Los Angeles 100% Renewable Energy Study

Advisory Group Meeting #6
Thursday, August 16, 2018, 8:45 a.m. to 1:45 p.m.

Meeting Summary[1]
(Meeting Notes Compiled by Kearns & West Staff)

Location

City of Los Angeles Department of Water and Power (LADWP)
John Ferraro Building
111 Hope St., Room 1514
Los Angeles, CA 90012

Attendees

Advisory Group Members

Rebecca Rasmussen, Office of the Mayor
Carlos Baldenegro, Port of Los Angeles
Bonny Bentzin, University of California, Los Angeles
Irene Burga, Environmental Defense Fund
Jim Caldwell, Center for Energy Efficiency and Renewable Technology
Christos Chrysillou, Los Angeles Unified School District
Camden Collins, Office of Public Accountability (Rate Payer Advocate)
Virginia Cormier, International Brotherhood of Electrical Workers (IBEW) Local 18
Molly Deringer Croll, California Energy Storage Alliance
Ellen Dux, University of Southern California
Lauren Faber O'Connor, Office of the Mayor
Russell Greene, City of Los Angeles Council District 5
Matt Gregori, Southern California Gas Company
Matt Hale, City of Los Angeles Council District 2
Michele Hasson, Natural Resource Defense Council
Ernesto Hidalgo, Neighborhood Council Sustainability Alliance
Andrea Leon-Grossman, Food and Water Watch

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[1] These meeting notes are provided as a summary of the meeting and not meant as an official record or transcript of everything that was presented or discussed. They are compiled to the best of the ability of the note takers.

Loraine Lundquist, California State University, Northridge
Martin Marrufo, IBEW Local 18
Alexandra Nagy, Food and Water Watch
Fred Pickel, Rate Payer Advocate
Allison Smith, Southern California Gas Company
Jasmin Vargas, RepowerLA
Randy Krager, Southern California Public Power Authority
Tony Wilkinson, Neighborhood Council

LADWP Commissioners
Aura Vasquez

LADWP Staff
James Barner
Dawn Cotterell
Jay Lim
Eric Montag
Ashkan Nassiri
Lauren Nguyen
Antique Rahman
Gabriel Rodriguez
Jason Rondou
Armen Saiyan
Greg Sarvas
Paul Schultz
Dan Scorza
Anton Sy
Lisa Tashiro
Louis Ting
Carol Tucker
Simon Zewdu

Project Team
Aaron Bloom, National Renewable Energy Laboratory (NREL)
Paul Denholm, NREL
Garvin Heath, NREL
Jack Hughes, Kearns & West
Joan Isaacson, Kearns & West
Melina Smith-Castro, Kearns & West
Taylor York, Kearns & West

Guests
Annie Cory, Environmental Defense Fund
Bruce Tsuchida, The Brattle Group
Don Morrow, Navigant
Ben Hwang, WorleyParsons

Welcome and Introductions

Joan Isaacson, lead facilitator from Kearns & West, welcomed members to the sixth meeting of the Advisory Group for the Los Angeles 100% Renewable Energy Study (hereafter Study). She provided an overview of the agenda (see Appendix A) and explained the primary goals of the meeting: prepare for discussion of the first round of modeling results, which will be presented in future meetings; continue to expand the Advisory Group's collective knowledge of Study methodology; and continue to solicit input and feedback from the Advisory Group on Study methodology. Joan noted that taking the time now to understand NREL's models and methodology is important to helping the Advisory Group understand, interpret, and discuss the eventual results.

Joan notified meeting attendees the meeting would be videotaped, with the exception of all Advisory Group discussion and feedback, and posted online. She noted that the recording would be available for viewing on the Study website. Presentations at future Advisory Group meetings will also be videotaped and posted.

Eric Montag, Senior Manager of Planning & Strategic Initiatives for LADWP, welcomed the Advisory Group and thanked them for their dedication, time, and passion. He reported that he had recently learned more about the NREL team and their approach to the project during partnering week held at the NREL campus in Golden, CO. He also noted that Advisory Group members would receive an update on the Once-Through Cooling Study immediately following the Advisory Group meeting.

Anton Sy, LADWP 100% Renewable Energy Study Project Manager, welcomed the Advisory Group and thanked members for their efforts and commitment. He explained that the Advisory Group would have the opportunity to learn about the tools NREL is using for the Study, some of which are unique to NREL. He echoed Joan's comments about the presentation aiding in the Advisory Group's understanding of the finished Study.

Aaron Bloom, the NREL Project Manager for the Study from NREL, also welcomed the Advisory Group, and reiterated that the meeting today and the next meeting (November 15, 2018) would focus on learning about Study methodology in preparation for understanding what the models will produce. He noted that there are 50 people at NREL working on the Study. His role is not only to work with the Advisory Group but also to ensure that the NREL laboratory team members work together and align their work with the Study goals.

Slides from all presentations are contained in Appendix B and are available on the LADWP 100% Renewable Energy Study website. The videotaped presentations are also located on the website.

Update Exchange

Joan invited attendees to participate in the Update Exchange agenda item.

Owens Valley Site Tour

Dawn Cotterell of LADWP announced that there are no remaining spaces for the September, October, or November 2018 Owens Valley site tours. However, if Advisory Group members are interested in attending, they should reach out to her (Dawn.Cotterell@ladwp.com), as she will be tracking cancellations and will notify those interested should space become available.

Updated Advisory Group Meeting Plan

The Advisory Group meeting plan chart has been updated to include more finely-tuned terminology, but the timelines have not changed. Through June 2019, NREL will be sharing information about Study methodology and approach so that the Advisory Group has a solid foundation for understanding results, as well as opportunities for posing questions and providing input.

Advisory Group Member Updates

There were no updates provided by Advisory Group members.

Meeting Recaps

Aaron from NREL provided a summary of topics from the last Advisory Group meeting in June 2018, as follows below.

Scenarios for the 100% Renewable Energy Study

Aaron recapped that the City of Los Angeles faces a unique challenge in reaching 100% renewable energy generation. Because LADWP is a balancing authority, and must maintain an ability to balance the system in real time, 100% renewable energy on the LADWP system cannot be addressed through energy credits alone: LADWP must maintain adequate generation and transmission systems. Although LADWP might achieve 100% renewable energy in a number of ways, through methods that involve storage, generation, or load management, the Study must consider the impact and cost of all of these options; their impact on other industries, such as transportation; and environmental justice concerns.

Two issues that must be studied in the pursuit of 100% renewable energy are marginal curtailment and the seasonal mismatch. Marginal curtailment is most evident with solar generation, as more solar energy is generated in the middle of the day without an increase in load. The energy is essentially wasted, and its overall value decreases. Addressing this issue will involve an analysis of how this otherwise wasted energy might be used or stored. Similarly, seasonal mismatch is excess generation that occurs throughout the year when more energy is produced in the spring and fall for which there is not demand.

Framing the 100% Renewable Energy Study

Aaron reviewed the modeling scenarios, which can be viewed in detail on slides 21-23 of the presentation (see Appendix B). He noted that few changes have been made since the last Advisory Group meeting as the general consensus was that these current scenarios represent an acceptable balance of strategies that may lead to a 100% renewable system. The range of scenarios also captures the various perspectives of the Advisory Group members. Aaron also noted that the NREL team has designed the scenarios to be flexible to accommodate future changes.

Questions and Comments from Advisory Group Members

Question: All scenarios list 2030 as the target date for net 100% renewable energy. Why does the Net 100% scenario also list 2045?

> Answer: Policies used to achieve the goals of the Net 100% scenario will be extended through 2045 to maintain net 100% renewable energy.

Question: Has the project team considered giving the LA Leads scenario a more aggressive deadline than 2030?

> Answer: The project team considers the 2030 timeline aggressive. While consideration has been given to making that timeline more aggressive, challenges exist with the timeline for building new transmission infrastructure and changing consumer behavior so rapidly.

Question: Is it necessary to accelerate infrastructure if distributed sources of generation can be added faster?

> Answer: The scenarios already consider the highest amount of distributed energy and efficiency.

Question: When do actions in each scenario begin?

> Answer: In general, scenarios begin after 2030, once the City of Los Angeles meets the net 100% renewable energy goal that is set in the Integrated Resource Plan.

Question: Is seasonal variation common in the West?

> Answer: There are differences in timing, but most places deal with the same seasonal variation problem. All scenarios will examine the entire Western Interconnection, so NREL will be able to study how Los Angeles can best work with its neighbors.

Question: Does the Transmission Renaissance scenario assume deeper interconnection with others?

> Answer: More remains to be done before concluding exactly how any actions related to 100% renewable energy would affect connections within the Western Interconnection and potentially across interconnections.

Question: Why is the load category moderate in the Emissions Free scenario? Should it be considered high due to the electrification of transportation?

Answer: The NREL team wanted to isolate the impact on emissions. Other scenarios investigate the effects of changes caused by the different loads.

Question: Is it possible that the Emissions Free scenario could be cheaper with increased energy efficiency and demand response?

Answer: There are many ways to configure the scenarios, and the NREL team has designed each to examine certain tradeoffs. The Emissions Free scenario was designed to exclude combustion sources, such as bio energy, with a focus on zero emissions, and other scenarios will look more deeply at efficiency and demand response.

Question: Do the scenarios assume that other parts of the region adopt photovoltaics and electric vehicles at the same pace as California?

Answer: Absolutely. Exactly how we will do this is the subject of considerable discussion at the lab.

Comment: The Emissions Free scenario does not include other things that produce emissions.

Response: It is true that when aspects of the residential sector are electrified, there are changes to the emissions profile. It is a difficult balancing act. The moderate energy efficiency targets included in this scenario are impressive compared to national standards.

Question: Can energy efficiency and demand response reduce peak load?

Answer: Yes they can, but it's a delicate and detailed question. It all depends on how you do it. Demand response can shift the peak load. The NREL team is conducting sophisticated load modeling and should be able to characterize the difference between energy efficiency and demand response and isolate their impacts on the system. Load analysis will be covered in more detail at the June 27, 2019 meeting.

Methods and Data for the 100% Renewable Energy Study

Paul Denholm, NREL Technical Lead presented the methods and data that will be used by NREL to study the transition to 100% renewable energy. He noted that the City Council motion, which drives the Study, directs LADWP to determine needed investments that will lead to a 100% renewable energy portfolio. In conducting the Study, three main questions guide the analysis:

- What are the pathways to achieving the different scenarios (What gets built? How much? Where? When?)?
- Would system reliability be maintained?
- How much would the scenarios cost?

The Study is similar to the Integrated Resources Plan in that it evaluates an optimized mix of generation, seeking a "least cost" mix, while considering environmental and other constraints. An ideal modeling study would use raw data, along with scenario definitions and parameters, to create a capacity expansion model. However, this ideal model is not feasible and must be enhanced with output modeling and validation.

The Study will be conducted on a much larger scale than traditional integrated resource plans, and will involve analysis that has not been done on projects of this scale in the past. A number of factors differentiate the Study from traditional integrated resource plan studies:

- Additional geographic considerations, including detailed load modeling, adoption of distributed resources, and analysis of the distribution system
- Additional scope, including analysis of new sources of demand such as vehicle electrification, as well as economic and environmental factors
- Use of best-in-class commercial tools or cutting-edge tools developed by NREL
- Additional environmental analysis
- Analysis of impacts to environmental justice communities

The following sections outline the 11 steps to be used in completing the Study. More details on these steps can be found in the meeting presentation (see Appendix B).

Non-Modeling
The first step in modeling involves data collection and scenario development. This step sets the stage for the modeling process and is closely overseen by the NREL team. During this phase, there will be significant coordination with the Once-Through Cooling study to acquire relevant data, and the different study scenarios will be defined.

Input Modeling
The second through fourth steps in modeling address load growth and demand, renewable resource availability, generation profiles, distribution capacity, and upgrade costs. To help in understanding how demand will grow and how flexible the loads will be, NREL will generate data that represents possible future load. Loads include residential, commercial, and industrial buildings, as well as electric vehicles and other miscellaneous loads. Renewable resource analysis will generate a data set representing resources available to LADWP, consider wind and solar potential, and determine the amount of land that may be needed for future development.

Distribution system cost analysis will consider the ability of LADWP's distribution network to accommodate distributed solar generation. An important aspect of this analysis will be hosting capacity, which determines the point at which no more distributed solar can be added without additional system upgrades.

Main Scenario Modeling
The fifth step marks the beginning of capacity expansion model development, which explores the generation mix of each scenario. This process considers both utility-scale generation and customer adoption of distributed resources. It is the core model of the Study.

The geographic scope of the utility-scale analysis includes both LADWP and the broader Western Interconnection and does not estimate the likelihood of customers adopting rooftop solar. This is addressed in a separate model (dGen). The capacity expansion model for the regional electrical system includes consideration of individual generation units and related transmission, detailed system operation data, generator siting options, flexible data structure to accommodate custom models, and cost and value of storage and other enabling technology.

Distributed generation modeling forecasts customer adoption of distributed technology generation for residential, commercial, and industrial uses. Analysis has a high geographic resolution, enabling state, utility, or city-specific analysis.

At the end of this phase, the NREL team will have generated a plan to meet 100% renewable energy and will have calculated the costs and estimated emissions reductions. However, validation of these results would now be necessary.

Validation Modeling

The sixth through eighth steps will provide important validation of the modeling results by addressing resource adequacy, ramping requirements, operating reserve requirements, ability to meet contingency events, and reliability of transmission and distribution systems. These steps will help determine if the resulting power system:

- Can balance the load
- Can meet demand
- Can provide a reliable transmission and distribution network that is responsive to any failures
- Is subject to negative impacts from generation fed from the distribution system.

Output Modeling

The ninth and tenth steps will evaluate environmental benefits and impacts, as well as local job and economic development impacts of the modeling results. These methods are outlined later in this summary.

Visualization and Communication

During the final step of the Study, NREL will create engaging visuals and methods for communicating the Study results in a meaningful, easily understood manner.

Questions and Comments from Advisory Group Members

Question: Is demand forecasting in the Study different from demand forecasting done for the Integrated Resource Plan?

> Answer: Many integrated resource plans are focused on economic growth, but the Study more closely addresses changes in energy efficiency over the next 5-10 years and takes a more granular approach.

Question: What building codes do the scenarios assume? Do they consider that the City of Los Angeles could adopt new codes?

Answer: The model assumes existing codes and regulations. It is very risky to speculate on regulations that might be adopted. We are closely monitoring current events to accommodate any changes in this space that we can.

Question: Will the analysis consider detailed regional industrial demand?

Answer: The NREL analysis is being conducted for LADWP's service territory. For the rest of the state and Western Interconnection, the NREL team will be using forecasting data from other entities.

Question: How will interrelated impacts to transmission upgrades, distributed generation, and small-scale residential solar be considered?

Answer: This is one of the major questions that the Study will seek to answer.

Question: Will there be a future opportunity to adapt the Study based on changes to LADWP renewable energy goals or changes in the Integrated Resource Plan before adoption of the scenarios begins?

Answer: The NREL team is working with the Integrated Resource Plan group and will try to be as agile as possible in accommodating those changes.

Question: Does NREL have data on building age, and will this data be used to conduct economic analysis of potential retrofitting requirements?

Answer: Yes, there is consideration of this in the models.

Question: Are there articles for non–electrical engineers that could help with understanding some of the more technical concepts?

Answer: We can provide some resources on this topic, but unfortunately this is a highly technical subject area. The best thing for people to do is to come to every AG meeting where we are trying to distill this into material non-engineers can understand.

Question: Does the model take into account climate change?

Answer: The NREL team will incorporate historical data on extreme weather years, as gathering detailed weather data at the scale of the Study would be very resource-intensive.

Question: How detailed is the data in the Plexos model?

Answer: The model has technical specifications for every power plant in the western interconnection and every transmission line. You can't add much more resolution to the PLEXOS model, while others possess all of this data, NREL is likely the only organization that can study the entire interconnection in this level of detail.

Question: Will the Study consider the entire Western Interconnection?

Answer: Yes, that will be necessary.

Question: How are weather and temperature factored into these models?

Answer: There are many ways. For example, there are thermal line limits for transmission and distribution lines and NREL will run simulations to see if those temperature limits are exceeded in the scenarios.

Question: Have other entities studied the effects of distributed generation feeding through the distribution system? Is this too large or expensive a challenge to consider?

Answer: This has not been studied on the scale proposed for the Study. A number of safety measures and pieces of protection equipment could be impacted by such a large quantity of electricity traveling in the opposite direction on the distribution system. This is a technically challenging study, but some distribution systems may be able to support it.

Question: Did the Los Angeles City Council motion direct NREL to seek the least cost option?

Answer: This is a very important question and can quickly be taken out of context. We should be very careful when we talk about cost. We follow the state of the science when it comes to planning modern power systems. The primary objective of the motion is to reach 100% renewable energy, but NREL is using tools that help us figure out the feasible pathways to reaching the goal. Least cost optimization is the standard for this type of study. If cost wasn't a constraint for reaching the goals, the solution would be relatively easy but potentially infeasible. For example, we could just build a power line all the way to Quebec where they have the largest storage system in the world. Unfortunately that solution, is likely so expensive that it isn't worth considering, not to mention the challenge of building a line across the continent.

Question: What is the Rate Payer Advocate analysis?

Answer: The Los Angeles City Council requested an independent rate payer impact analysis of the Study, once NREL's study is complete the Rate Payer Advocate will perform the analysis to determine the impact on rate payers. NREL's role is to design systems that will meet all reliability requirements and to do an accurate accounting for all costs associated with meeting the reliability needs of the system. Then NREL passes the costs to the Rate Payer Advocate to calculate potential rate impacts

Environmental Modeling

Garvin Heath, NREL Senior Scientist, provided an overview of methods and approaches to modeling the potential environmental effects of different scenarios for reaching 100% renewable energy. Whereas most components of this modeling will be conducted near the end of the Study process, the environmental justice aspect will begin during the first step of the project, data collection and scenario development. This will help determine which neighborhoods are to be targeted for energy efficiency and distributed renewable energy deployment during the Study process.

The environmental modeling process has four components:

- Greenhouse gas (GHG) emissions
- Air quality
- Public health
- Environmental justice

Given the status of assembling the team and that there is a later AG meeting whose agenda includes “environmental modeling II” discussion, this session provides details of the GHG emission accounting methods and an overview of the methods for the other three environmental modeling areas. The latter areas’ methods will be described in more detail in the subsequent AG meeting.

Greenhouse Gas Emissions
The GHG emissions modeling will consider all attributable GHG emissions from each scenario, including:

- CO_2 emissions from combustion of fuels used to generate electricity
- GHG emissions from the construction, operation, and demolition of facilities deployed in each 100% RE scenario (life cycle assessment)
- Emissions that may result from changes in interconnected electricity generation resources owned and operated in other service territories and balancing areas outside of LADWP’s
- GHG emissions other than carbon dioxide (CO2) such as methane and nitrous oxide, which can be emitted by from resources considered renewable

Life-cycle assessment (LCA) is a well-recognized method practiced for over 40 years that aims to quantify resource consumption, energy use, and emissions for different scenarios from cradle to grave. In the Study, LCA will be used to comprehensively and fairly account for all attributable GHG emissions from the scenarios evaluated in the Study. Estimating GHG emissions in the Study takes the following two-stage approach beginning with the Resource Planning Model estimating CO_2 emissions from combustion sources. The second step leverages NREL’s exhaustive review of all published LCAs for generation technology’s life cycle GHG emissions (work that has been maintained for the last 7 years and published in IPCC reports, academic journals and many DOE reports) to extract emission factors applied to three additional life-cycle phases, including upstream materials manufacturing, downstream plant decommissioning, and ongoing (non-combustion) operations, maintenance, and fuel cycle emissions. As compared to previous NREL-led studies accounting for GHG emissions from power sector scenarios, this study will assess battery storage, for which NREL will follow the same approach as demonstrated for their other studies in leveraging available published findings and translating their results for use here.

Air Quality and Public Health Effects
Air quality modeling has a long history in Los Angeles, and many models exist that are calibrated to the area. Air quality and environmental (public) health effects could be considered

on a continuum, with air quality modeling being concerned with air pollutant emissions and resulting pollutant concentrations, and environmental health modeling concerned with human inhalation exposure, intake/dose of pollutants, and resultant health effects based on well-vetted epidemiological studies.

The NREL team will evaluate Study scenarios for air quality and public health benefits, considering both emissions created within the air basin and those transported into the basin from sources whose operations may be impacted by changes in the LADWP system. More information about the specific model to be used and other methods will be presented in the “environmental modeling II” session of a future AG meeting.

Environmental Justice

There are many approaches to defining environmental justice neighborhoods, and active discussion about this topic is occurring among several regional organizations in the Los Angeles area as well as the State of California. The NREL team is currently consulting with the City of Los Angeles Planning Department to learn more about various local efforts to define environmental justice.

Per requirements of a City Council motion, the NREL team will use California Environmental Protection Agency’s (CalEPA) CalEnviroScreen 3.0 EJ screening tool to determine which neighborhoods should be designated as EJ neighborhoods for the purpose of targeting energy efficiency and distributed renewable energy investments that are part of scenarios to be evaluated in this study. CalEnviroScreen evaluates the pollution burden in California communities from multiple sources while accounting for potential vulnerability to adverse effects of air pollution. At the end of the study, the total benefits of each scenario in terms of air quality and public health will be differentiated between those accrued to EJ neighborhoods and those in non-EJ neighborhoods.

Questions and Comments from Advisory Group Members

Comment: The higher the cost of electric power, the less likely it will be that electrification will replace fossil fuels in transport. A feedback effect of changes in cost of energy can affect the uptake of clean technologies, especially in the transportation sector.

> Response: The study does not explicitly examine dynamic effects of how increased electricity prices could affect adoption of technologies such as electric vehicles. However, a number of different levels of electrification will be assumed throughout the study, which should help address this issue.

Question: Do the studies consider effects of methane leakage from natural gas transportation and storage?

> Answer: Good life-cycle assessments will include data on leakage. This Study will not specifically analyze Los Angeles’ infrastructure, but data will be incorporated from other high-quality analyses to guide the Study. And NREL is an expert in this field.

Question: Could the results of the life-cycle assessment be included in other LADWP efforts, such as the Integrated Resource Plan?

> Answer: Analysis conducted for this task will be conducted specifically on the output of the 100% renewable energy modeling. It will be at the discretion of LADWP whether they can include these results in other efforts.

Question: When analyzing bio gas sources, does NREL see a potential for incentivizing more waste in order to create more bio gas? Will the Study consider changes to infrastructure for properly transporting and treating bio gas?

> Answer: The NREL team does not anticipate an increase in waste streams for the purpose of increasing bio gas production. The Study will focus on existing policy, not on potential policy. Clear standards are set for bio gas entering the pipeline, so it is not anticipated that this will be an issue in the Study.

Question: Can NREL share some literature with the Advisory Group on the life-cycle assessment process?
Answer: Yes.

Comment: State GHG emissions inventory might be less comprehensive than the Study's life-cycle assessment.

> Answer: Inventories and life-cycle assessments analyze the same set of data differently. Inventories consider GHGs occurring in a time or geography and attribute them to different industries within that time and place. A life-cycle assessment is longitudinal, studying all emissions that are attributable to the end product one is studying, which here is a kWh of electricity generation, and thus sums over time and space all emission related to generating that kWh. So the State's inventory isn't less comprehensive than an LCA, but cuts the same data differently for different purposes.

Question: Will the Study consider life-cycle analysis for criteria and other pollutants?

> Answer: The issues of concern for air pollutants are about local public health effects, which is something you study with air quality and public health models, not life cycle assessment. Air quality models require knowledge of where and when air pollutants are emitted, which is not included in most LCAs. Also, not all emissions associated with renewable energy production will impact local air quality (e.g., solar panels manufactured in China), so LCAs including those emissions occurring in different places and times are not relevant to local air quality. Thus, we will use air quality and public health modeling and not LCA to assess criteria and other (non-GHG) air pollutants.

Comment: Changes in LADWP generation assets may reduce emissions in Los Angeles but can cause emissions elsewhere and impact air quality in other regions.

> Answer: The scope of the air quality and public health analysis for the Study is focused only on the South Coast Air Basin, per direction from the City Council motion. For GHG emissions, the scope will include effects on regional generators from the scenarios of this Study

Question: Will analysis include a global accounting of GHG emissions?

Answer: Yes, GHG emissions have a much greater effect on the larger globe than do criteria pollutants.

Question: Will analyses include analysis of HFCs, in particular refrigerants in buildings?

Answer: Because analysis is being conducted on the electric sector, it will focus on how any changes in building stock (and their appliances) affect the electric load, but not include other impacts of changes to building stock.

Question: Will health impact analysis include a monetized impact from health effects?

Answer: This is not in the scope of the Study.

Question: Will the Study conduct a life-cycle assessment of battery storage?

Answer: We will not conduct our own LCA, but use the same approach taken in our many previous studies by conducting a comprehensive literature review and synthesizing the results from other researchers to estimate GHG emission from the life cycle of battery storage.

Question: Will the Study differentiate between impacts to air quality from the power system and impacts from oil and gas refineries?

Answer: This Study will identify impacts from changes to the electrical system but will not analyze impacts from oil and gas production, as the Study's focus is on the electrical system.

Comment: Consider broadening the scope of the GHG emissions to include light-duty vehicles.

