NREL
NATIONAL RENEWABLE ENERGY LABORATORY

LA DWP

Los Angeles 100% Renewable Energy Study
Advisory Group Meeting #5
June 7, 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

- Call to Order and Agenda Overview
- Welcome and Introductions
- Update Exchange
- Considerations for Planning a 100% Electric Power System
- Lunch Served
- Revised Scenarios and Sensitivities
- Wrap-up and Next Steps

Advisory Group Schedule

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QUARTER	Phase 1 | 2017 LAUNCH AND ORGANIZATION	Phase 2 | 2018 SCENARIOS	Phase 3 | 2019 ANALYSIS AND MODELING	Phase 4 | 2020 FINAL REPORT
Q1	■ COMPLETED MEETINGS/TASKS ■ PLANNED MEETINGS/TASKS	FEBRUARY 15 • Advisory Group Meeting Plan • Preliminary Scenarios and Sensitivities • Field Trip Itinerary • Power Strategic Long-Term Power Resources Plan • Once-Through Cooling Study Update	• Capacity Value • Electricity Operations Modeling II • Jobs & Economic Analysis II	• White Papers on Electricity Modeling Results • Final Results 1) Jobs & Economic Analysis and 2) Environmental Analysis • Final Visualization of Electricity Operations
Q2	JUNE 23 • Advisory Group Launch • City Council Motion: 100% Renewable Energy Study	JUNE 7 FIELD TRIP April 26 • Draft 100% Papers: Framing, Data, Methods • Final Scenarios and Sensitivities • Once-Through Cooling Study Update	• Planning Reserves • Operating Reserves • Load Modernization • Environmental Analysis II • Publication Plan	• Final Report • Final Presentation
Q3	AUGUST 3 • Advisory Group Charge and Operating Protocols • Introduction to NREL and 100% Renewable Energy Study	AUGUST 16 • Final 100% Papers • Electricity Operations Modeling I • Jobs & Economic Analysis I • Environmental Modeling I • Once-Through Cooling Study Update	• Final Scenarios and Sensitivities Results • Final Visualization of Scenarios • Initial Electricity Operations Modeling Results	
Q4	NOVEMBER 16 • Defining Clean Energy and Renewable Energy • Considerations for Study • Once-Through Cooling Study Overview • Public Outreach Overview	NOVEMBER 15 • Initial Scenario Results • Draft Visualizations of Scenarios • Once-Through Cooling Study Results	• Final Electricity Operations Modeling Results and Draft Visualizations • Draft results on Jobs and Economic Development • Draft results on Environmental Analysis	

LA DWP Los Angeles Department of Water & Power

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As of June 2018


LADWP Site Tour
Recap

Owens Valley Site Tour

2018 Tour Dates

- Fri., Jun. 22 – Sat., Jun. 23
- Fri., Sep. 21 – Sat., Sep. 22
- Fri., Oct. 19 – Sat., Oct. 20
- Fri., Nov. 2 – Sat., Nov. 3

- Tour the 233-mile route that the city's water travels to arrive at the tap.
- Two-day tour
- Learn about delivering water and power safely and reliably to the City of Los Angeles.

Early reservations are recommended as availability is limited.





Considerations for Planning a 100% Electric Power System

P. Denholm

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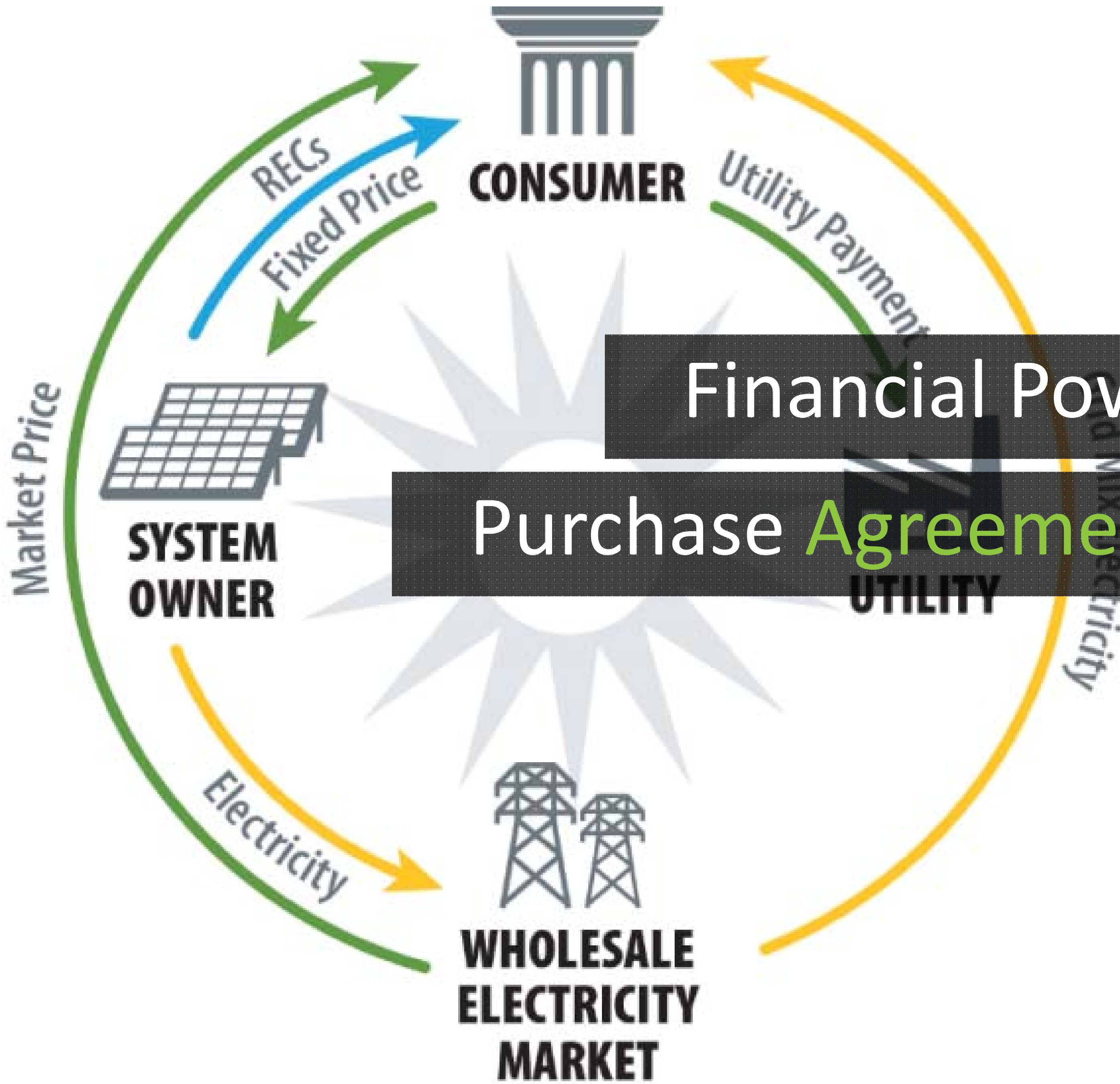
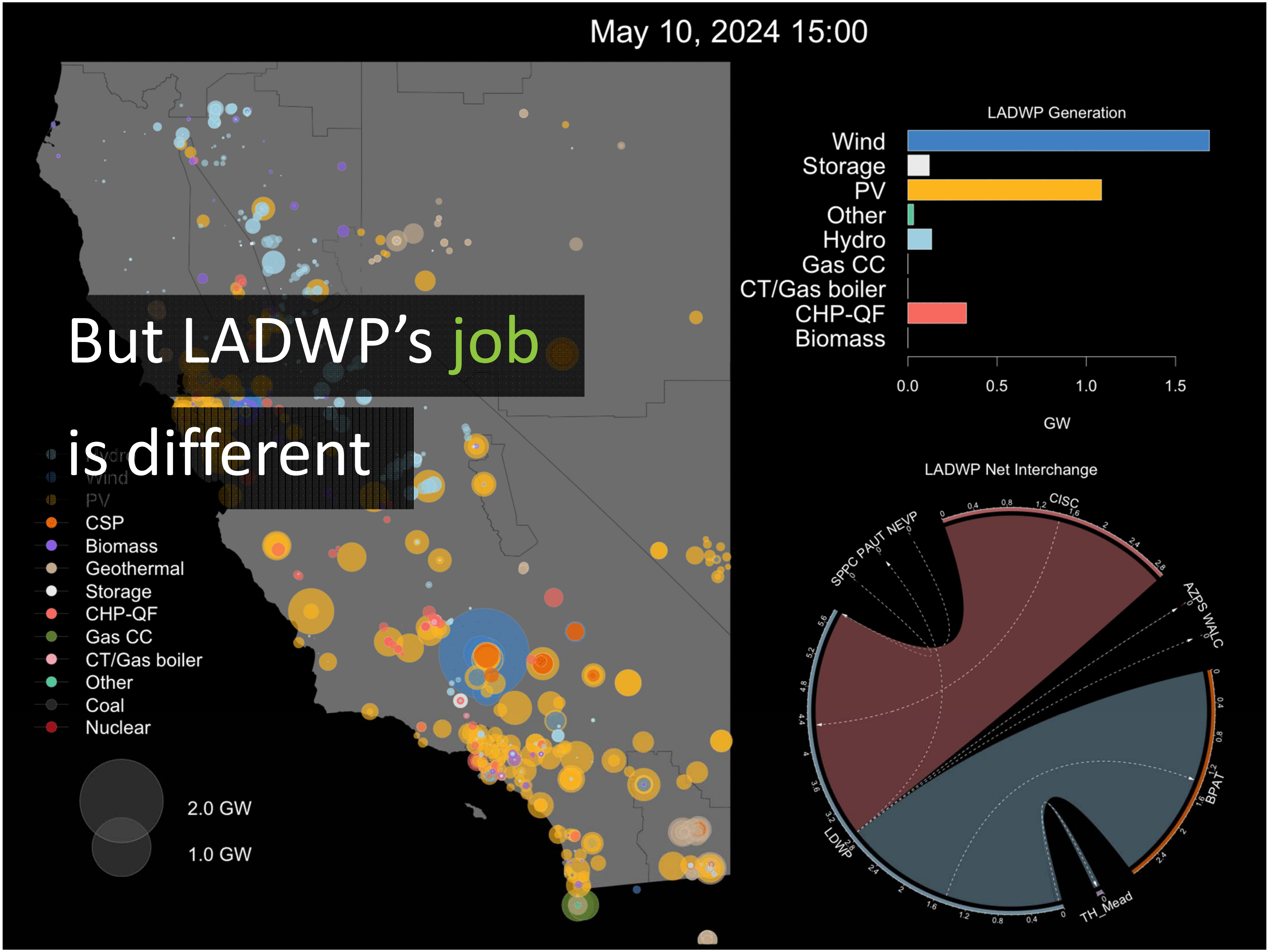
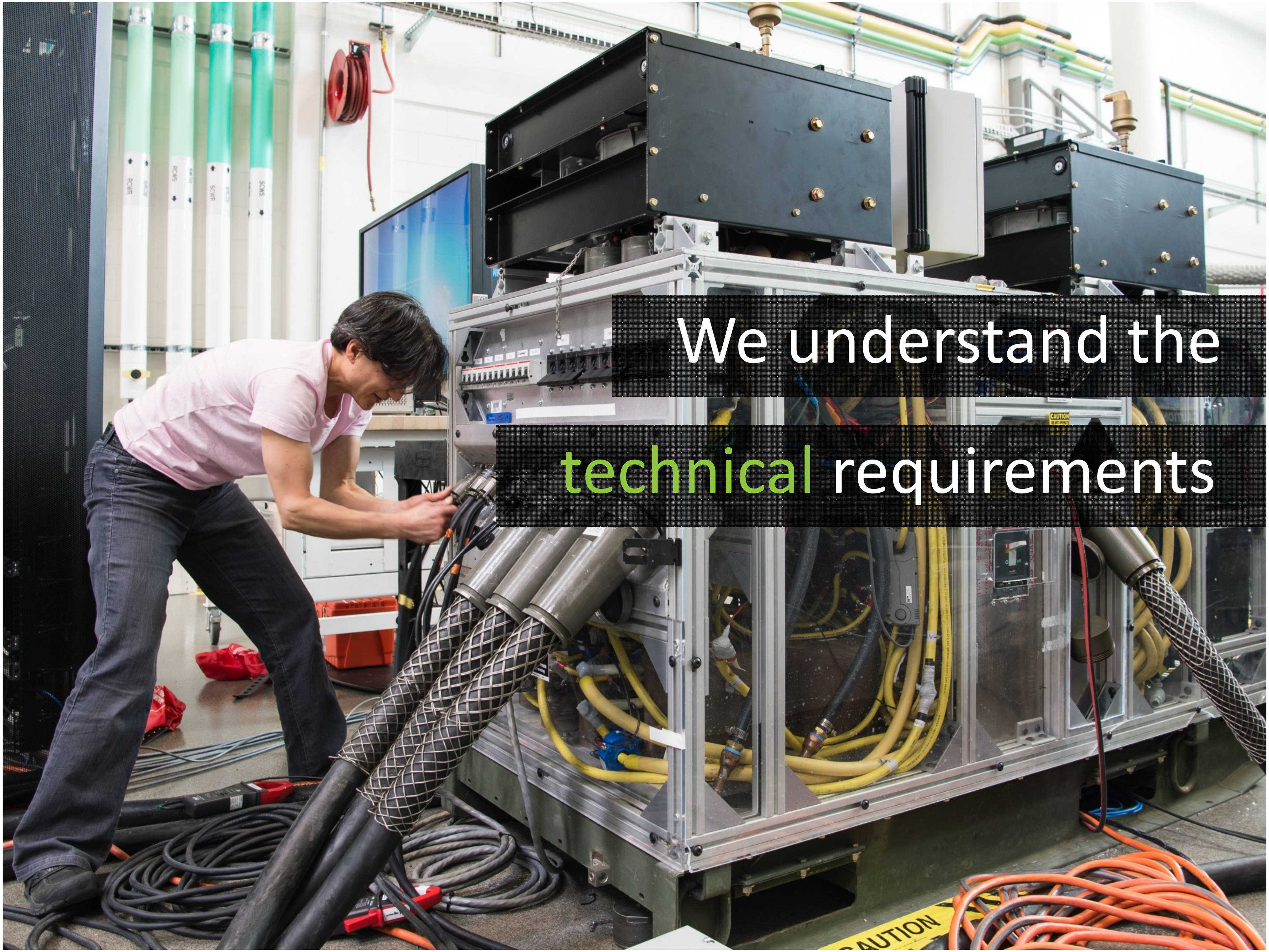
How do most cities and corporations
achieve 100%?
By Austin McKinley - Own work, CC BY 3.0,
https://commons.wikimedia.org/w/index.php?curid=26332560

