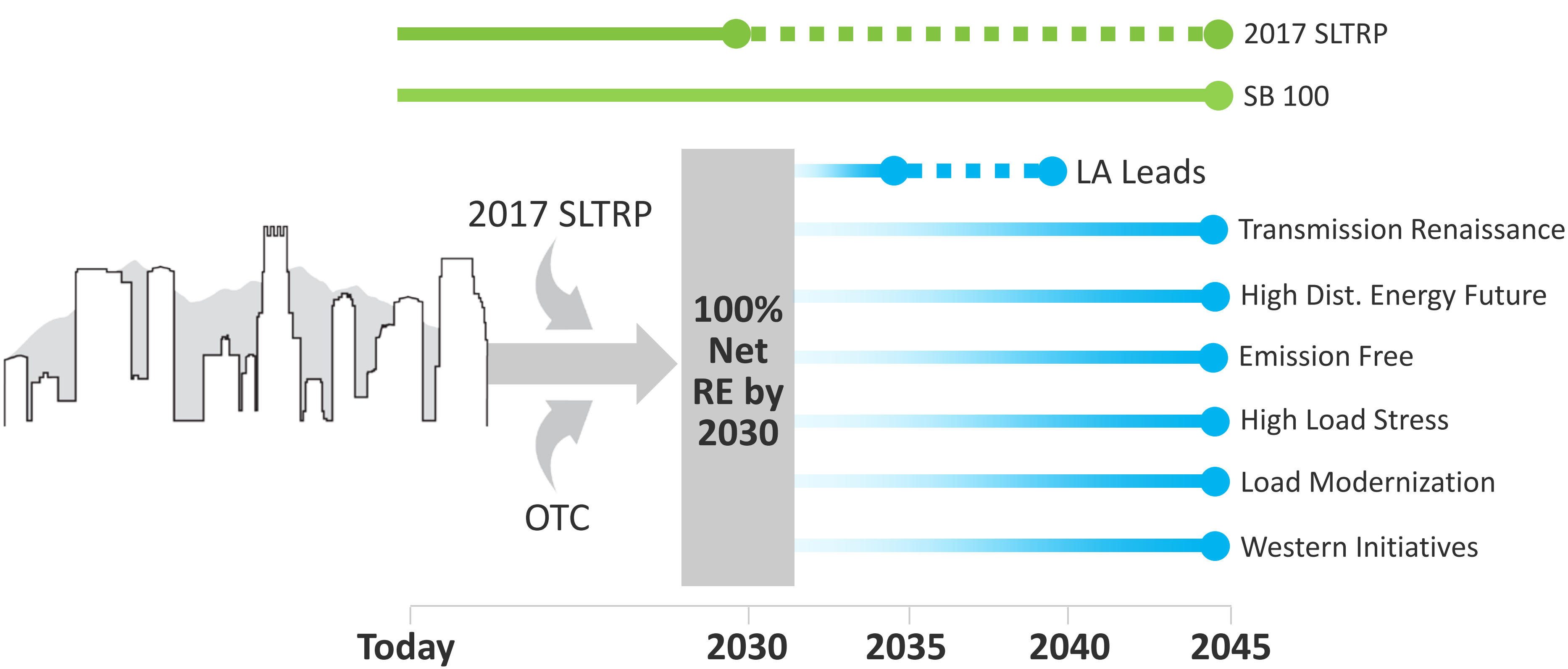
for **decades** to come.

LA100 is studying all of this to help LA decide **which path to take** to get to 100%.



# Here are the scenarios.

# Scenario Framework



# Scenario Descriptions

| | Scenario Name | Scenario Abbreviation | Net 100 RE* Target Year | Final Target Year | Scenario Description |
|---|---|---|---|---|---|
| Reference | LADWP 2017 SLTRP *Recommended Case* | DWP-SLTRP17 | - | - | The DWP-SLTRP scenario matches the planned generation, tranmission, and distribution system investments, as well as the planned end-use initiatives--energy efficiency, demand response, and electrification--from LADWP's 2017 SLTRP *Recommended Case* . In addition, this scenario will incorporate relevant results from the OTC Study. Under this scenario, renewable generation comprises 65% of load by 2036. |
| | Senate Bill 100 | SB100 | - | 2045 | The SB100 scenario ensures that the LADWP system is compliant with Senate Bill--100; 60% net renewable energy by 2030 & 100% carbon-free energy by 2050. |
| LA100 | LA-Leads | LA-Leads | 2030 | 2035/2040** | Through more aggressive pursuit of both energy efficiency, demand response, and electrification initiatives, as well as rapid deployment of both distributed and utility-scale resources, a 100% clean energy system is achieved by 2035. Importantly, the Palo Verde Nuclear Plant continues to provide generation through the early 2040s, but is retired by and offset with new renewable sources by 2045. RECs are not allowed as part of compliance. |
| | Transmission Renaissance | Trans+ | 2030 | 2045 | New transmission corridors (along with upgrades to existing corridors) allow rapid increases in the availability of transmission capacity; adoption of distributed generation is decreased relative to the 100-RE case, due to the decreased barriers to importing utility scale renewable generation from out-of-basin. RECs are not allowed as part of compliance. |
| | High Distributed Energy Future | Hi-DEF | 2030 | 2045 | Adoption of distributed generation is aggresively pursued to make up for decreased ability to import out-of-basin renewable generation; similarly, energy efficiency, demand response, and electrification are rapidly implemented. RECs are not allowed as part of compliance. |
| | Emissions Free | No-Emis | 2030 | 2045** | Compliance must be achieved without any combustion-based generation (including biomass and biofuels), but nuclear generation is allowed to contribute towards compliance. RECs are not allowed as part of compliance. |
| | High Load Stress | HiStress | 2030 | 2045**ǂ | Identical to the SB-100 case--i.e. net carbon-free--but load evolves in a way that is highly challenging for renewable integration: electrification is large and rapid, while flexibility in load (demand response) and efficiency are minimal. |
| | Load Modernization | Load-Mod | 2030 | 2045 | Energy efficiency measures, demand response measures, and electrification are rapidly implemented through robust incentives, programs, and technology breakthroughs; RECs are not allowed as part of compliance. |
| | Western Initiatives | WECC | 2030 | 2045 | Variable renewable generation achieves high penetration in the rest of WECC; RECs are not allowed as part of compliance. |

*'All LA100 scenarios (blue) will reach 100% net renewable energy by 2030. This approach mirrors the one taken by many corporations and municipals to reach 100% renewable energy. It allows LADWP to meet a portion of the 100% goal using Renewable Energy Credits (RECs) that net out the emissions caused by LADWP generation.

**'Nuclear generation is allowed to contribute towards the 100% target

ǂ RECs can be used as a component of compliance

# Old Scenario Matrix

| | | LADWP 2017 IRP *Recommended Case* | 100% RE Reference | LA-Leads | Transmission Renaissance | High Distributed Energy Future | Emissions Free | Net 100% | Load Modern-ization | Western Initiatives |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Compliance Year:** | -- | 2045 | 2035/2040 | 2045 | 2045 | 2045 | 2045 | 2045 | 2045 |
| Technol-ogies Eligible in the Compliance Year | Biomass | Matches 2017 IRP Technology Mix | Y | Y | Y | Y | N | Y | Y | Y |
| | Biogas | | Y | Y | Y | Y | N | Y | Y | Y |
| | Electricity to Fuel (e.g. H2) | | Y | Y | Y | Y | Y | Y | Y | Y |
| | Fuel Cells | | Y | Y | Y | Y | Y | Y | Y | Y |
| | Hydro - Existing | | Y | Y | Y | Y | Y | Y | Y | Y |
| | Hydro - New | | N | N | N | N | N | N | N | N |
| | Hydro - Upgrades | | Y | Y | Y | Y | Y | Y | Y | Y |
| | Natural Gas | | N | N | N | N | N | Y | N | N |
| | Nuclear - Existing | | N | Y | N | N | Y | Y | N | N |
| | Nuclear - New | | N | N | N | N | N | N | N | N |
| | Wind, Solar, Geo | | Y | Y | Y | Y | Y | Y | Y | Y |
| | Storage | | Y | Y | Y | Y | Y | Y | Y | Y |
| DG | Distributed Adoption | Reference | Balanced | High | Low | High | Balanced | Balanced | Balanced | Balanced |
| RECS | Financial Mechanisms (RECS/Allowances) | - | N | N | N | N | N | Yes | N | N |
| Load | Energy Efficiency | Reference | Moderate | High | Moderate | High | Moderate | Moderate | High | Moderate |
| | Demand Response | Reference | Moderate | High | Moderate | High | Moderate | Moderate | High | Moderate |
| | Electrification | Reference | Moderate | High | Moderate | High | Moderate | Moderate | High | Moderate |
| Trans-mission | New or Upgraded Transmission Allowed? | Matches 2017 IRP | Only Along Existing or Planned Corridors | Only Along Existing or Planned Corridors | New Corridors Allowed | No New Transmission | Only Along Existing or Planned Corridors | Only Along Existing or Planned Corridors | Only Along Existing or Planned Corridors | Only Along Existing or Planned Corridors |
| WECC | WECC VRE Penetration | Reference | Reference | Reference | Reference | Reference | Reference | Reference | Reference | High |