Response: If Advisory Group members have examples of studies that have done the analysis differently, please send those to Anton Sy.

Question: What baseline of air pollutant emissions are we using for the air quality modeling?

Answer: More analysis is needed to answer this question.

Comment: Consider a broader definition of environmental justice that includes racial disparity.

Answer: The City Council motion requires us to use the CalEnviroScreen tool for the Study's EJ analysis. The California Environmental Protection Agency designed the current version of the CalEnviroScreen tool to not include racial disparity, instead including other socio-economic factors life language isolation and income disparity.

Comment: Consider how AB 617 might affect the Study.

Response: Advisory Group members are encouraged to send Anton Sy any links to relevant resources.

Conclusions and Next Steps

Joan of Kearns & West reminded Advisory Group members to send comments or questions on any topic at any time to Anton Sy, Project Manager: anton.sy@ladwp.com or (213) 367-2332.

The next quarterly Advisory Group meetings are scheduled for November 15, 2018 and March 28, 2019.

Los Angeles 100% Renewable Energy Study

Advisory Group Meeting #6
Thursday, August 16, 2018, 8:45 am to 1:45 pm

Appendix A

Agenda

City of Los Angeles 100% Renewable Energy Study
Thursday, August 16, 2018
8:45 am – 1:45 pm
Los Angeles Department of Water and Power, Room 1514

Meeting Purpose:

a) **Prepare for discussion of the first round of modeling results in future meetings by continuing to expand the Advisory Groups collective knowledge of the study methodology.**

b) **Continue to hear input and feedback on the study methodology from the Advisory Group.**

8:45 – 9:00 am	**Arrive at LADWP / Networking / Continental Breakfast**
9:00 – 9:10 am	**Call to Order and Agenda Overview** **Kearns & West (K&W):** Joan Isaacson, Facilitator
9:10 – 9:20 am	**Welcome and Introductions** **LADWP:** Eric Montag and Anton Sy **NREL:** Aaron Bloom
9:20 – 9:30 am	**Update Exchange** • **Updated Advisory Group Meeting Road Map and Dates** All
9:30 – 10:10 am	**Recaps** • **Scenarios for the Renewable Energy Study** • **Framing the 100% Renewable Energy Study** **NREL: Aaron Bloom, Project Manager**
10:10 – 10:25 am	**Break**
10:25 – 11:55 am	**Methods and Data for the 100% Renewable Energy Study** • **Input Modeling** • **Scenario Modeling** • **Validation Modeling** • **Output Modeling** • **Discussion/Q&A** **NREL: Paul Denholm, Technical Lead**
11:55 – 12:25 pm	**Lunch Served**

12:25 – 1:40 pm	**Environmental Modeling 1** • **GHG** • **Air Quality** • **Public Health** • **Environmental Justice and CalEnviro Screen** • **Discsussion/Q&A** **NREL: Garvin Heath, Senior Scientist**
1:40 – 1:45 pm	**Wrap-up and Next Steps** • Next meeting date: November 15, 2018

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Appendix B
Presentations

NREL NATIONAL RENEWABLE ENERGY LABORATORY | LA DWP

Los Angeles 100% Renewable Energy Study
Advisory Group Meeting #6
August 16, 2018

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Agenda

LA DWP

- Agenda Overview
- Welcome and Introductions
- Update Exchange
- Recaps
- Methods and Data for the 100% Renewable Energy Study**
- Lunch
- Environmental Modeling 1**
- Wrap-up and Next Steps

***Q&A and Discussion*

Tips for Productive Meetings

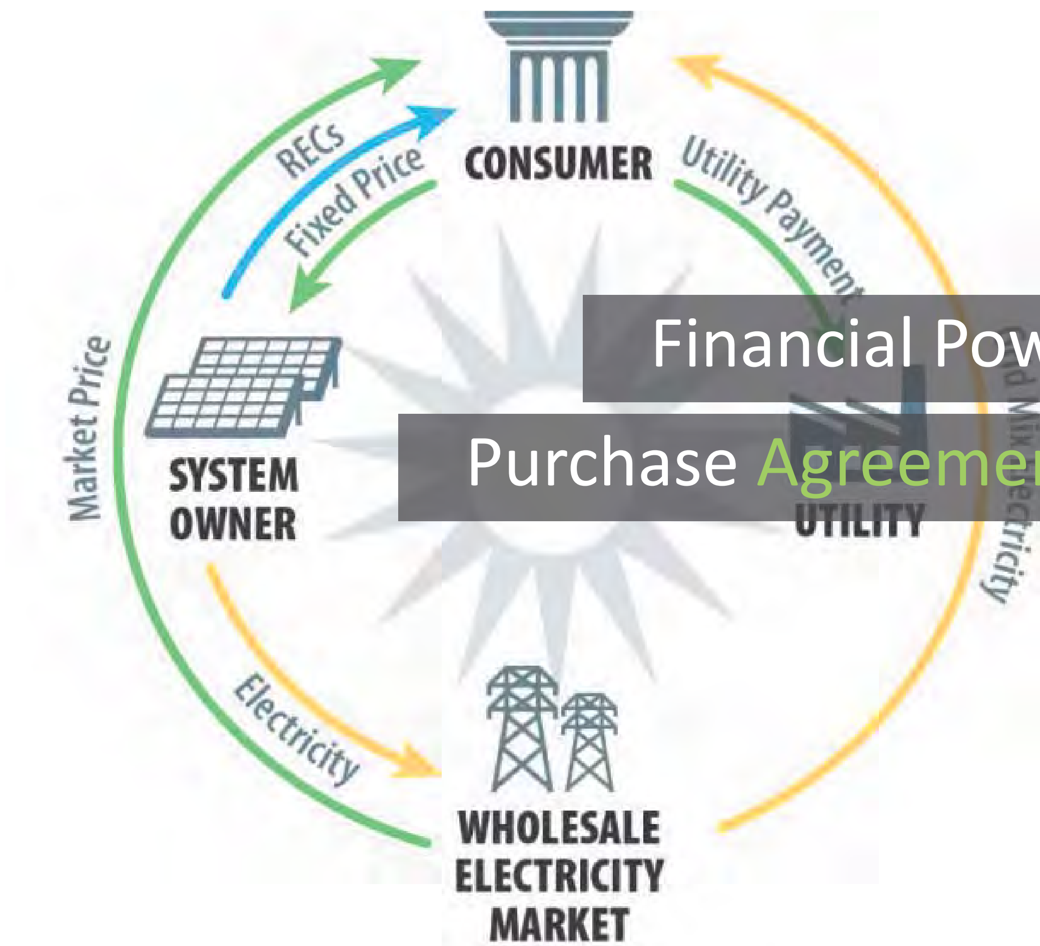
- Let one person speak at a time
- Help to make sure everyone gets equal time to give input
- Keep input concise so others have time to participate
- Actively listen to others, seek to understand perspectives
- Offer ideas to address questions and concerns raised by others

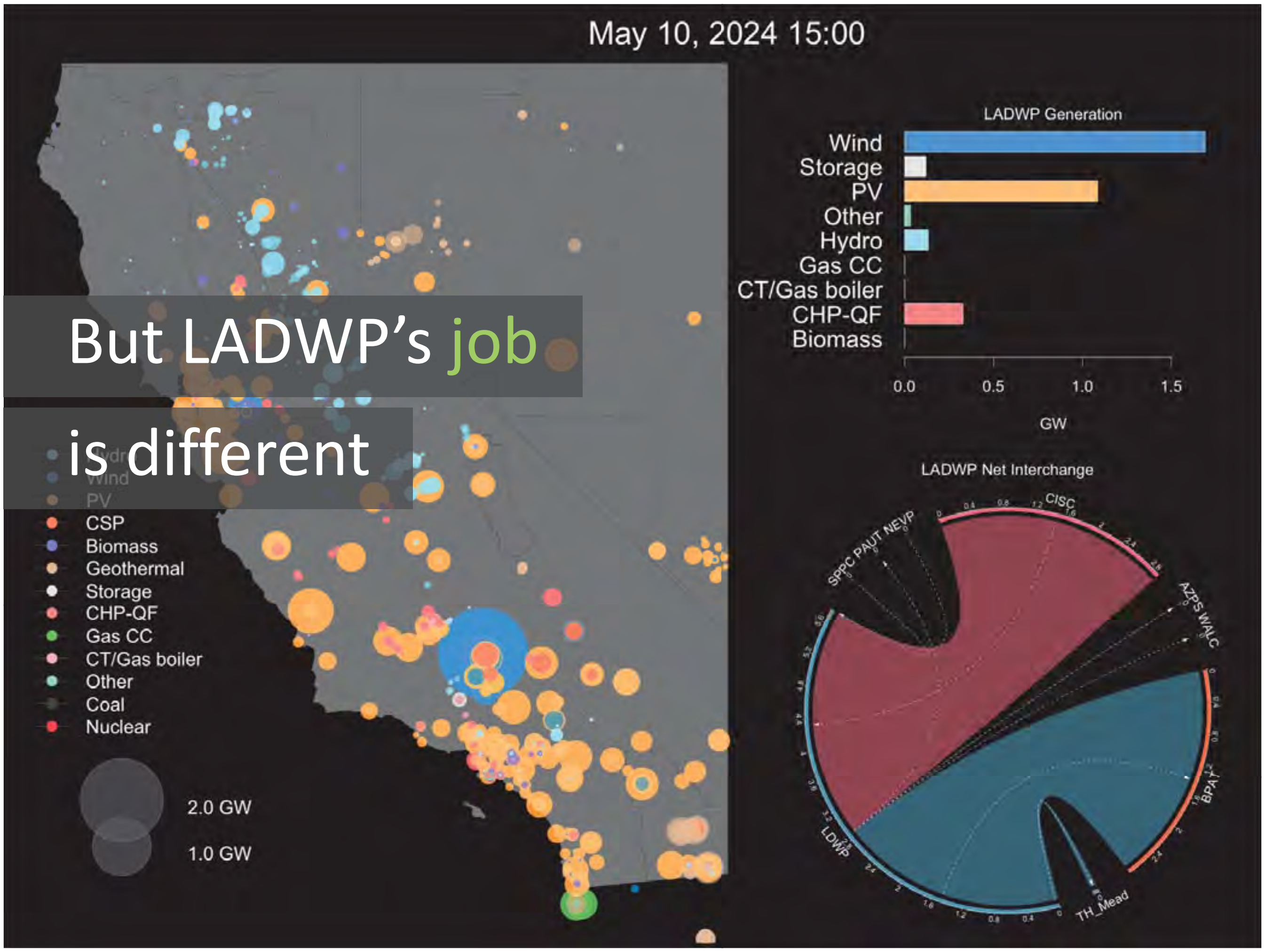
Welcome and Introductions

Update Exchange

How do most cities and corporations achieve 100%?

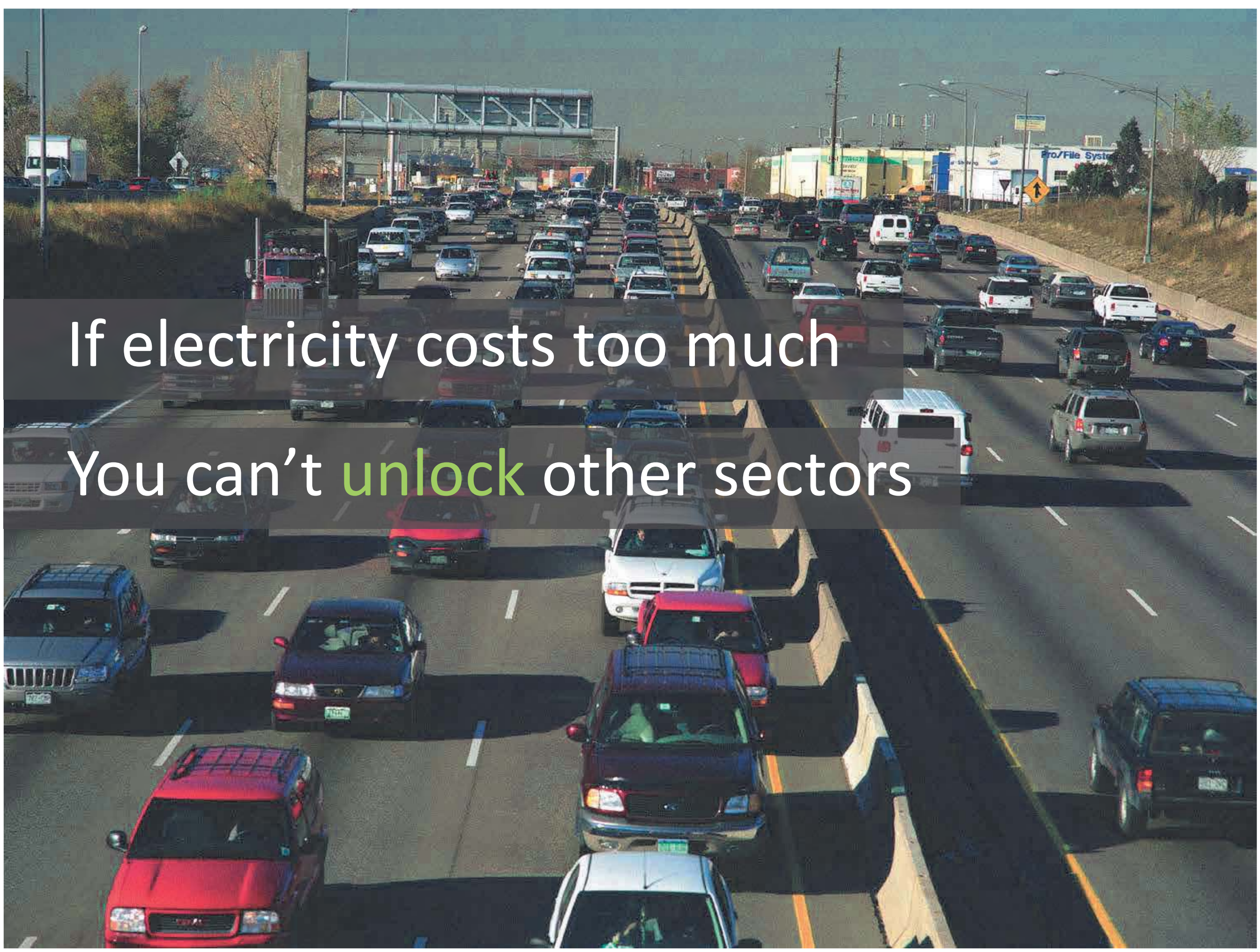
Financial Power Purchase Agreements

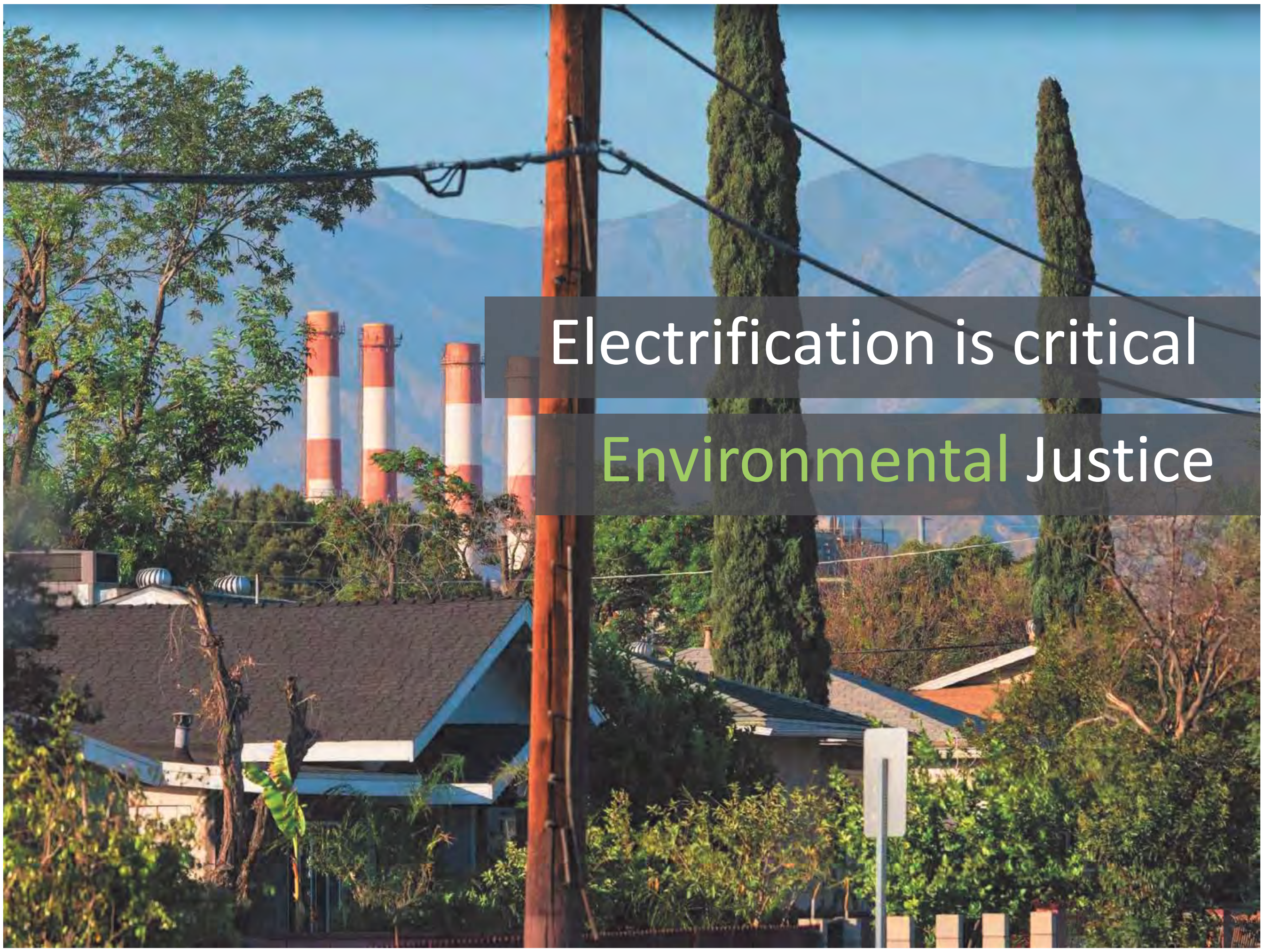


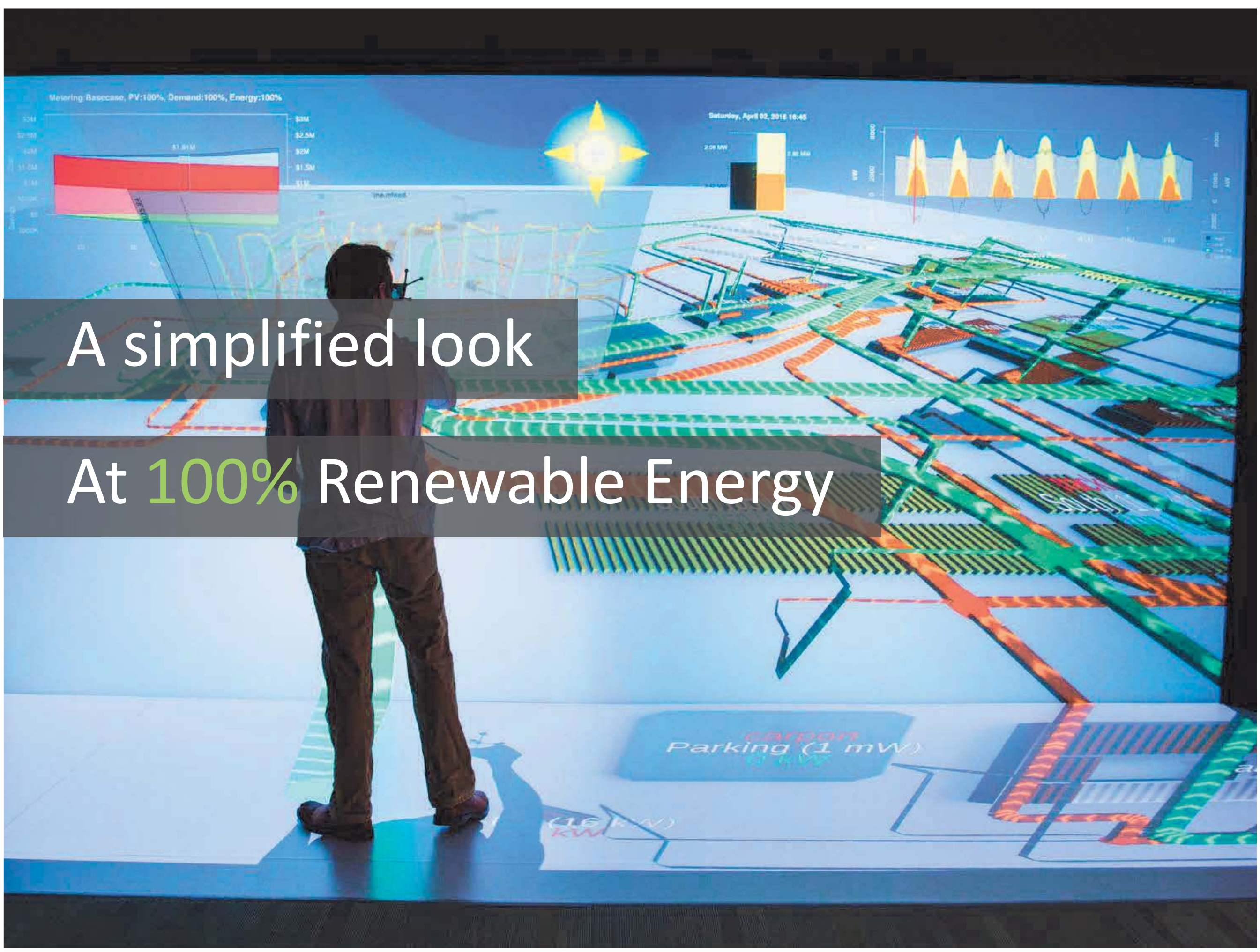

May 10, 2024 15:00
But LADWP's job
is different
LADWP Generation
Wind
Storage
PV
Other
Hydro
Gas CC
CT/Gas boiler
CHP-QF
Biomass
0.0
0.5
1.0
1.5
GW
LADWP Net Interchange
CISC
SPPC PAUT NEVP
AZPS WALC
BPAT
LDWP
TH_Mead
PV
CSP
Biomass
Geothermal
Storage
CHP-QF
Gas CC
CT/Gas boiler
Other
Coal
Nuclear
2.0 GW
1.0 GW

LADWP Needs to physically
balance the system

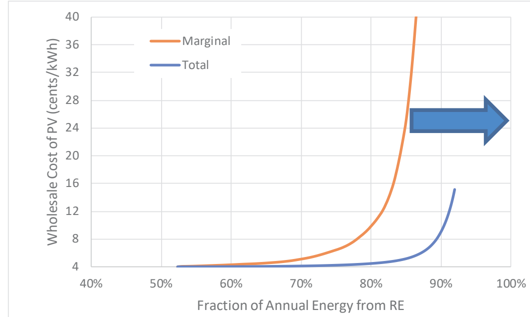

Renewable
Engineering solutions


If electricity costs too much
You can't unlock other sectors


Electrification is critical
Environmental Justice

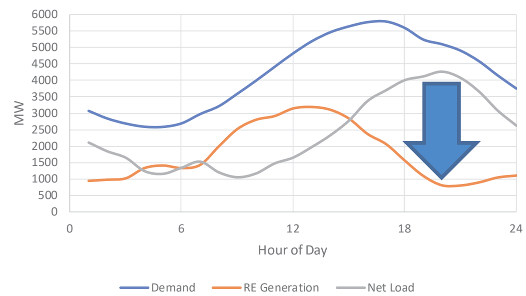

A simplified look
At 100% Renewable Energy
Parking (1 mW)

Marginal Curtailment and the Diurnal Mismatch



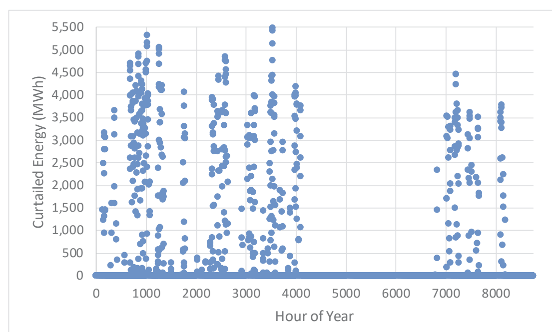
Marginal Curtailment

This study is about finding solutions and understanding the technical and economic challenges of 100%. We need to find a mix of resources that shift the cost curve and meet the economic challenges…



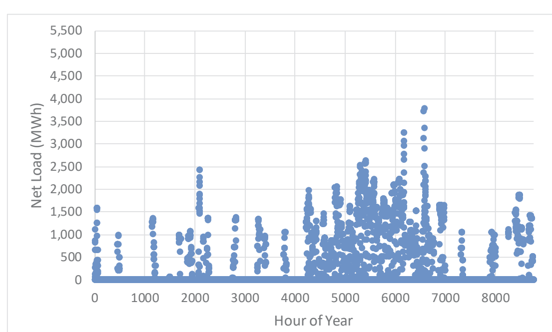
Peak Net Load

Seasonal Mismatch



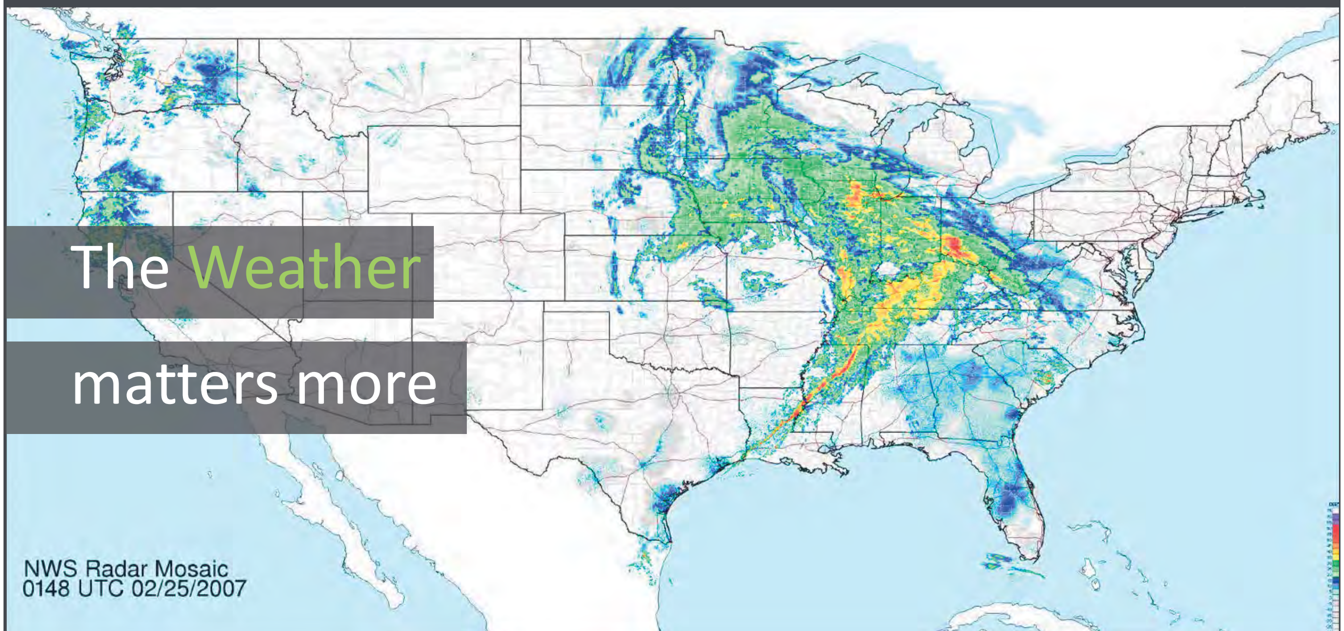
Hours of Surplus Energy

In the spring and fall there are many hours of excess energy. There are also many intervals where there is insufficient supply and demand. As we get closer to reaching 100% renewable energy, the importance of seasonal solutions grows.