Financial Power Purchase Agreements



But LADWP's job is different




We understand the
technical requirements


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

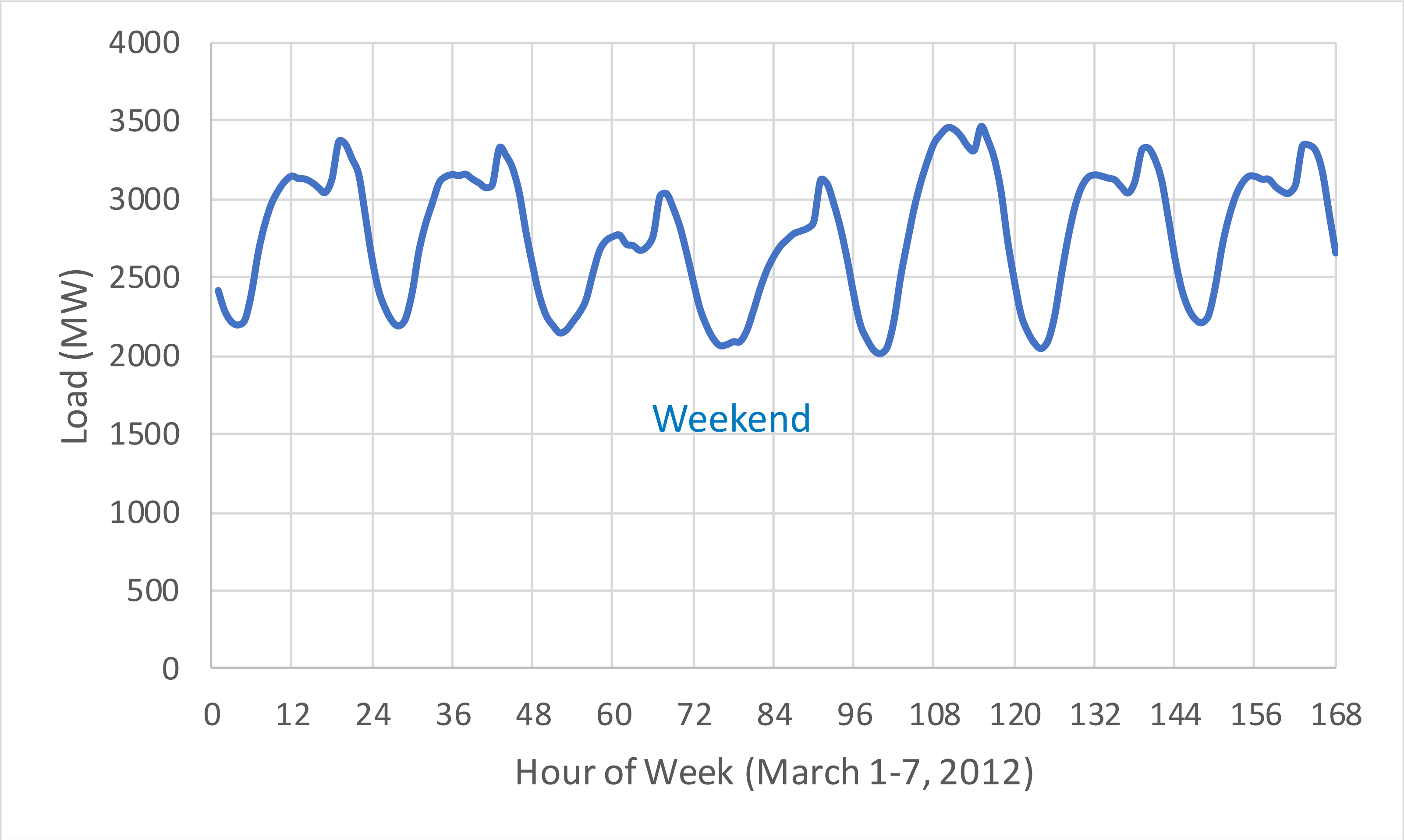
The Two Topics

1. Maintaining economic generation of Variable Generation (VG) due to supply/demand mismatch
2. Maintaining resource adequacy overall time scales without the “backup” of fossil generators

Important Topics We Will Not be Talking about Here

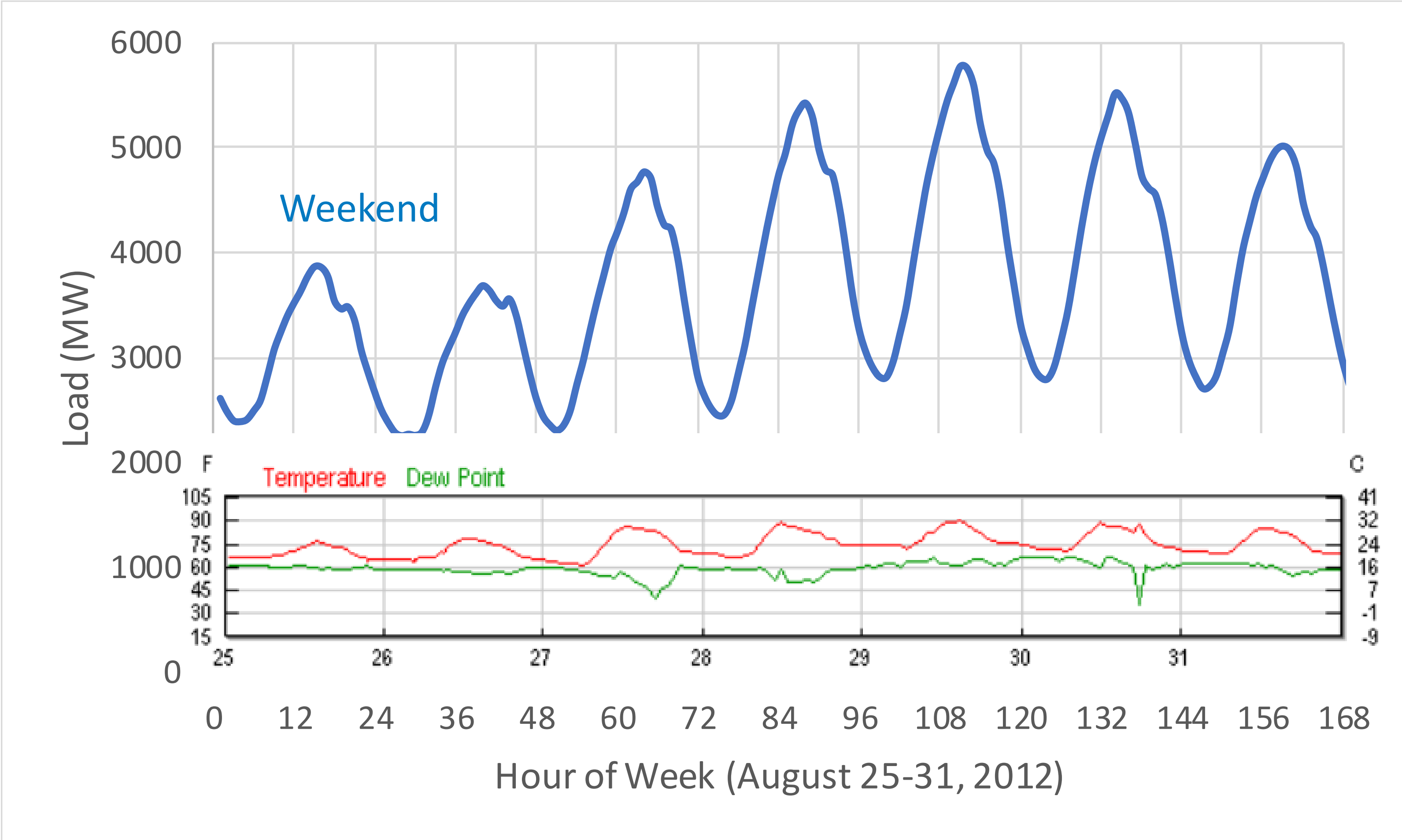
1. Transmission upgrades
2. Wind and Photovoltaic (PV) siting

Topic #1:Economics of Supply/Demand Mismatch



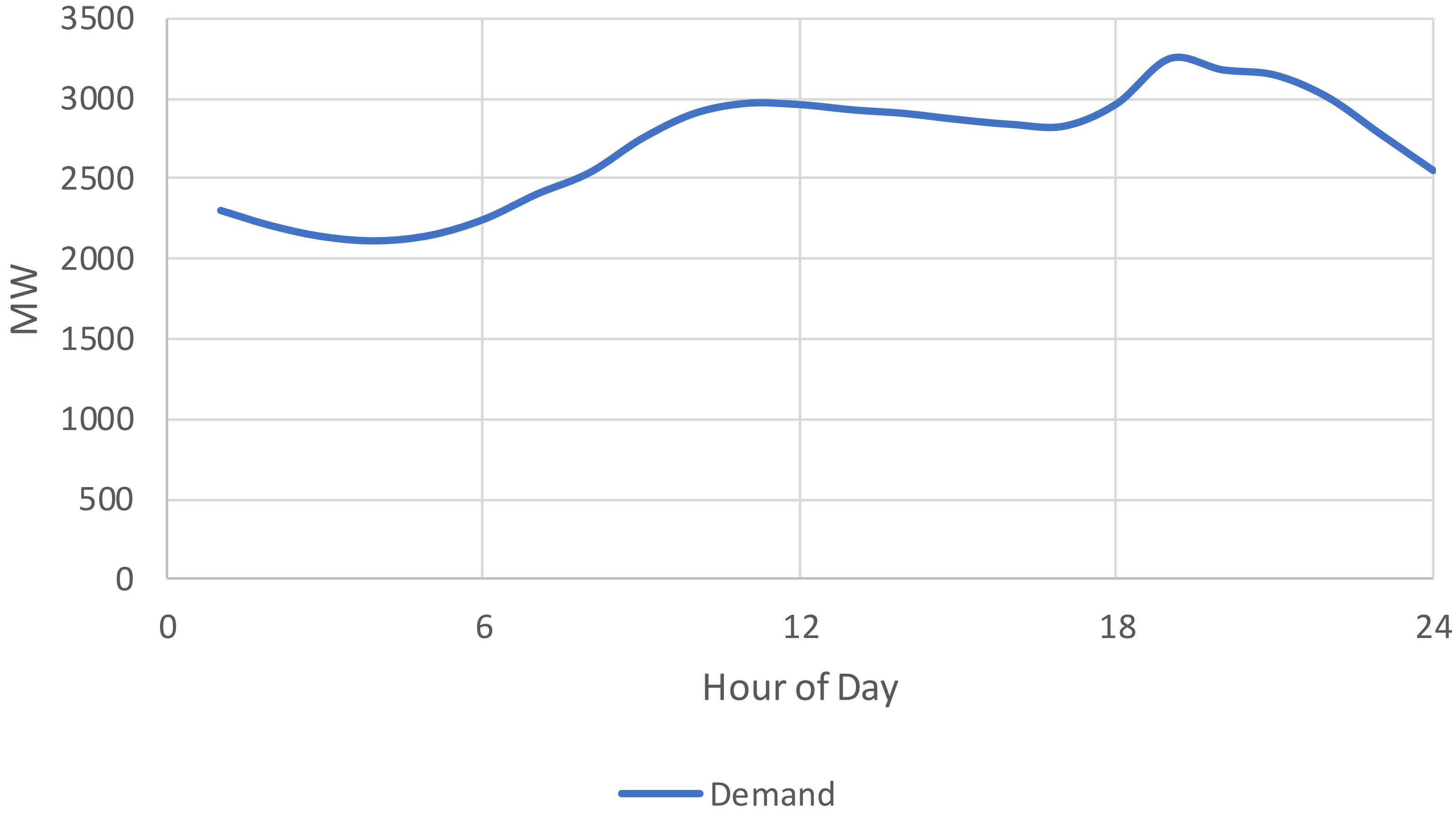
Here is there demand from March 1-7 (a low demand week).

Topic #1:Economics of Supply/Demand Mismatch



Here is there demand from August 25-31 (the week with highest demand).

Topic #1:Economics of Supply/Demand Mismatch



Here is the demand for electricity on Feb 20. This is a typical "low demand" period we see in the spring, or other periods with mild weather.