# Updated Scenario Matrix-changes

| | | Reference | | LA100 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | LADWP 2017 SLTRP *Recommended Case* | SB 100 | LA-Leads | Transmission Renaissance | High Distributed Energy Future | Emissions Free | High Load Stress | Load Modern-ization | Western Initiatives |
| | | | | All LA100 cases reach 100% Net Renewable Energy by 2030 | | | | | | |
| | Compliance Year: | 2045 | 2045 | 2035/2040 | 2045 | 2045 | 2045 | 2045 | 2045 | 2045 |
| Technologies Eligible in the Compliance Year | Biomass | Matches 2017 SLTRP Technology Mix | Y | Y | Y | Y | N | Y | Y | Y |
| | Biogas | | Y | Y | Y | Y | N | Y | Y | Y |
| | Electricity to Fuel (e.g. H2) | | Y | Y | Y | Y | Y | Y | Y | Y |
| | Fuel Cells | | Y | Y | Y | Y | Y | Y | Y | Y |
| | Hydro - Existing | | Y | Y | Y | Y | Y | Y | Y | Y |
| | Hydro - New | | N | N | N | N | N | N | N | N |
| | Hydro - Upgrades | | Y | Y | Y | Y | Y | Y | Y | Y |
| | Natural Gas | | Y | N | N | N | N | Y | N | N |
| | Nuclear - Existing | | Y | Y | N | N | Y | Y | N | N |
| | Nuclear - New | | N | N | N | N | N | N | N | N |
| | Wind, Solar, Geo | | Y | Y | Y | Y | Y | Y | Y | Y |
| | Storage | | Y | Y | Y | Y | Y | Y | Y | Y |
| DG | Distributed Adoption | Reference | Balanced | High | Low | High | Balanced | Balanced | Balanced | Balanced |
| RECS | Financial Mechanisms (RECS/Allowances) | Y | Y | N | N | N | N | Y | N | N |
| Load | Energy Efficiency | Reference | Moderate | High | Moderate | High | Moderate | Reference | High | Moderate |
| | Demand Response | Reference | Moderate | High | Moderate | High | Moderate | Reference | High | Moderate |
| | Electrification | Reference | Moderate | High | Moderate | High | Moderate | High | High | Moderate |
| Transmission | New or Upgraded Transmission Allowed? | Matches 2017 SLTRP | Only Along Existing or Planned Corridors | Only Along Existing or Planned Corridors | New Corridors Allowed | No New Transmission | Only Along Existing or Planned Corridors | Only Along Existing or Planned Corridors | Only Along Existing or Planned Corridors | Only Along Existing or Planned Corridors |
| WECC | WECC VRE Penetration | Reference | Reference | Reference | Reference | Reference | Reference | Reference | Reference | High |

# Updated Scenario Matrix

| | | Reference | | LA100 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | LADWP 2017 SLTRP *Recommended Case* | SB 100 | LA-Leads | Transmission Renaissance | High Distributed Energy Future | Emissions Free | High Load Stress | Load Modern-ization | Western Initiatives |
| | | | | All LA100 cases reach 100% Net Renewable Energy by 2030 | | | | | | |
| | **Compliance Year:** | 2045 | 2045 | 2035/2040 | 2045 | 2045 | 2045 | 2045 | 2045 | 2045 |
| Technologies Eligible in the Compliance Year | Biomass | | Y | Y | Y | Y | N | Y | Y | Y |
| | Biogas | | Y | Y | Y | Y | N | Y | Y | Y |
| | Electricity to Fuel (e.g. H2) | | Y | Y | Y | Y | Y | Y | Y | Y |
| | Fuel Cells | | Y | Y | Y | Y | Y | Y | Y | Y |
| | Hydro - Existing | | Y | Y | Y | Y | Y | Y | Y | Y |
| | Hydro - New | Matches 2017 SLTRP Technology Mix | N | N | N | N | N | N | N | N |
| | Hydro - Upgrades | | Y | Y | Y | Y | Y | Y | Y | Y |
| | Natural Gas | | Y | N | N | N | N | Y | N | N |
| | Nuclear - Existing | | Y | Y | N | N | Y | Y | N | N |
| | Nuclear - New | | N | N | N | N | N | N | N | N |
| | Wind, Solar, Geo | | Y | Y | Y | Y | Y | Y | Y | Y |
| | Storage | | Y | Y | Y | Y | Y | Y | Y | Y |
| DG | Distributed Adoption | Reference | Balanced | High | Low | High | Balanced | Balanced | Balanced | Balanced |
| RECS | Financial Mechanisms (RECS/Allowances) | Y | Y | N | N | N | N | Y | N | N |
| Load | Energy Efficiency | Reference | Moderate | High | Moderate | High | Moderate | Reference | High | Moderate |
| | Demand Response | Reference | Moderate | High | Moderate | High | Moderate | Reference | High | Moderate |
| | Electrification | Reference | Moderate | High | Moderate | High | Moderate | High | High | Moderate |
| Transmission | New or Upgraded Transmission Allowed? | Matches 2017 SLTRP | Only Along Existing or Planned Corridors | Only Along Existing or Planned Corridors | New Corridors Allowed | No New Transmission | Only Along Existing or Planned Corridors | Only Along Existing or Planned Corridors | Only Along Existing or Planned Corridors | Only Along Existing or Planned Corridors |
| WECC | WECC VRE Penetration | Reference | Reference | Reference | Reference | Reference | Reference | Reference | Reference | High |

# Summary of Changes in Light of SB 100

- Reference scenario was replaced by new SB 100 scenario
- New LA100 scenario was added to replace Net 100% scenario
  - High Load Stress
  - Designed to reflect what could happen if load grows and there is no improvement in energy efficiency
- All scenarios meet or exceed requirements of SB 100
- Goal of these changes is not to perfectly model SB 100
  - CPUC, CEC, and Courts will likely spend considerable time interpreting SB 100
  - NREL objective is to maintain schedule and include a reasonable representation of SB 100

# Jobs and Economic Development Analysis

# Overview

- City Council Motion
  - "Work with local academic institutions to examine…the potential for high quality careers and equitable local economic development, including local hiring programs.."
- Partnerships
  - University of Southern California
    - Prof. Adam Rose, Prof. Dan Wei
  - Cutler Consulting
    - Prof. Harvey Cutler, Prof. Martin Shields
- Cutler consulting will develop the model, USC is responsible for the analysis.
- Both will work with each other throughout the project

# Model Selection

- Several modeling options, all commonly used
- All assume projects are feasible
- Input-Output (I-O)
  - ”Gross” economic impacts that are based on demand
  - Cannot take into account changes such as changes in prices and taxes
  - Cannot estimate substitution between inputs (i.e., if pork becomes expensive perhaps households would eat more chicken)
- REMI
  - Proprietary impact model that is based on I-O, CGE, and econometric models
  - Some ability to change prices
- Computable general equilibrium (CGE)
  - Economic impact model that is custom built and highly flexible
  - Captures a highly detailed representation of an economy
  - All prices flexible and substitution is allowed

# CGE Decision

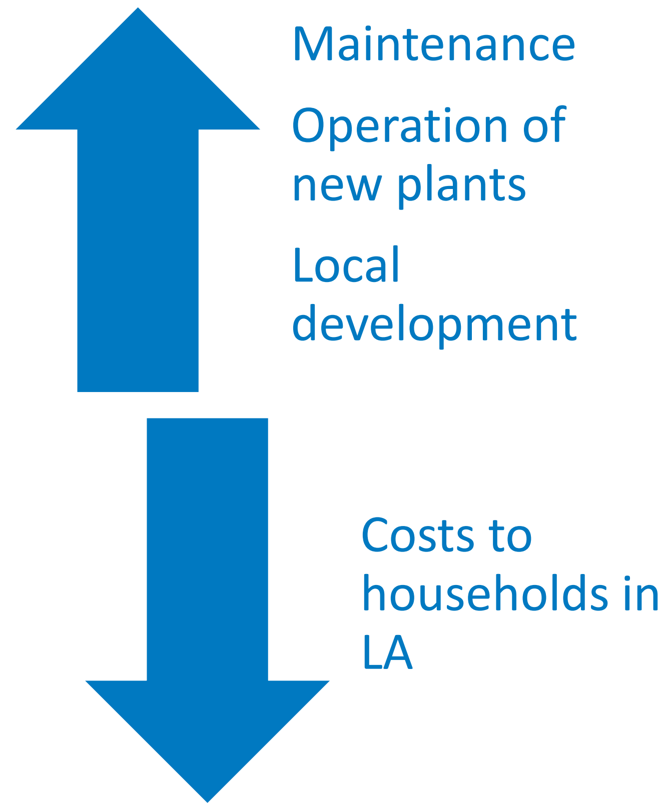
- Decision to use a CGE model
- CGE models capture detailed interactions between households, industries, government, and the region outside of the City of LA
- CGE models are flexible, so the electricity sector – the focus of the study – can be modified to better capture details and differences between different renewable and fossil technologies