Hours of Energy Deficiency

The Weather matters more



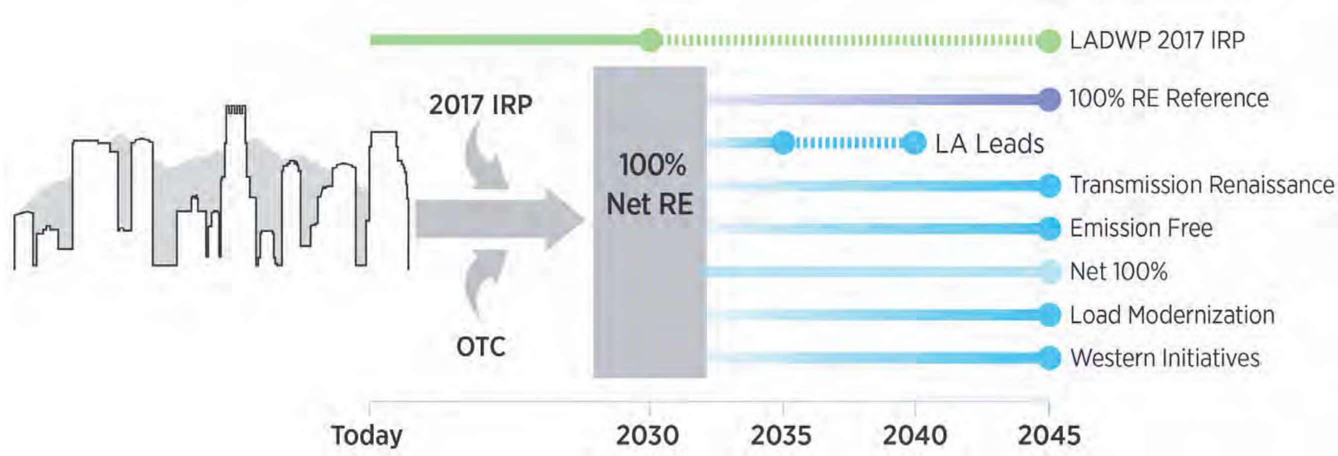
Daily patterns drive demand and supply

https://www.youtube.com/watch?v=hVymyJ9q5a0

Key Take-aways

- There are fundamental economic and technical considerations for achieving a 100% power system.
- These are mostly centered around the mismatch of renewable supply and demand.
  - We need to address both the daily mismatch AND the seasonal mismatch.
- This study will examine the host of flexibility options which can minimize the cost impacts of achieving very high levels of RE.
- This overview has ignored many of the technical and engineering issues associated with designing, modeling and analyzing a 100% RE power system. However the study will address them in detail, and we will be doing a deep dive on many of them at future meetings.

Scenario Framework



Scenario Descriptions

Scenario Name	Scenario Abbreviation	Net 100 Target Year	Final Target Year	Scenario Description
LADWP 2017 IRP *Recommended Case*	DWP-IRP	-	-	The DWP-IRP 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 IRP *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.
100% Renewable Reference Case	100-RE	2030	2045	By 2030, a net-100% portfolio is achieved through a balanced mix of both distributed and utility scale renewable resources, implementation of energy efficiency, demand response, and electrification programs, as well as purchased RECs. By 2045 the use of RECs is phased out through further investments in both supply and demand side resources.
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.
Transmission Renaissance	Trans+	2030	2045	Identical to the *100-RE* case, but new transmission corridors (along with upgrades to existing corridors) are allowed; 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.
High Distributed Energy Future	Hi-DEF	2030	2045	Identical to the 100-RE case, but only planned transmission upgrades (from the LADWP IRP) are allowed; 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.
Emissions Free	No-Emis	2030	2045*	Identical to the 100-RE case, but compliance must be achieved without any combustion-based generation (including biomass and biofuels), and nuclear generation is allowed to contribute towards compliance.
Net 100%	Net-100	2030	2045*ǂ	Identical to the 100-RE case, but renewable energy credits (RECs), both bundled and unbundled, and nuclear can be used as a source of compliance
Load Modernization	Load-Mod	2030	2045	Identical to the 100-RE case, but energy efficiency measures, demand response measures, and electrification are rapidly implemented through robust incentives, programs, and technology breakthroughs
Western Initiatives	WECC	2030	2045	Identical to the 100-RE case, but variable renewable generation achieves high penetration in the rest of WECC

* Nuclear generation is allowed to contribute towards the 100% target
ǂ RECs can be used as a component of compliance

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

Questions

Methods to Model a 100% Renewable Electric Power System

Paul Denholm

Modeling and Analysis Lead

August 16, 2018

Today's Presentation

- City Council's motion is

  "to determine what investments should be made to achieve a 100 percent renewable energy portfolio"

- So how exactly *do* we do this?

- That's what the next hour is all about.....

Framing The Problem

- What are pathways to achieve the various 100% clean energy scenarios?
  - What gets built?
  - How much?
  - Where?
  - When?

- Would these scenarios achieve the same level of reliability that LADWP currently achieves?

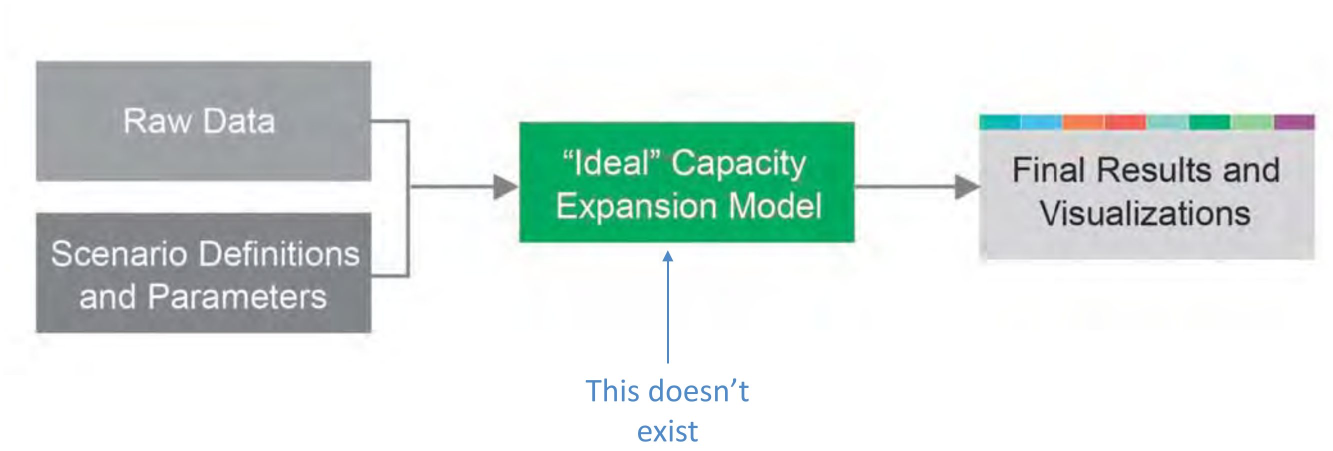
- How much would these scenarios cost?

Traditional Resource Planning

- The LA100 study is similar to integrated resource plans (IRPs) and other planning exercises to evaluate portfolios that "optimize" the mix of generators built.

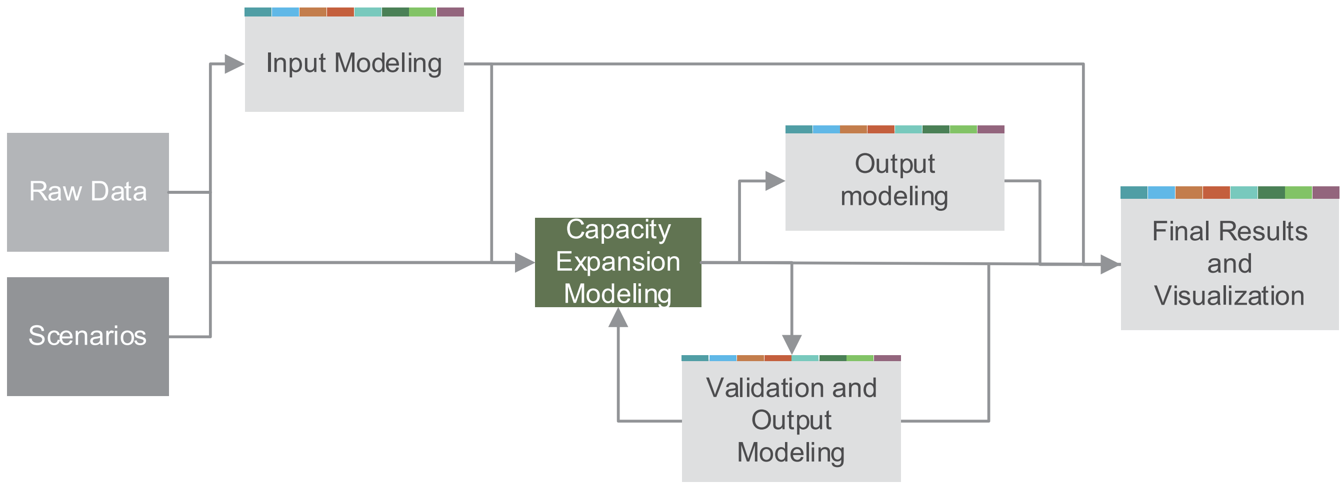
- The historical focus is developing a "least cost" mix, while meeting environmental or other constraints.

An Ideal Planning Study

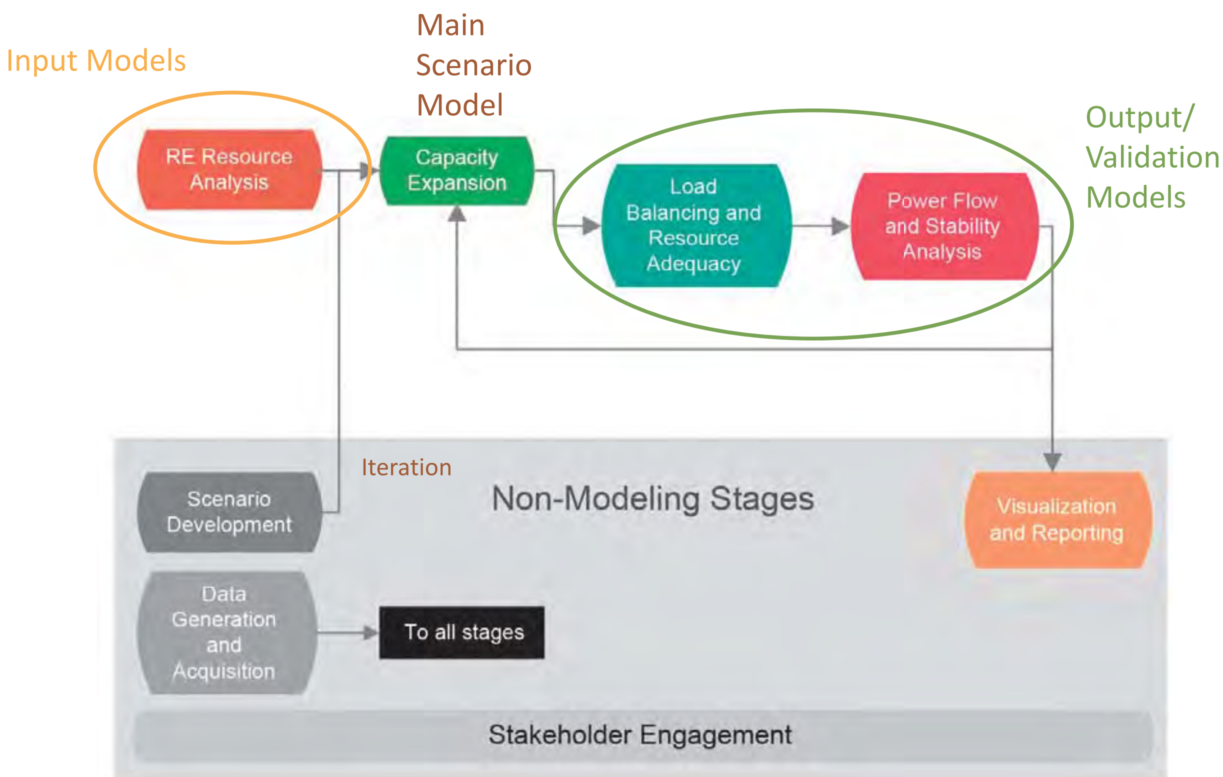


The core of many planning studies is the "Capacity Expansion Model". But it can't do everything…..

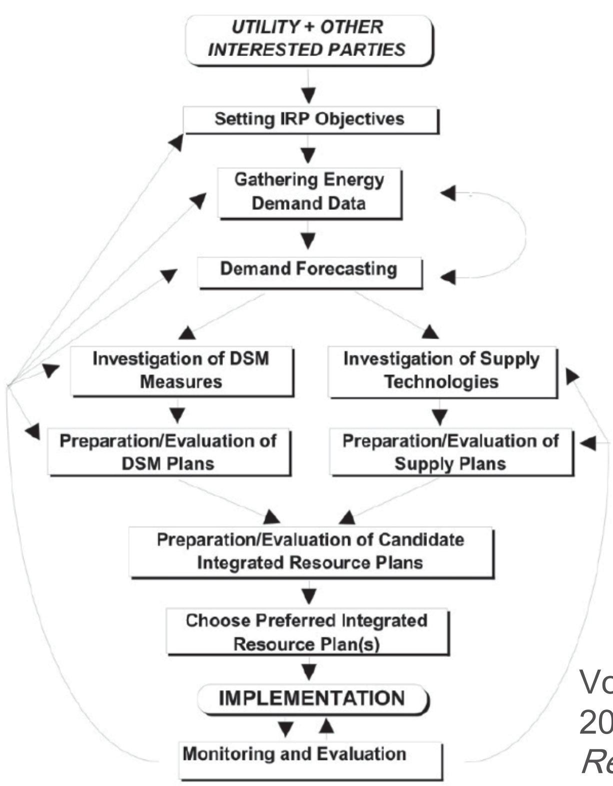
Traditional Planning Study Flow



Traditional (Detailed) Integrated Resource Plan Process

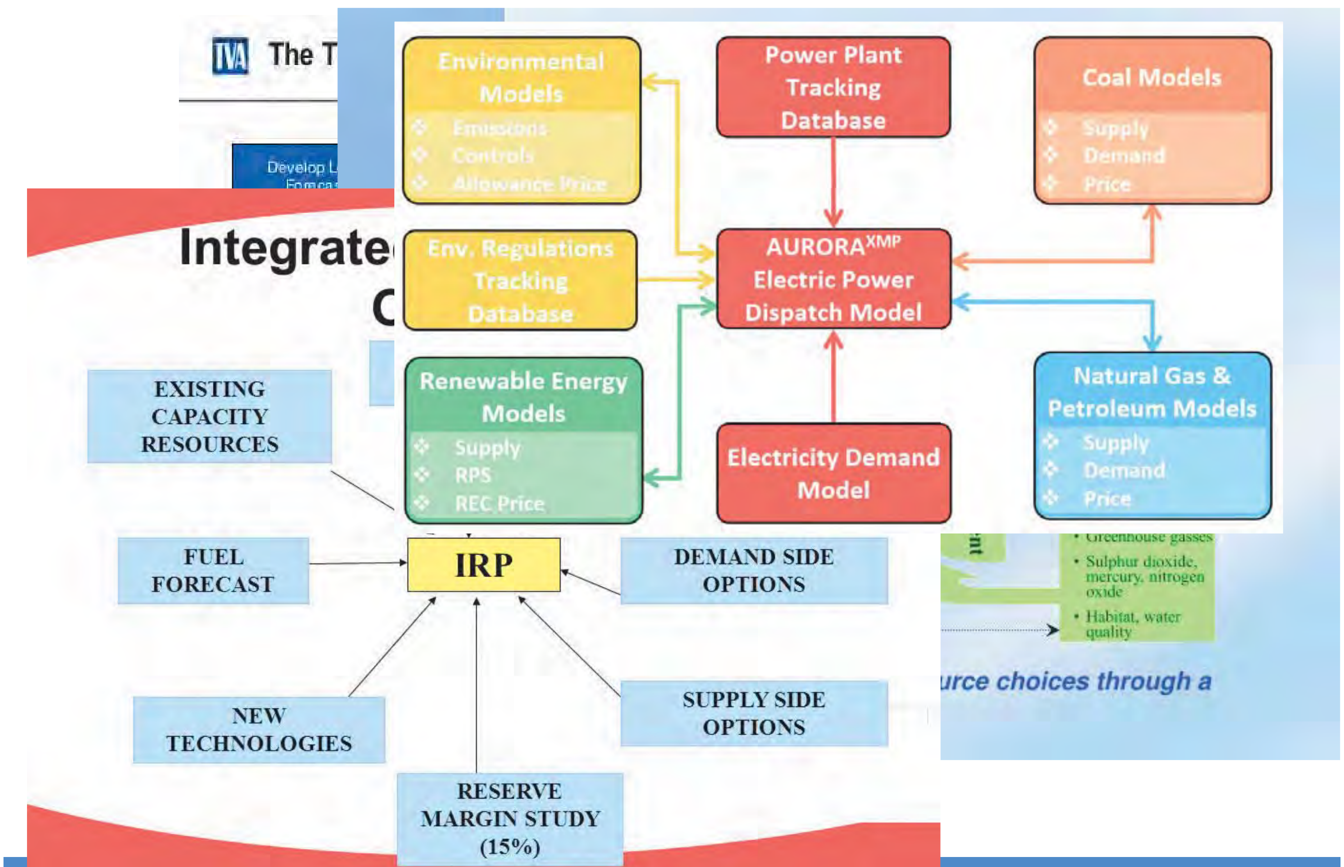


This is Nothing New…..



Von Hippel, David, and David Nichols. 2000. *Best Practices Guide: Integrated Resource Planning For Electricity*.

Many IRP Planning Processes and Tools…..

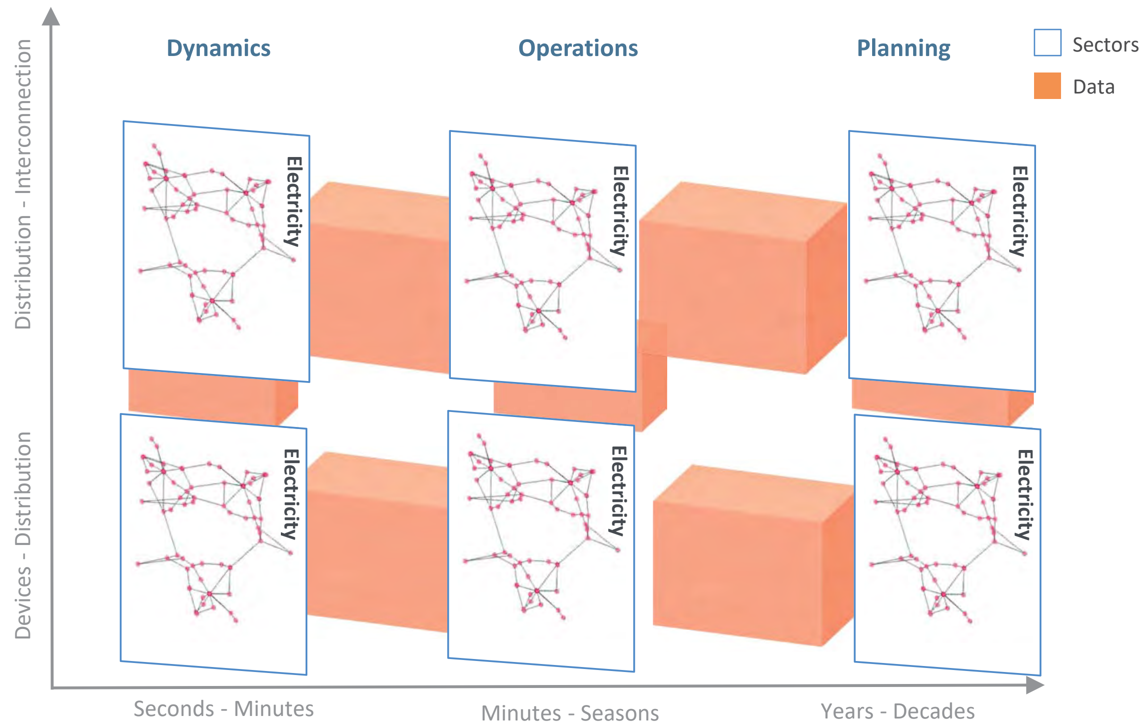


What's Different About This Study?