Topic #1:Economics of Supply/Demand Mismatch

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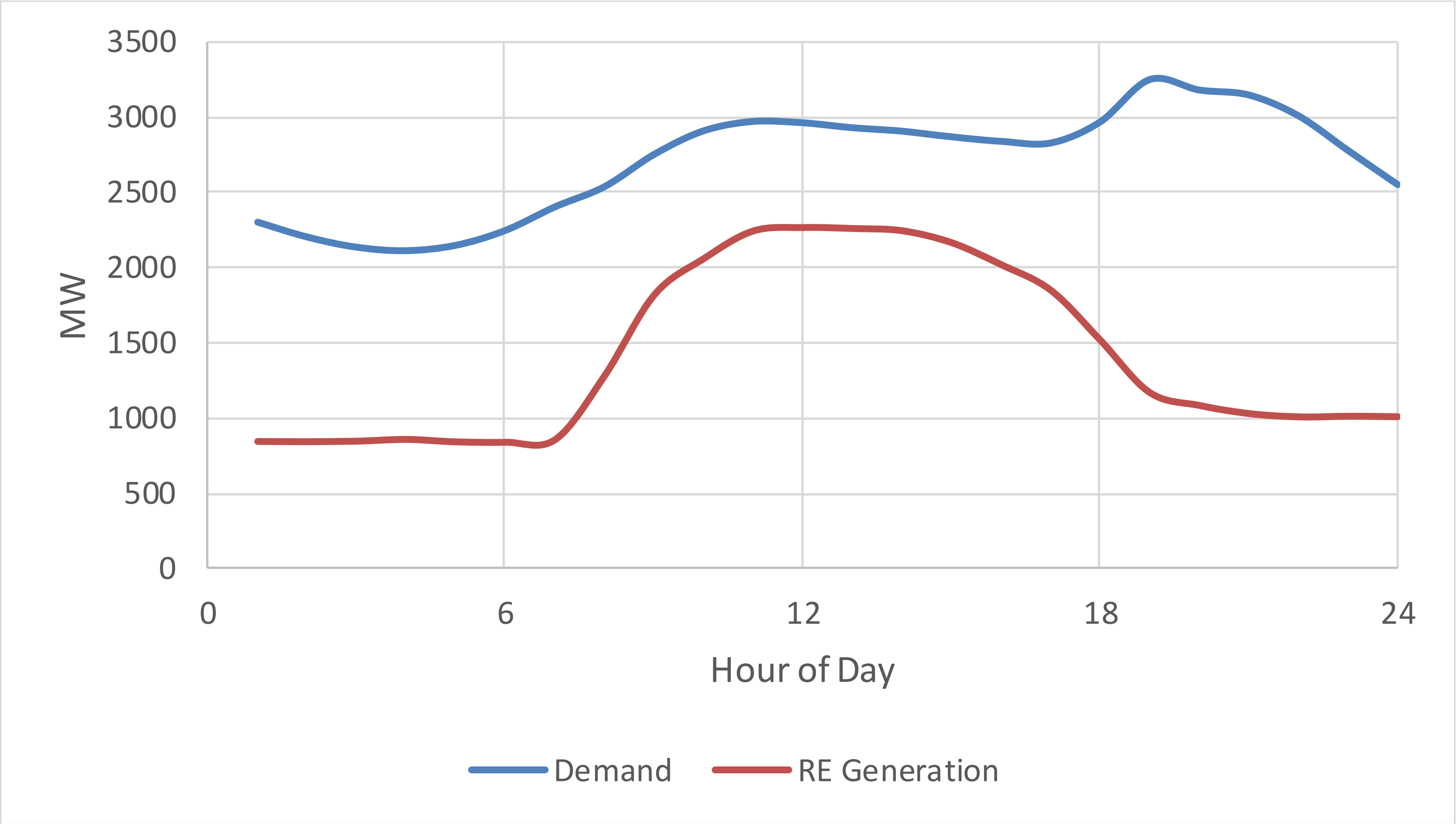
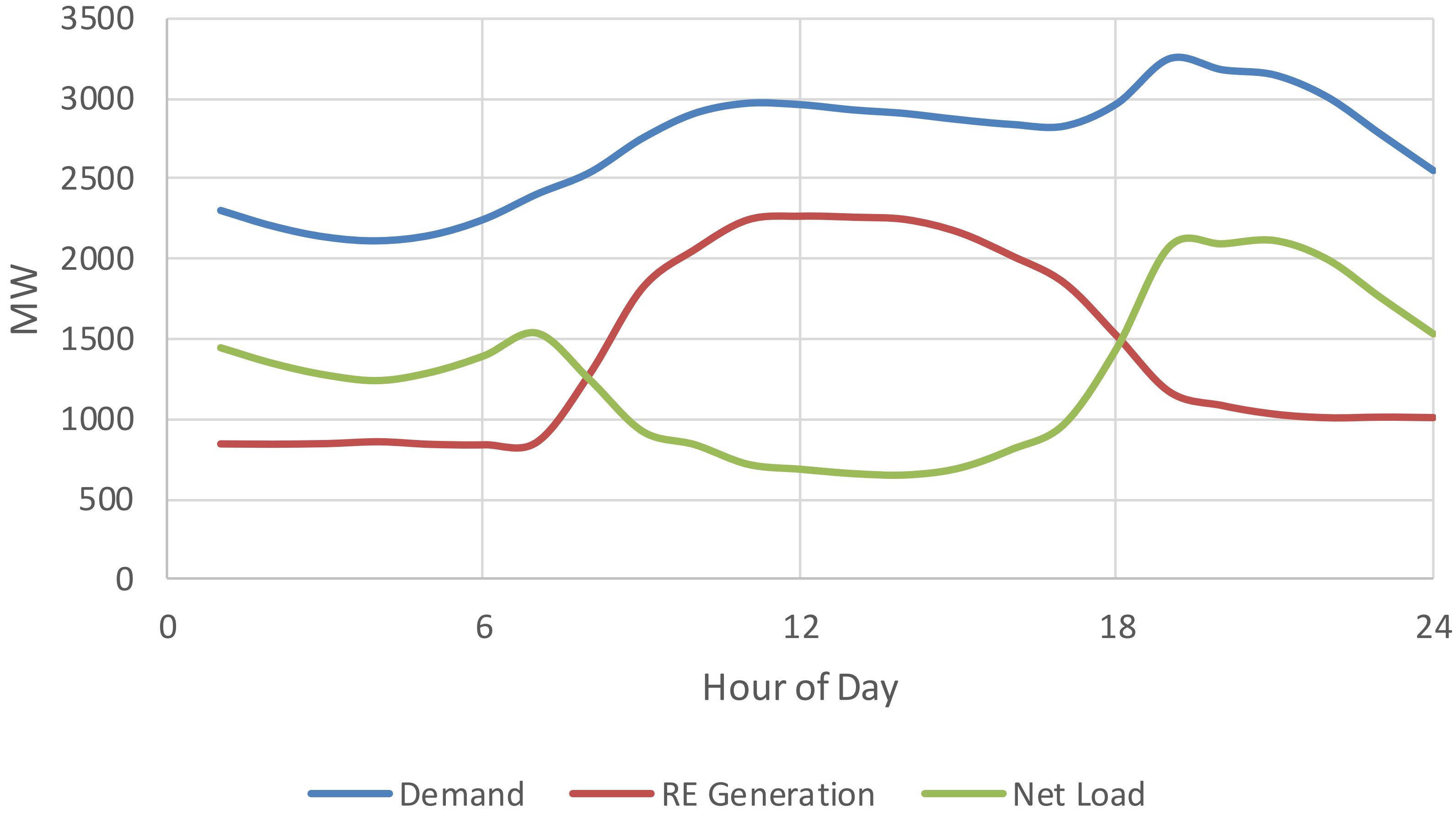


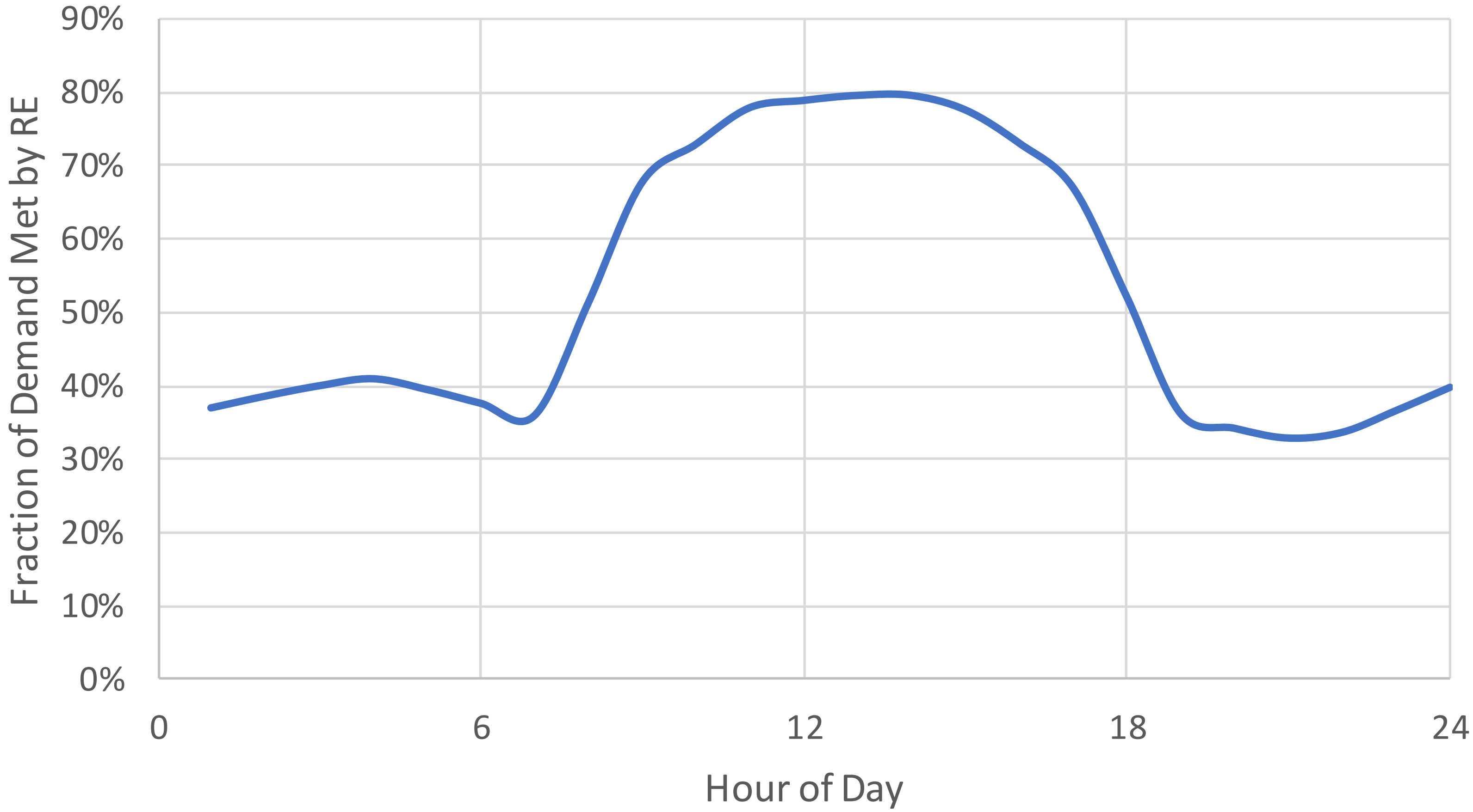
Here is the supply of renewable energy for this day.

Topic #1:Economics of Supply/Demand Mismatch



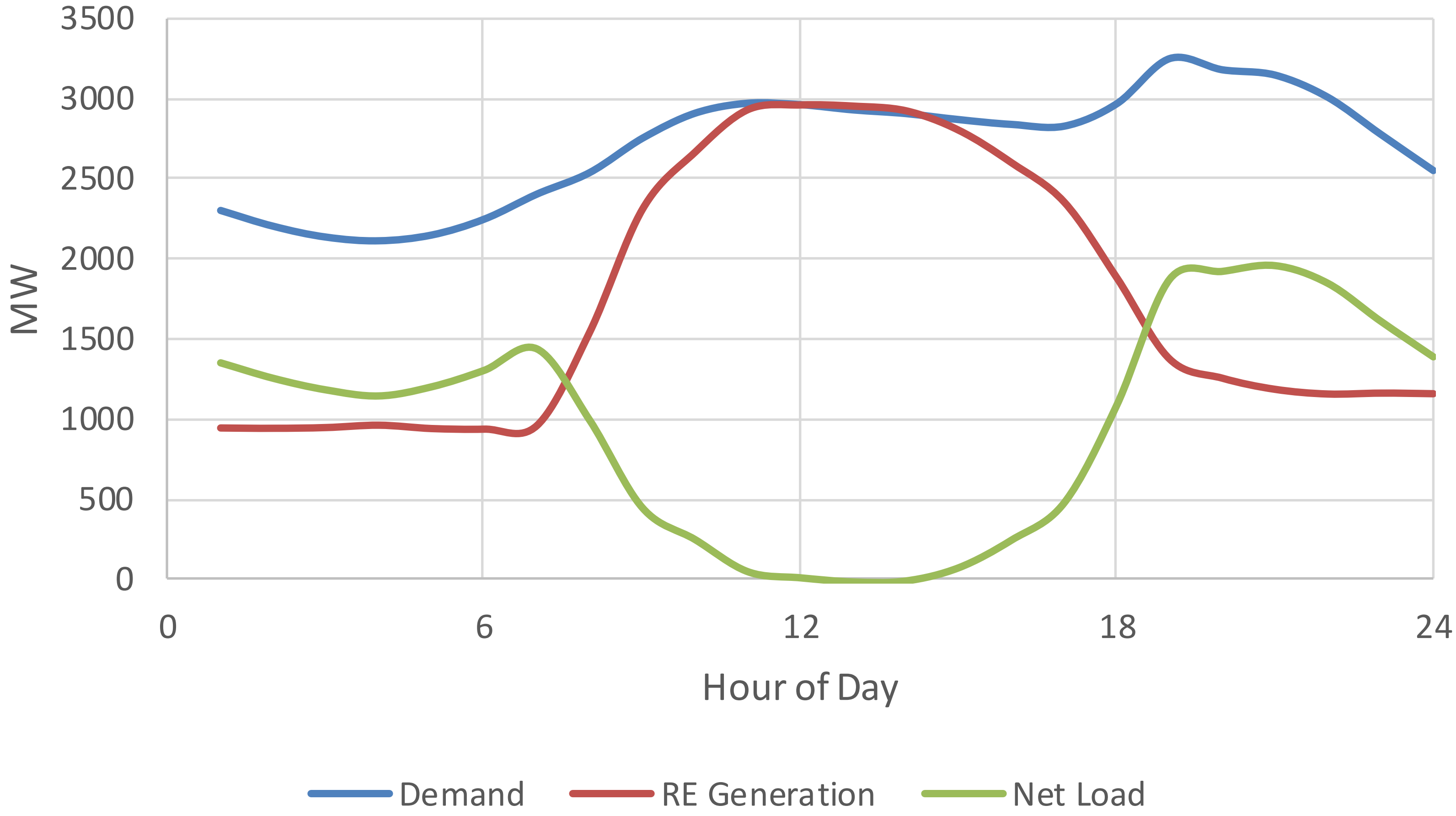
And here is the net demand, or the demand that LADWP must meet with other resources.

Topic #1:Economics of Supply/Demand Mismatch



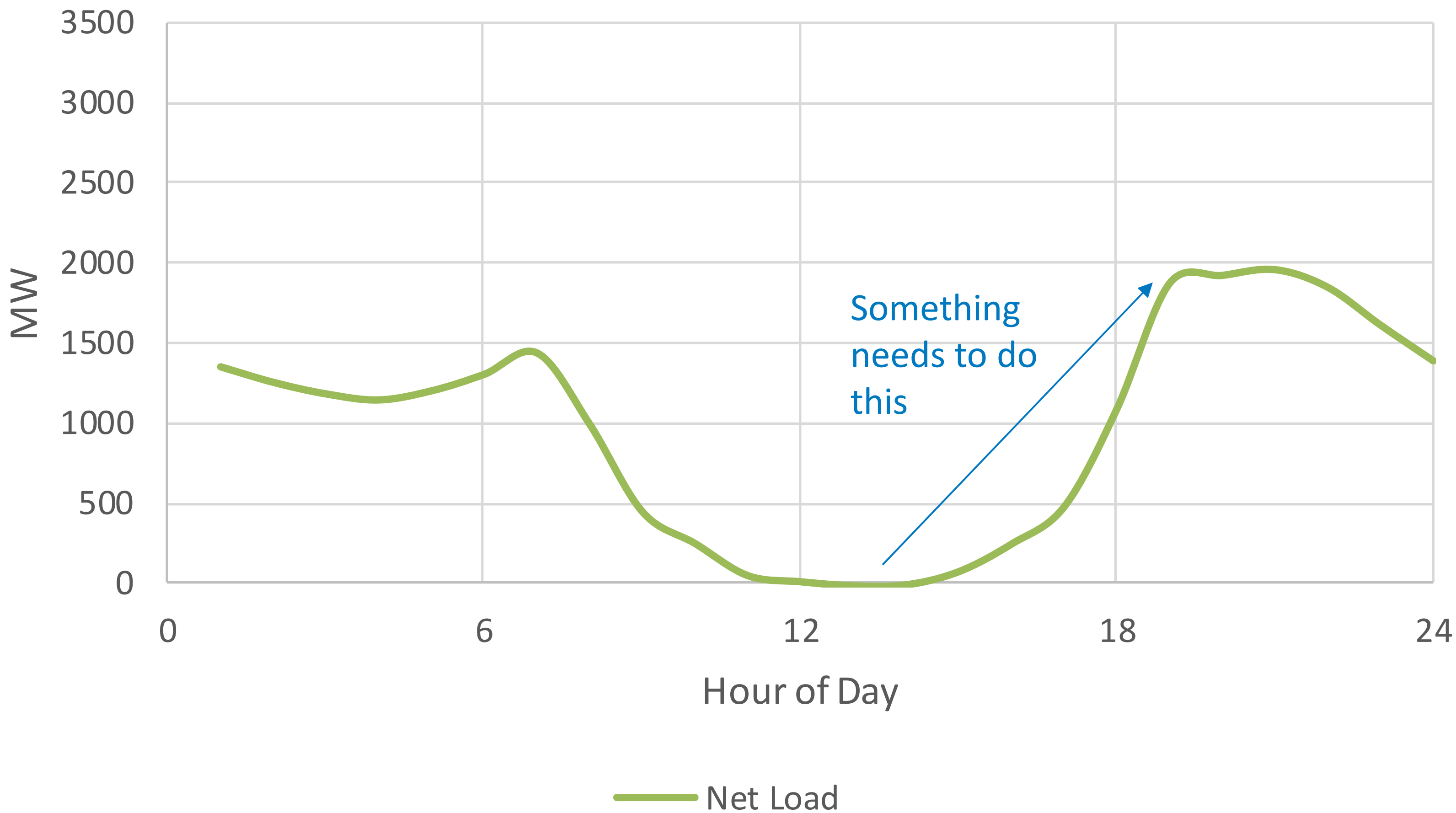
Because the mismatch of supply and demand, the fraction of demand met by RE in each hour varies considerably. Overall the fraction of demand met by RE on this day is 54% (compared to annual average of 40%).