# Unique Characteristics of CGE Model Used

- Model used was initially developed by Professor Cutler at Colorado State University
- Original intent was to be a regional model to capture impacts within focused areas
- NREL worked with Professor Cutler through the NREL Joint Institute for Strategic Analysis to refine the electric sector to capture specific types of energy deployment and operation

# CGE Model

- Model captures changes in prices, taxes as well as demand for goods and services
- “Net” impact because these interactions are captured
- Positive economic growth from new capacity
- Potential downward pressure on growth from displaced fossil industries, higher costs for electricity

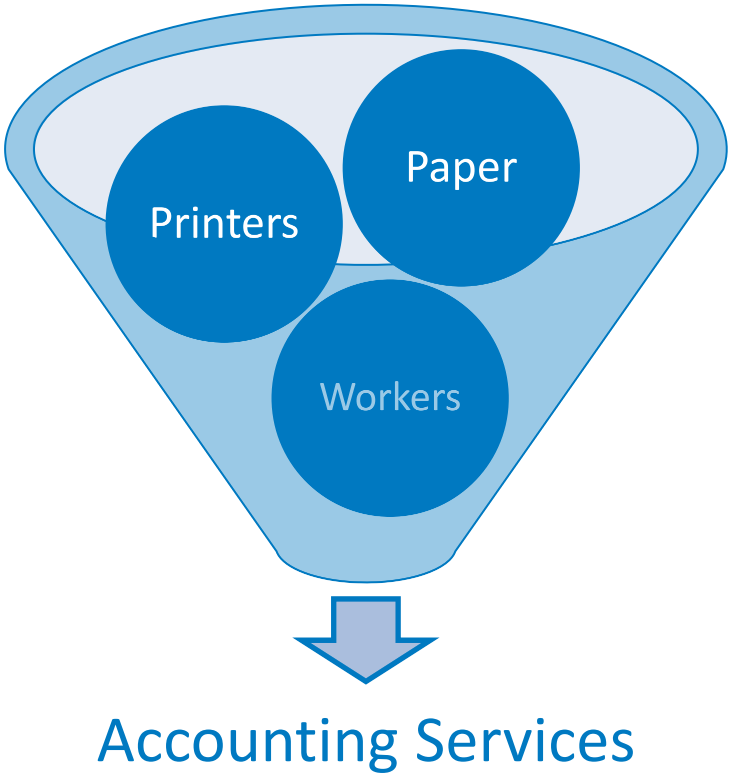


# What the Model Doesn't Capture

- Impacts from activity outside of LA
  - Goods manufactured outside of the city such as solar panels or appliances
  - Services performed by companies outside of LA such as computer software providers or outside engineering firms
- Economic activity that might arise as a result of the LA100 project that aren't directly related to the project
  - Companies may choose to locate in LA because they value renewable energy or for branding
  - Economic activity may arise due to co-location benefits. For example, an electrical company that doesn't do much PV work may locate in LA to increase the pool of available electricians

# Producing Detail – Base Data

- Social accounting matrix (SAM) is the core dataset that goes into the CGE model
- The SAM represents interactions between industries, workers, households, the government, and outside regions as inputs and outputs
- Every input such as goods industries use for production is an output provided by another sector
- I.e., an accounting firm provides accounting services and purchases paper from a paper manufacturer. Paper is an input for the accounting firm and an output from the paper manufacturer.



# CGE Base Data: Social Accounting Matrix

Social accounting matrix (SAM) shows initial structure of the economy via inputs and outputs

| | | Consumption (Inputs) | | | Final Demand (GDP) | | | | Total Output |
|---|---|---|---|---|---|---|---|---|---|
| | | Industry A | Industry B | Industry C | Households | Investment | Government | Rest of World (Net Exports) | |
| Production (Outputs) | Industry A | Intermediate Inputs and Outputs | | | Final Demand | | | | |
| | Industry B | | | | | | | | |
| | Industry C | | | | | | | | |
| Value Added (GDP) | Labor | Value Added | | | | | | | |
| | Property-type income | | | | | | | | |
| | Taxes | | | | | | | | |
| | Total Output | | | | | | | | |

# New Industries

- Additional detail added by creating new industries in the construction and utility sectors
- Utility does not differentiate between technologies
- Construction not even specific to electricity
- Industries disaggregated and allocated to different electricity technologies
- Input data pulled from a number of sources such as journal articles, reports, and the NREL Jobs and Economic Development Impacts (JEDI) suite of economic impact models
- JEDI has been validated (Billman and Keyser 2013) and results are similar to other studies (Wei et al. 2009)

# New Industries

SAM example of how different energy technologies are treated

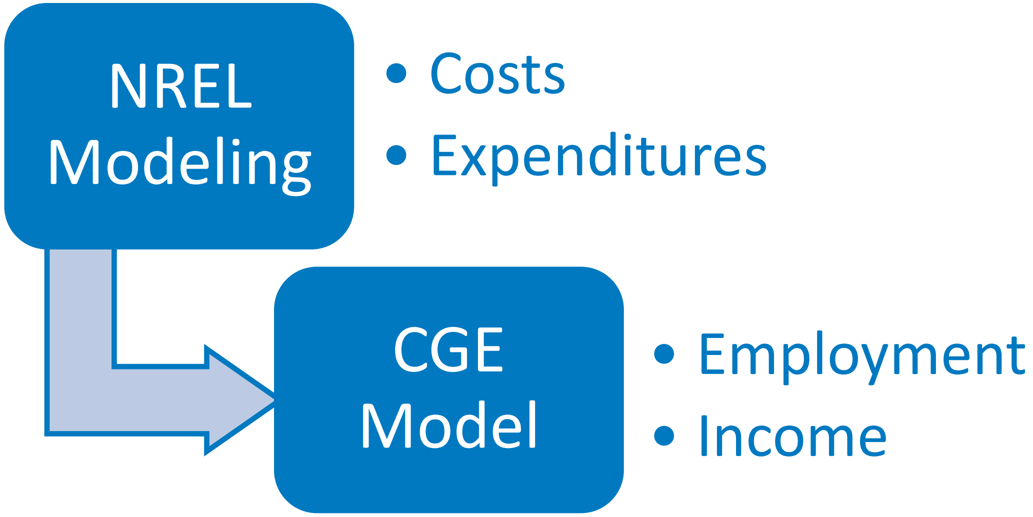
| | Industry A | Industry B | Industry C | Energy |
|---|---|---|---|---|
| **Industry A** | $A_1$ | $B_1$ | $C_1$ | $E_1$ |
| **Industry B** | $A_2$ | $B_2$ | $C_2$ | $E_2$ |
| **Industry C** | $A_3$ | $B_3$ | $C_3$ | $E_3$ |
| **Energy** | $A_4$ | $B_4$ | $C_4$ | $E_4$ |
| **Property-type Income** | $A_5$ | $B_5$ | $C_5$ | $E_5$ |
| | | | | |
| **Taxes** | $A_6$ | $B_6$ | $C_6$ | $E_6$ |
| **Labor** | $A_7$ | $B_7$ | $C_7$ | $E_7$ |
| **Total Output** | A-out | B-out | C-out | E-out |

# Two Major Publications to Date With the Modified Model

- Hannum, Christopher; Cutler, Harvey; Iverson, Terrance; Keyser, David. "Estimating the Implied Cost of Carbon in Future Scenarios using a CGE Model: The Case of Colorado." Energy Policy. Vol. 102 (2017): pp. 500-511.
- Hurlbut, David; Haase, Scott; Barrows, Clayton; Bird, Lori; Brinkman, Greg; Cook, Jeff; Day, Megan; Diakov, Victor; Hale, Elaine; Keyser, David; Lopez, Anthony; Mai, Trieu; McLaren, Joyce; Reiter, Emerson; Stoll, Brady; Tian, Tian; Cutler, Harvey; Bain, Dominique; Acker, Tom. "Navajo Generation Station and Federal Resource Planning; Volume 1: Sectoral, Technical, and Economic Trends." (2016). NREL/TP-6A20-66506. https://www.nrel.gov/docs/fy17osti/66506.pdf
- Many more publications of the model before additional detail added to energy sector