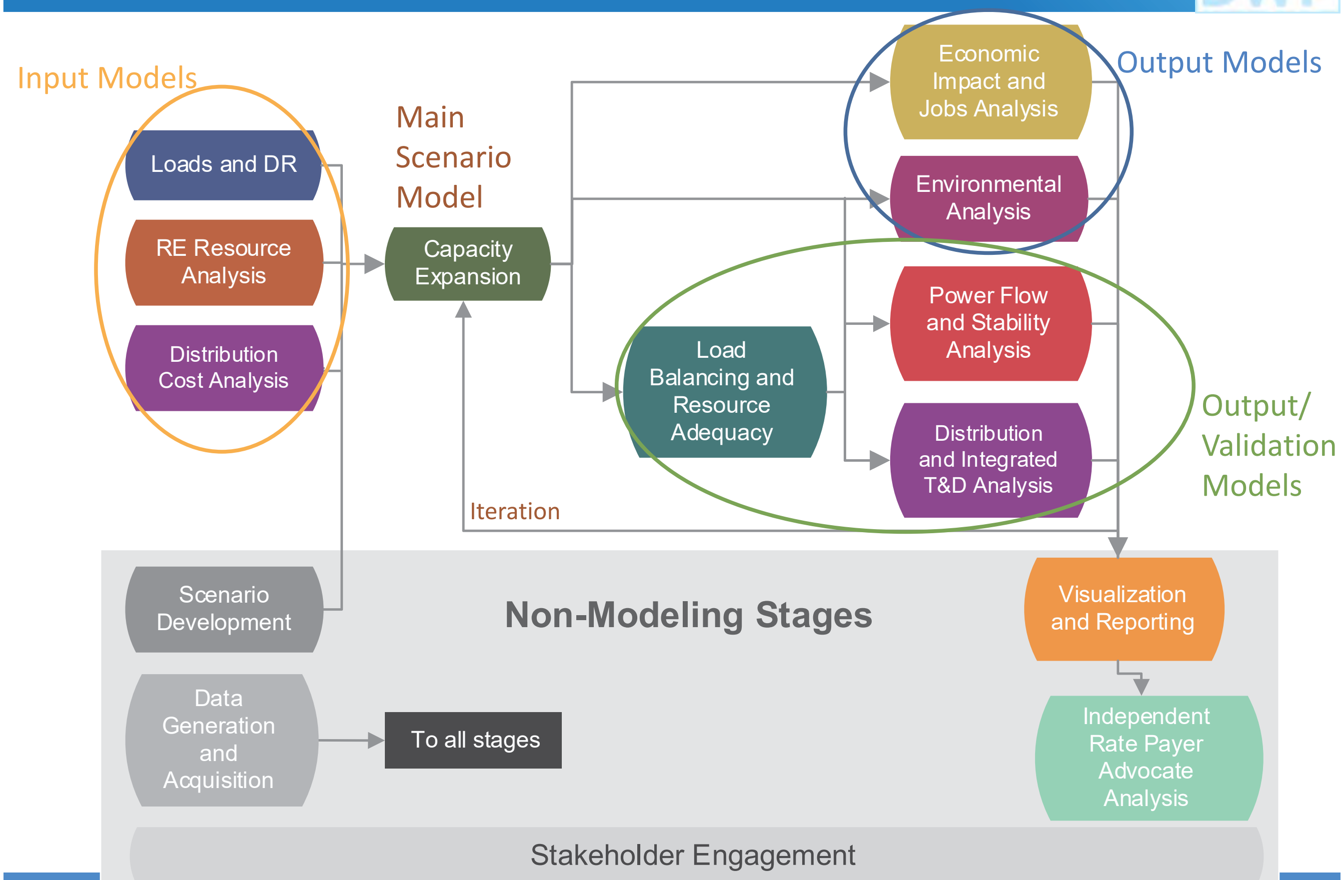
- We are adding additional
  - *Geographic* considerations including
    - Detailed load modeling,
    - Adoption of distributed resources
    - Analysis of distribution system
  - *Scope*
    - New sources of demand in industry and electric vehicles
    - Economic Analysis
    - Environmental Analysis

- We will follow proven methods and use state-of-the-art tools
  - Where commercial tools are best in class, we will use them
  - Where we think commercial tools are insufficient, we will use NREL tools

Study Scale



Steps of the LA 100% Renewable Energy Study



Step 1 (Non-Modeling)

1. Data collection and scenario development

Steps 2-4 (Input Modeling)

1. Data collection, scenario development
2. Estimate load growth and demand profiles
3. Determine renewable resource availability and generation profiles
4. Estimate distribution system hosting capacity and upgrade costs

Step 5 (Main Scenario Modeling)

1. Data collection, scenario development
2. Estimate load growth and demand profiles
3. Determine renewable resource availability and generation profiles
4. Estimate distribution system hosting capacity and upgrade costs
5. Develop optimal expansion plan and distributed resource adoption scenario

Steps 6-8 (Validation Modeling)

1. Data collection, scenario development
2. Estimate load growth and demand profiles
3. Determine renewable resource availability and generation profiles
4. Estimate distribution system hosting capacity and upgrade costs
5. Develop optimal expansion plan and distributed resource adoption scenario
6. Simulate grid operations and performance including load balancing, operating reserves, and resource adequacy
7. Evaluate transmission system reliability
8. Validate operation of integrated transmission and distribution system

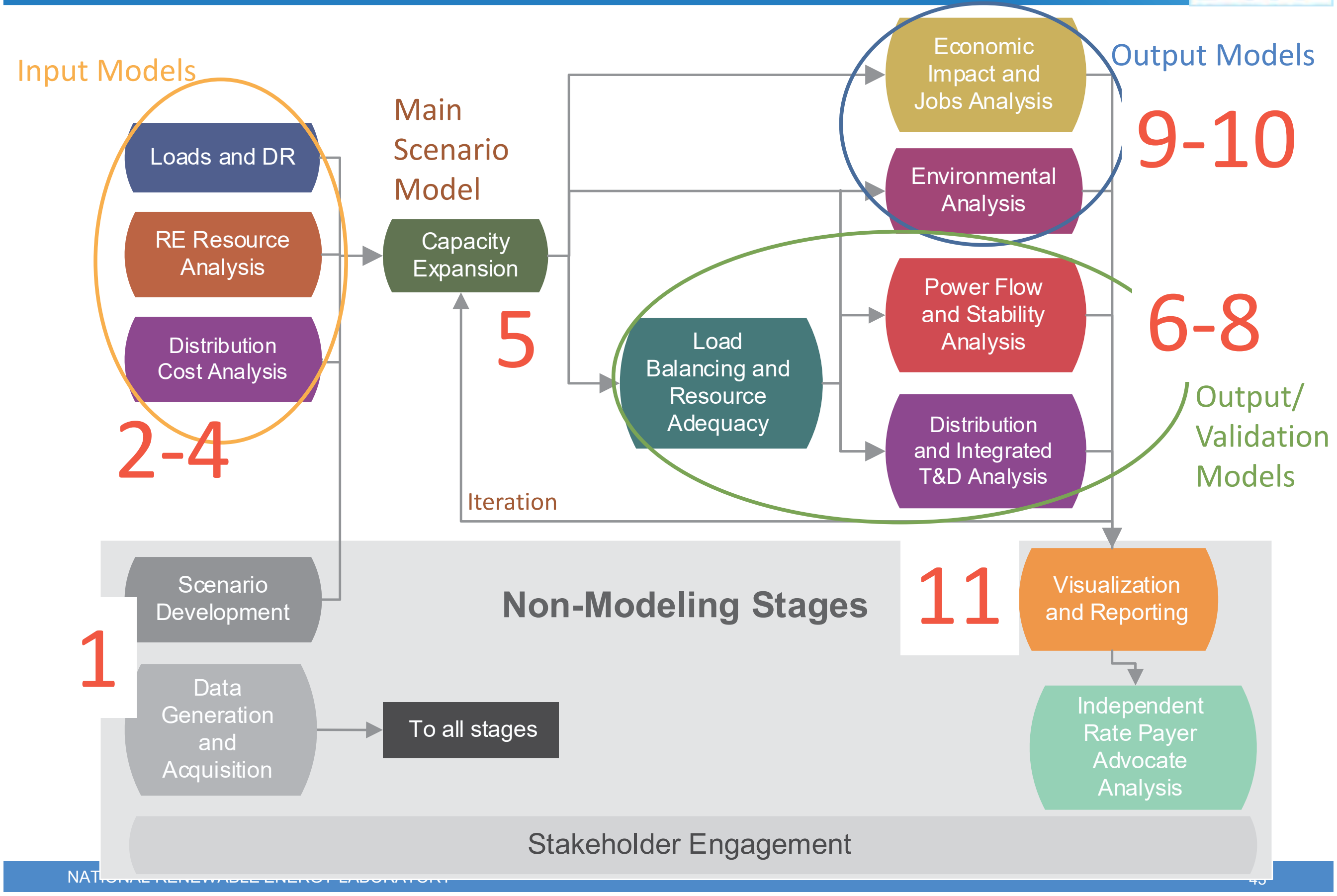
Steps 9-10 (Output Modeling)

1. Data collection, scenario development
2. Estimate load growth and demand profiles
3. Determine RE resource availability and generation profiles
4. Estimate distribution system hosting capacity and upgrade costs
5. Develop optimal expansion plan and distributed resource adoption scenario
6. Simulate grid operations and performance including load balancing, operating reserves, and resource adequacy
7. Evaluate transmission system reliability
8. Validate distribution system operation and integrated T&D system performance
9. **Evaluate environmental benefits and impacts**
10. **Evaluate local job and economic development impacts**

Step 11 (Visualization and Communication)

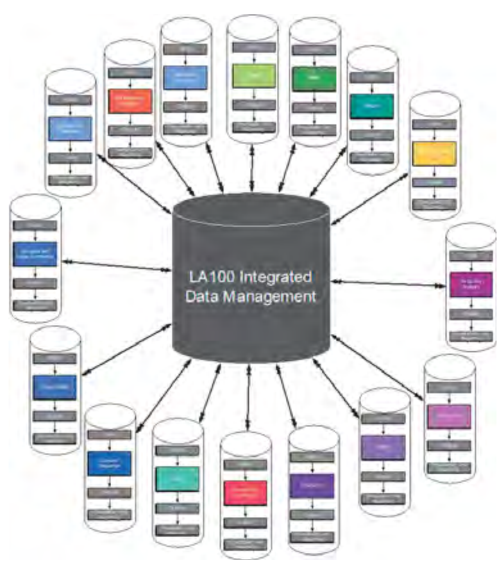
1. Data collection, scenario development
2. Estimate load growth and demand profiles
3. Determine RE resource availability and generation profiles
4. Estimate distribution system hosting capacity and upgrade costs
5. Develop optimal expansion plan and distributed resource adoption scenario
6. Simulate grid operations and performance including load balancing, operating reserves, and resource adequacy
7. Evaluate transmission system reliability
8. Validate distribution system operation and integrated T&D system performance
9. Evaluate environmental benefits and impacts
10. Evaluate local job and economic development impacts
11. **Visualization and communication**

Steps of the LA 100% Renewable Energy Study



Step 1 – Data Collection and Scenario Development

- Data collection for each step
- Significant coordination with OTC study
- Also need processes for data in different formats
- Dedicated project data traffic cop



Meghan Mooney

Step 1 – Data Collection and Scenario Development

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	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
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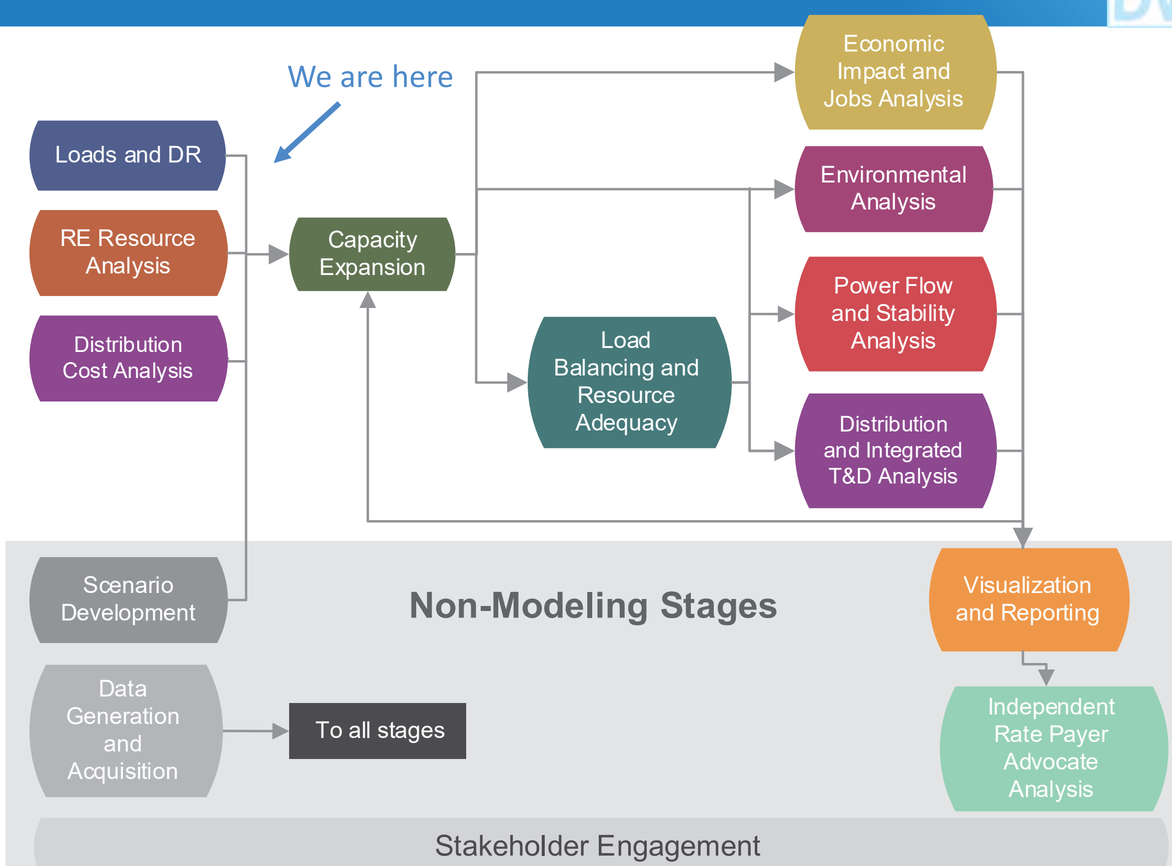
WECC	WECC VRE Penetration	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	High

Dan Steinberg

Recap - Scenarios

Step 2 – Loads and Demand Response



Step 2 – Loads and Demand Response: Goals

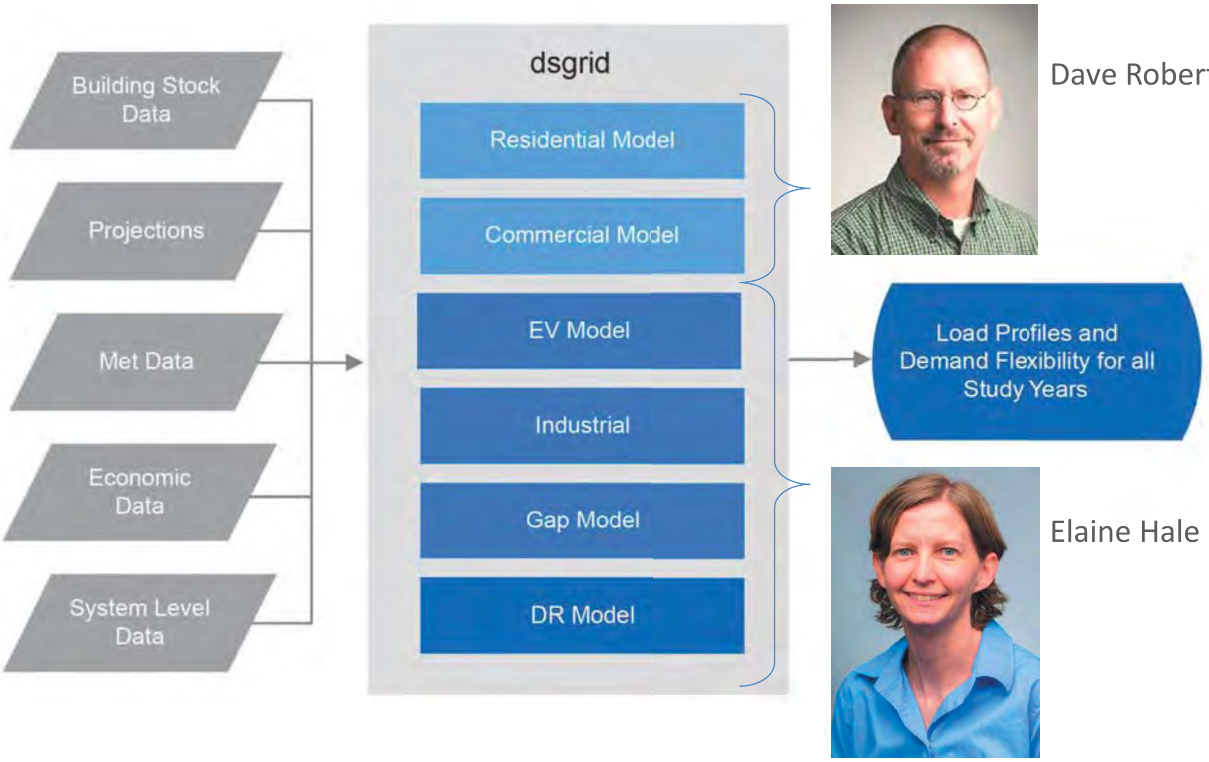
- Generate a dataset that represents the load that LADWP will need to serve in the coming decades
- Helps us understand interesting “standalone questions,” such as:
  - How will demand grow (or not)?
    - How much electric vehicle (EV) charging will LADWP need to serve?
    - What about electrification of loads served by natural gas?
  - How flexible will loads get?

Step 2 – Load Profiles

Five types of loads modeled:

1. Residential Buildings
2. Commercial Buildings
3. Industrial Loads
4. Electric Vehicles
5. Leftovers

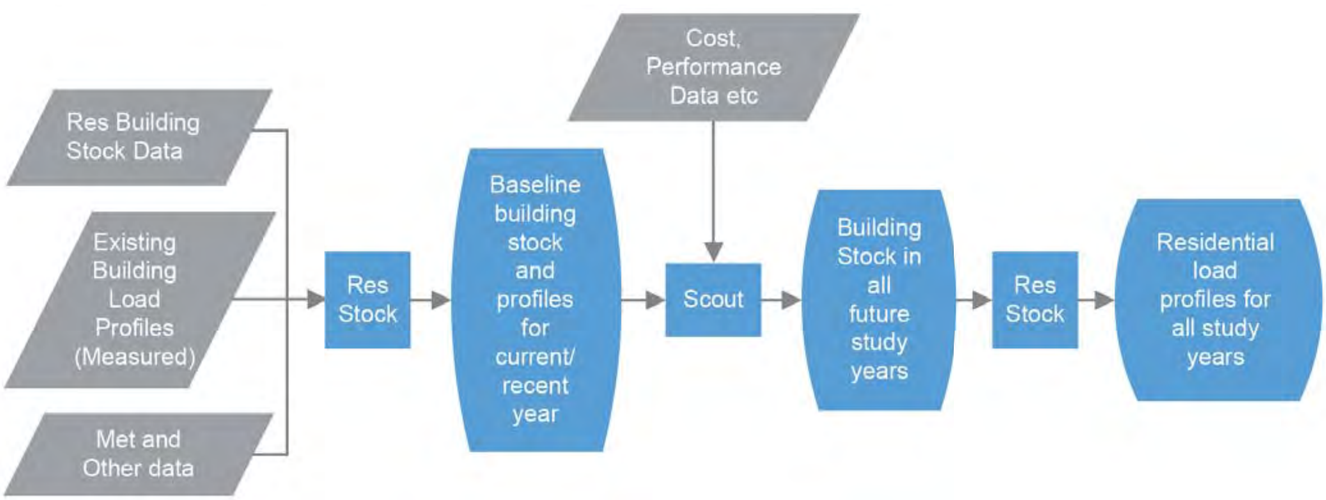
Loads Evaluated with NREL's dsgrid Model



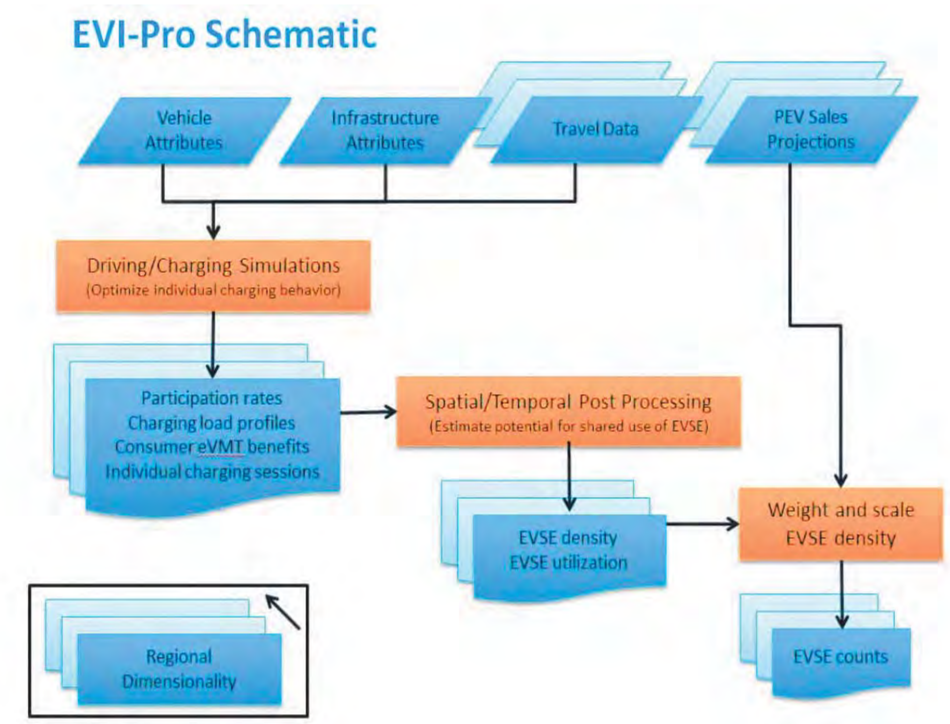
Dave Roberts

Elaine Hale

Example – Residential Building Loads



Electric Vehicles

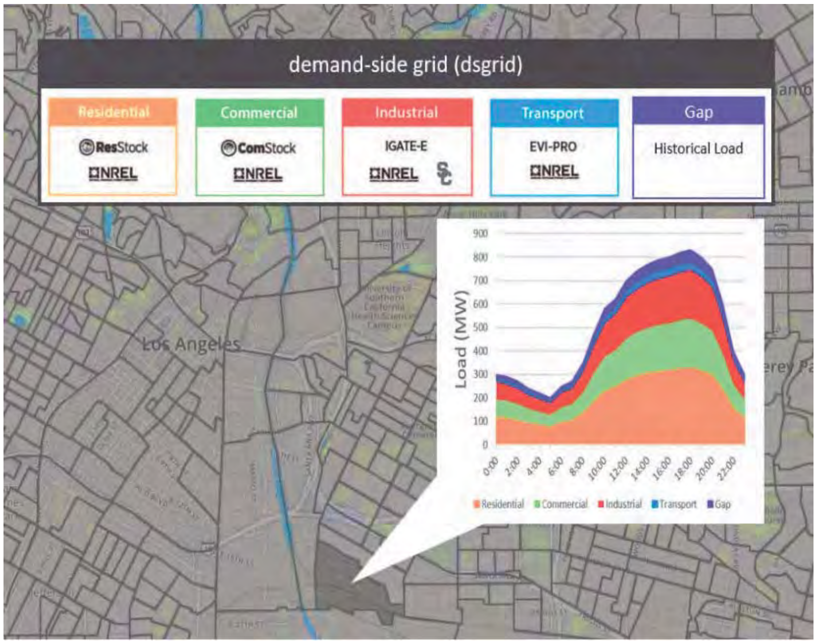


Industrial Demand

Not a single model—combines:

- Individual analysis for certain large loads (airport, port, large industries) derived from existing data and regional projections
  - Use data from advanced metering infrastructure (AMI)
- Analysis by University of Southern California for electricity associated with water infrastructure

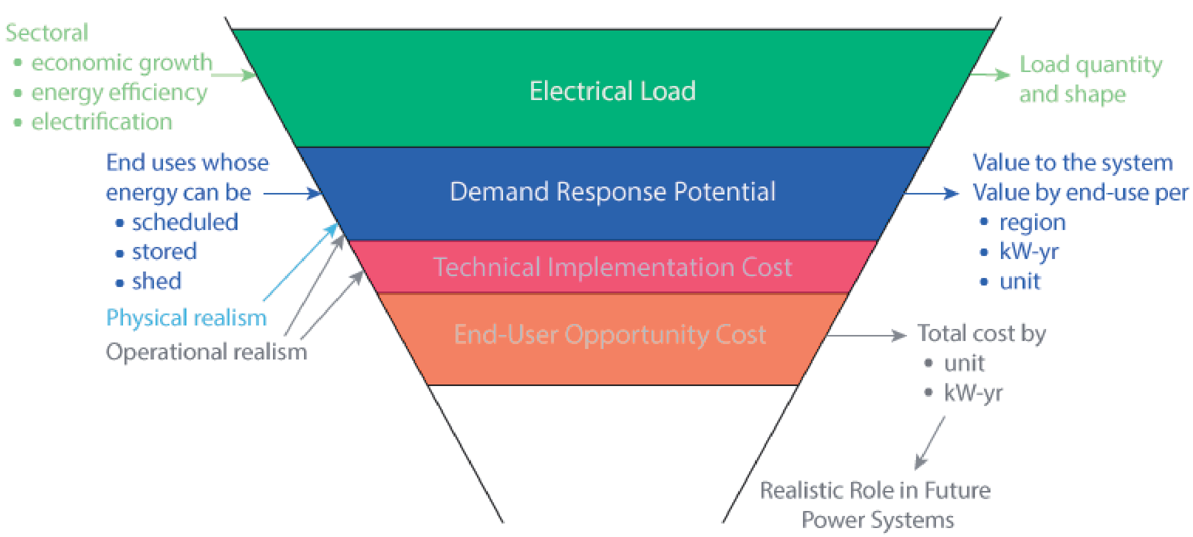
Gap Model



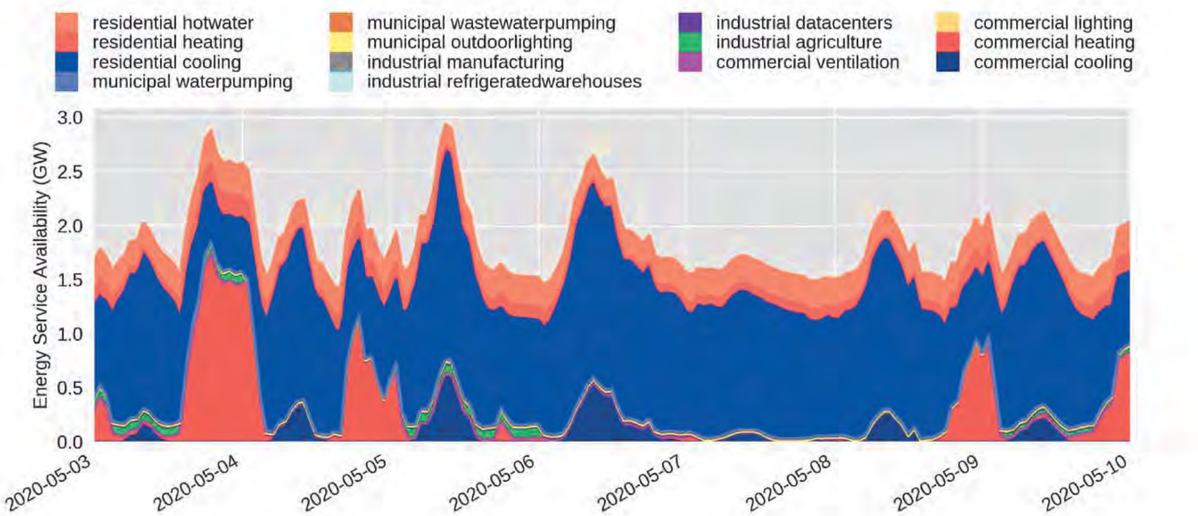
Outdoor lighting, other non-modeled loads.
This should be small if we do our job correctly.