Topic #1:Economics of Supply/Demand Mismatch



Adding another 300 MW of wind and 600 MW of solar gets us here. We are up to just under 50% annual energy from Renewable Energy (RE). During 1 hour of the day RE now provides 100% of the systems total demand.

Topic #1:Economics of Supply/Demand Mismatch



This presents some problems as we transition from a hydro/thermal based system to an all RE based system. Meeting this net load curve would require turning off all of LADWP's power plants for an hour, then turning them back on, and quickly ramping them back up. This isn't really possible, so we probably couldn't accommodate all this RE generation.

Topic #1:Economics of Supply/Demand Mismatch

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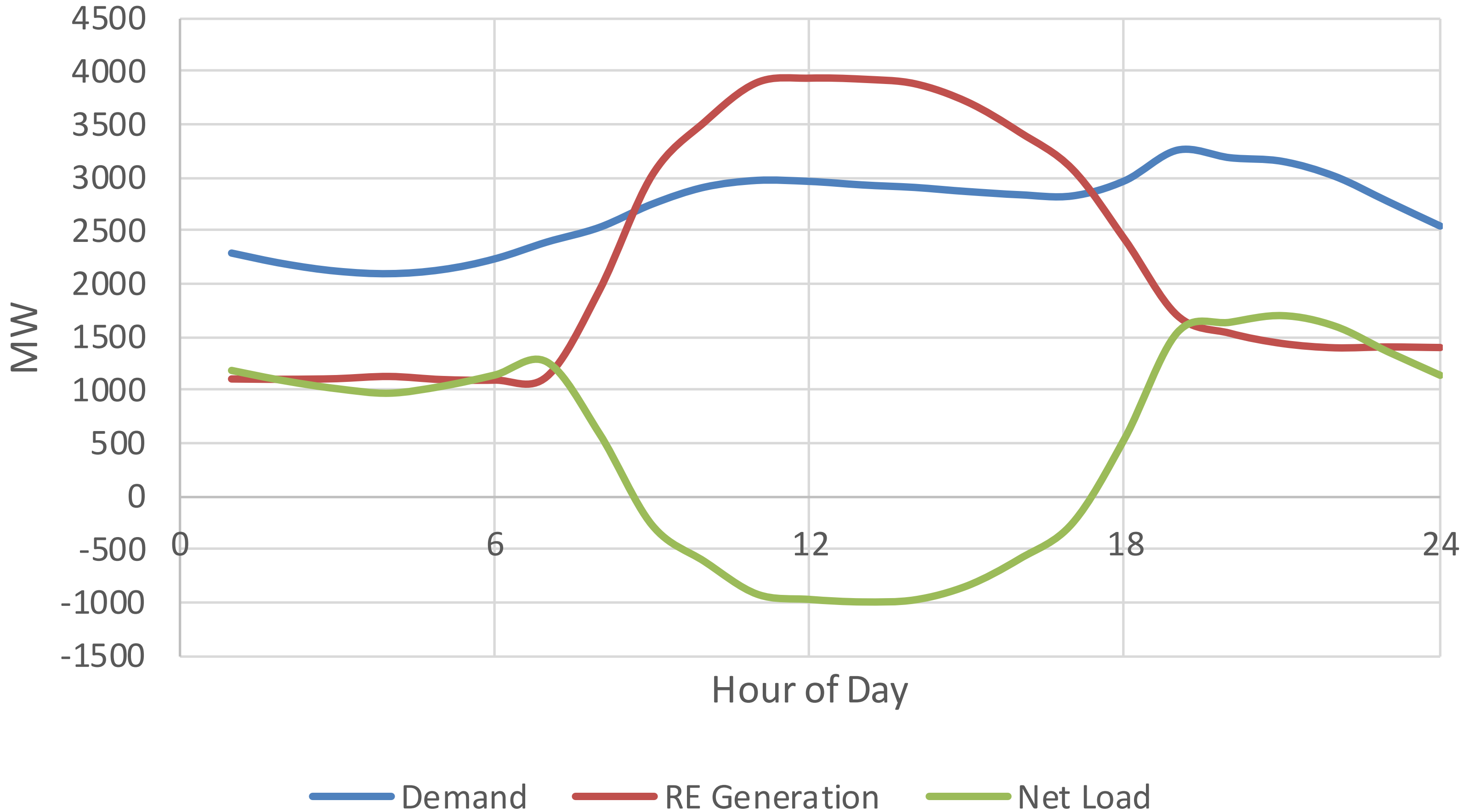
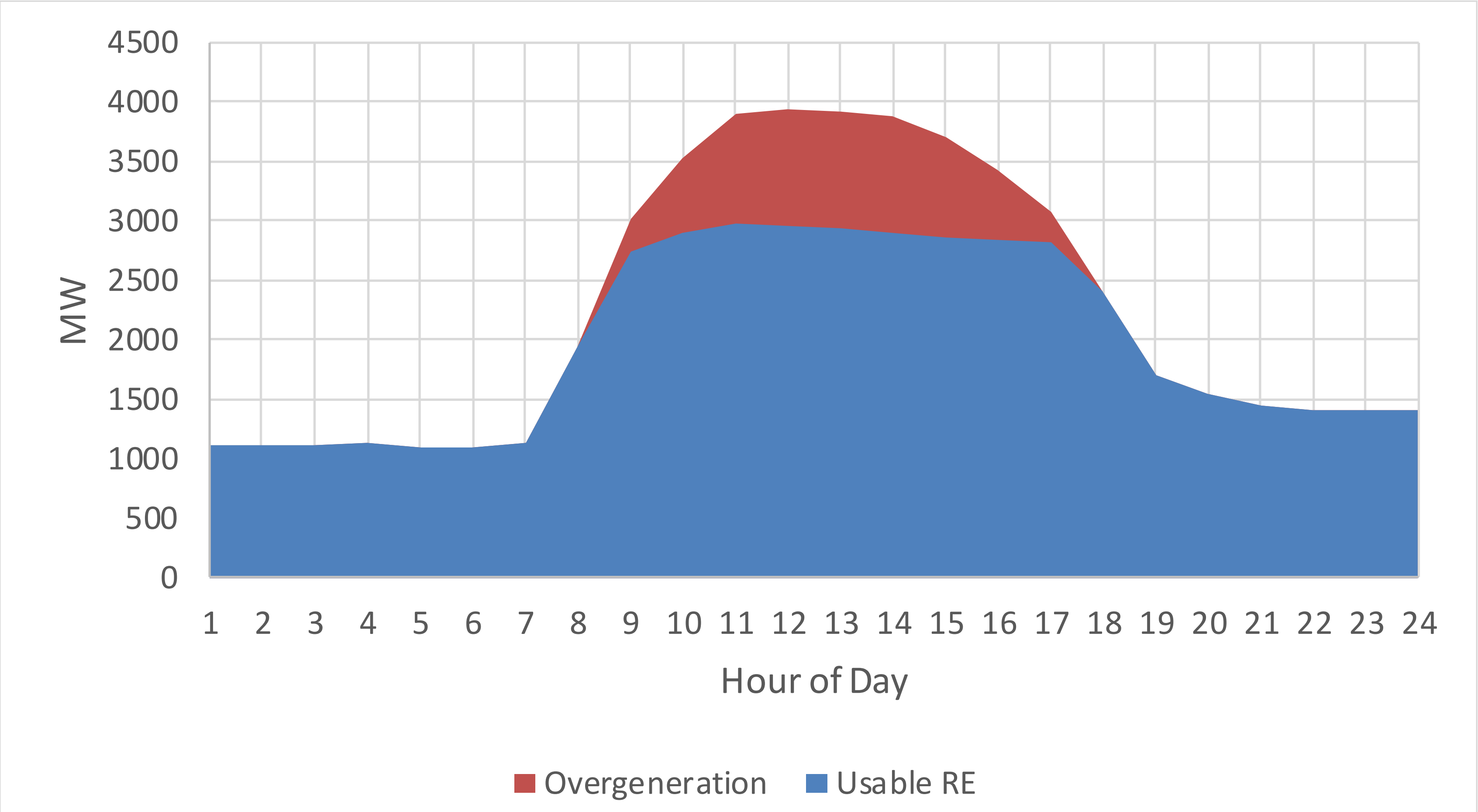


Even if we had "perfectly flexible" plants, we still have challenges as we increase RE penetration. Here is a case where we try to get 60% of LADWP's energy from RE (including 1,800 MW of wind and 2,700 MW of solar). On this day the supply of RE exceeds demand.

Topic #1:Economics of Supply/Demand Mismatch

LA DWP



Even if LADWP could reduce the output of all its other generators to zero, it would still need to curtail or sell this surplus energy. This excess supply is sometimes called “overgeneration”.

Topic #1:Economics of Supply/Demand Mismatch

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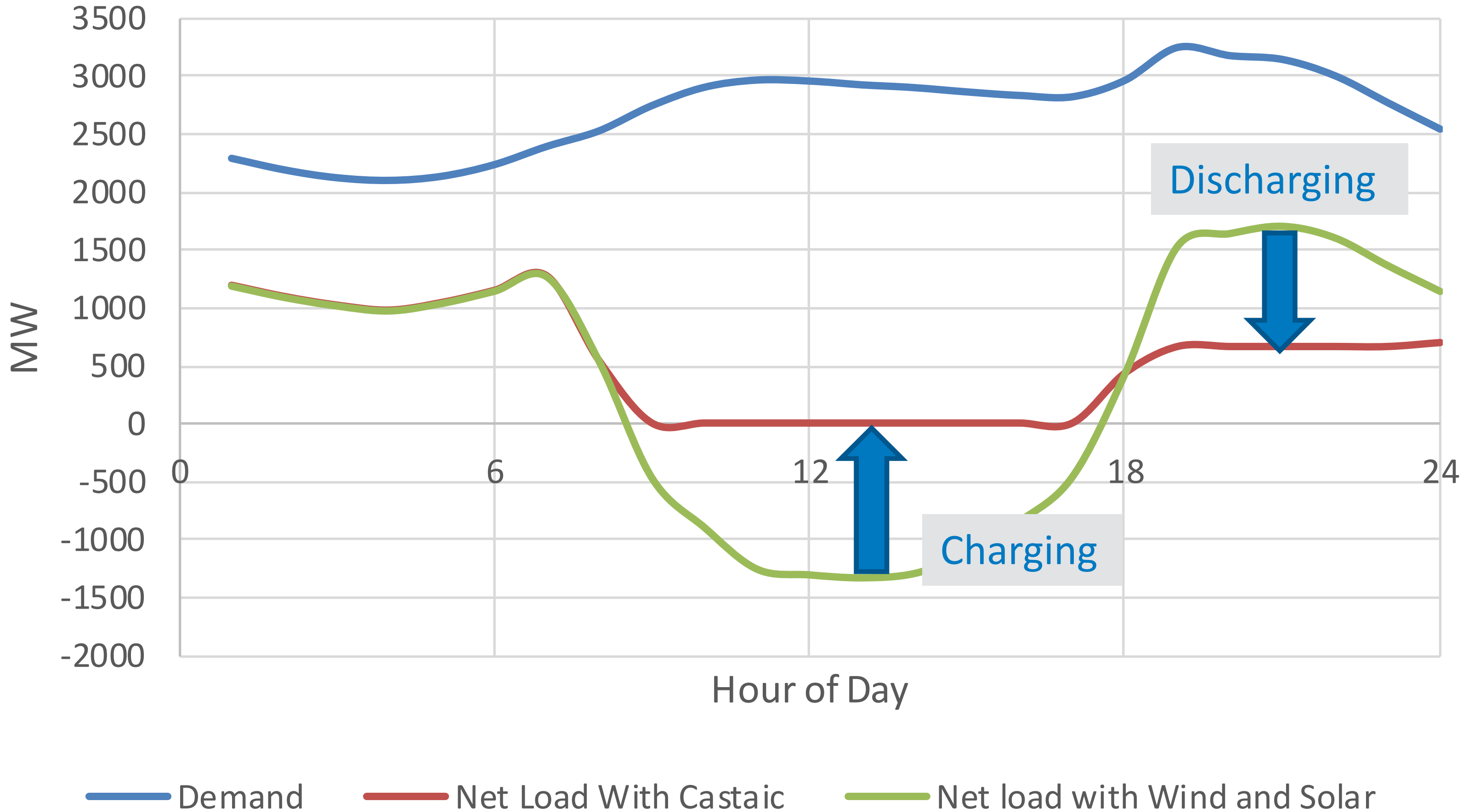
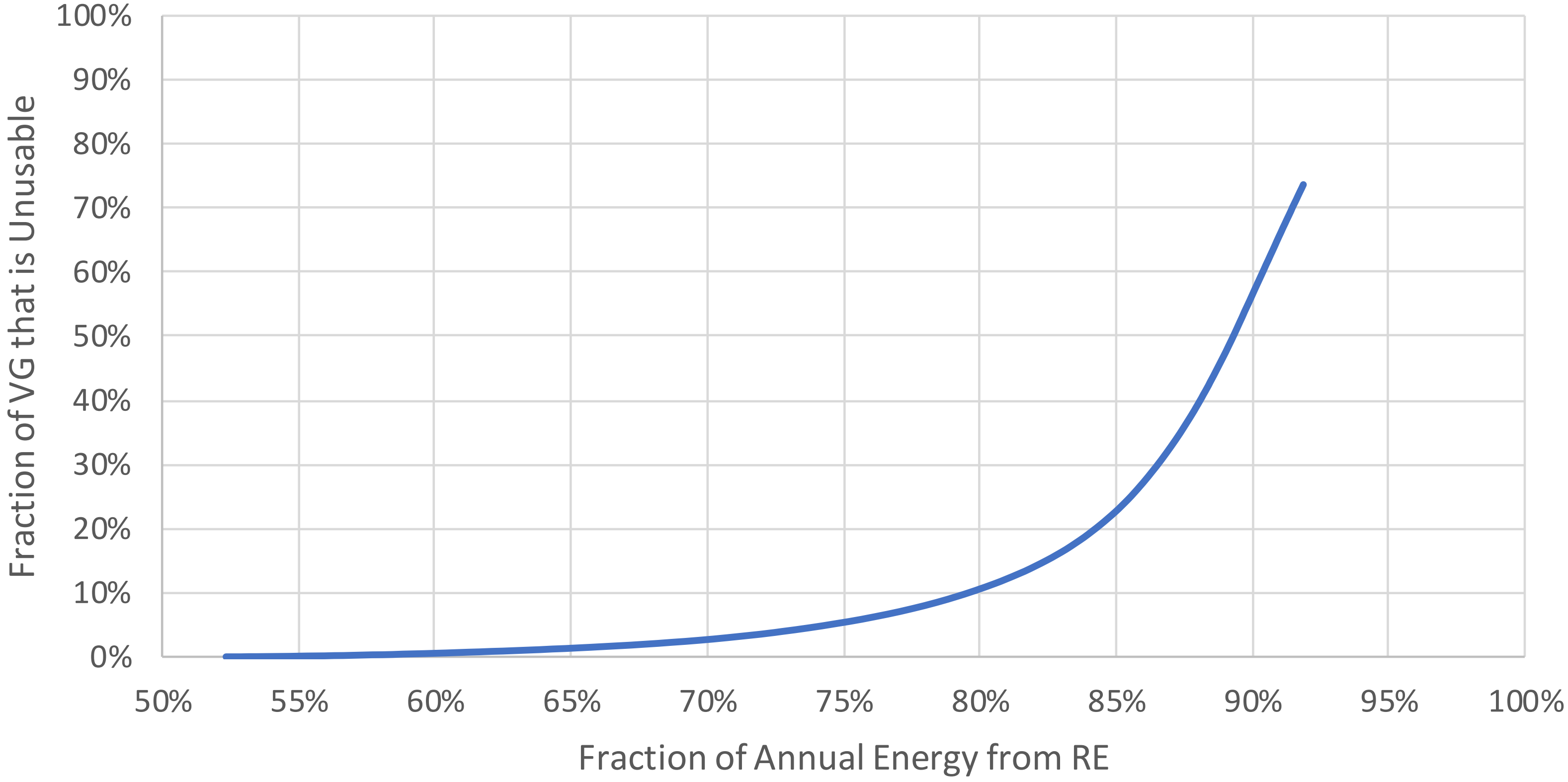
Currently deployed options to deal with overgeneration including storing energy in the Castaic pumped storage plant or selling the energy to its neighbors. Castaic is rated at about 1,175 MW of capacity and is about 70% efficient, meaning it throws away 30% of the energy it stores. Selling energy to neighboring utilities is an important options, but what happens when LA’s neighbors are saturated with RE?