# CGE Parameterization

- Primarily informed by RPM model
- Costs for new infrastructure
- Expenditures to operate new infrastructure



# Technologies Explicitly Captured in the LA 100 Study

**Selections made based on technologies represented in the RPM model**

- Land-based wind
- Offshore wind
- CSP
- Solar PV
- Geothermal
- Natural gas
- Bioenergy
- Storage
- Coal

NREL/13762

NREL/02425

NREL/0500

# Model Results: Labor and Households

- Results by labor earning and household income category
- Labor is specific to a worker
- Can be more than one income source for a household

Nine Earnings and Income Categories

- ≤ $10,000
- $10,001 ≤ $15,000
- $15,001 ≤ $25,000
- $25,001 ≤ $35,000
- $35,001 ≤ $50,000
- $50,001 ≤ $75,000
- $75,001 ≤ $100,000
- $100,001 ≤ $150,000
- ≥ $150,001

# Sample Results: Colorado RPS

| | Absolute Change | Percent Change |
|---|---|---|
| Employment | 7,115 | 0.19% |
| State tax revenue ($millions) | $21.4 | 0.07% |
| Local tax revenue ($ millions) | $0.4 | 0.00% |
| $SO_2$ (tons) | -81,651 | -72.39% |
| NOX (tons) | -60,973 | -40.68% |
| $CO_2$ (tons) | -43,619,599 | -42.41% |

- 30% renewables for investor owned utilities, 20% larger co-ops, 10% small co-ops and municipal utilities
- Sample scenario in which renewables replace coal-fired generation
- Low variability scenario uses Xcel Energy's figures
- Results can also be negative based on the scenario, especially with increased taxes or rates

# Household Income Impacts (example from CO analysis)

| Household Income Group | Absolute Change ($mil) | Percent Changes |
|---|---|---|
| ≤ $10,000 | $151 | 0.08% |
| $10,001 ≤ $20,000 | $87 | 0.08% |
| $20,001 ≤ $40,000 | $170 | 0.09% |
| $40,001 ≤ $50,000 | $164 | 0.08% |
| $50,001 ≤ $70,000 | $212 | 0.05% |
| $70,001 ≤ $100,000 | $398 | 0.06% |
| ≥ $100,001 | $832 | 0.07% |

# Geography and Sub-City Detail

- Model covers the City of LA as defined by zip codes
- Results, therefore, are citywide
- Working with the California demography office to identify where households are clustered by income group at the sub-city level
- Level doesn’t have to be zip codes – defined by Census demographic data
- The model may say, for example, that income increases 4% for households that earn $25,001 to $35,000. We can identify where households in this income cohort tend to live.

# Thank you. Questions?

# Lunchtime

LA100

The Los Angeles 100% Renewable Energy Study

# Accounting for Costs in Power Systems Planning

Daniel Steinberg

LADWP Los Angeles Department of Water & Power

NREL Transforming ENERGY

# Outline

- Why do costs matter?
- Defining power system costs
- Estimating future power system costs
- Rate impact preview

# Why do costs matter?

# Why Costs Matter

Los Angeles Department of Water & Power
www.ladwp.com

**BILL DATE** Nov 12, 2013
**ACCOUNT NUMBER** 000 000 1000

**DATE DUE** Dec 2, 2013
**AMOUNT DUE** $ 244.29

Page 3 of 5

Los Angeles Department of Water & Power
**www.ladwp.com 1-800-342-5397**
*Hours of operation - 7 am to 10 pm*

**DEFINITIONS**

**CRPSEA** – (Capped Renewable Portfolio Standard Energy Adjustment) a charge reflecting the costs associated with RPS Operations and Maintenance, RPS debt service, and Energy Efficiency Programs.

**ECA** – (Energy Cost Adjustment) an adjustment that reflects the variations of fuel, energy and other associated costs.

**ESA** – (Electric Subsidy Adjustment) a charge reflecting the costs of subsidies including senior, disabled, low income, traffic control lighting, and enterprise zone.

**IRCA** – (Incremental Reliability Cost Adjustment) a charge reflecting Operations and Maintenance and debt service related to Power Reliability Program cost and legacy RCA under-collection.

**kWh** – (kilo-watt-hour) the units in which electric usage is measured. One kWh equals 1000 watts of electricity used for one hour.

**RCA** – (Reliability Cost Adjustment) a charge reflecting the costs to support additional capital investments needed to improve reliability in areas of power distribution, transmission and generation infrastructure.

**VEA** – (Variable Energy Adjustment) a charge reflecting the costs of fuel, non-RPS power purchase agreements, non-RPS economy purchases, legacy ECAF under-collection, and base rate decoupling from energy efficiency impact.

**VRPSEA** – (Variable Renewable Portfolio Standard Energy Adjustment) a charge reflecting the costs of RPS market purchases and RPS costs above and beyond any Operations and Maintenance and debt service payments.

**Electric Charges**

Questions about these charges? 1-800-342-5397

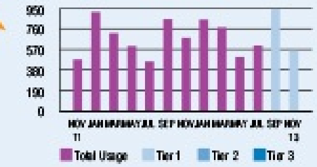
**BILLING PERIOD** 9/12/13 - 11/11/13 **DAYS** 60 **ZONE** 2

**RATE SCHEDULE**
R-1 and R-1 [i] Residential Electric - Rate A Standard Service

**NEXT SCHEDULED READ DATE**
1/13/14

10

**USAGE HISTORY** *(Total kWh)*




| | Prev Yr | Nov 13 |
|---|---|---|
| Total kWh used | 684 | 558 |
| Average daily kWh | 12 | 9 |
| Days in billing period | 59 | 60 |
| Your average daily cost of electricity | | $1.43 |

| METER NUMBER | CURRENT READ | – PREVIOUS READ | = TOTAL USED |
|---|---|---|---|
| 00006-00334905 | 7068 | 6510 | 558 kWh |

| | | |
|---|---|---|
| Tier 1 Energy | 558 kWh x $0.13935/kWh | 77.76 |
| **Subtotal Energy Charges** | | **$77.76** |
| City of Los Angeles Utility Tax | $77.76 x 10% | 7.78 |
| State Energy Surcharge | 558 kWh x $0.00029/kWh | 0.16 |
| **Total Electric Charges** | | **$ 85.70** |

***This service was previously billed on Account Number 1042614809.***

11

**Your Electric Usage by Tier**

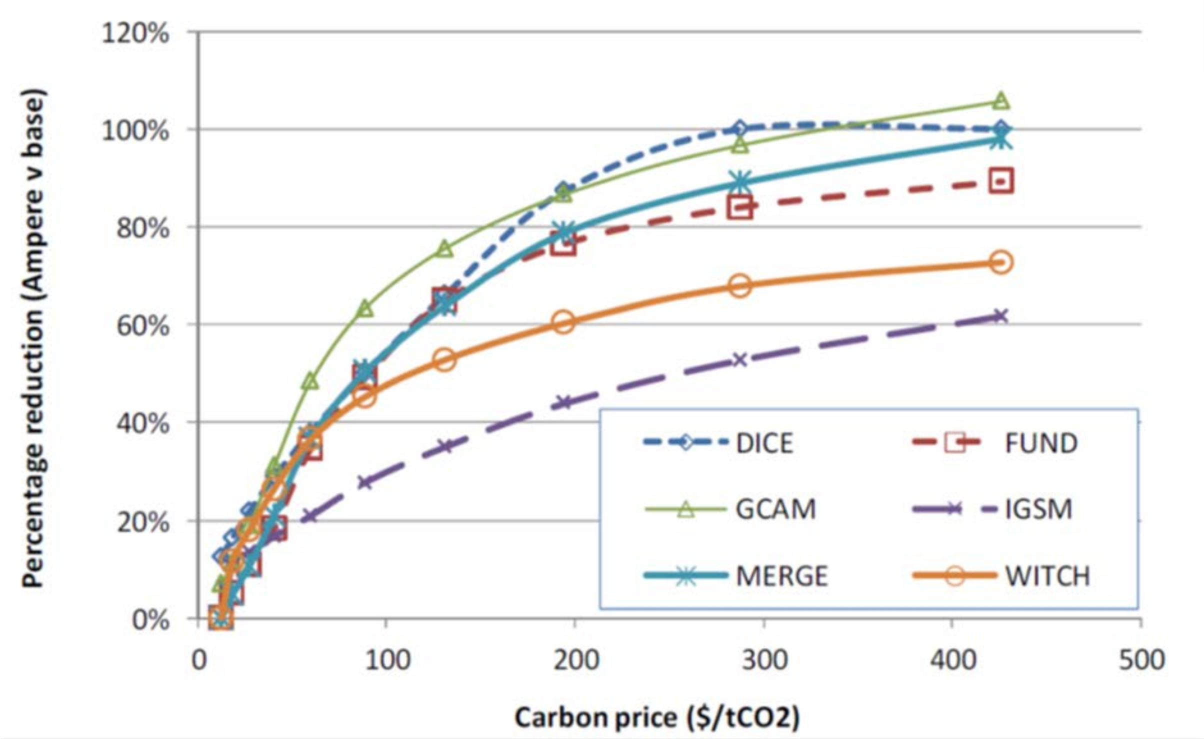
| Tier 1 $0.13935/kWh | Tier 2 | Tier 3 |
|---|---|---|
| First 1,000 kWh | Next 2,000 kWh | More than 3,000 kWh |