Demand Response and Flexibility

- Traditional load modeling can capture efficiency, but not price-responsiveness—particularly for electric vehicles and smaller commercial and residential loads
- Separate modeling effort applied to demand response and load flexibility:

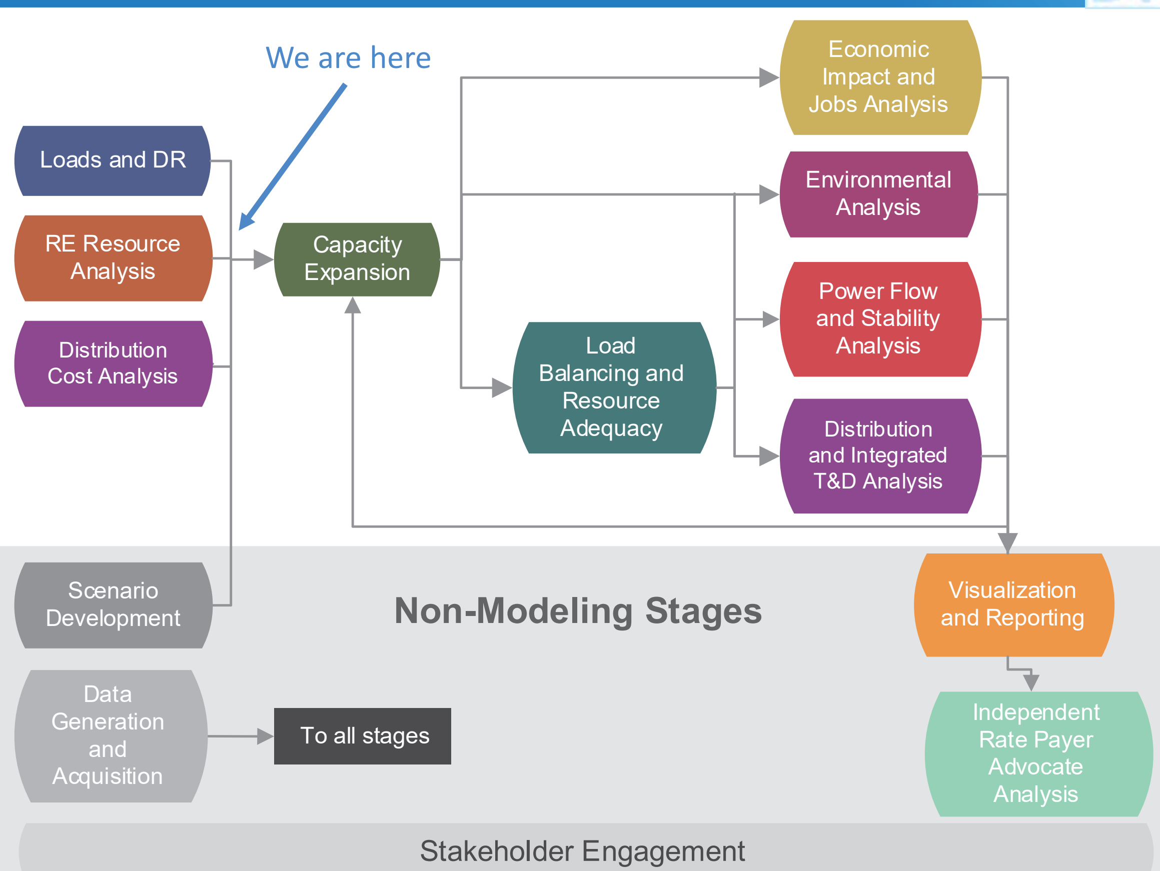


Demand Response and Flexibility



Example outputs: Demand available for load shifting in the Western U.S. during one week

Step 3 – Renewable Resource Analysis

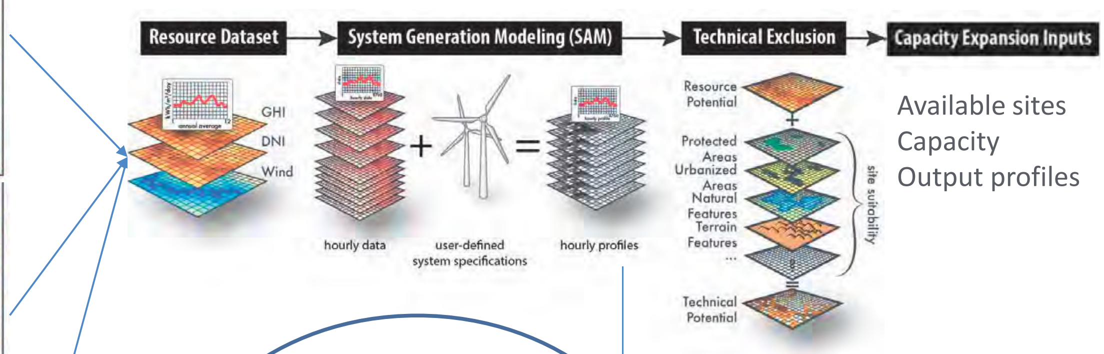


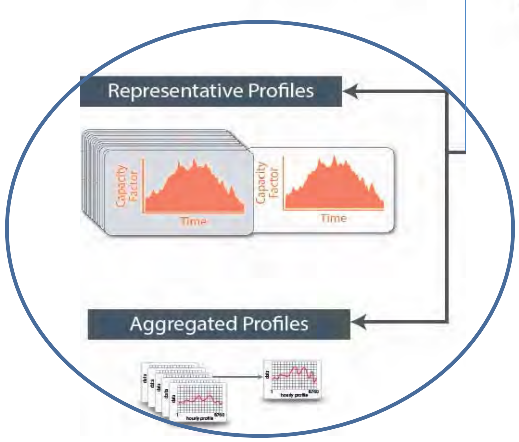
Step 3 – Renewable Resource Analysis: **Goals**

- **Generate a dataset that represents the renewable resources available to LADWP**
- **Helps us understand interesting “standalone questions,” such as:**
  - How many MW of wind are available in Southern California or other locations?
  - How much solar is available in-basin?
  - How much land area might be required to meet the 100% goal?

Step 3: Renewable Resource Analysis

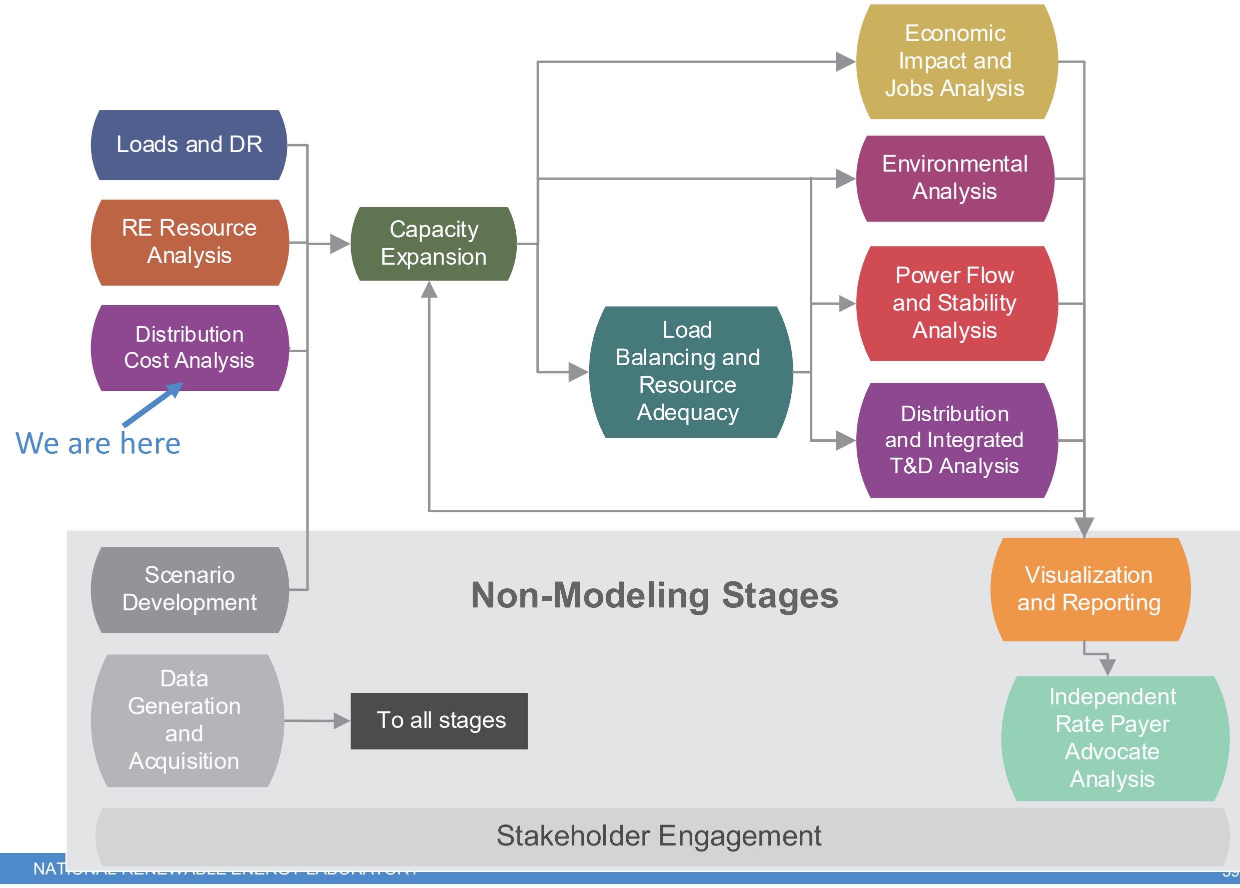
NREL’s Renewable Energy Potential (reV) Model





Nick Grue

Step 4 – Distribution System Cost Analysis

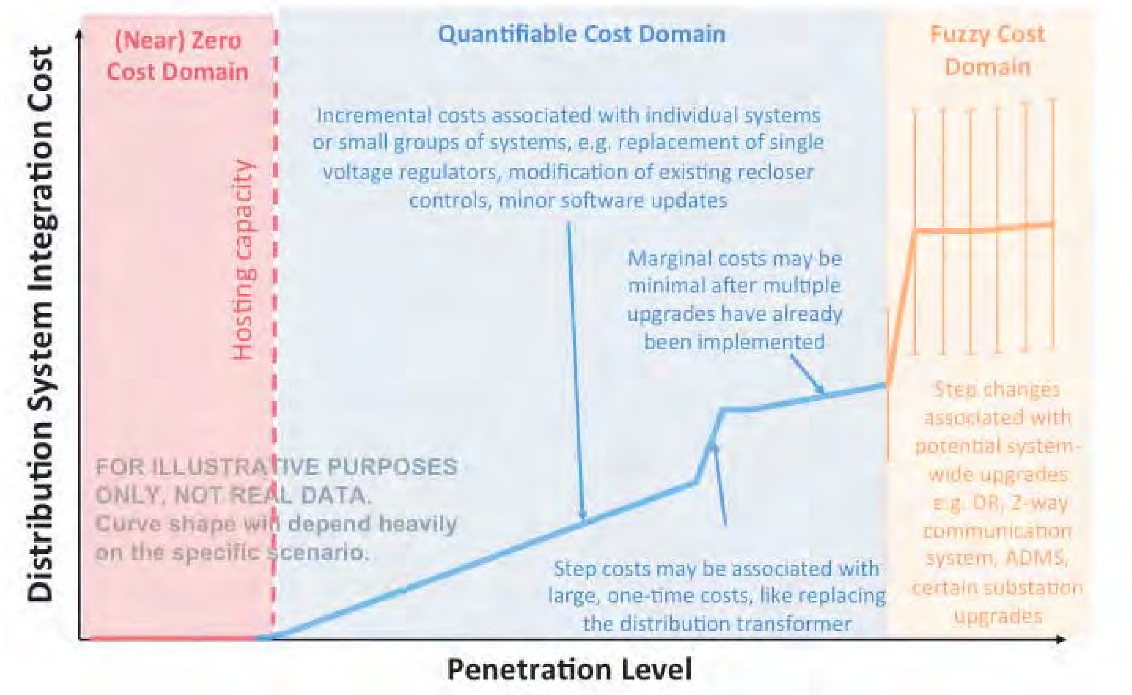


Step 4 – Distribution System Cost Analysis: **Goals**

- Generate a dataset that represents the ability of LADWP's distribution network to accommodate DGPV
- Helps us understand interesting "standalone questions," such as:
  - How many distributed PV can be accommodated in the city of Los Angeles?
  - How much will it cost to upgrade the distribution network to add more PV?

Bryan Palmintier   Kelsey Horowitz

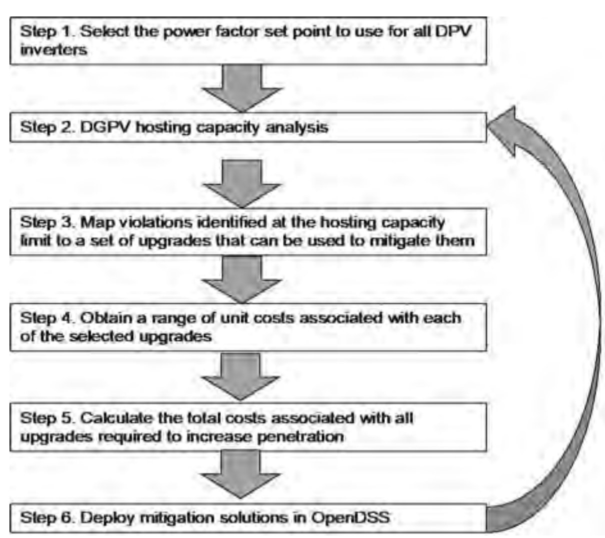
Step 4 – Distribution System Cost Analysis



Key Concept: Hosting Capacity – Point at which you can't add any more PV without additional upgrades

Distribution Cost Analysis

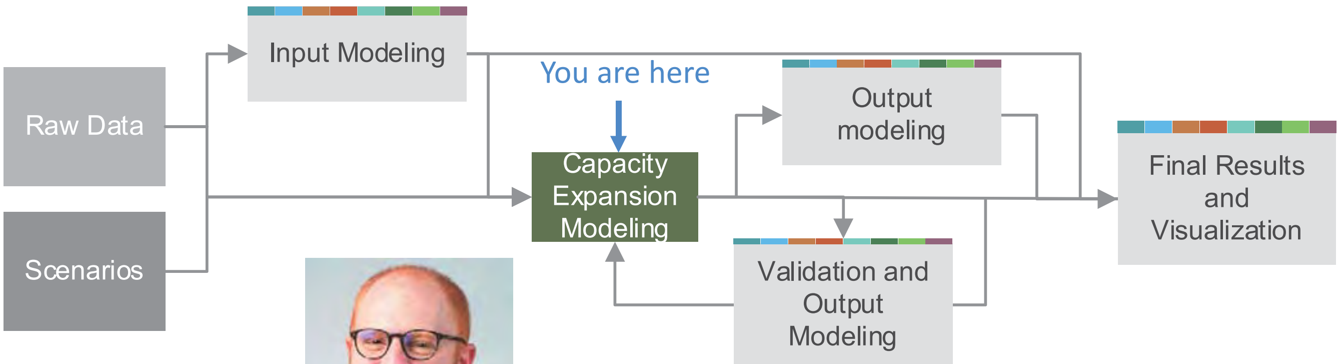
Violation	Mitigation Approaches
Overvoltage	• Advanced inverters • Modification of voltage regulator equipment or increased use of voltage regulators (LTC, SVC, capacitor banks) • Modifications to voltage regulator controls equipment • Energy storage
Voltage stabilization	• PF control via inverter • Modification of capacitor bank control settings • Reconductoring
Overload	• Transformer replacement • Reconductoring • Energy Storage



Cost Analysis –
How much $ per unit of PV to add additional hosting capacity

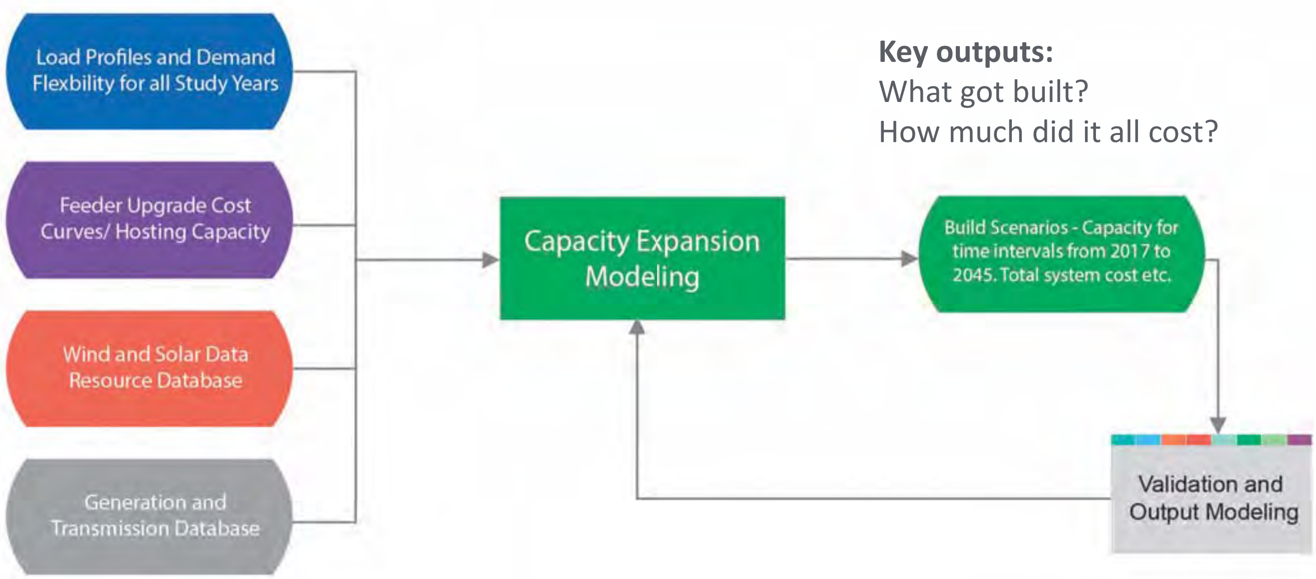
Step 5 – Capacity Expansion

- Determines the generation mix for each scenario
- Considers utility-scale generator development and customer adoption of DERs
- The "core" model of the LA100 study



Dan Steinberg

General Flow of Capacity Expansion Modeling

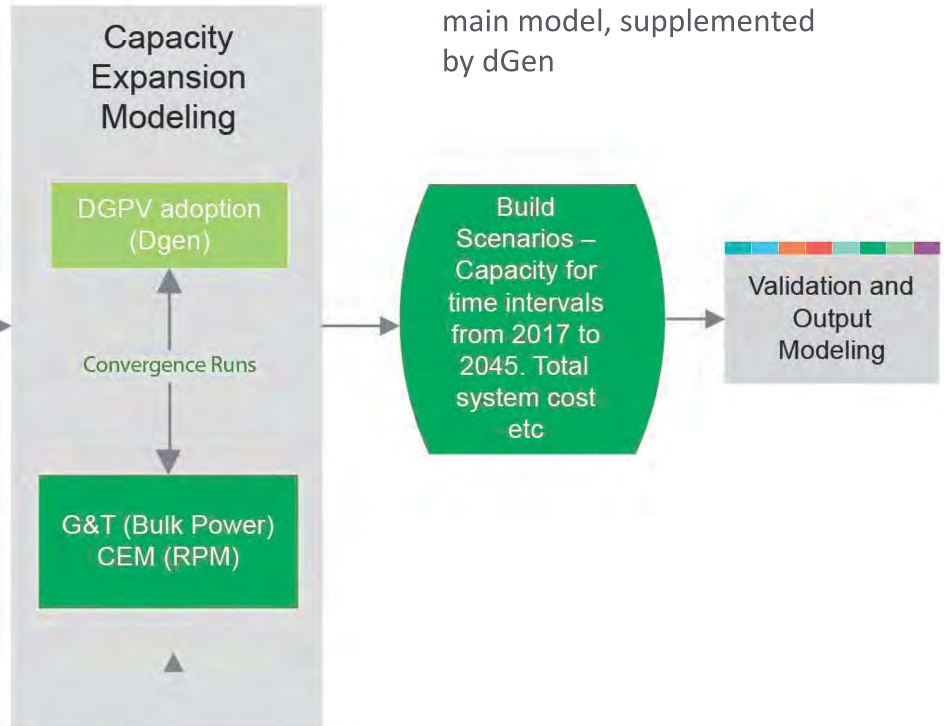


NREL's Capacity Expansion Modeling System

Ben Sigrin

This stage uses RPM as the main model, supplemented by dGen

Input Data



Brady Stoll

Resource Planning Model (RPM)

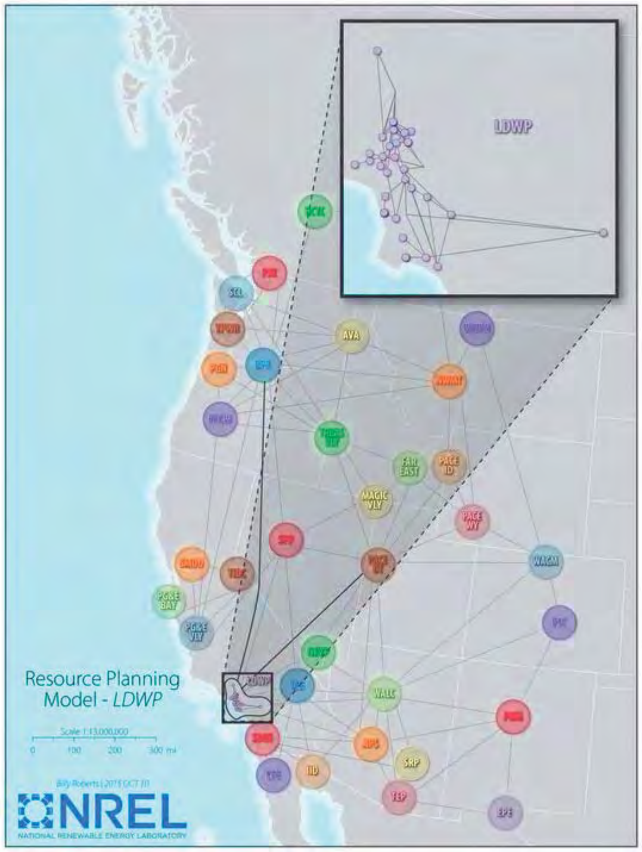
Capacity expansion model for a *regional* electric system

Key features:

- Individual generation unit and transmission line representation
- Hourly chronological dispatch and detailed system operation representation
- High spatial resolution informs generator siting options, particularly for renewable resources
- Flexible data structure to develop models for customized regions
- Models the cost and value of storage and other enabling technologies

http://www.nrel.gov/analysis/models_rpm.html

Geographical Scope



RPM is a mixed nodal/zonal model

System Requirements Simulated

- **Firm Capacity.** Capacity on the system that is ready to be scheduled and dispatched to meet load. Of particular interest here is having sufficient capacity to meet peak or near-peak load, the magnitude and timing of which is uncertain.
- **Energy.** Basic provision of real power that is transmitted to utility customers. RPM also captures the ability of certain resources to shift generation from low price to high price times.
- **Spinning Reserves.** Capacity that can quickly ramp up to make up for unexpected large generator or transmission line outages.
- **Regulation Reserves.** Load following capacity that continuously (e.g., every 4 to 6 seconds) balances out net-load forecast errors.
- **Flexibility Reserves.** These reserves are similar to regulation, but are used to balance out longer-term (1-4 hour) uncertainty in variable generation.