Topic #1:Economics of Supply/Demand Mismatch



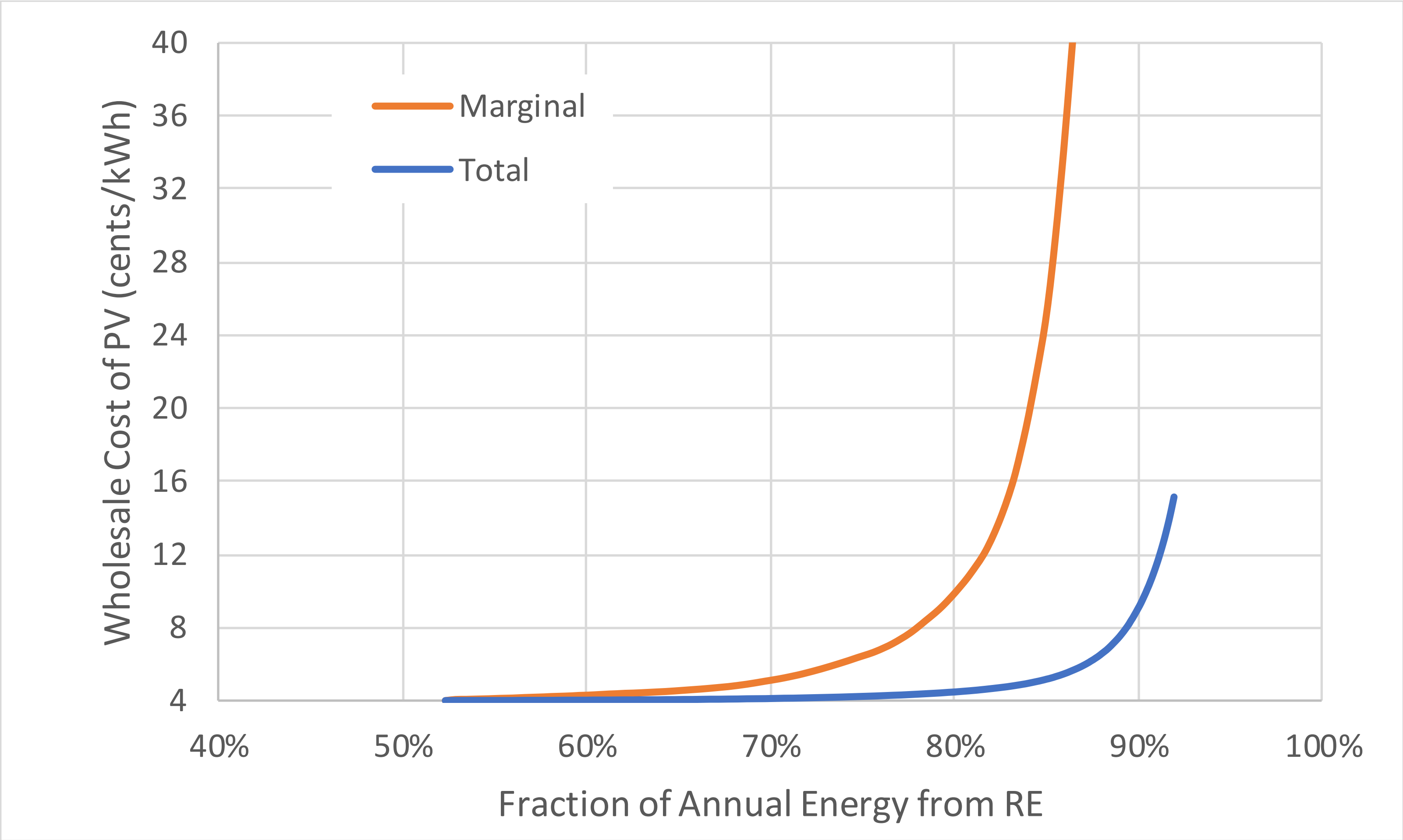
Adding in Castaic eliminates curtailment on Feb 20. But we have just about saturated the power capacity of this storage plant. More solar on this day will create more overgeneration.

Topic #1:Economics of Supply/Demand Mismatch



So without more storage or some other mechanism to improve the coincidence of supply and demand, the amount of unusable energy just keeps going up…

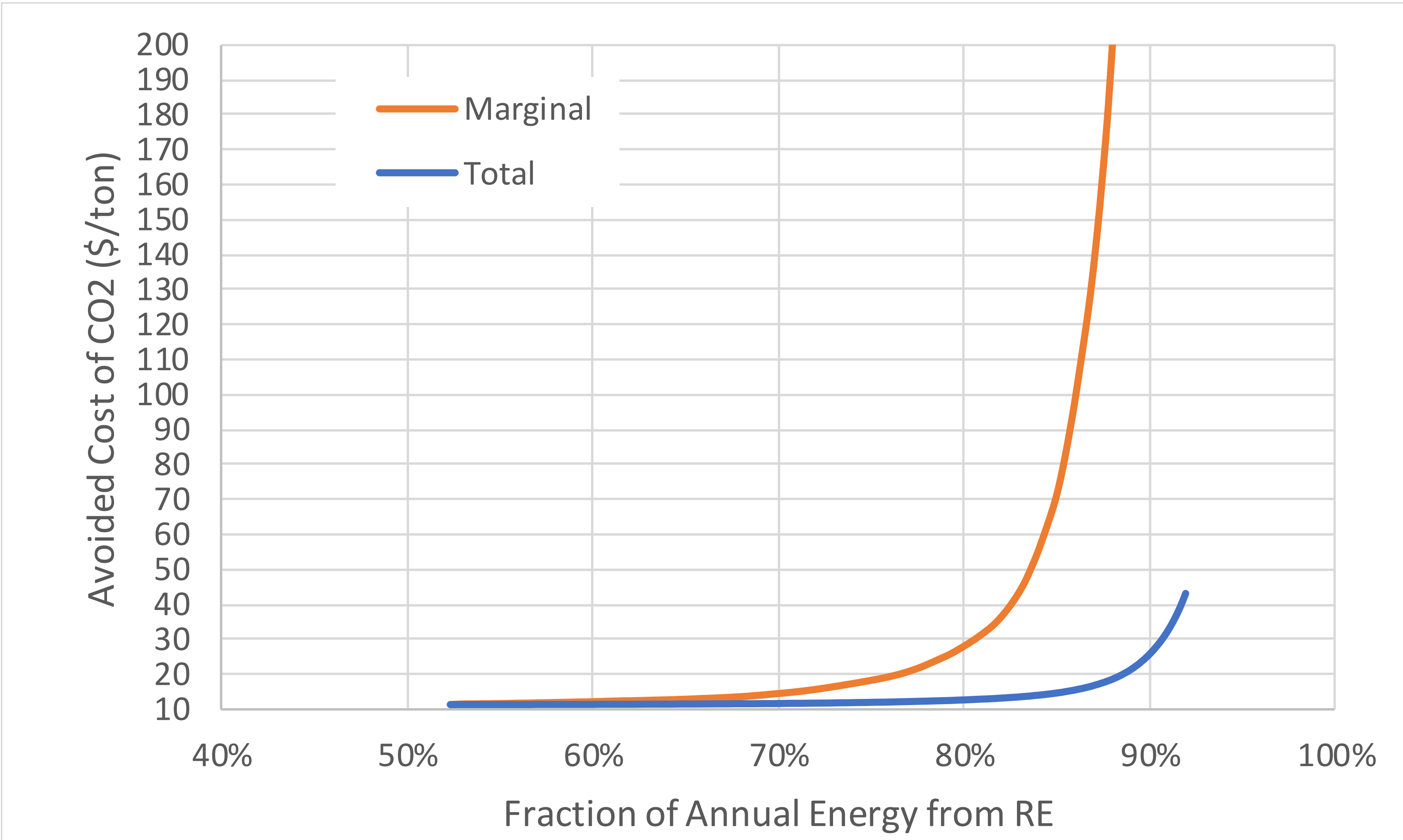
Topic #1:Economics of Supply/Demand Mismatch



If we cannot sell overgeneration to surrounding utilities, find better ways of using RE, or build more storage, here is a rough estimate of what LADWP would have to pay for PV as it moves towards 100% RE.

Topic #1:Economics of Supply/Demand Mismatch

LA DWP

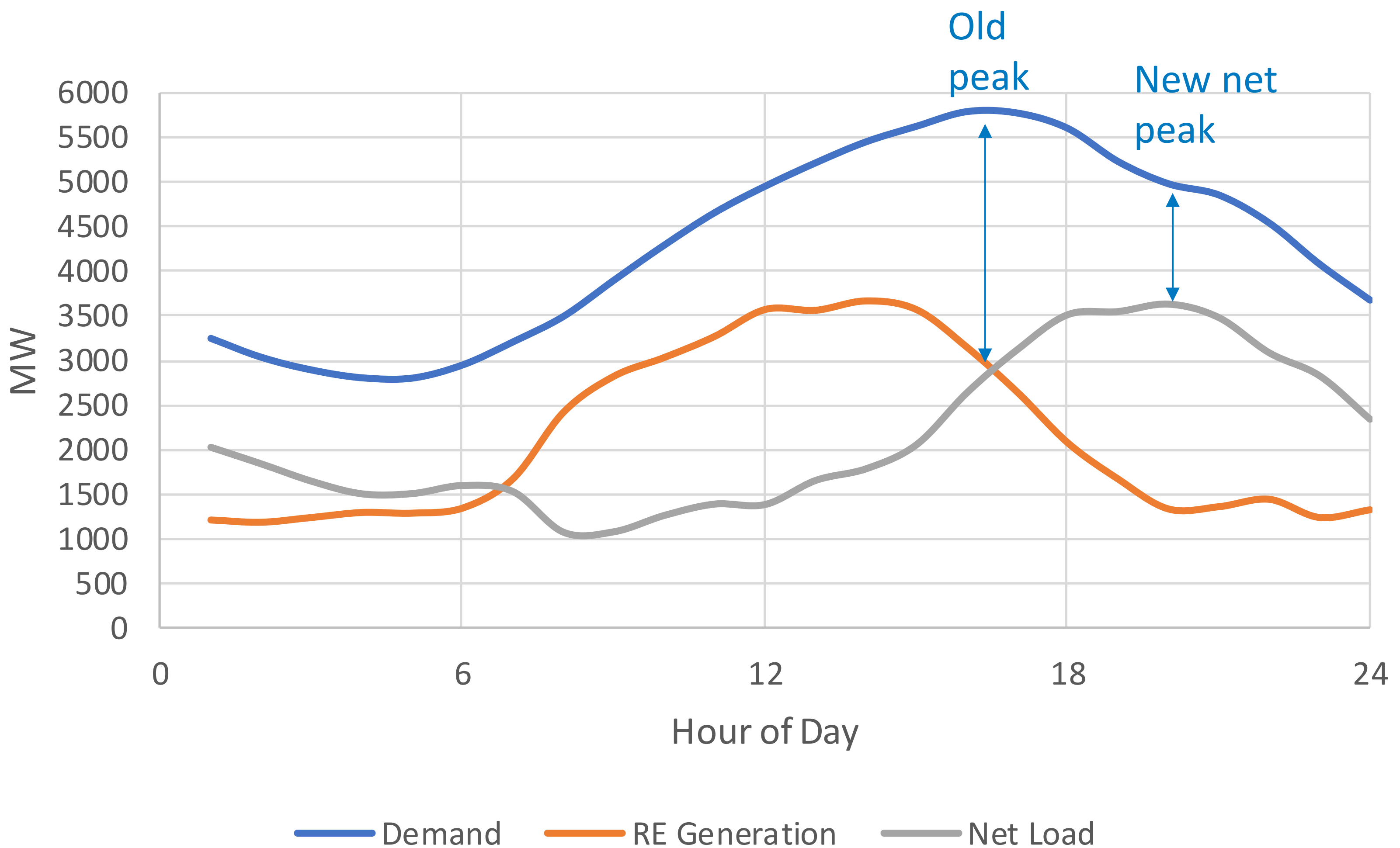


Here is a rough estimate of the avoided cost of CO_2 in our base scenario. This assumes that RE avoids $4/MMBTU gas at a 7,500 BTU/kWh average heat rate.

Before we start talking about solutions….