*Usage is billed at different rates, depending on how much you use. This graph shows how your energy usage relates to these tiers, and the rate you paid in each tier. For more, visit www.ladwp.com/res_electric*

***Green Power for a Green LA*** *– LADWP's Green Power program replaces electricity from polluting power plants with energy generated from renewable resources. To learn more and sign up, visit www.ladwp.com/greenpower*

*Source: LADWP Website: How to Read the LADWP Bill*

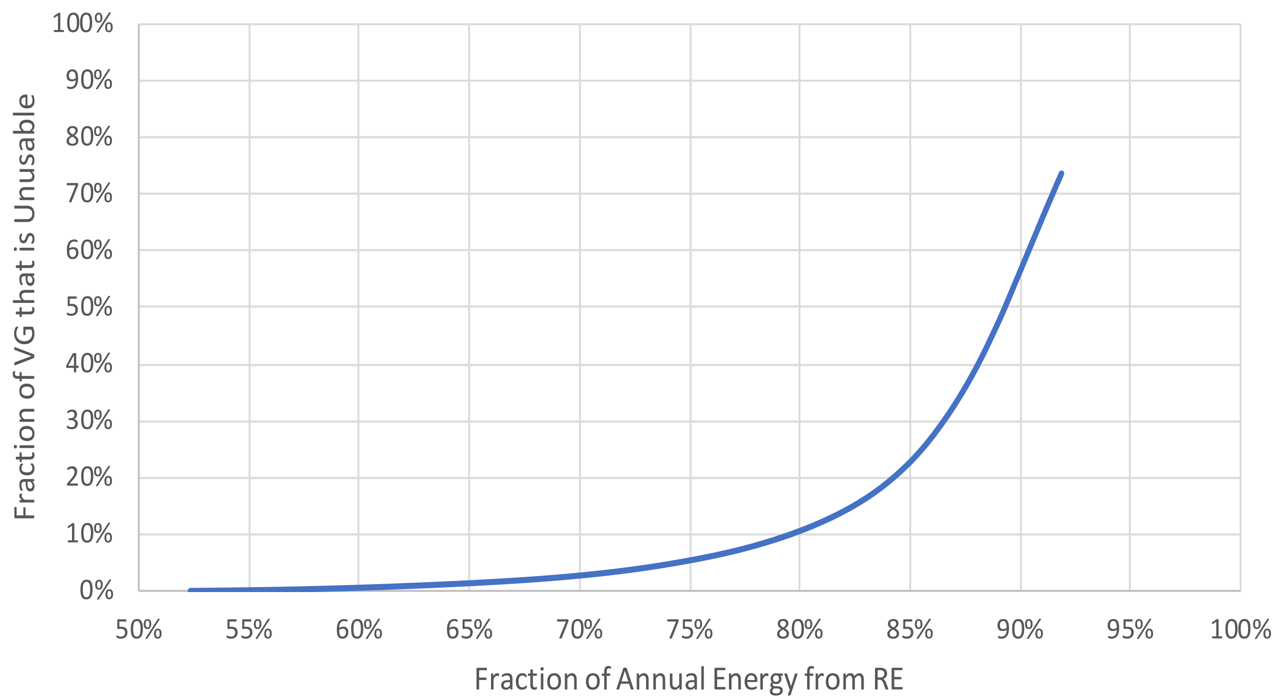
# The Lower You Go, the Higher the Cost




*Source: K. Gillingham, Nordhaus, W., Anthoff, D., Blanford, G., Bosetti, V., Christensen, P., McJeon, H., Reilly, J., Sztorc, P. 2015. Modeling uncertainty in climate change: a multi-model comparison. National Bureau of Economic Research.*

- Scientific consensus is that the cost of carbon abatement increases significantly as total emissions approach zero.

# Cost Challenges Arise Due to Variable Generation Sources



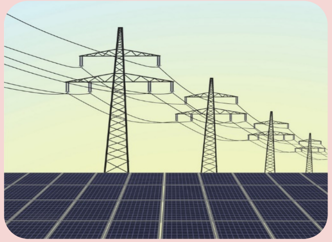
# Defining Power System Costs

# Power System Costs

**Capital Costs**: all one-time fixed costs associated with investment in bulk system infrastructure, distribution infrastructure, and/or end-use efficiency or demand response measures

**Operating Costs**: all fixed and variable operation and maintenance costs associated with least-cost unit commitment and dispatch of all generation, transmission, distribution, and consumption assets

# Power System Costs



## Generation and Transmission

- Capital: generation and transmission capacity, storage capacity
- Operating: fuel, labor, environmental compliance, purchased energy (e.g., PPAs)

## Distribution

- Capital: transformers, distributed generation capacity, advanced inverters, new lines (overhead or underground), reconductoring, capacitors
- Operating: labor, fuel, trucks, cranes, parts

## End-use

- Capital: device replacement, building envelope improvement, smart-meters
- Operating: labor, fuel, parts

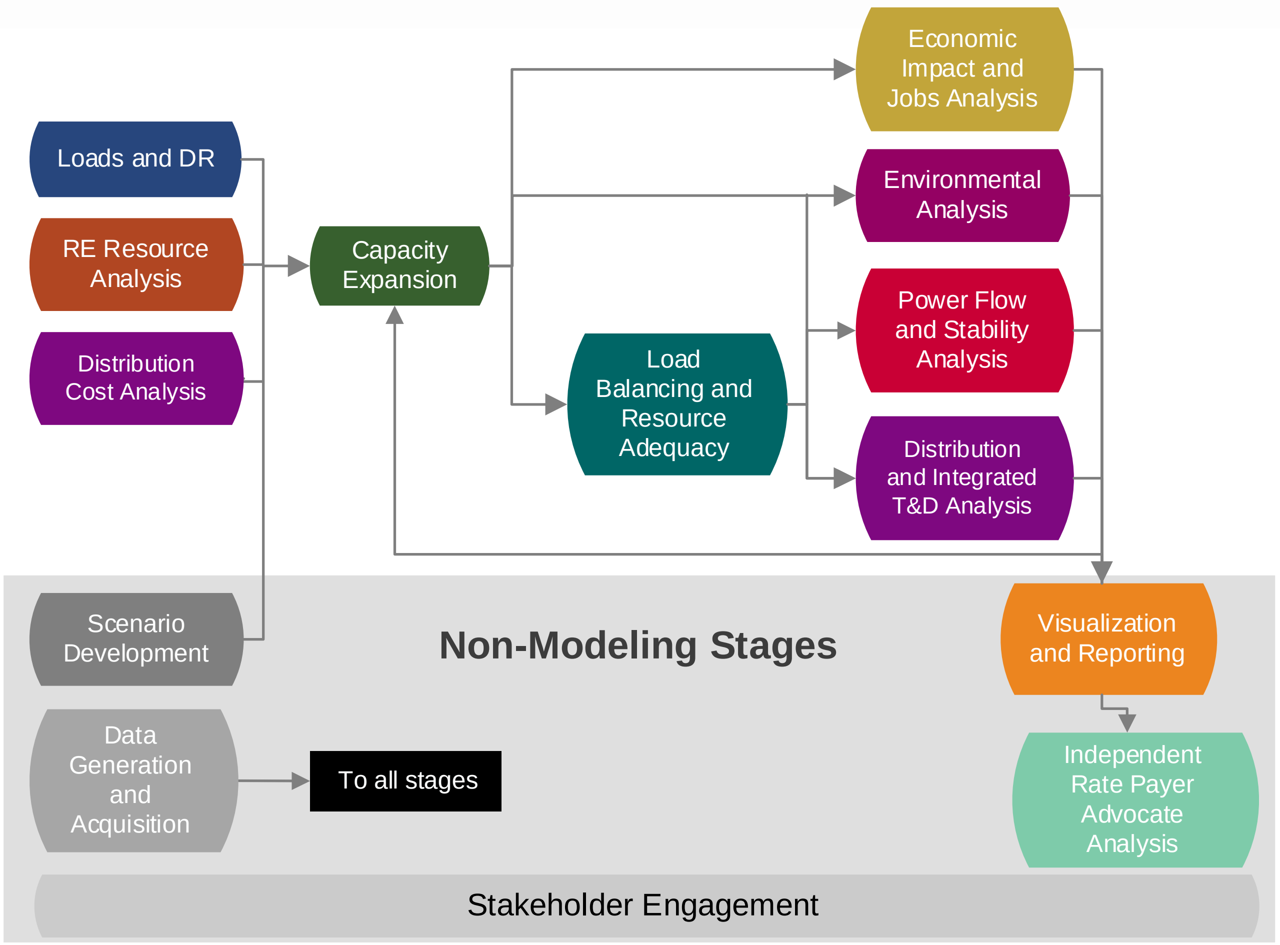
# How Do We Calculate Costs?