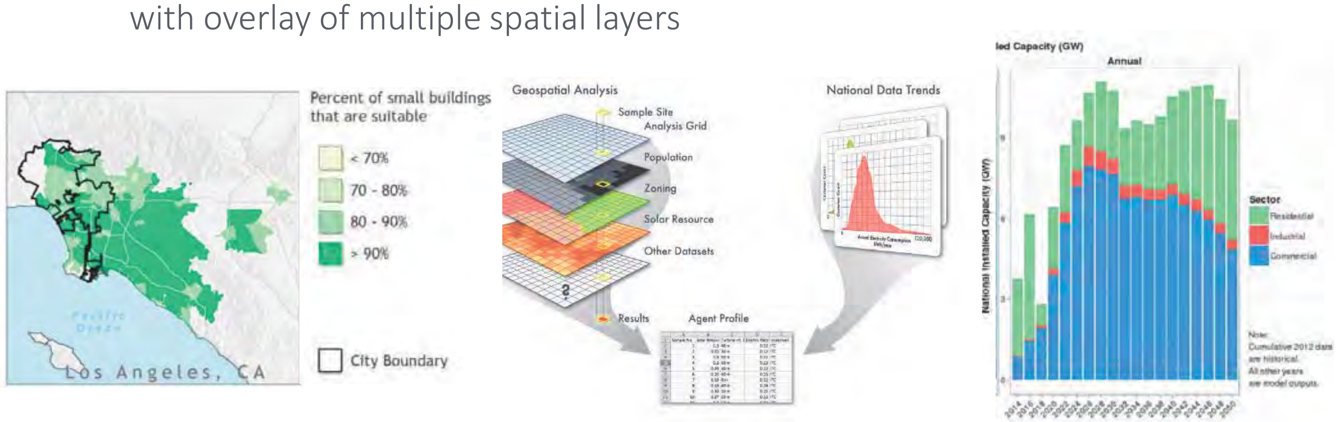
Services Provided by Generator Class

	Dispatchable Generator	Variable Generators	CSP with TES	Battery Storage
Firm Capacity	Full CV	Partial CV	Partial CV	Partial CV
Energy	Yes	Yes, as energy is available	Yes, from array or if energy in storage	Yes, if energy is in storage
Spinning Reserves	Yes	No	Yes	Yes, if long enough storage
Regulation Reserves	Yes, ramp rate constrained	No	Yes, if energy in storage	Yes, if energy in storage
Flexibility Reserves	Yes	No	Yes, if long enough storage	Yes, if long enough storage

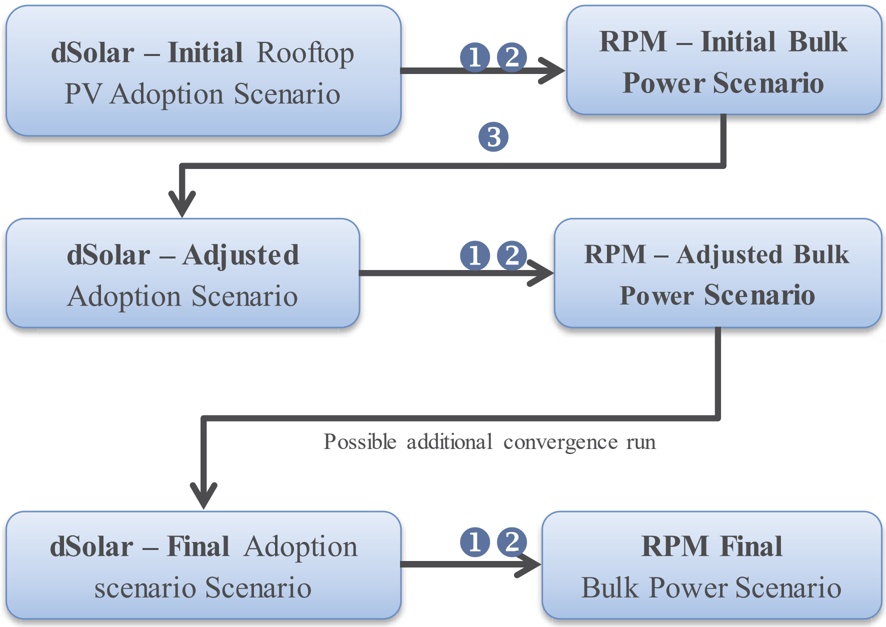
Distributed Technology Diffusion (dGen)

RPM does not estimate DG adoption.
A separate model (dGen) is used.

- Forecasts customer adoption of distributed generation technologies (solar, storage, wind, geothermal) for residential, commercial, and industrial entities, given assumptions about future electricity costs, technology cost and performance, policy and regulation, and customer behavior
- High geographic resolution enables state, utility, or city-specific analysis with overlay of multiple spatial layers

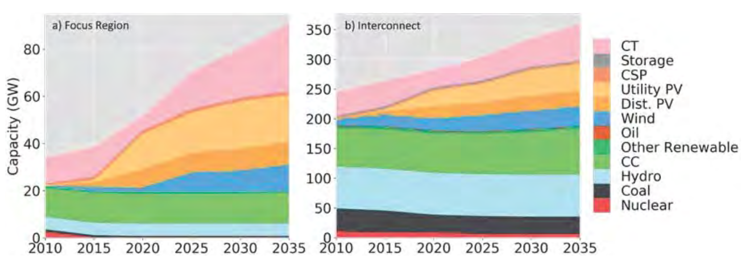


RPM/dGen Linkage

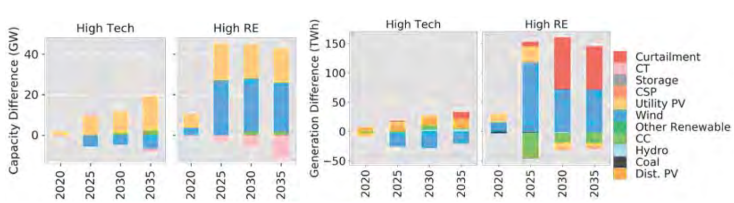


❶ Rooftop PV capacity by region
❷ Rooftop PV generation
❸ Impact on rooftop PV curtailment rate and value

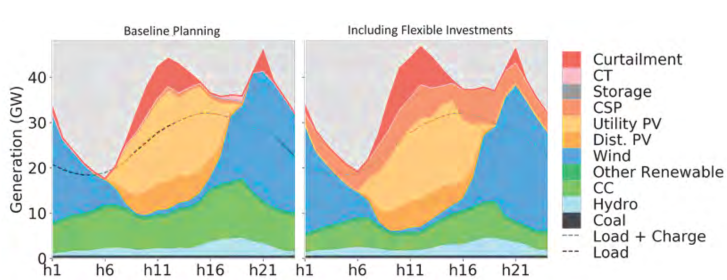
Example Results



Growth in capacity



Comparisons across scenarios



System dispatch (for *preliminary* validation and analysis)

At This Point…

- We have now generated a plan to meet 100% RE using what we believe is the most advanced capacity expansion tool in existence and best-in-class renewable resource data
- We have calculated system costs and estimated emissions reductions

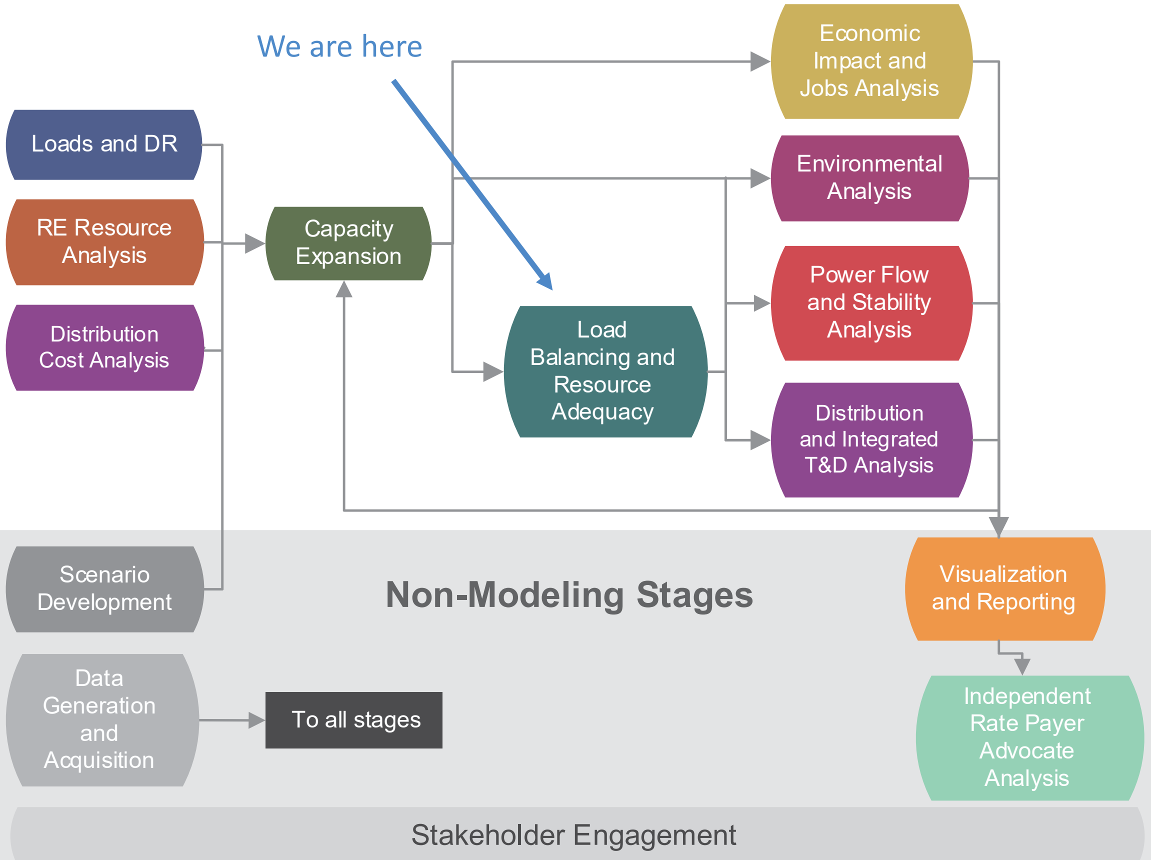
But we are not done yet.

We need to validate all of this and make sure this plan really works.

Why We Are Not Done at This Point of The Study

- **We have not yet validated:**
  - Resource adequacy
  - Hourly and subhourly ramping requirements for all time intervals
  - Operating reserve requirements for frequency stability including frequency response obligation
  - Ability to meet contingency events
  - Transmission system reliability
  - Distribution system reliability
- **In addition to these other key metrics:**
  - Air quality and public health benefits
  - Economic and job impacts

Step 6 – Load Balancing and Resource Adequacy

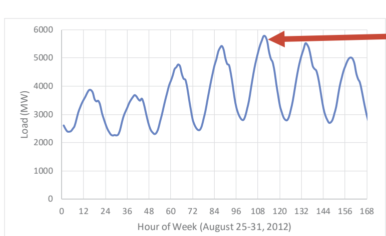


Step 6 – Load Balancing and Resource Adequacy

Goals - Answer two main questions:

1. Can the bulk power system actually balance load in each time period?
   - Production Cost (Dispatch) Modeling

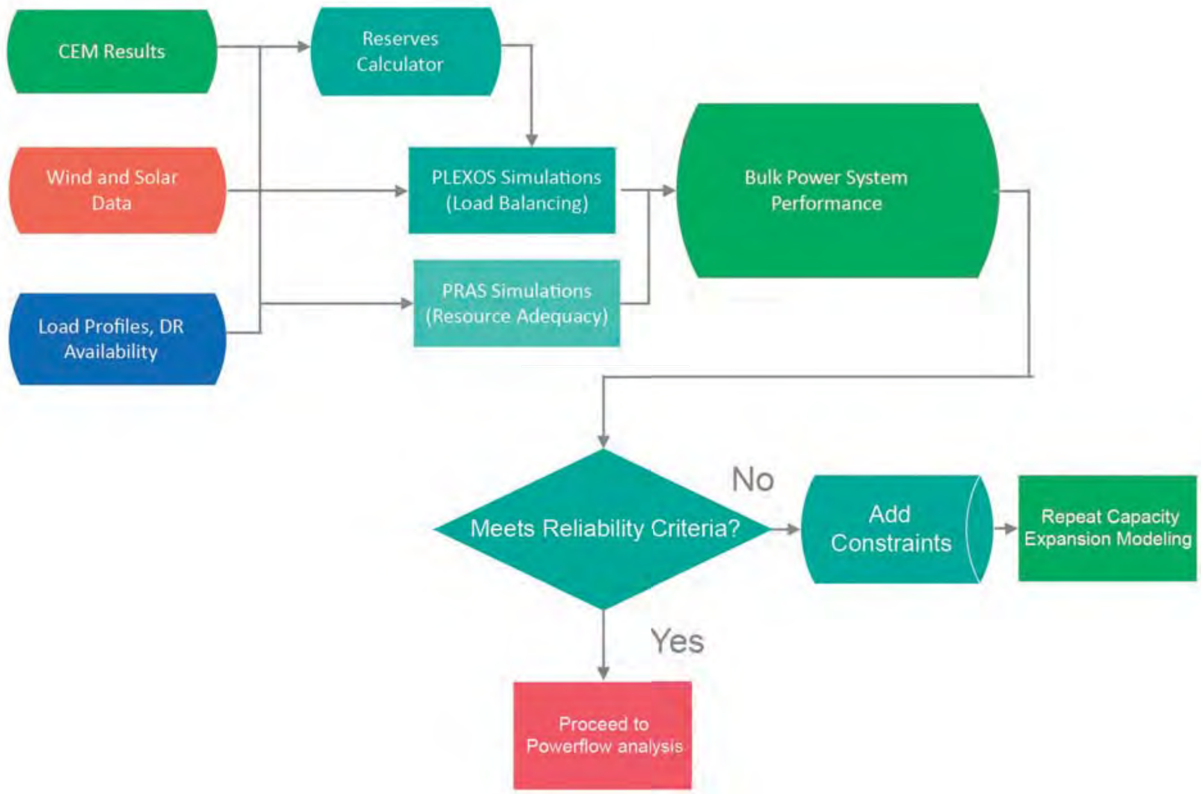
2. Does the system have enough generation resources to meet the demand on a really hot summer day?
   - Resource Adequacy Modeling



What is the probability that LADWP will have enough generation capacity here?

Jennie Jorgenson

Flow of Load Balancing and Resource Adequacy

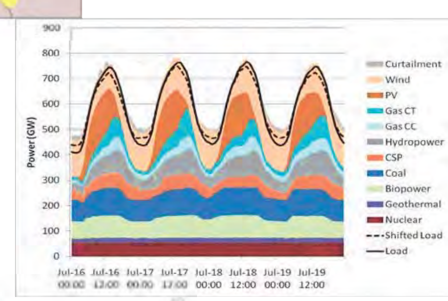


PLEXOS Production Cost Model

- Hourly or subhourly chronological
- Commits and dispatches generating units based on:
  - Electricity demand
  - Operating parameters of generators
  - Transmission grid parameters
- Used for system generation and transmission planning
  - Increasingly used for real-time operation

Locational prices, production cost

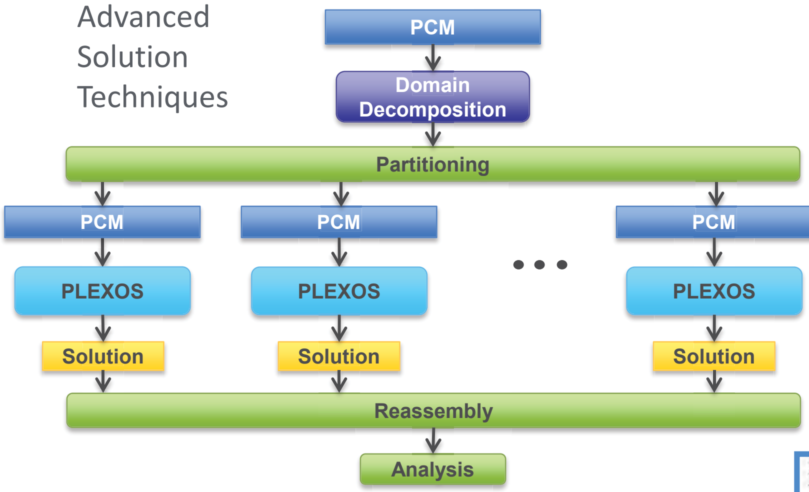
Dispatch information, fuel usage



Transmission congestion

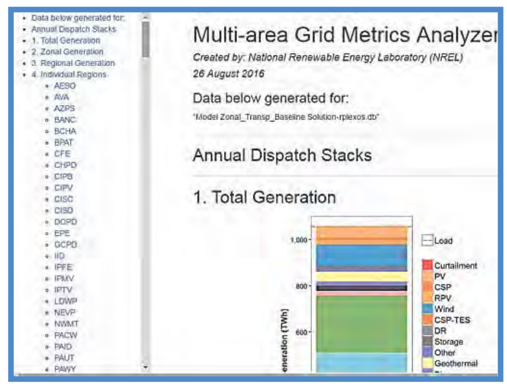
NREL's Value Add

Advanced Solution Techniques

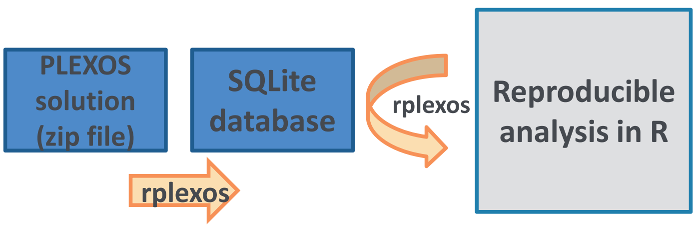


NREL Peregrine HPC

Automated Solution Processing

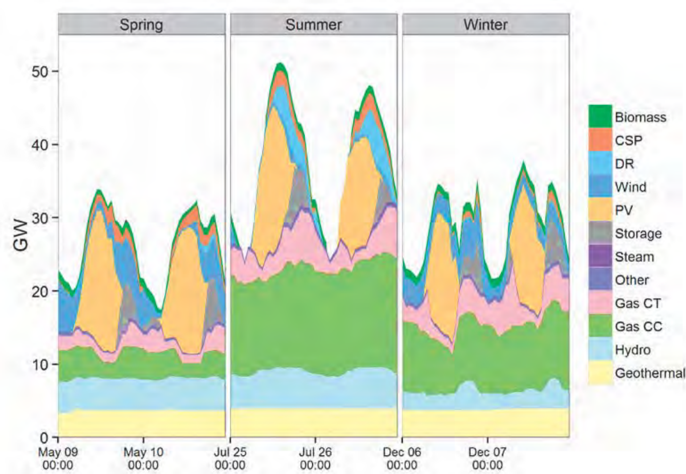


Automated Data Processing

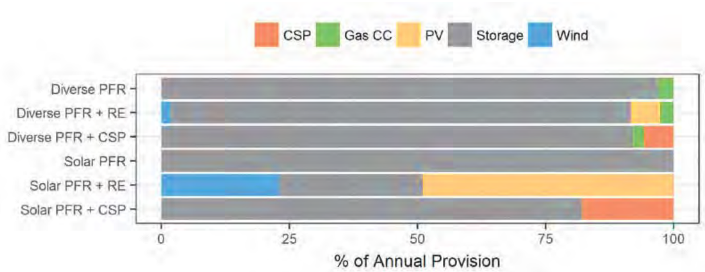


Example Results

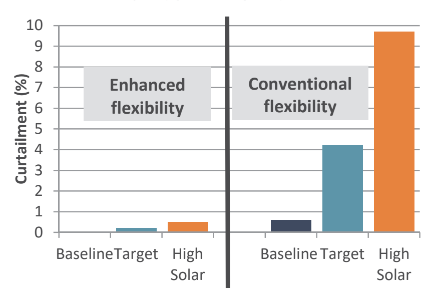
System Dispatch



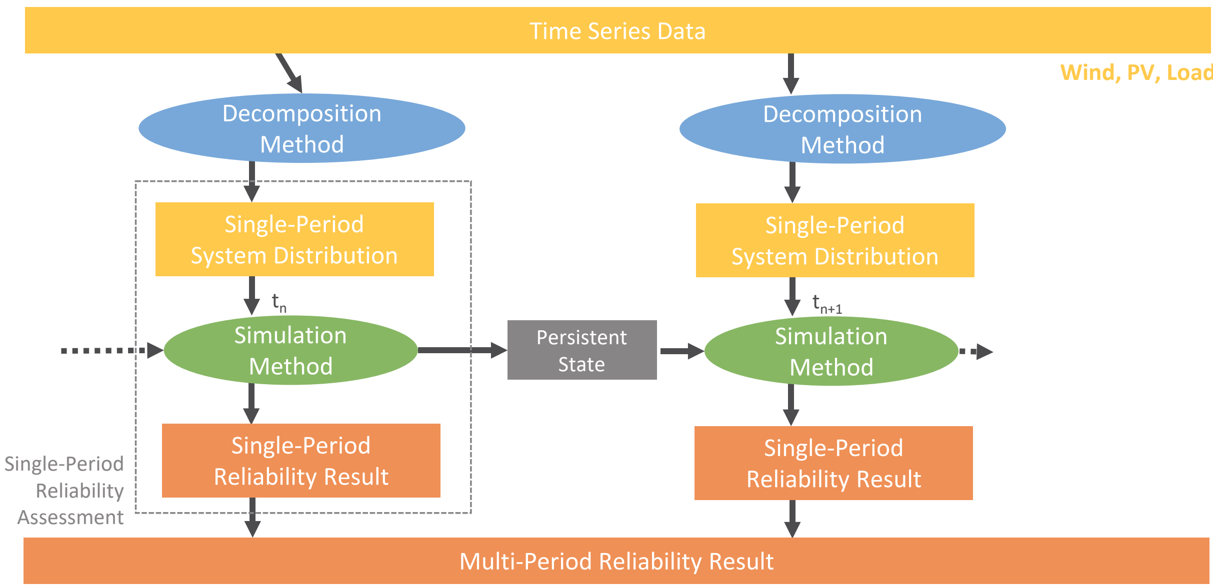
Operating Reserves Provision



Curtailment



NREL's Probabilistic Resource Adequacy Suite (PRAS)

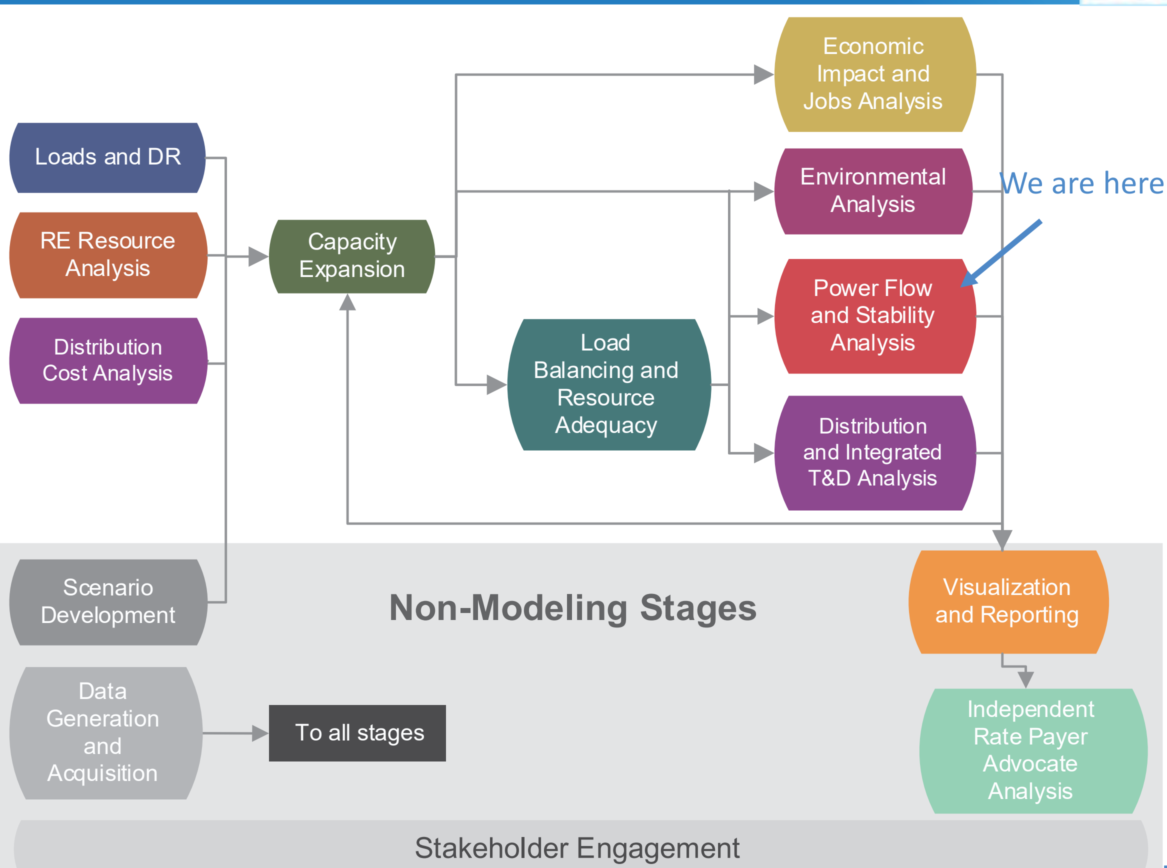


Performs a statistical analysis of the likelihood that LADWP will not have enough generation to meet load during every hour of the year

Resource Adequacy Metrics:

- Loss-of Load Probability (LOLP)
- Loss-of-Load Expectation (LOLE)
- Expected Unserved Energy (EUE)

Step 7 – Transmission and Stability Analysis

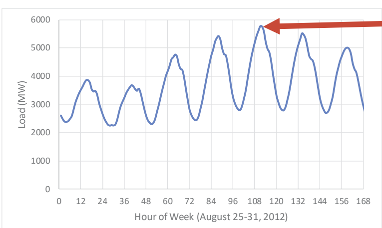


Step 7 –Transmission and Stability Analysis

Goals - Answer two main questions:

1. Will the transmission system work reliably?
   - AC Power Flow Analysis

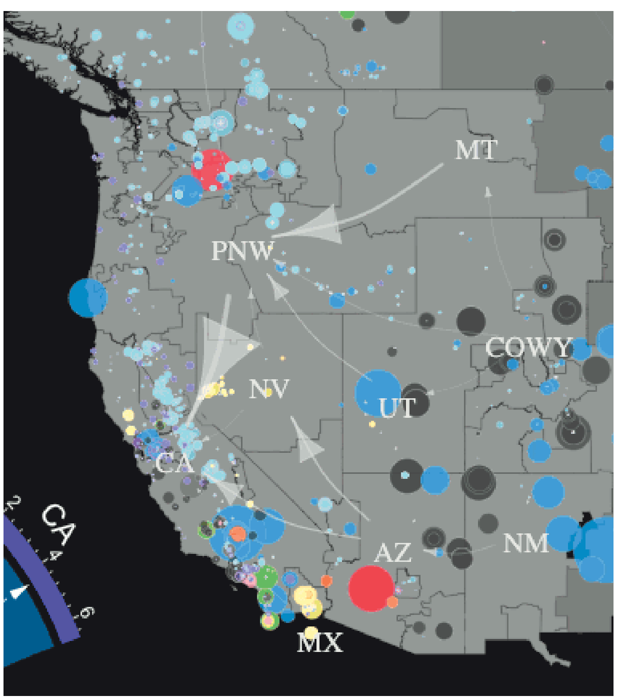
2. Will the system continue to work if there is a failure of any single component
   - Contingency/Stability Analysis



What happens if a power line fails here?