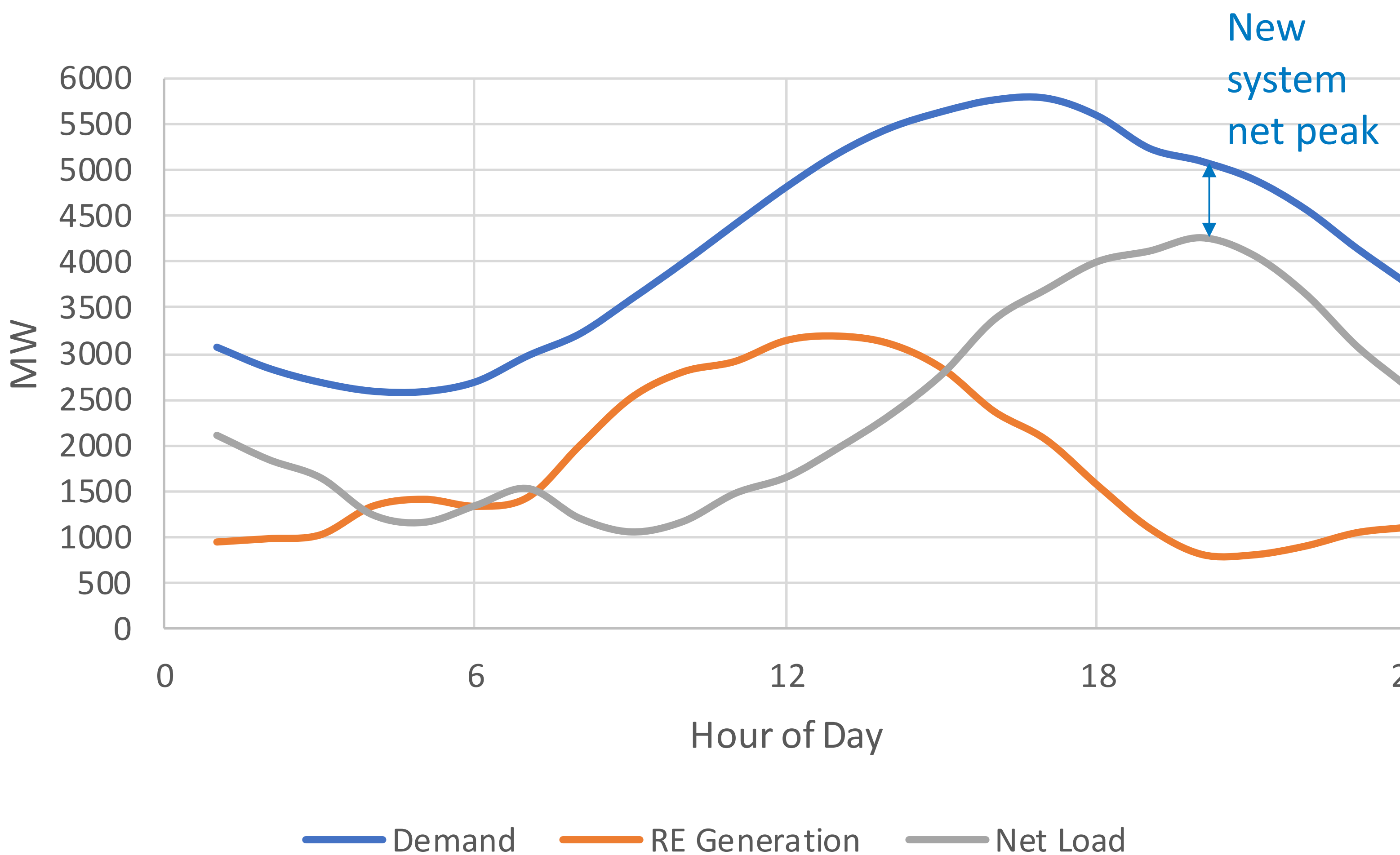
We need to talk about resource adequacy. Because topic two is closely related to topic one. So bear with us and we will get to the fun stuff…..

Topic #2: Resource Adequacy



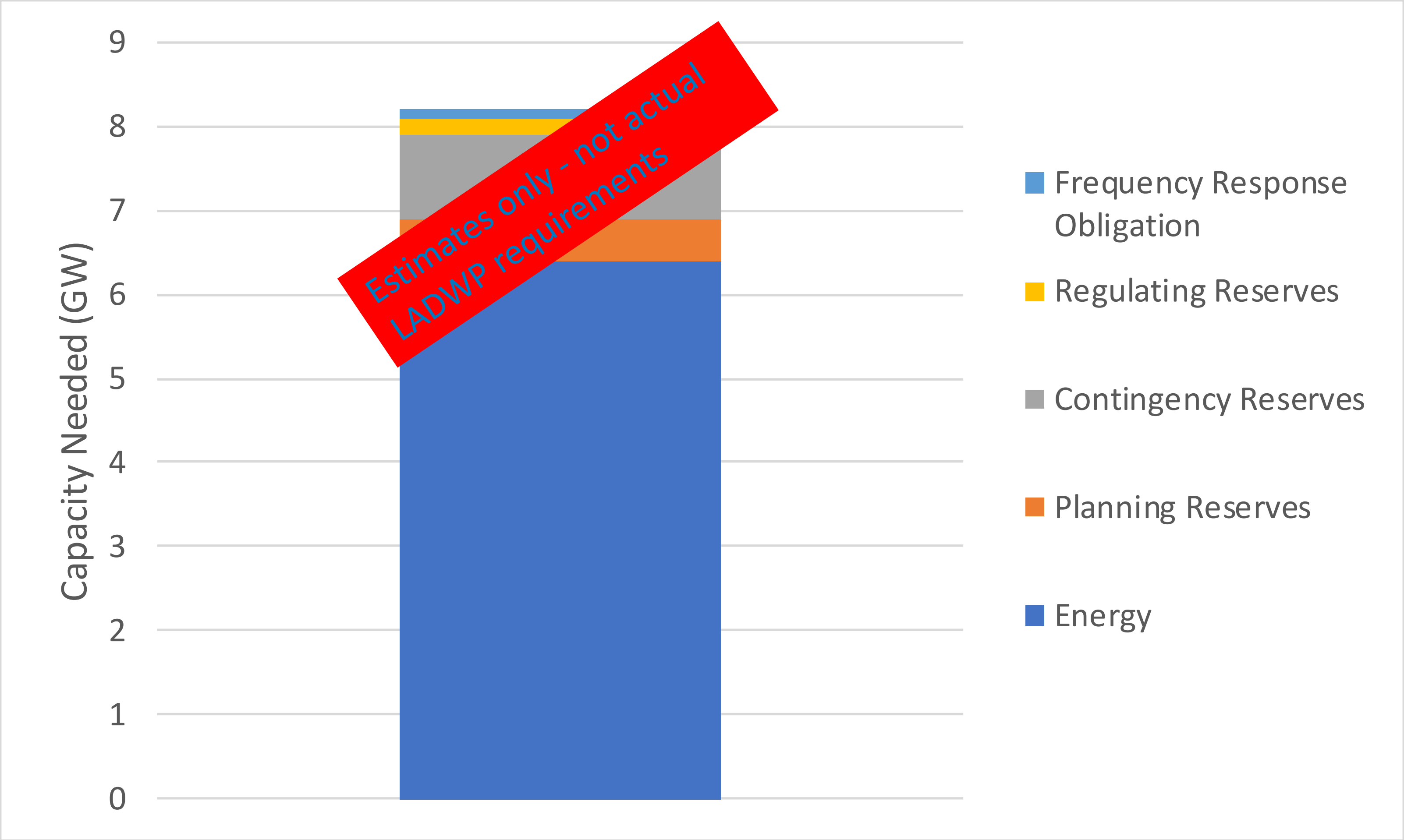
Here is LADWPs peak demand on August 29th in a 65% RE scenario. During the hour of peak demand, we got a decent amount of sun and wind. But the PV shifts the peak demand to later in the day after the sun has set and we still need about 3500 MW of something else.

Topic #2: Resource Adequacy



Unfortunately, there are other hot days with even less RE supply. Here is September 14th. We have less wind, slightly earlier sunset, and a slightly later peak. Our 5,000 MW of wind and solar capacity is producing less than 500 MW and our net peak demand is over 4,000 MW. Even with Castaic, we need about 3,000 MW of additional capacity.

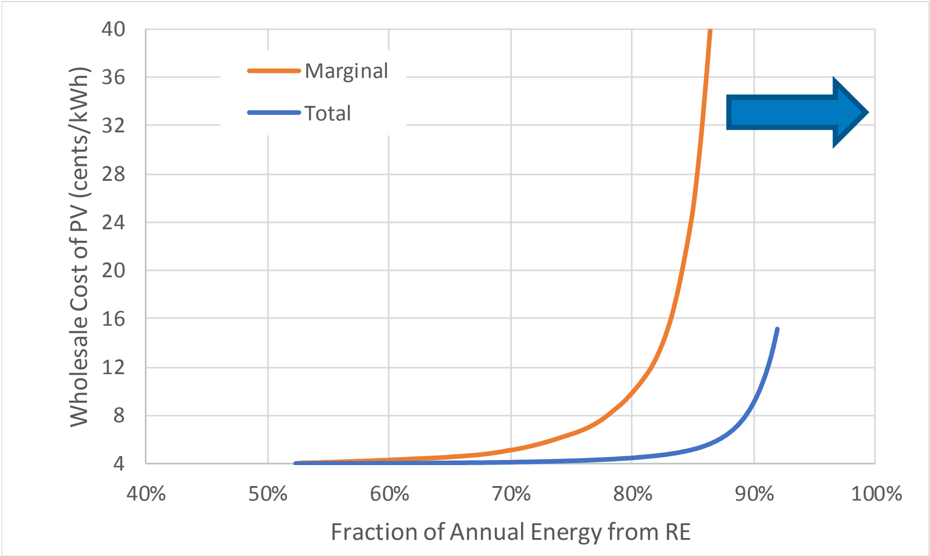
Topic #2: Resource Adequacy



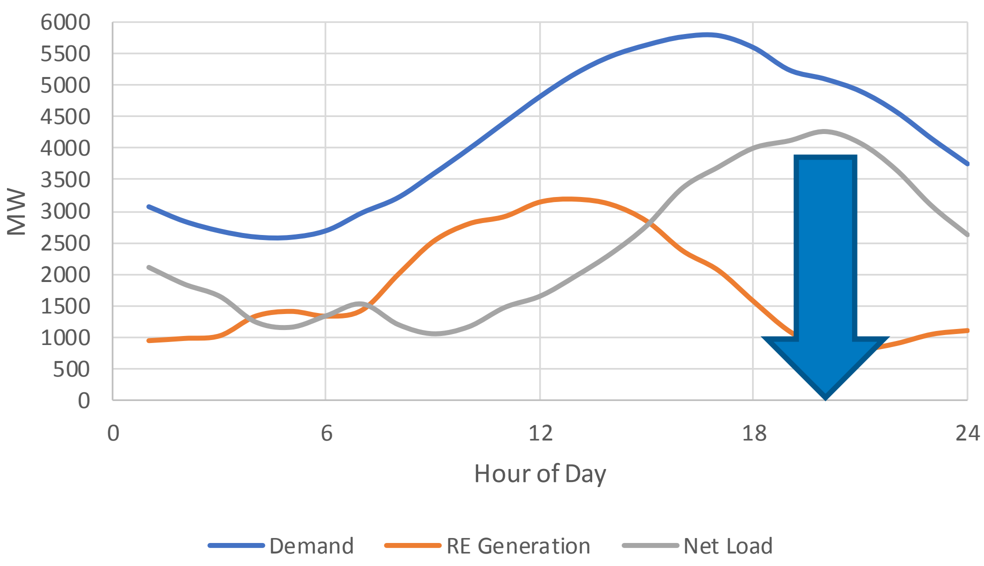
And LADWP also needs to plan around outages of their transmission network and generation resources. This means even more “firm” capacity is needed during the hours of peak demand. This capacity is unlikely to be provided from wind and solar, because as we have shown, there is relatively little solar and wind available during the hours of peak demand.

Finding Solutions

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…



And find a mix of resources that will meet the demand for reliable energy during all hour of the year.



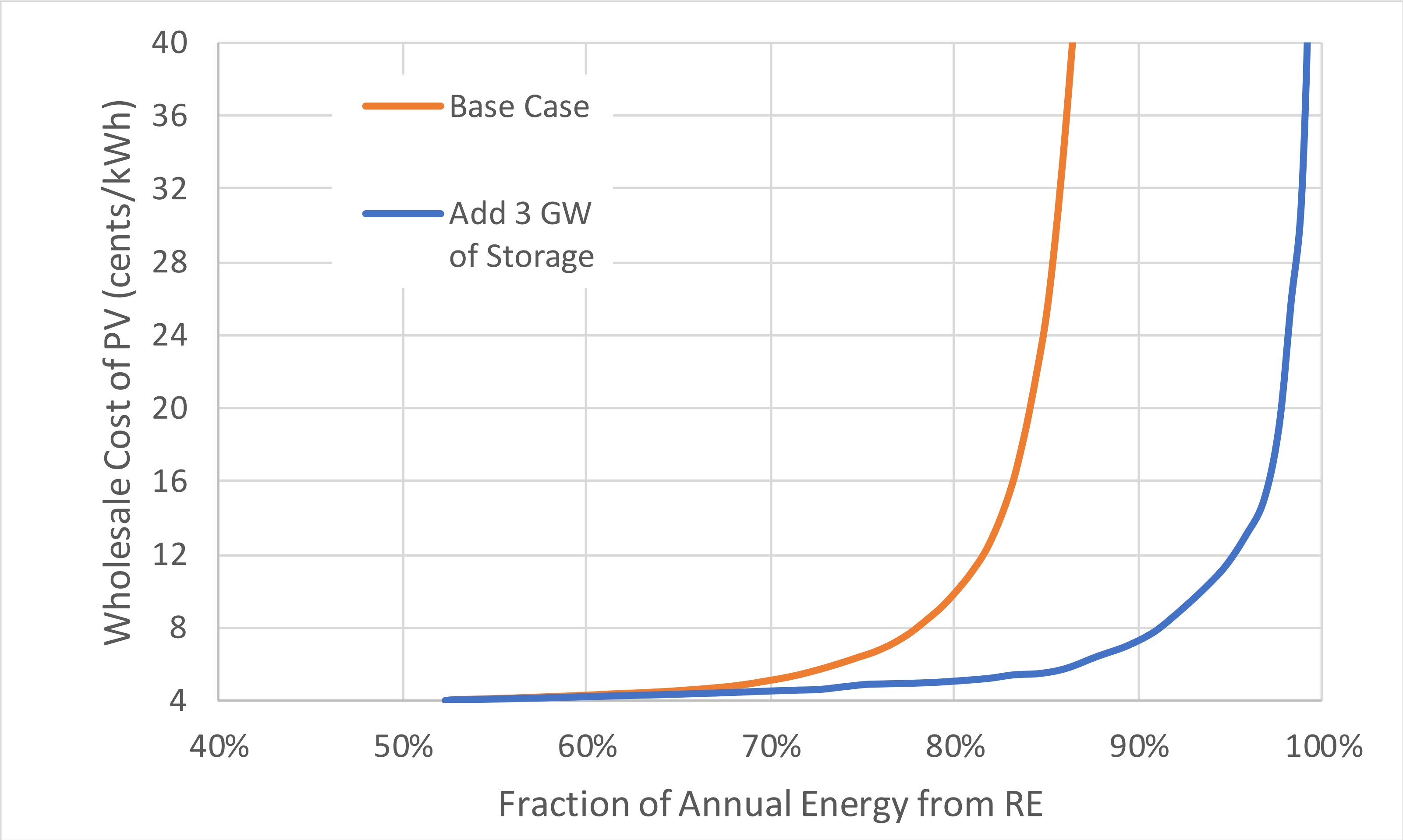

We pioneer
Engineering solutions

Possible Solutions

- Dispatchable renewables
- Spatially diverse wind and solar resources
- Demand response/load shifting
- Energy storage
- Net energy exchanges
- Controlled Electric Vehicle (EV) charging

Example: Storage and Load Shifting

LA DWP



Here is an very simple example where adding 3 GW of battery storage gets us along way. But it doesn't get us all the way, and adding more batteries has very rapidly diminishing returns due to the seasonal mismatch problem.