# The Ideal

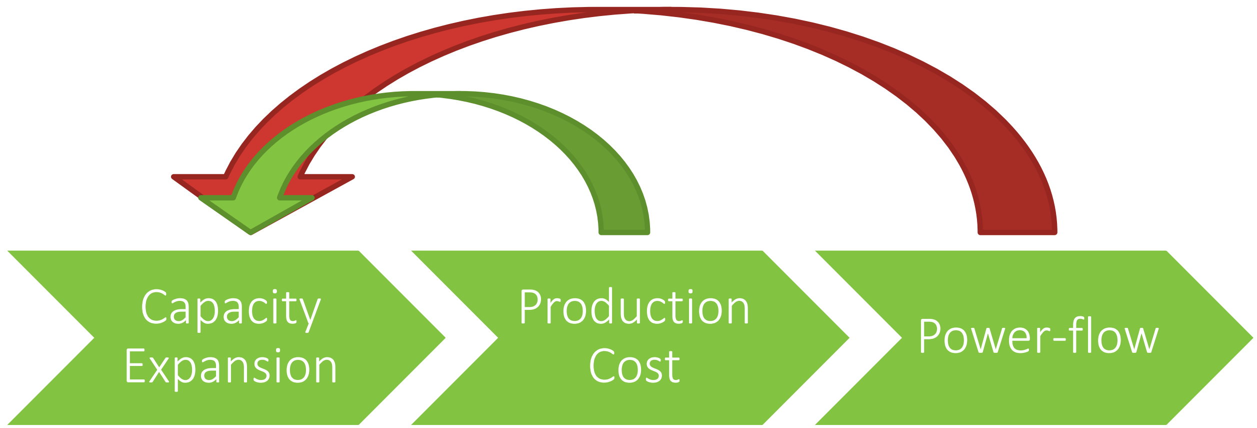
$$\min \sum_{t,y} \frac{I_{t,y} + O_{t,y}}{(1+r)^y}$$

Where *I* is a vector of investment costs;
*O* is a vector of operating costs in timestep, *t*, in year, *y*;
*r* is the discount rate

# Too Big a Problem for One Model



# General Approach: Estimate, Then Refine



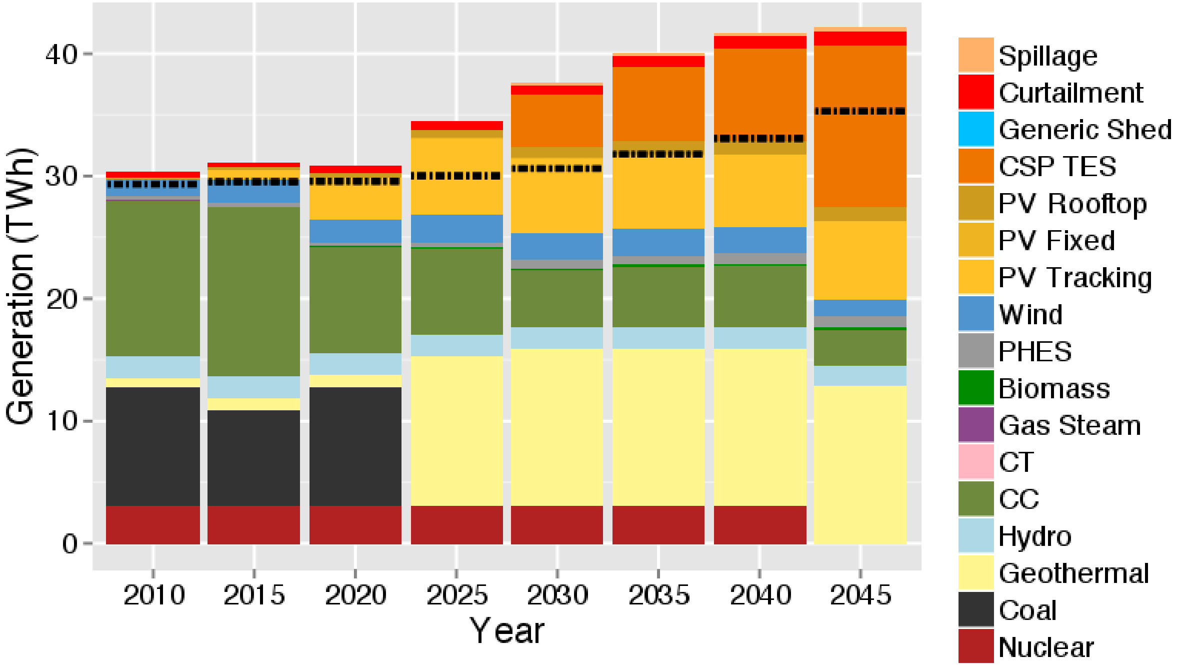

Estimate investment & reduced-form operational costs

Calculate detailed operational costs; identify additional investments needed to address congestion

Identify any other necessary bulk and distributed infrastructure to mitigate power-flow issues

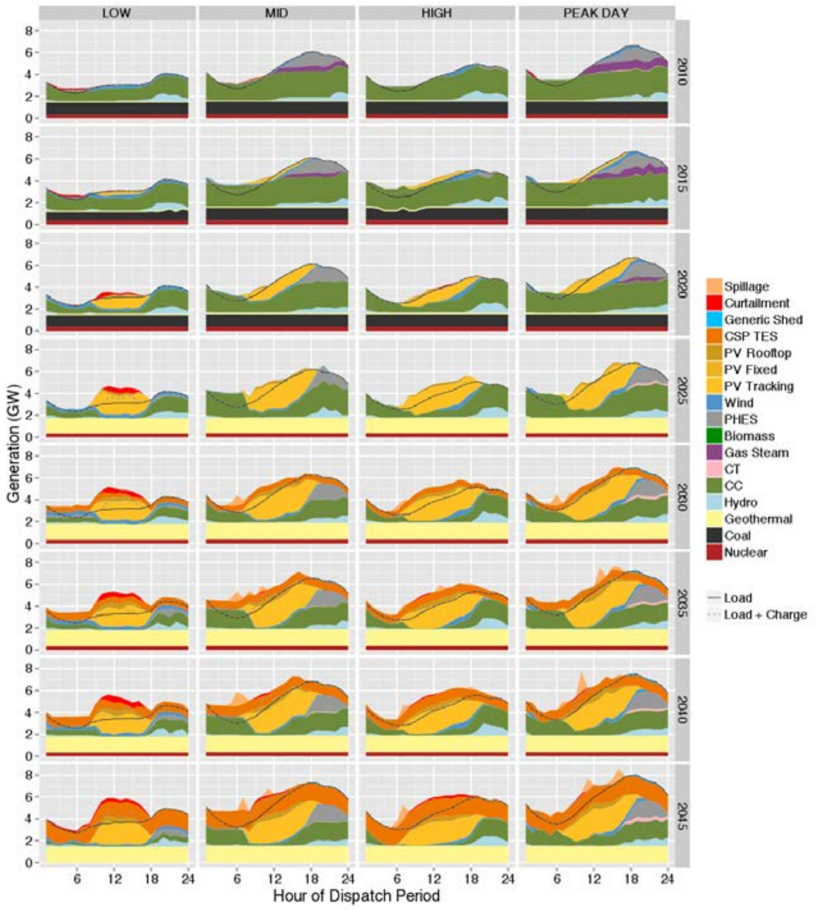
# Capacity Expansion Models (CEMs)

- Main goal is to <u>identify</u> optimal investment pathway to future
- This study utilizes multiple investment and adoption models:
  - RPM (bulk system generation and transmission), dGen (distributed generation), DISCO (distribution-scale transmission)