Himanshu Jain

Step 7 – Transmission and Stability Analysis



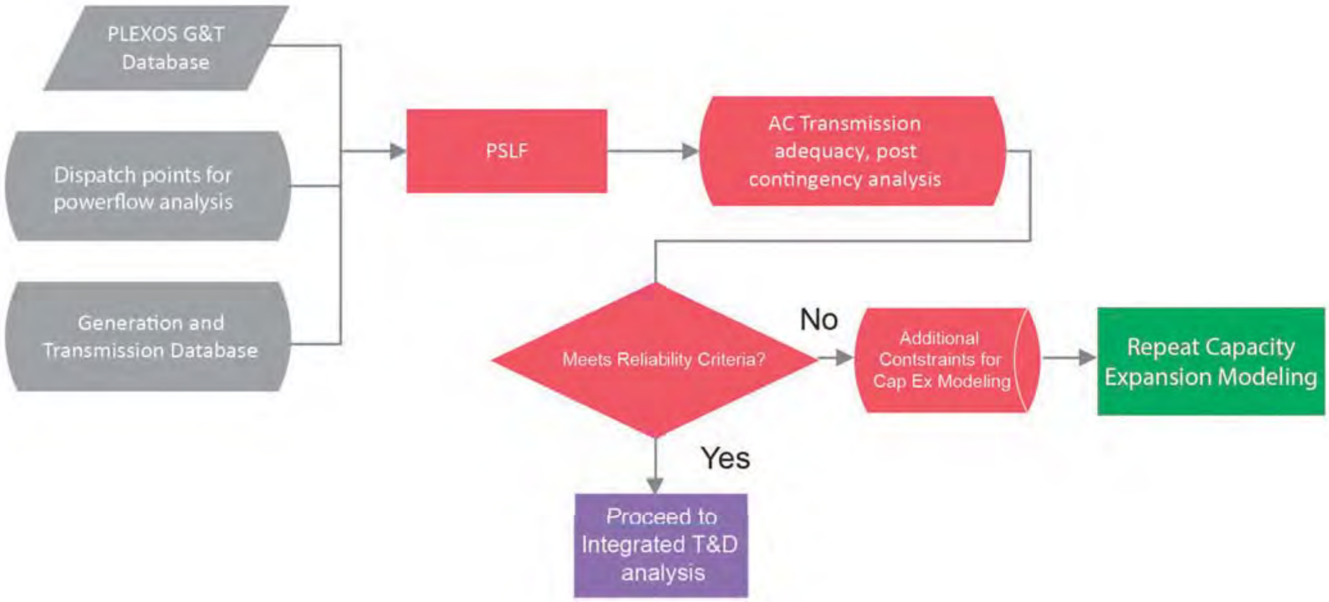
- Performs a deep dive on transmission system adequacy using detailed physics-based models of the entire interconnection; ensures the system is stable

- Looks for conditions where the transmission system will break, typically by exceeding the capacity of individual lines or other components

- Simulates a few very short snapshots (typically less than 30 seconds) of system operation

Power Flow and Stability

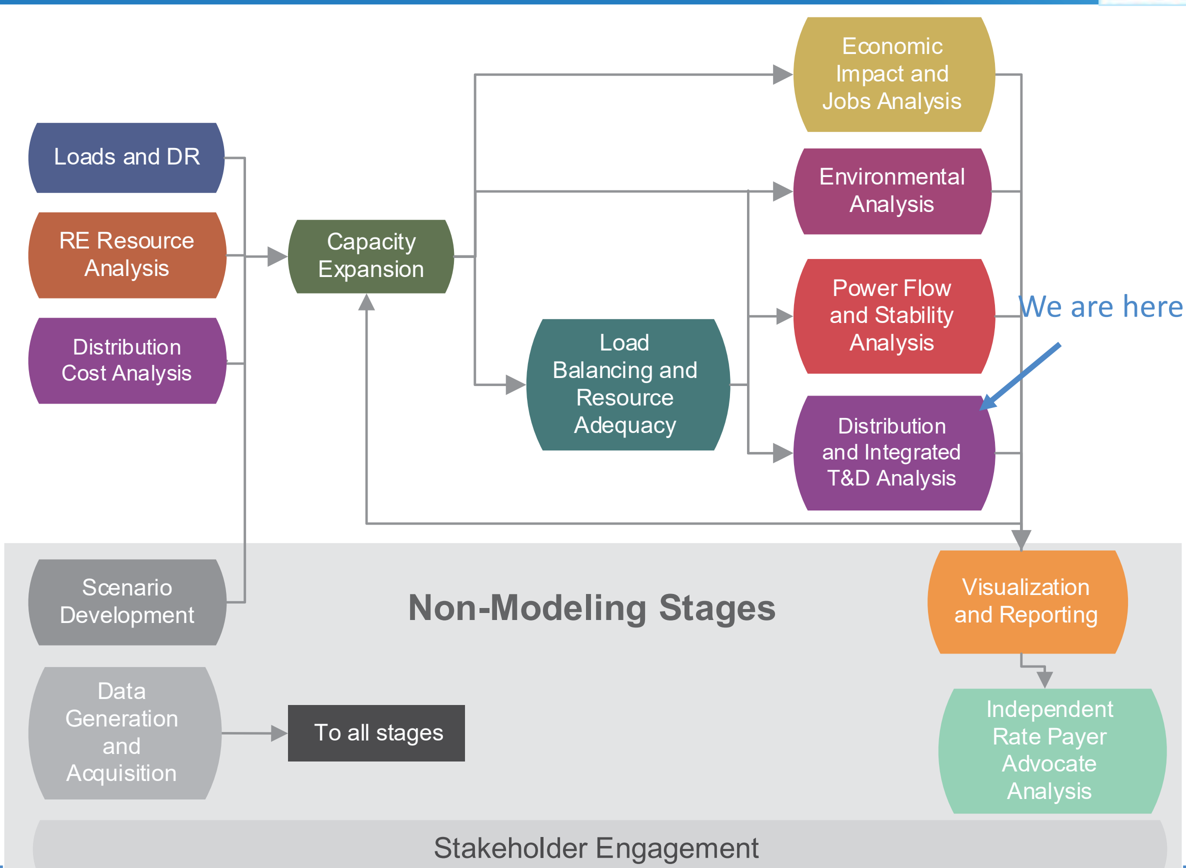
LA DWP



We use General Electric's industry-standard transmission simulation tool, "Positive Sequence Load Flow" (PSLF)—the same tool used by LADWP and many other organizations.

Step 8 – Integrated T&D Analysis

LA DWP

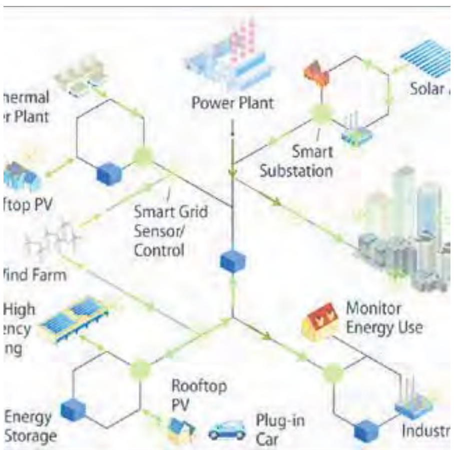


Step 8 –Transmission and Stability Analysis

Goals - Answer two main questions:

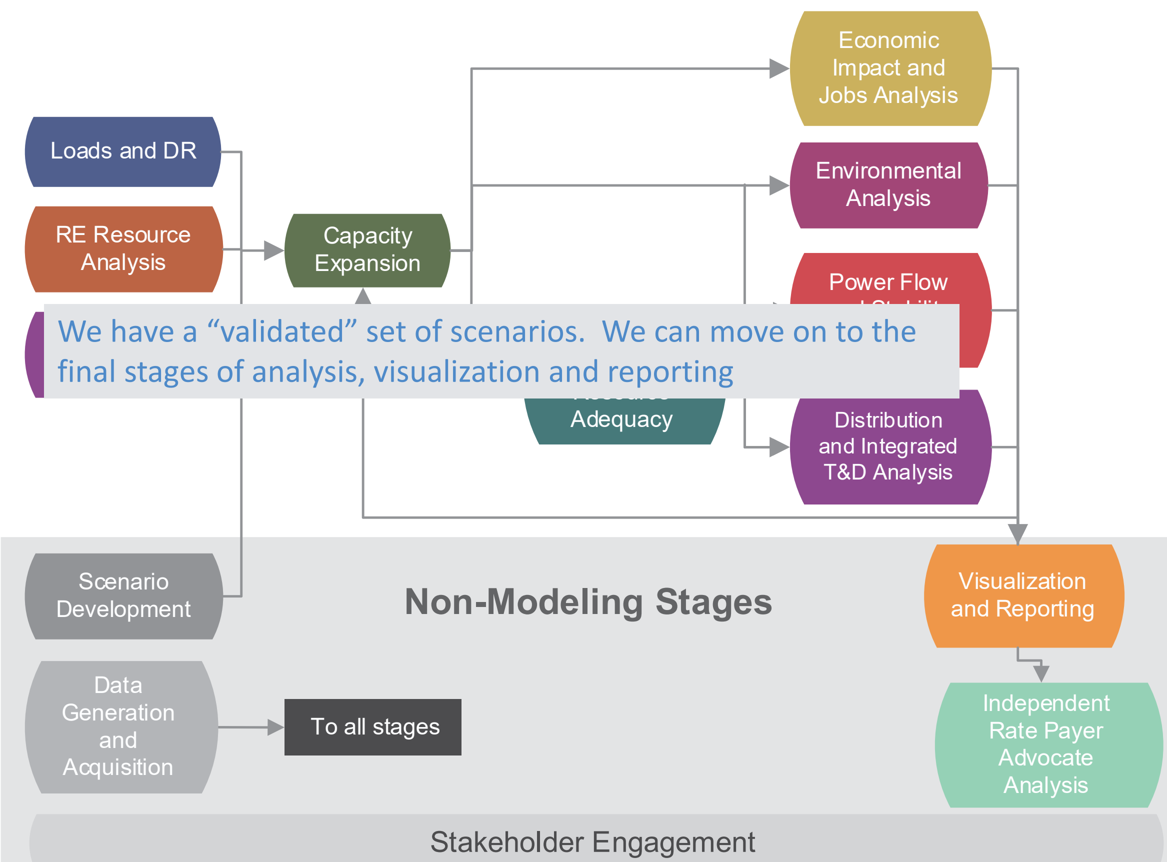
1. Does the distribution system work reliably?

2. Are their negative impacts on the transmission system due to generation fed from the distribution system?



Bryan Palmintier

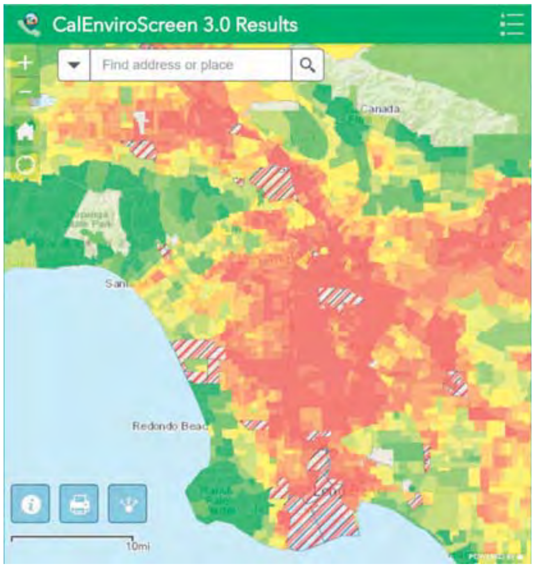
At This Point.....



We have a "validated" set of scenarios. We can move on to the final stages of analysis, visualization and reporting

Steps 9-10 – Environmental, Economic, and Jobs Analysis

Methods discussed in separate presentations

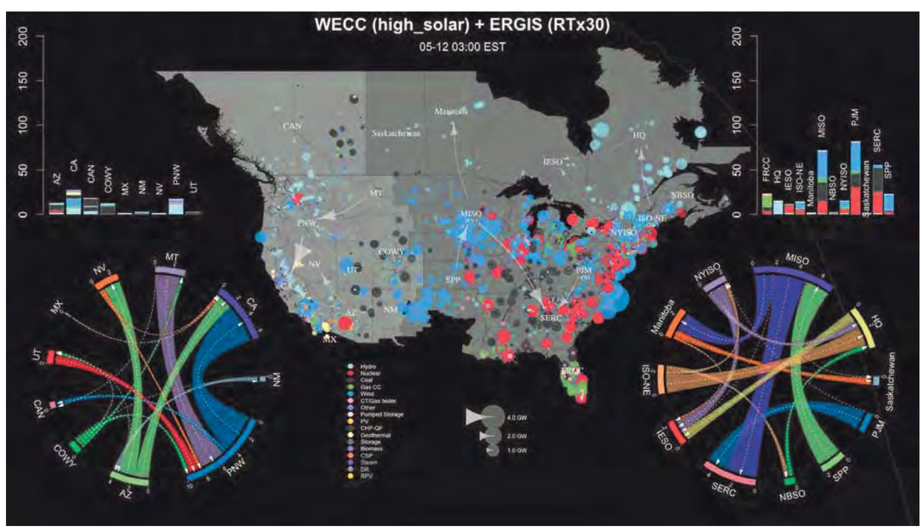


Up next → Garvin Heath

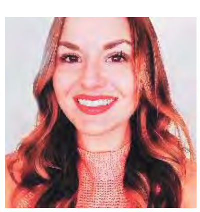
David Keyser

Step 11 – Visualization and Communication

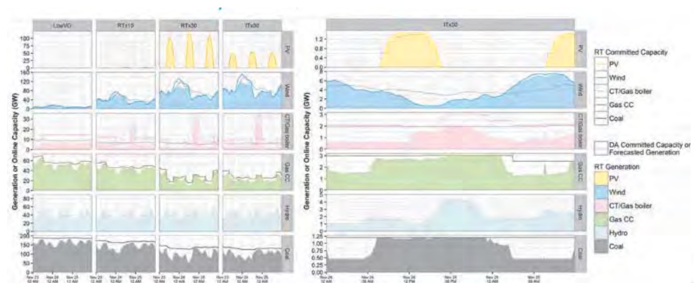
Aaron Bloom



Kenny Gruchalla



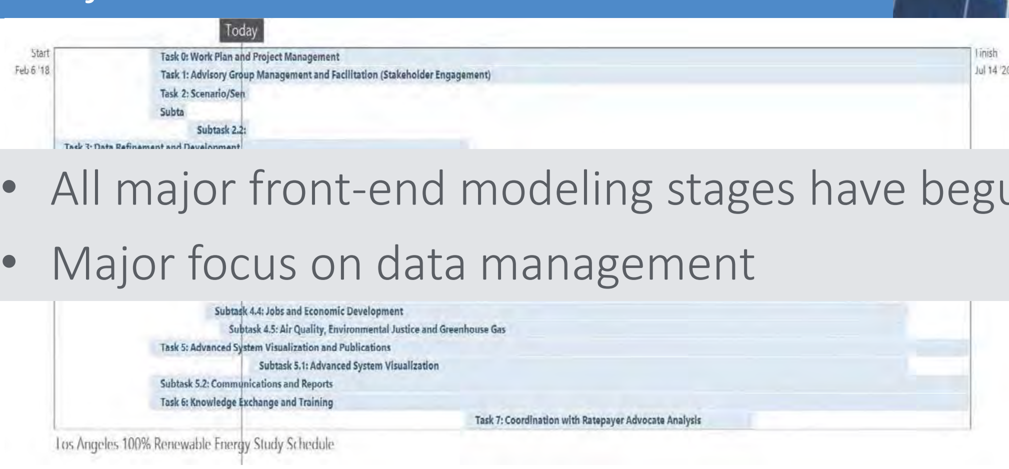
Devonie McCamey



Summary

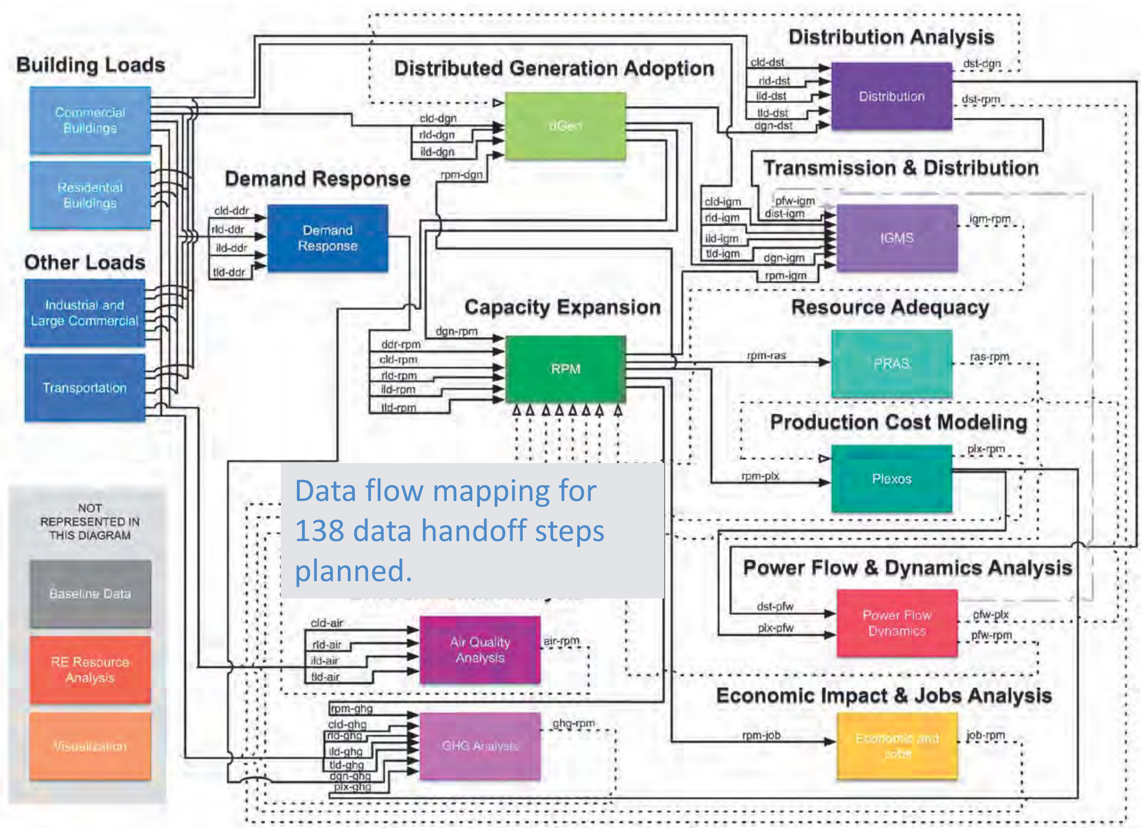
- Ensuring a reliable 100% renewable system requires simulation across large geographic and temporal scales
  - Individual circuits to the Western Interconnection
  - Seconds to years
- Multiple models are routinely used for traditional grid plans to explore this range of issues
- Moving to 100% RE will require even more detailed simulations to understand new elements of the evolving power system

Project Status



- All major front-end modeling stages have begun.
- Major focus on data management

Example of What are Working On…



Data flow mapping for 138 data handoff steps planned.

Questions and Discussion

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

LA DWP

Environmental Modeling for Los Angeles 100% Renewable Energy Study

Garvin Heath, PhD
Haley Lewis

August 16, 2018

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Goals for Presentation

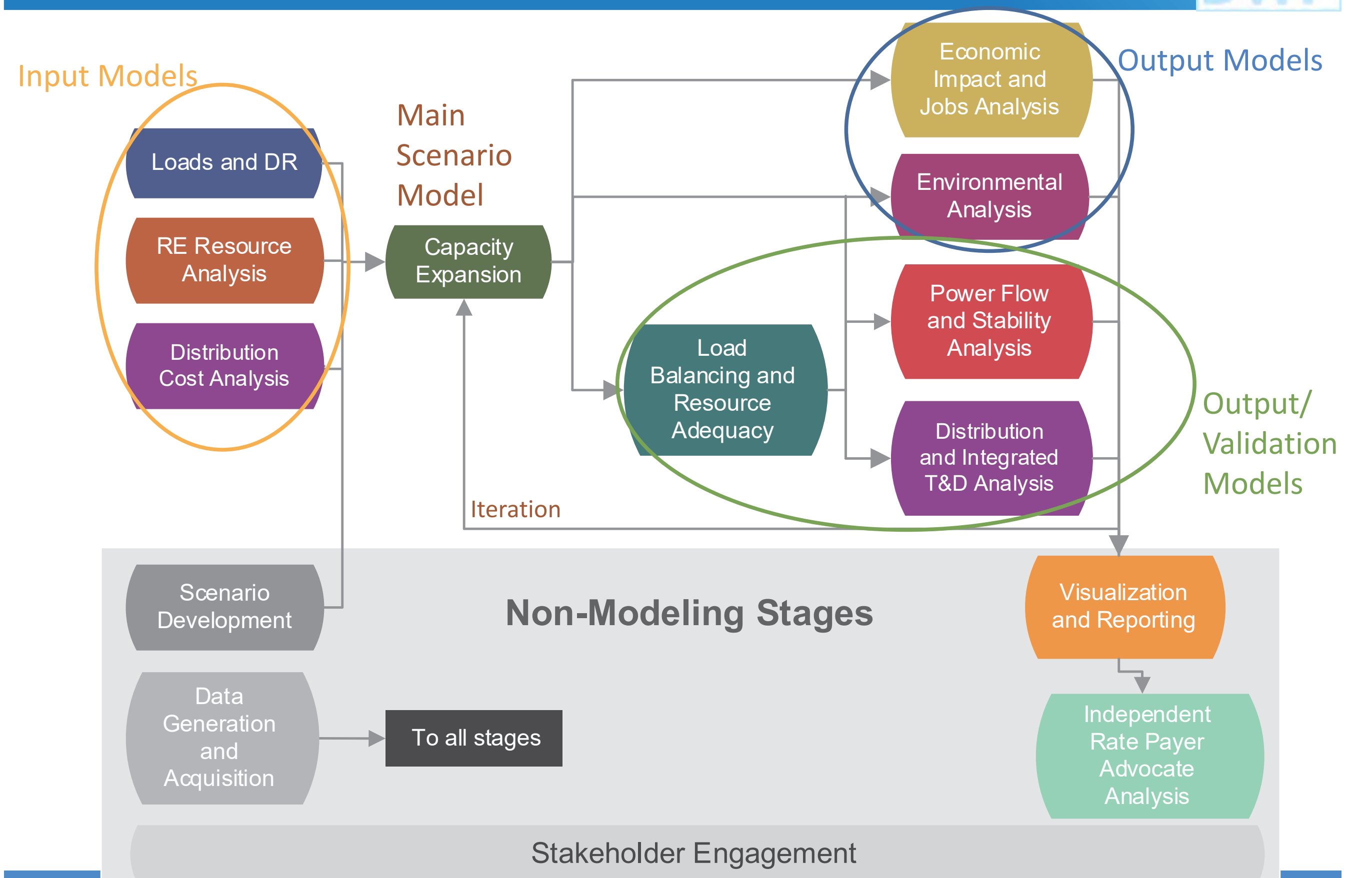
LA DWP

- Establish familiarity with our methods
  - More detailed for GHG emissions analysis
  - General approach for air quality, public health, and environmental justice
- Demonstrate how environmental modeling will meet the City Council Motions
- Convey timing of environmental modeling (follows main modeling and analytical tasks of the study)
- **Use your questions and comments to clarify and improve the study!**