Managing the Seasons

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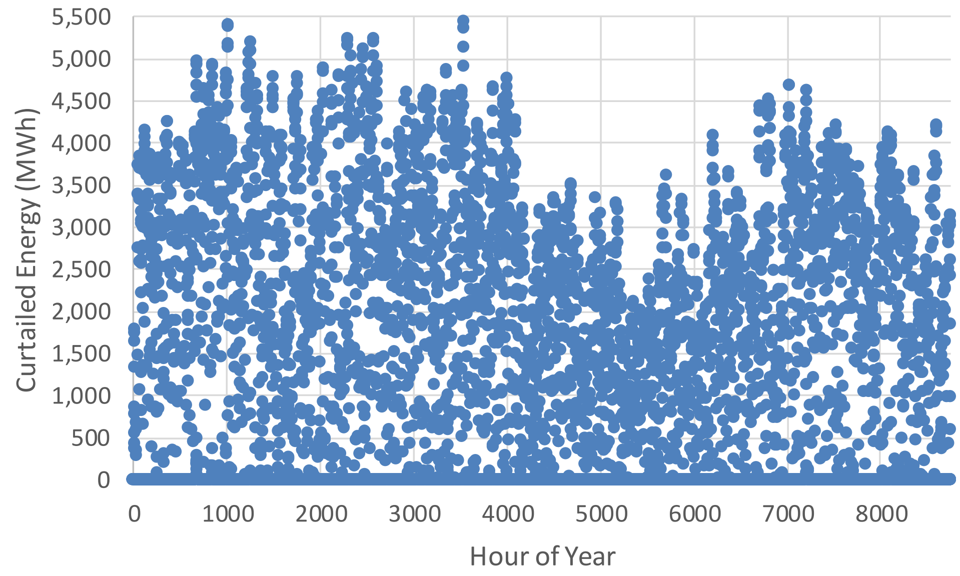
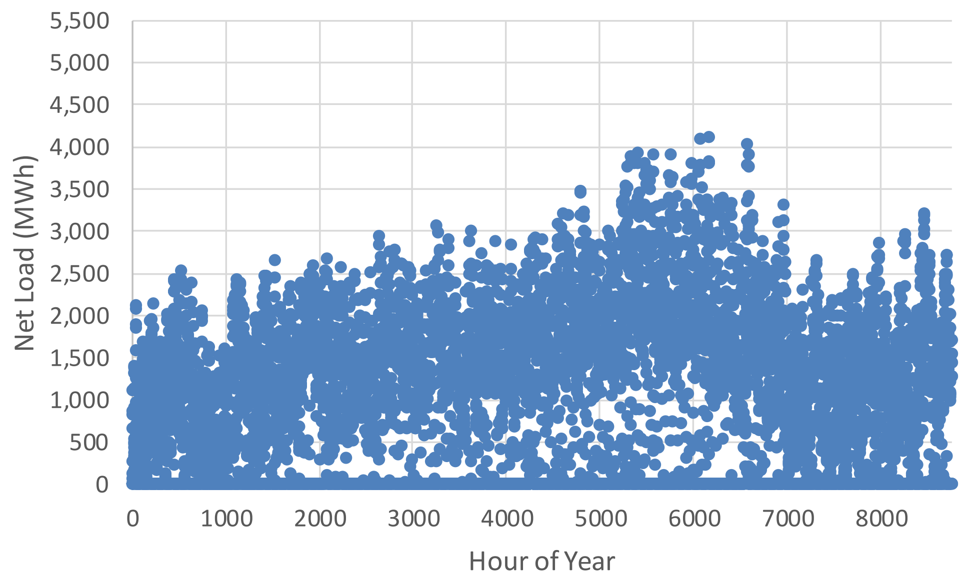
Here is the curtailed energy in a system where we have built enough RE capacity to meet 100% of annual demand. We haven't added any storage or included Castaic.



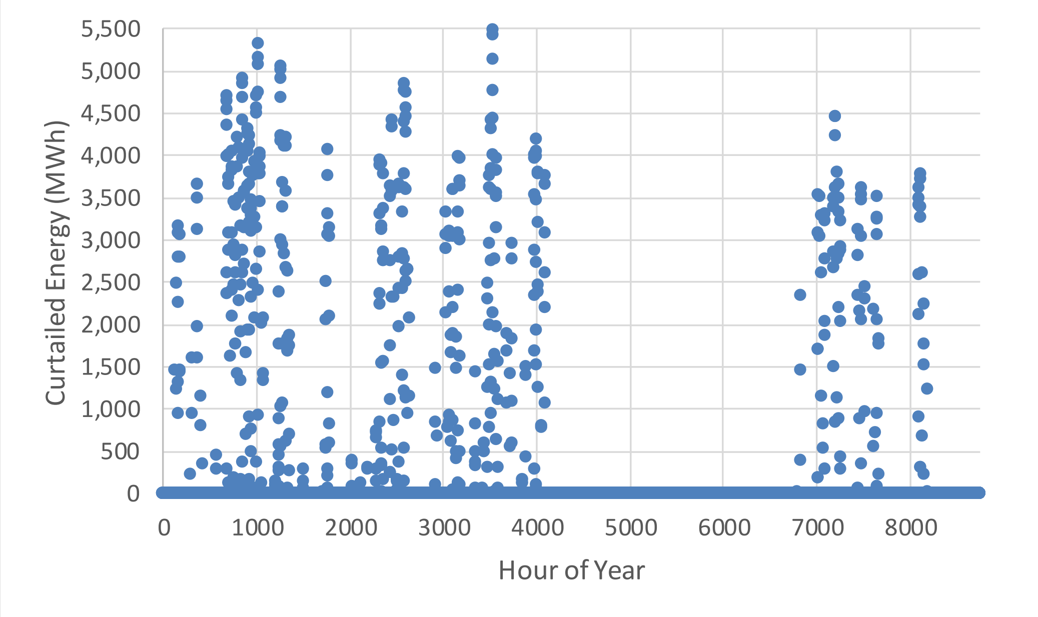
Here is the net load (the amount of demand left over that would need to be met with storage or something else).



Now lets see what happens when we ad Castaic and another 3 GW of batteries….

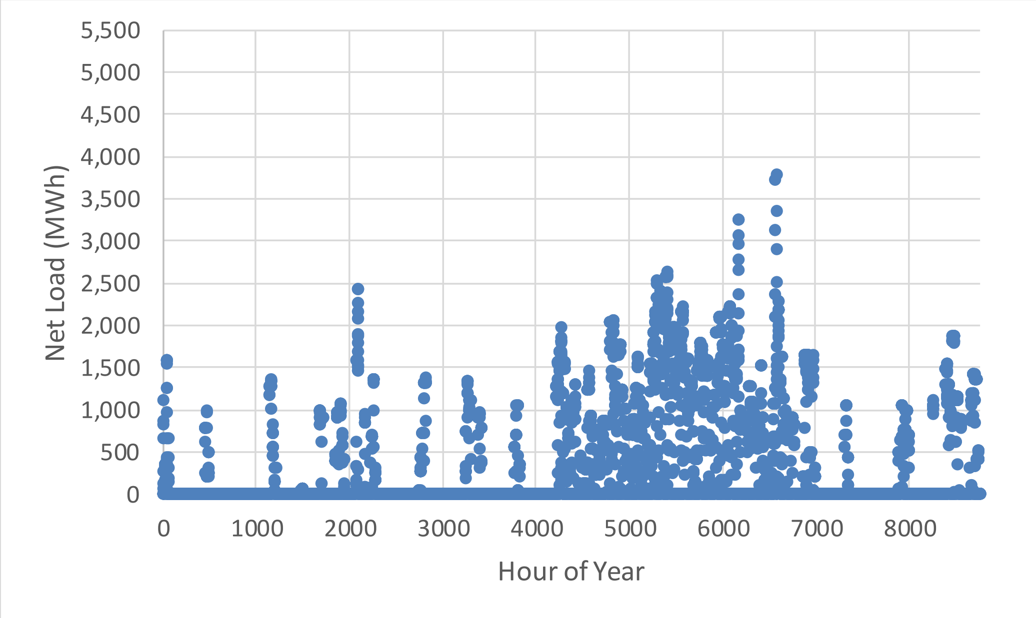
Managing the Seasons

We have completely absorbed all the curtailed energy in the summer. We still have some left in the spring.

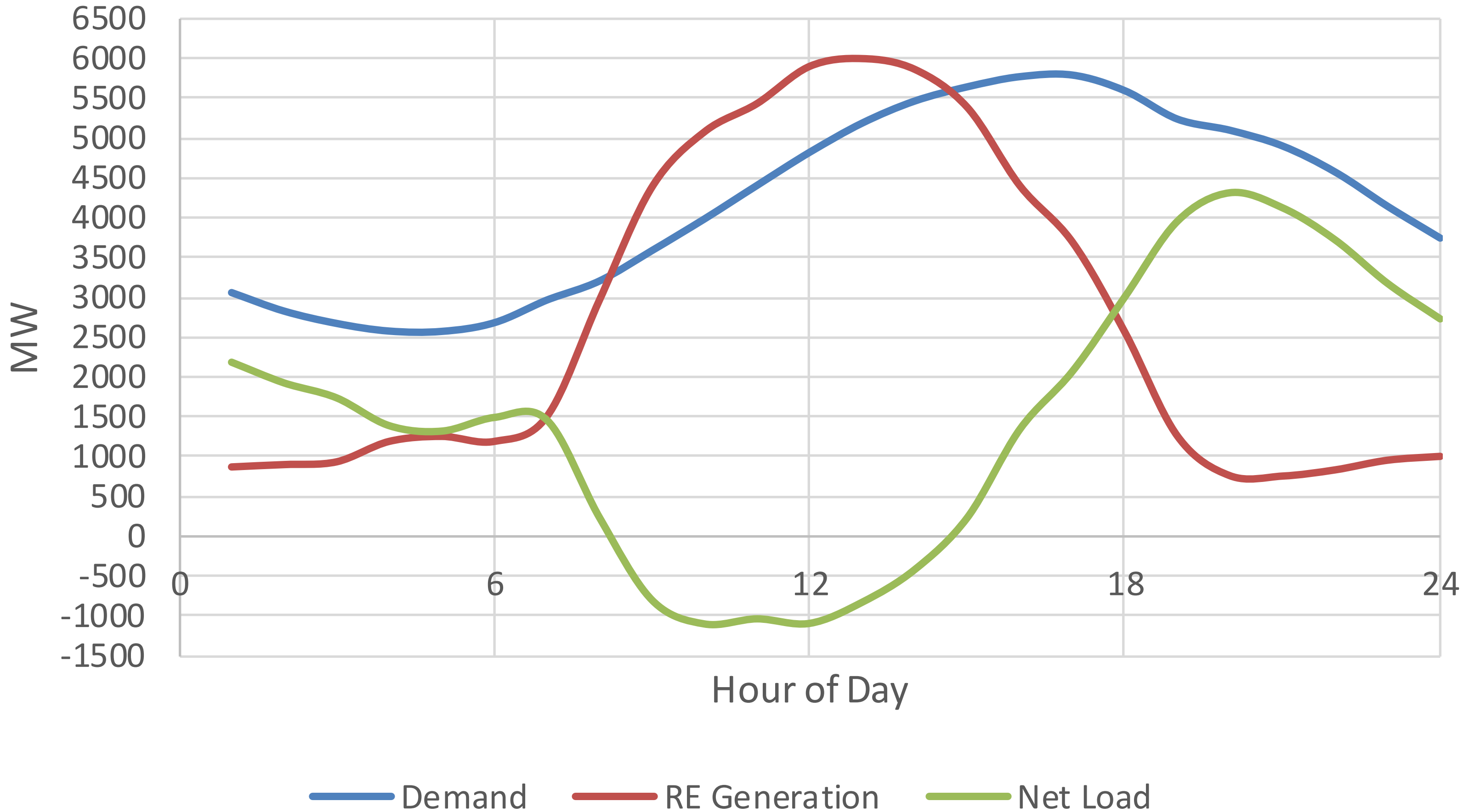


And we still have significant demand left in the summer.

So more short duration storage won't help. Let's look at a peak day to look at this another way.

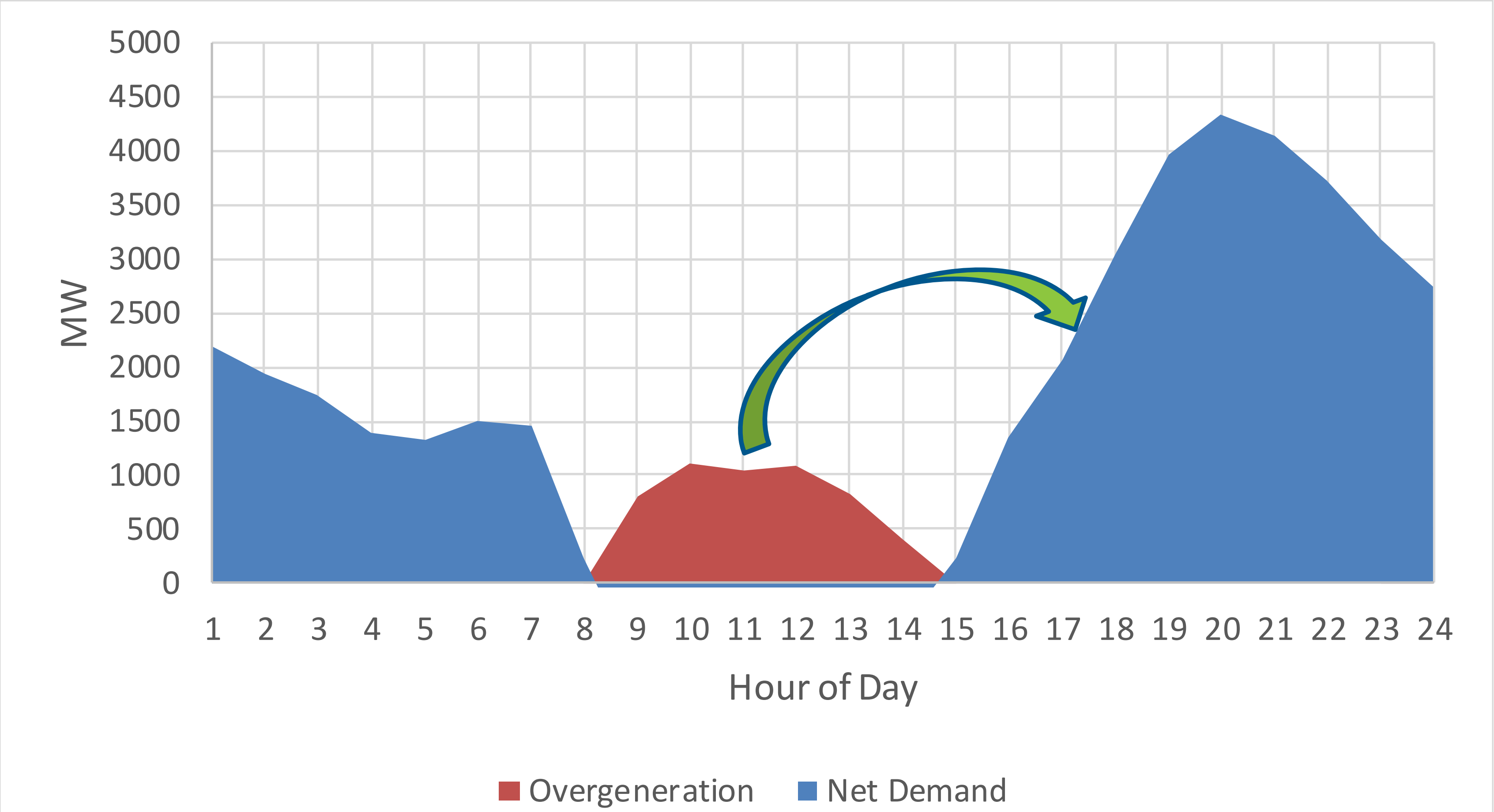


Managing the Seasons



Here is a very high demand day in a case where we have built enough RE to meet 100% of demand. Our net load peaks at about 4,300 MW. So our storage case (Castaic plus 3 GW of batteries) could provide us almost enough capacity to meet the energy requirements. This ignores reserve requirements, so we do NOT have a reliable system.