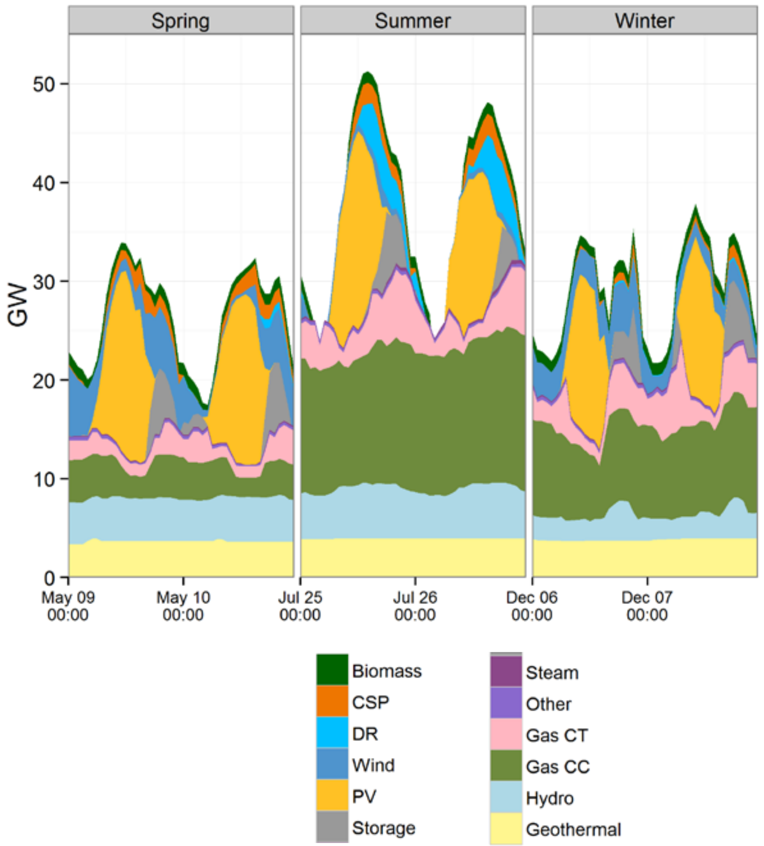
# CEMs Estimate and Rely on Reduced-Form Dispatch

- RPM informs investment decision-making based on hourly dispatch for 4 representative days within the year
- Operational costs are relatively rough estimates



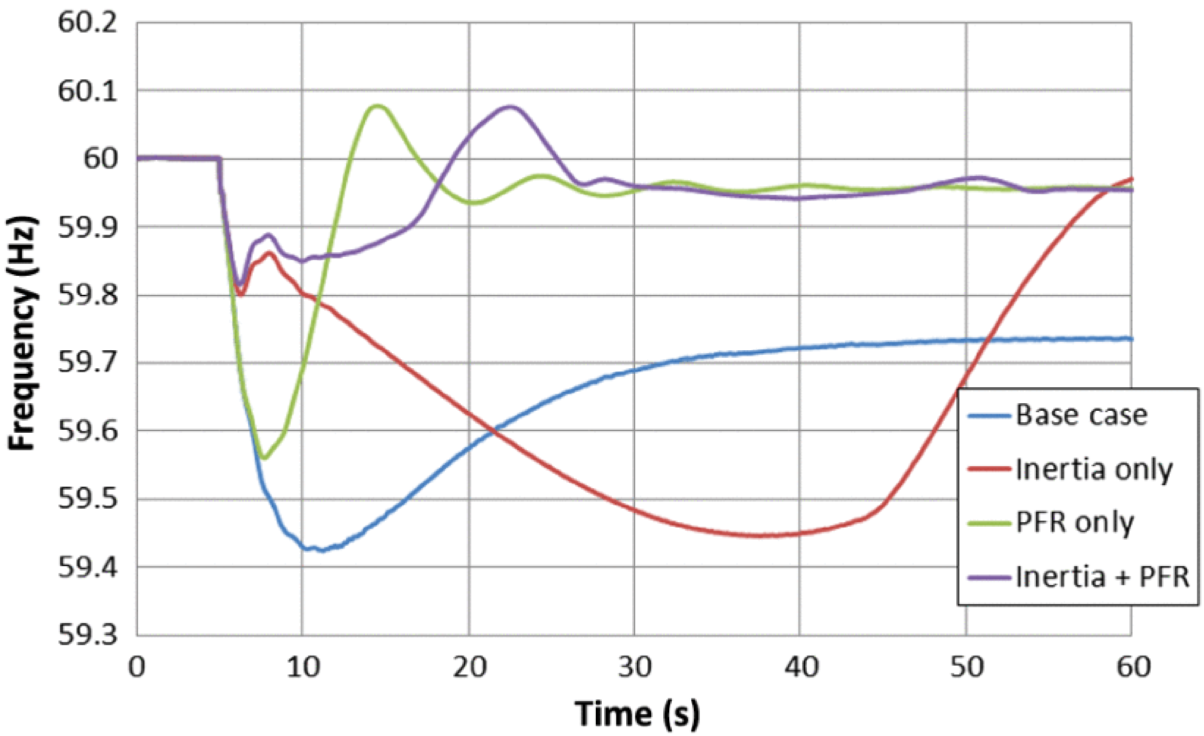
# Detailed Operational Modeling: Production Cost Models (PCMs)

- PCMs use the system specified by CEMs and calculate detailed 5-minute dispatch for a full year
- Allows for detailed accounting of operational costs—fuel, startup, shutdown, ramping, etc.
- Identify any substantial congestion issues that could be resolved with additional bulk or distributed assets (e.g. additional transmission or generation capacity)



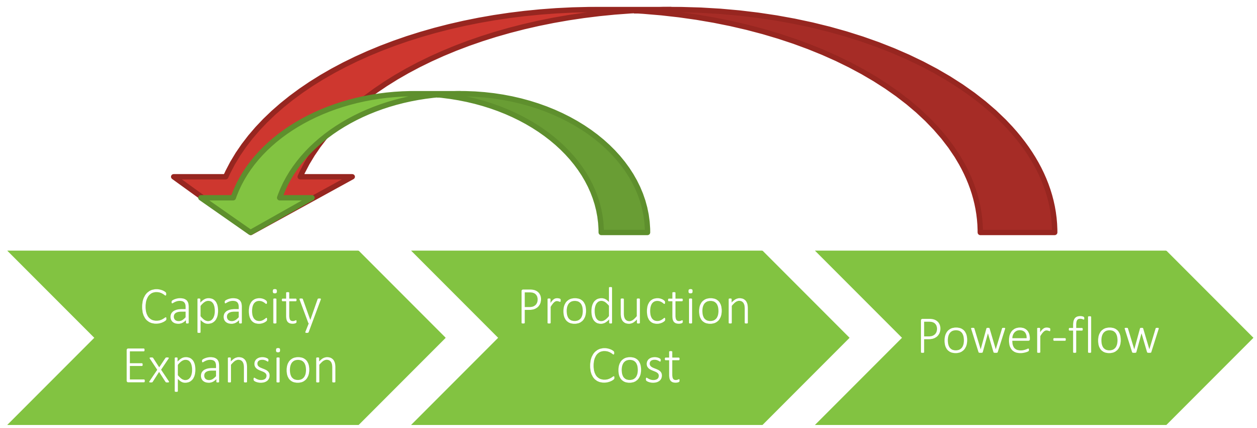
# Power-Flow Modeling Identifies Steady-State Issues That Need to Be Resolved with Additional Capital Investments

Steady-state analysis can identify and demonstrate the value of alternative options for mitigating power-flow constraints and very short-term disruptions in the grid




*Source: Gevorgian, V., Y. Zhang, and E. Ela. 2015. Investigating the impacts of wind generation participation in interconnection frequency response. IEEE Trans. on Sustainable Energy. 6 (3): 1004-1012*