Outline

- Where environmental modeling fits in the LA 100% RE study
- Relationship to City Council Motions
- Major components of environmental modeling and (planned) team
- Greenhouse gas (GHG) analysis: experience, methods, and sample results
- Air quality and public health approach
- Environmental justice (EJ) approach

Study Modeling Stages *(previously presented)*



Environmental Modeling Requires Results of Electric-Sector and Loads Modeling

1. Data collection, scenario development
2. Estimate load growth and demand profiles
3. Determine renewable resource availability and generation profiles
4. Estimate distribution system hosting capacity and upgrade costs
5. Develop optimal expansion plan and distributed resource adoption scenario
6. Simulate grid operations and performance including load balancing, operating reserves and resource adequacy
7. Evaluate transmission system reliability
8. Validate distribution system operation and integrated T&D system performance
9. Evaluate environmental benefits and impacts
10. Evaluate local job and economic development impacts
11. Visualization and reporting

Determination of EJ Neighborhoods Early in Study Will Help Target Approach for EE/RE

LA DWP

1. Data collection, scenario development
- *Define EJ neighborhoods for energy efficiency (EE)/renewable energy (RE) targeting*
2. Estimate load growth and demand profiles
3. Determine renewable resource availability and generation profiles
4. Estimate distribution system hosting capacity and upgrade costs
5. Develop optimal expansion plan and distributed resource adoption scenario
6. Simulate grid operations and performance including load balancing, operating reserves and resource adequacy
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Relationship of Env. Modeling to City Council Motions

LA DWP

Motion Date	Motion Language	Action
March 2, 2016	"Develop and implement a research partnership … to achieve a 100% renewable energy portfolio for LADWP."	Study initiated
Sept. 16, 2016	"work with local academic institutions."	Academics are on Advisory Group; Contracting in progress
August 1, 2017	"The prioritization of environmental justice [EJ] neighborhoods as the first immediate beneficiaries of localized air quality improvements and GHG reduction."	Requires the analysis of GHG emissions and air quality-related health impacts
August 1, 2017	"Incorporation of the CalEnviro Screen …"	Basis of EJ neighborhood determination early in the project

Environmental Modeling Components

Integration of renewable energy into LADWP generation assets and managed loads has numerous benefits:

- Reduction in GHG Emissions
- Improved Air Quality
- Improved Public Health

These analyses are followed by spatial assessment of air quality and public health improvements to compare differences across neighborhoods (EJ and non-EJ)

Team *(pending finalization)*

- GHG Emissions → NREL (Heath)
- Air Quality Modeling → [under discussion]
- Health Effects Modeling → [under discussion]
- EJ Effects → NREL (Heath, GIS team)

Bio: Garvin Heath

- 10 years at NREL leading sustainability analyses for all generation technologies as well as fuels, both renewable and conventional
- PhD from UC Berkeley
  - Energy and Resources Group
  - Dissertation advisor was an air quality engineer (which is what I am trained as)
  - Dissertation looked at the implications for inhalation exposure of shifting from large-scale power plants to small-scale (distributed generation) sources that still emit air pollutants

Methods for GHG Analysis

Scope of GHG Analysis

- NREL's Resource Planning Model directly estimates CO_2 emissions from combustion
- The study could simply use this output for LADWP-owned assets and finish there
  - This is perhaps where most analysts would stop

Goal of GHG Analysis: Include all *Attributable* GHG Emissions from Each Scenario

Besides combustion, there are other GHG emissions that are attributable to the electric sector:

1. Every electric generation technology, even RE, has to be built, operated, and decommissioned—and those activities have GHG emissions
   - Life-Cycle Assessment is a well-recognized method to quantify these emissions (see next slide)

2. Changes to one part of the electric network can impact how other parts of the network function, so changes to LADWP assets can affect assets in CAISO and beyond
   - Increasing variable RE generation can cause increased ramping, part-loading, and cycling of remaining fossil assets that degrade their performance (efficiency)
   - Not found to lead to significant degrading of the GHG emission benefits of increasing RE, but should be taken into account to address concerns

3. There are other GHGs besides CO_2—methane, nitrous oxide—that are important for certain generation technologies, even those considered renewable
   - Examples include biogas sources (landfill gas, waste water treatment plants, etc.)

Life-Cycle Assessment (LCA): Quantifying Attributable Impacts (e.g., Energy Choices)

LCA quantifies resource consumption, energy use, and emissions, from cradle to grave

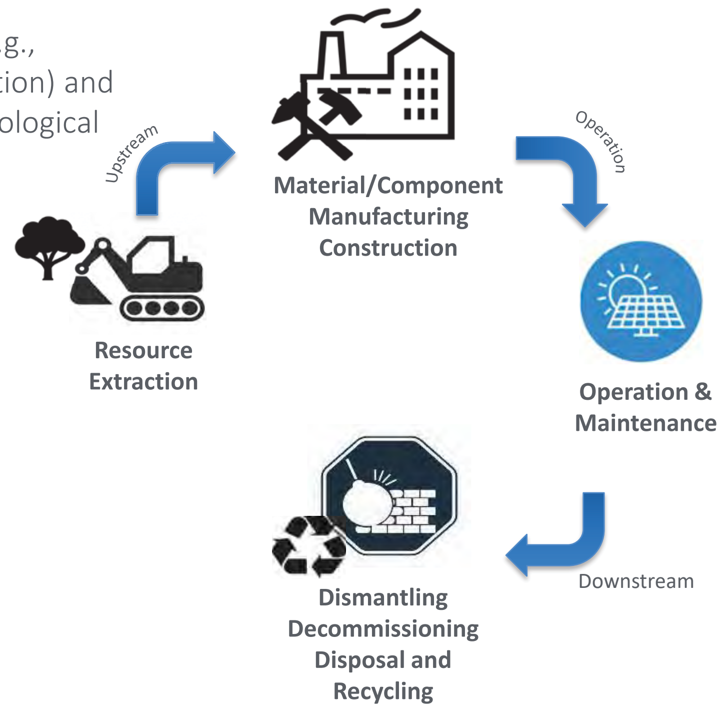
- Practiced for 40 years
- Methods codified in standards (e.g., International Standards Organization) and guidelines, though some methodological issues persist

Forms a basis for consistent comparison of renewable and conventional energy technologies, internationally recognized and used in, for example, Intergovernmental Panel on Climate Change (IPCC) reports

Typical metrics:

- GHG emissions
- Water consumption and discharges
- Energy use
- Raw material consumption
- Air pollutant emissions

All Technologies



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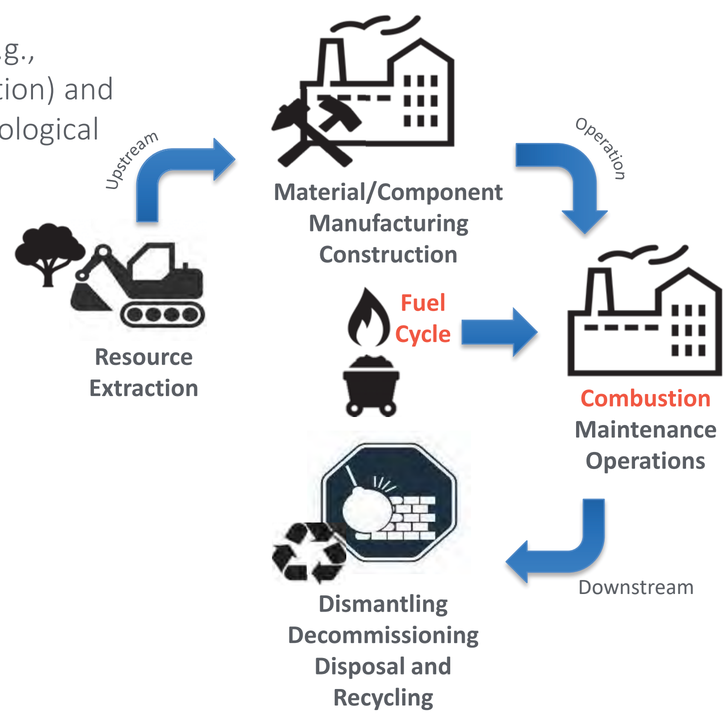
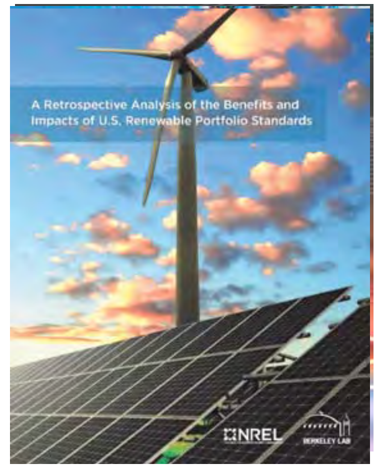
Combustion Technologies



NREL's GHG Emissions Analysis for Electric-Sector (and Fuel) Transformation Is Unparalleled

- IPCC Special Report on Renewables (SRREN)
- Renewable Electricity Futures
- On the Path to SunShot (SunShot Vision II)
- IPCC 5th Assessment Report (AR5)
- Wind Vision
- Hydropower Vision
- Renewable Portfolio Standards (RPS) Retrospective Benefits Analysis

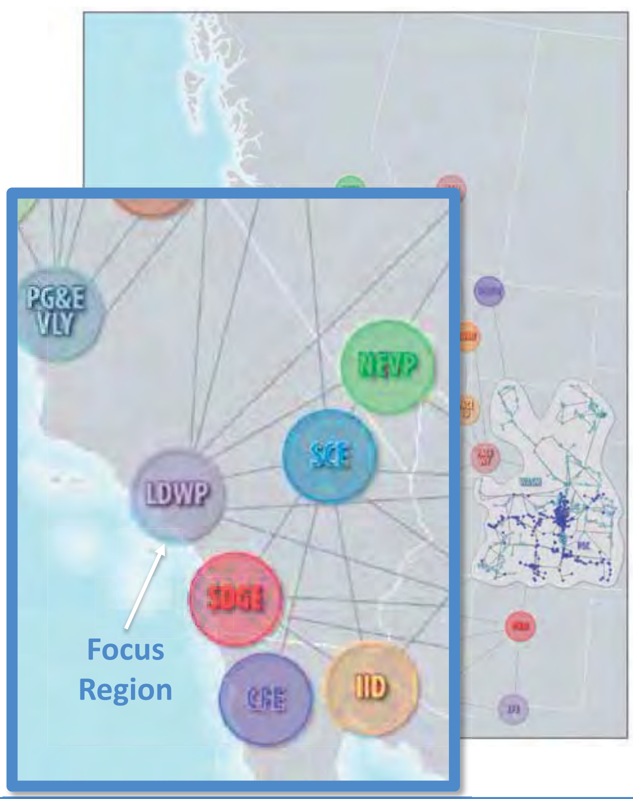


General Approach to Estimating Life-Cycle GHG Emissions

Step 1:

Resource Planning Model directly estimates combustion CO_2 emissions

- Resource Planning Model is NREL's regional electric sector capacity expansion model
- These emissions are estimated for LADWP (for each unit) and all regionally connected generators (in technology categories within each balancing area)



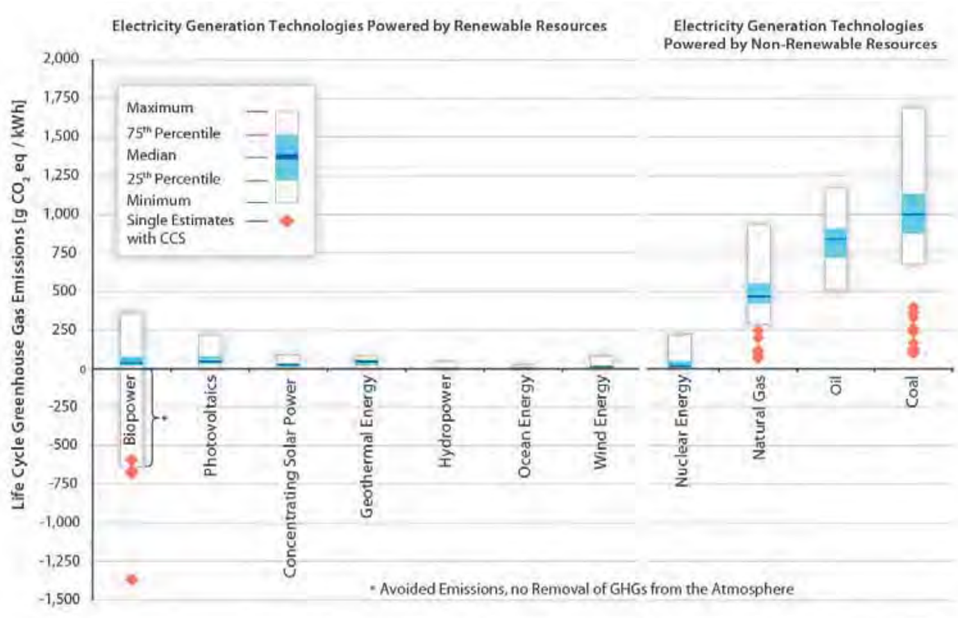
General Approach to Estimating Life-Cycle GHG Emissions

Step 2:

NREL's prior reviews of LCAs supporting the previous list of studies provide estimates for non-combustion GHG emissions, including non-CO_2 emissions:

- Three additional life-cycle phases:
  1. Upstream materials manufacturing and plant construction (per unit capacity)
  2. Downstream plant decommissioning (per unit capacity)
  3. Ongoing operations and maintenance, as well as fuel cycle emissions that are modulated by generation (per unit generation)
- One technology not previously evaluated: **battery storage**
  - Will follow same systematic literature review approach as for all prior evaluations

Systematic Review of ALL Published LCAs: IPCC Special Report on Renewables (2012)



	Biopower	Photovoltaics	Concentrating Solar Power	Geothermal Energy	Hydropower	Ocean Energy	Wind Energy	Nuclear Energy	Natural Gas	Oil	Coal
Count of Estimates	222(+4)	124	42	8	28	10	126	125	83(+7)	24	169(+12)
Count of References	52(+0)	26	13	6	11	5	49	32	36(+4)	10	50(+10)

This plot shows the data that will be used in LA100, plus about 500 more studies subsequently reviewed (total close to 3,000, with consistent results to those shown here)

IPCC SRREN, Summary for Policy Makers, Fig. 8

CCS = carbon capture and sequestration

Illustrative Example of How Study Results Can Be Presented: National Benefits of End-of-2014 (existing) Solar Capacity

GHG EMISSIONS	SULFUR DIOXIDE	NITROGEN OXIDES	PARTICULATE MATTER 2.5
-12%	-10%	-17%	-13%
Reduced by: **17 million** metric tons	Reduced by: **10,000** metric tons	Reduced by: **10,300** metric tons	Reduced by: **1,200** metric tons

-x% reduced mortality
-y% reduced ozone-induced asthma hospitalizations

We will differentiate between emissions reductions within and outside of the City of LA

(percent results are illustrative of how study results can be presented)

Source: The Environmental and Public Health Benefits of Achieving High Penetrations of Solar Energy in the US

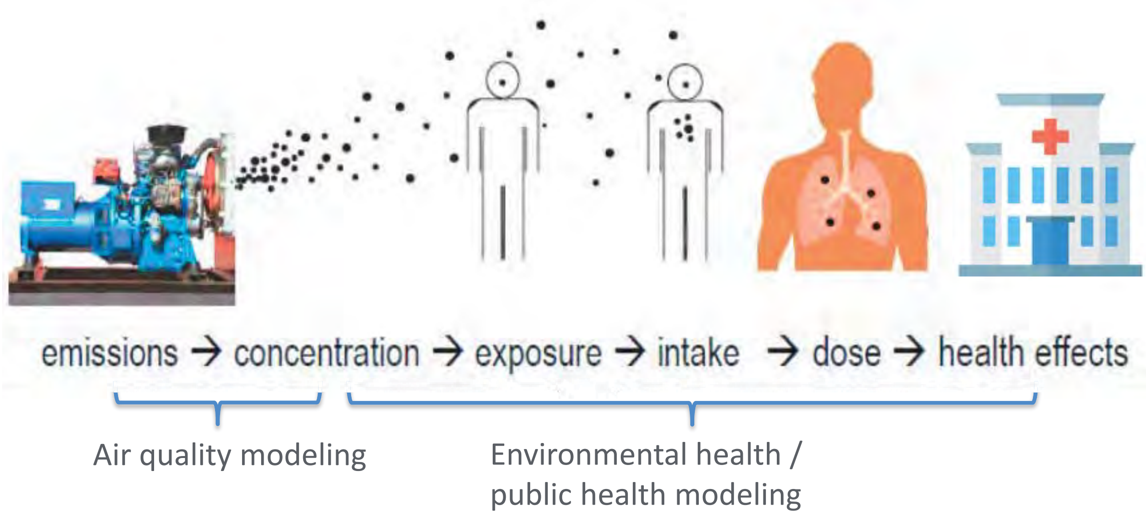
Approach for Air Quality and Public Health Modeling

City Council Requirements

August 1, 2017	"The prioritization of environmental justice neighborhoods as the first immediate beneficiaries of localized air quality improvements and GHG reduction."	Requires the analysis of air quality-related impacts

- This study fits into a long history of air quality challenges for LA and the South Coast Air Basin that continue today
- Reducing emission sources is the **key strategy** to managing air quality (once emitted, there is almost no way to control air pollution)
- "Local air quality improvements" relates to the concentration of air pollutants where people are
  - Further, they relate to the health impacts caused by these localized air pollutant concentrations

The Environmental Health Continuum



- Air quality modeling began in LA; many models to choose from that have been built or calibrated for LA
- Public health is based on observed relationships between (ambient) pollutant concentrations and health effects (epidemiology)
  - Reduced air emissions → reduced concentrations → reduced health impacts = benefits of 100% RE scenarios

Source: Heath, 2006

Air Pollutants and Health Effects of Concern

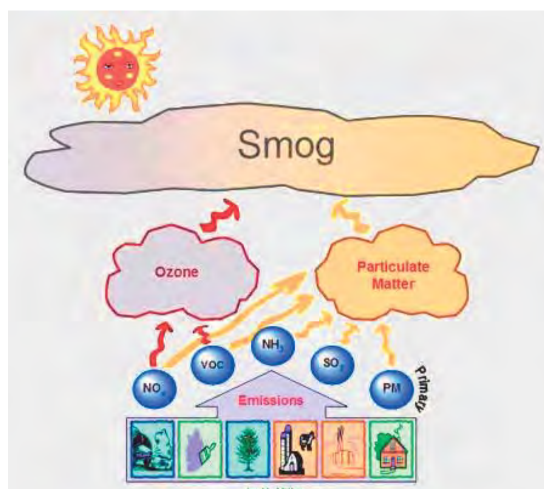
- LA is out of compliance (AKA "nonattainment") with the National Ambient Air Quality Standards (NAAQS) for two key pollutants:
  1. **Ozone (O_3)**
  2. **Particulate matter (PM)**, especially "fine PM" = $PM_{2.5}$

- Health effects with the greatest damages in monetary terms are:
  1. **Premature mortality** from long-term exposure to $PM_{2.5}$
  2. **Hospitalizations related to asthma** made worse (or instigated by) short-term exposure to ozone

- We will focus our air quality and public health modeling on these pollutants and health effects

(Simple) Science of Ozone and PM Formation

- Ozone forms in the presence nitrogen oxides (NOx), volatile organic compounds (VOCs), and sunlight
- Particulate matter has more and more complex formation pathways, and travels longer distances
- Both form urban "smog," which LA has long tried to control



- 100% RE scenarios for LADWP could help in achieving the region's air quality goals

Source: https://www.cumbriacrack.com/2011/04/21/defra-puts-uk-on-smog-alert/

Air Quality and Public Health Modeling: Final Points

- We plan to evaluate the 100% RE scenarios for air quality and public health benefits that show discernable changes to air emissions (compared to baseline and amongst themselves)
  - Criteria for scenario selection will be discussed further in a next AG meeting
- We will consider emissions transported into the basin from nearby sources, some of whose operations could be affected by the changes to the LADWP assets considered in this study
- Changes to health effects will be discerned at a spatial resolution to match with neighborhoods identified as EJ neighborhoods (see next slides)

Approach for Analysis of Impacts on EJ Neighborhoods

City Council Requirements

August 1, 2017	"The prioritization of environmental justice neighborhoods as the first immediate beneficiaries of localized air quality improvements and GHG reduction."	Requires the analysis of air quality-related impacts
August 1, 2017	"Incorporation of the CalEnviro Screen …"	Basis of EJ neighborhood determination early in the project

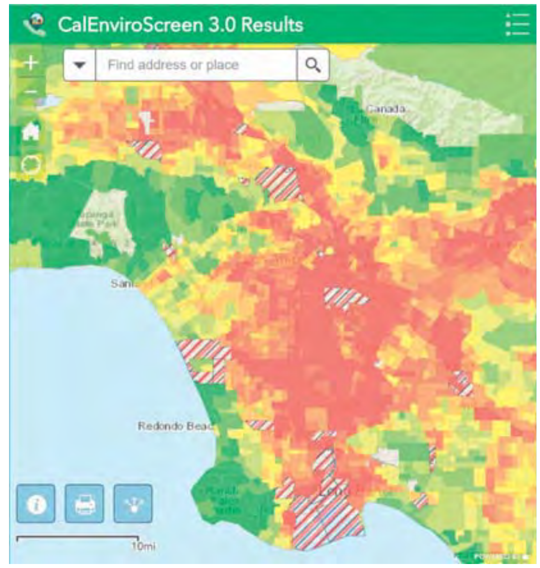
- Many neighborhoods in LA experience **socioeconomic** and **environmental** challenges; the simultaneous experience of both is what is known as **environmental justice or EJ**
- As with air quality, LA has a long history of identifying and addressing EJ challenges
- Reducing emission sources, especially local ones, is the **key strategy** to addressing EJ concerns, and all 100% RE scenarios should positively address EJ issues
- The study will discern differences in local air pollutant concentrations and health impacts between EJ neighborhoods and non-EJ neighborhoods, for the base case and evaluated 100% RE scenarios

How to Define EJ Neighborhoods

- There are many approaches to defining EJ
- Active discussion within several regional organizations as to the most appropriate definition for the LA region and (sometimes) for specific uses (grant funding, city services)
  - We are consulting with the City's Planning Department to learn about the status of various local efforts to define EJ
- City Council required that this study utilize **CalEnviroScreen** (latest version: 3.0)

Defining EJ Neighborhoods: CalEnviroScreen

- "CalEnviroScreen is a screening tool that evaluates the burden of pollution from multiple sources in communities while accounting for potential vulnerability to the adverse effects of pollution."
- "CalEnviroScreen is being used to identify communities that face multiple burdens of pollution and socioeconomic disadvantage, [which] helps CalEPA to prioritize its work in the state's most burdened communities."
  - Also used by other state agencies and to support administration of multiple state grant programs

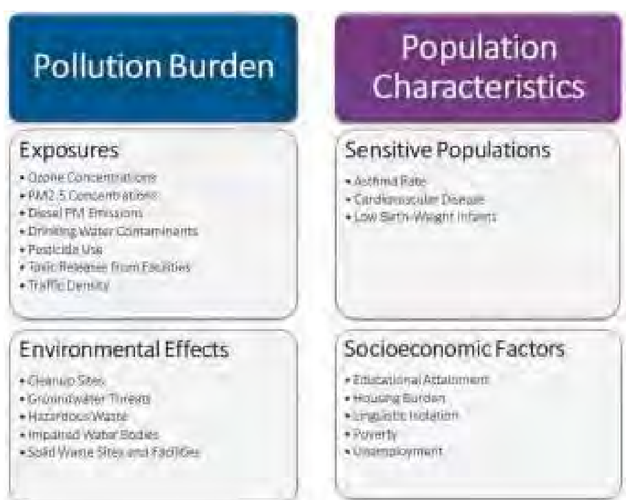


OEHHA, 2018

See: https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-30

CalEnviroScreen Score

- "CalEnviroScreen ranks census tracts in California based on potential exposures to pollutants, adverse environmental conditions, socioeconomic factors and prevalence of certain health conditions [using] data from national and state sources."
- The score is reported on a 0–100 scale, which is a composite of 20 indicators each normalized to its state-level distribution
- State programs using CalEnviroScreen often set their own score cutoff criteria for program eligibility or targeting;* thus, there is no unique definition for EJ with CalEnviroScreen scores
  - Our first job is to determine which score should be used for this study in terms of targeting EE and RE deployment
  - The score threshold we choose should be consistent with prior and current uses of CalEnviroScreen relevant to the goals of this study



*See https://oehha.ca.gov/calenviroscreen/how-use for examples

Summary

- Today's goals:
  - Establish familiarity with our methods
    - More detailed for GHG emissions analysis
    - General approach for air quality, public health, and environmental justice
  - Demonstrate how environmental modeling will meet the City Council Motions
  - Convey timing of environmental modeling (follows main modeling and analytical tasks of the study)
  - **Use your questions and comments to clarify and improve the study!**

Thank you!

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LA DWP Los Angeles Department of Water & Power

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- Next Meeting Date: Thursday, November 15, 2018
- Questions, comments, input: Please send to Anton Sy, Project Manager, Anton.Sy@ladwp.com

Thank you!