# Approach: Review

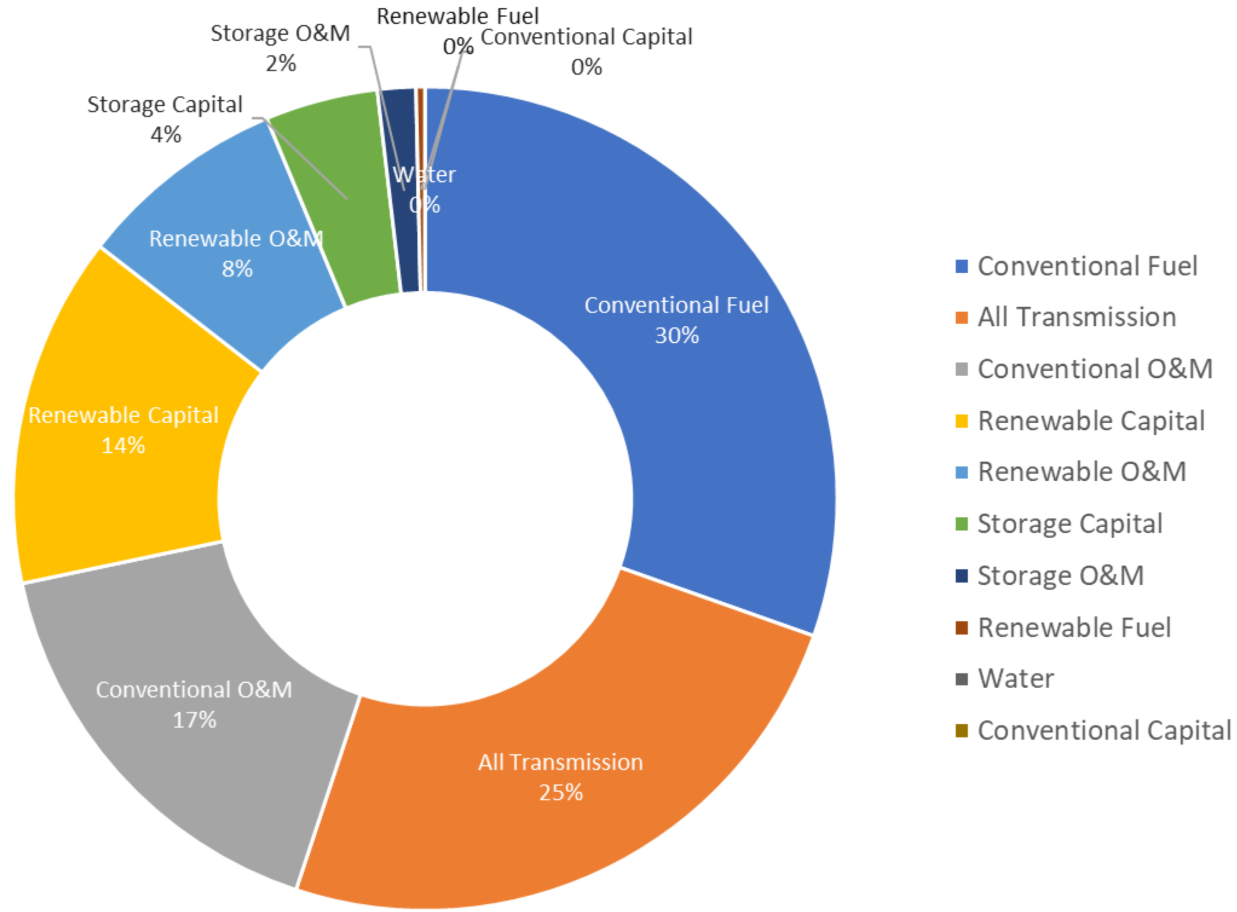



Estimate investment & reduced-form operational costs

Calculate detailed operational costs; identify additional investments needed to address congestion

Identify any other necessary bulk and distributed infrastructure to mitigate power-flow issues

# A Detailed View of System Costs




Example composition of the total present value of system costs

# Rate Analysis

- This study will include an analysis of the *potential* impacts of 100% renewable energy on LADWP rates
- NREL will calculate all costs necessary to calculate potential rate impacts
- LADWP will use NREL cost data to conduct rate impact analysis
- Rate Payer Advocate will review costs and rate analysis
- Results will be presented to Advisory Group
- *Caveat:* Estimating rate impacts accurately out to 2045 is very difficult. It is likely that rate structures will evolve considerably over the next 25 years.

# Thank you

The Los Angeles 100% Renewable Energy Study

# 100% Renewable Energy Study Summary/Milestones

Anton Sy
Project Manager

November 15, 2018

# LA100 Advisory Group

- City Council motion
- Representatives from environmental groups, neighborhood councils, academia, premier customers, City government, business associations, utilities
- Protocols and operating principles
- Meeting plan

# LA100 is Unique

- Over 4 million residents
- 1.5 million ratepayers
- Largest municipal utility
- Fully vertically integrated
- Balancing Authority

# LADWP Electrical System

- Study examines:
  - Reliability
  - Health
  - Equity
  - Affordability

# Advisory Group and Project Team Tour

**Pine Tree Wind**

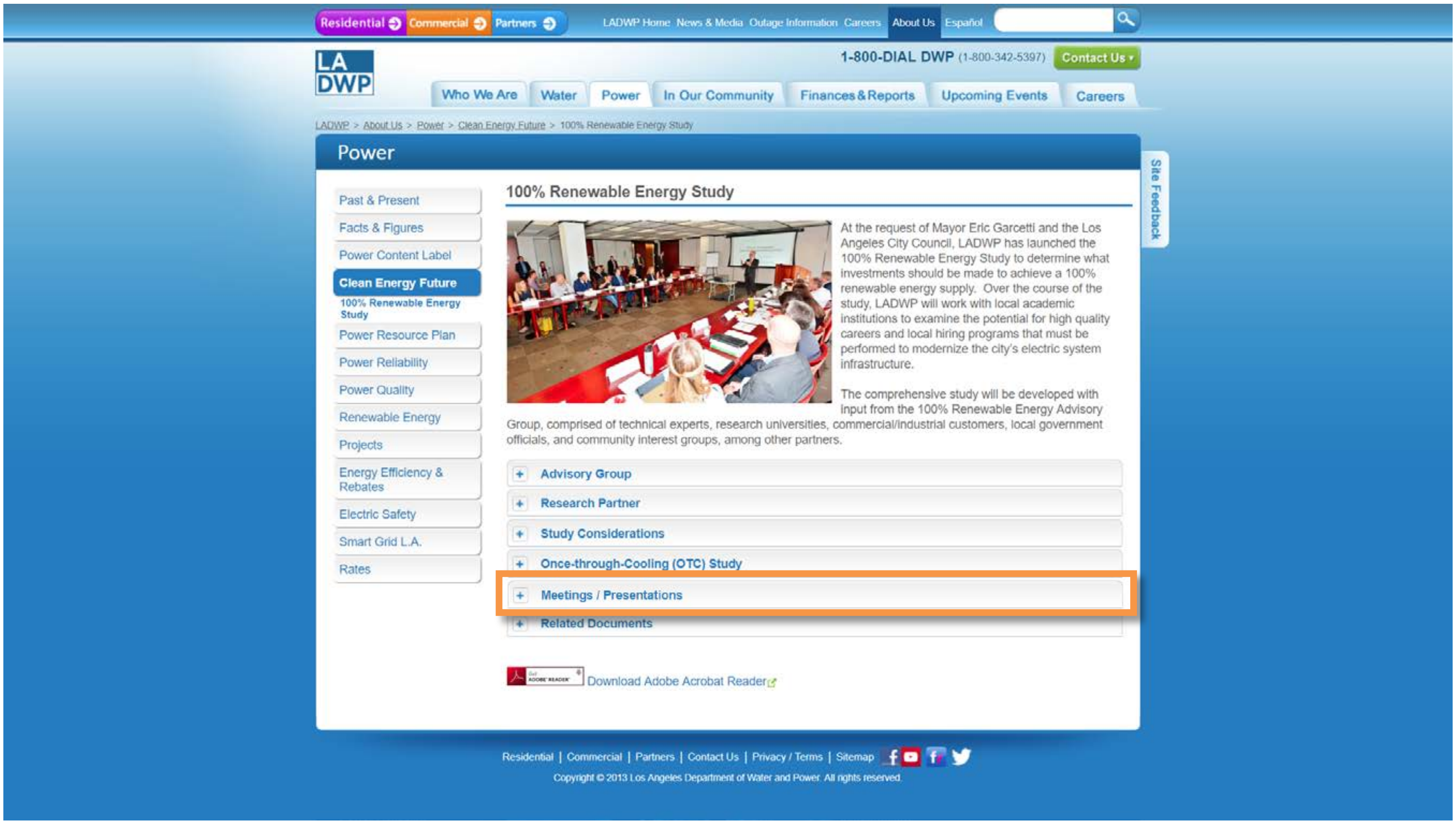
**Barren Ridge SS**

**Beacon Solar and Energy Storage**

# 2019 – 2020 Quarterly meetings

- Preliminary results
- Environmental analysis
- Visualizations
- Final results
- Final report
- Future quarterly meetings
  - March 28, 2019
  - June 27, 2019
  - September 19, 2019
  - December 5, 2019
  - March 5, 2020
  - June 25, 2020

# Project Website




LA DWP www.ladwp.com/CleanEnergyFuture

# Thank You!