Managing the Seasons



But even with storage, there just isn't enough RE to shift. This means that load shifting doesn't solve the problem either. We simply have too much demand overall on this day. We could build more solar, but we don't need more energy during most of the year, so it would just be wasted during fall through spring.

Possible Solutions

- Energy efficiency (targeted towards summer loads)
- Power to gas, hydrogen or other fuel production
- Bioenergy
- Net energy exchanges

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.

Discussion

Thank you!

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Los Angeles Department of Water & Power

NREL NATIONAL RENEWABLE ENERGY LABORATORY

LA100: Draft Scenarios
May 15, 2018

Revisiting the Motions: **March 2nd, 2016**

“The city has an opportunity to re-create its utility in a way that recognizes the **potential for a fossil-free future**, demonstrates **global leadership** in its commitment to clean energy, and **protects ratepayers** from the increasing costs of carbon-based fuels.”

“[T]he Council request that Los Angeles Department of Water and Power report with a program to develop and implement a research partnership…**with the objective of determining what investments should be made to achieve a 100% renewable energy** portfolio for the LADWP.”

Revisiting the Motions: September 16th, 2016

"[T]he Council request that the LADWP….**examine**, over the course of the research into a 100% renewable portfolio, **the potential for high quality careers and equitable local economic development**, including local hiring programs for work that must be performed to modernize the electric system infrastructure.."

Revisiting the Motions: **August 1st, 2017**

"…incorporate into its research efforts the following:

a. An analysis by the Rate Payer Advocate on how each scenario fits within the **current rate structure** to **include the impact, if any, each scenario would have on low income customers**.

b. Incorporation of the **CalEnviro Screen into each research area**, and as the context for any analysis, study, and/or recommendation.

c. The prioritization of **environmental justice neighborhoods** as the **first immediate beneficiaries of localized air quality improvements and greenhouse gas reduction**."

Goals of Scenarios

Address full suite of questions and issues raised in the City Council Motions

- **Broad objective**: determine what investments should be made to achieve a 100% renewable energy
- Examine the impacts on **local jobs and economic development**
- Understand the **electricity rate, air quality, and health impacts of achieving a 100% renewable system; identify environmental justice neighborhoods to be first beneficiaries of improvements**

Consider the full suite of options for achieving 100%

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Demand-side:

- Demand response, end-use efficiency, and electrification

Supply-side:

- Renewable generation (utility scale and distributed), existing nuclear, fossil with carbon capture and storage, existing hydro

Financial mechanisms:

- Renewable energy credits (RECs), greenhouse gas allowances

Robust

- To current trends, plans, policies, and regulations…
- To a broad set of future conditions/uncertainties
    - Evolution of load—efficiency, flexibility (DR), and electrification
    - Balance between centralized and distributed supply
    - Ability to develop additional transmission & distribution

Incorporates AG Feedback on Preliminary Scenarios

		Reference Cases		LA Leads			
	Candidate Technologies	2018 IRP	Draft SB 100	100% Carbon Neutral	100% Renewable	100% Carbon Neutral – Accelerated	Load Modernization
Scenarios	Natural Gas	•	•	•		•	
	Wind, Solar, Geothermal	•	•	•	•	•	•
	Existing Nuclear	•	•	•		•	
	New Nuclear			•		•	
	Bioenergy	•	•	•		•	
	Carbon Capture and Sequestration			•		•	
	Existing Hydro	•	•	•	•	•	•
	New Hydro		•	•		•	
	CO2 Allowances	•	•	•		•	
	RECs	•	•	•		•	
	Storage	•	•	•	•	•	•
Sensitivities	Electric Vehicles	Expected	Expected	Expected	Expected	Expected	HIGH
	Energy Efficiency	Expected	Expected	Expected	Expected	HIGH	HIGH
	Demand Response	Expected	Expected	Expected	Expected	HIGH	HIGH
	Transmission Feasibility	Expected	Expected	Expected	Expected	NEW PATHS	NEW PATHS
	Decentralization	Expected	Expected	Expected	Expected	Expected	HIGH
	Technology Cost	Expected	Expected	Expected	Expected	Low	Low
	Timeframe	2020-2050*	2020-2050*	2020-2050*	2020-2050*	2020–2045*	2020–2050*

Draft scenarios presented at the February 15th, 2018 Advisory Group Meeting

Summary of AG Feedback

- Accelerated compliance
- Financial vs physical compliance
- Carbon neutral, combustion free, or 100% renewable
- Detailed reporting of assumptions and exogenous inputs
- Current policies, plans, and initiatives reflected in load forecasts
- Interim targets—when do we reach 70, 80, 90%?
- Equity implications
- Environmental impacts beyond CO_2
- Regionalization/further participation with the Western EIM and CAISO

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LADWP

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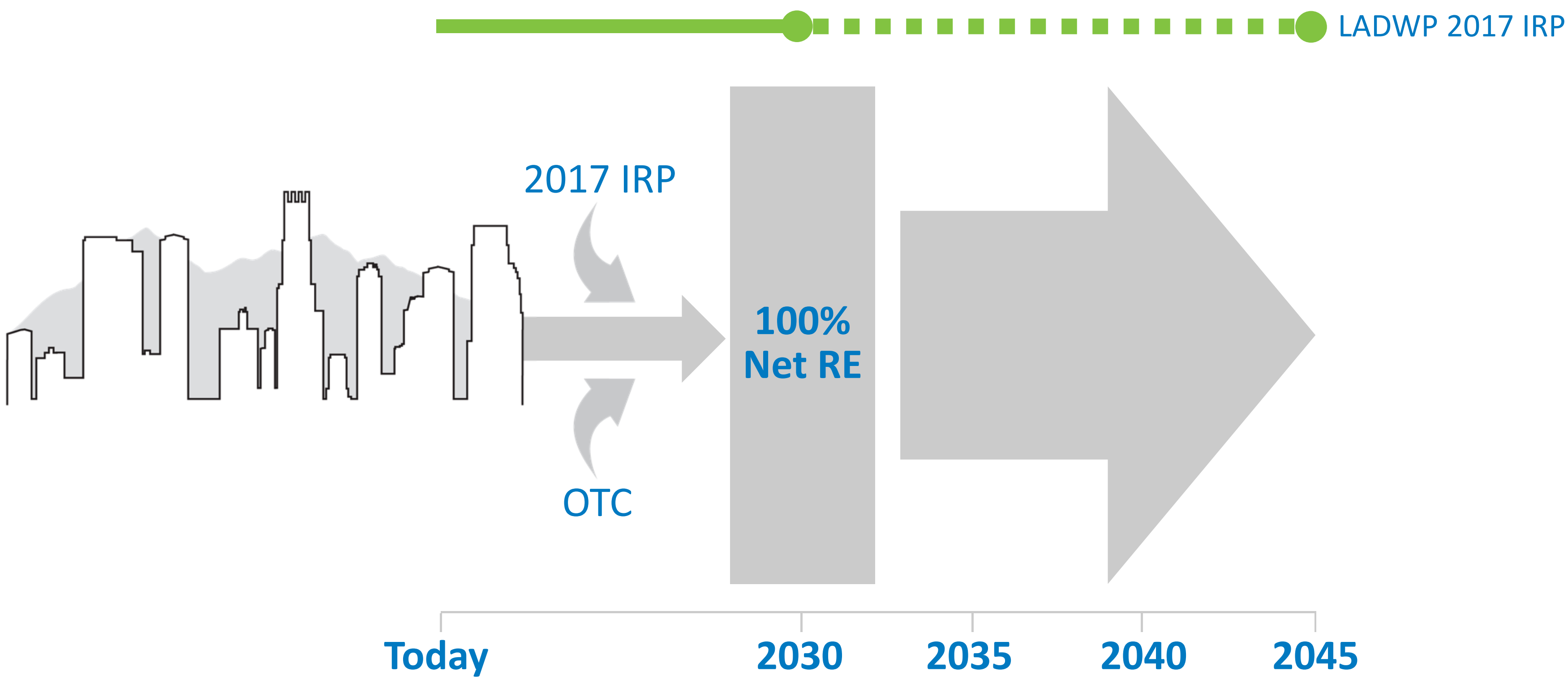
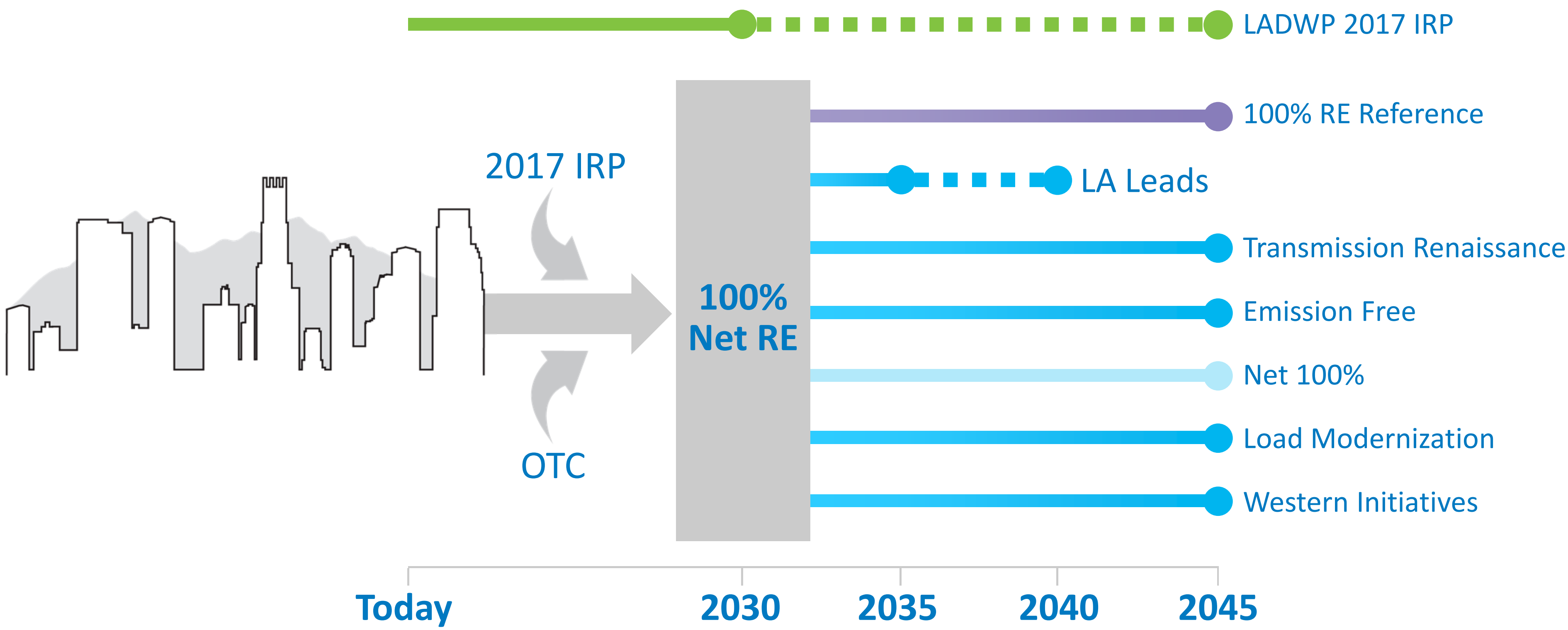
Scenario Framework



Scenario Framework



Revised Scenarios—Comment Mapping

	Scenarios								
Comment	**LADWP 2017 IRP *Recommended Case***	**100% Renewable Reference Case**	**LA-Leads**	**Transmission Renaissance**	**Limited Transmission**	**Emissions Free**	**Net 100%**	**Load Modernization**	**Western Initiatives**
Accelerated Compliance			√						
Interim Targets	√	√	√	√	√	√	√	√	√
Financial vs Physical Compliance		√					√		
Current Policies, Plans, and Intiatives	√	√	√	√	√	√	√	√	√
Detailed Reporting	√	√	√	√	√	√	√	√	√
Current Policies, Plans, and Intiatives	√	√	√	√	√	√	√	√	√
Equity Implications	√	√	√	√	√	√	√	√	√
Environmental Impacts Beyond CO2	√	√	√	√	√	√	√	√	√
Regionalization, EIM, CAISO									√

*All scenarios achieve net 100% renewable by 2030

Scenario Matrix

LA DWP

		LADWP 2017 IRP *Recommended Case*	100% RE Reference	LA-Leads	Transmission Renaissance	Limited Transmission	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

*All scenarios achieve net 100% renewable by 2030

Scenario Matrix

		LADWP 2017 IRP *Recommended Case*	100% RE Reference	LA-Leads	Transmission Renaissance	Limited Transmission	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

*All scenarios achieve net 100% renewable by 2030

Scenario Matrix

		LADWP 2017 IRP *Recommended Case*	100% RE Reference	LA-Leads	Transmission Renaissance	Limited Transmission	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

*All scenarios achieve net 100% renewable by 2030

Scenario Matrix

		LADWP 2017 IRP *Recommended Case*	100% RE Reference	LA-Leads	Transmission Renaissance	Limited Transmission	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

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Scenario Matrix

		LADWP 2017 IRP *Recommended Case*	100% RE Reference	LA-Leads	Transmission Renaissance	Limited Transmission	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

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Scenario Matrix

		LADWP 2017 IRP *Recommended Case*	100% RE Reference	LA-Leads	Transmission Renaissance	Limited Transmission	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**		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 IRP Technology Mix	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

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Scenario Matrix

		LADWP 2017 IRP Recommended Case	100% RE Reference	LA-Leads	Transmission Renaissance	Limited Transmission	**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

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Scenario Matrix

		LADWP 2017 IRP *Recommended Case*	100% RE Reference	LA-Leads	Transmission Renaissance	Limited Transmission	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

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Scenario Matrix

		LADWP 2017 IRP *Recommended Case*	100% RE Reference	LA-Leads	Transmission Renaissance	Limited Transmission	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

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Scenario Matrix

		LADWP 2017 IRP *Recommended Case*	100% RE Reference	LA-Leads	Transmission Renaissance	Limited Transmission	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

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Scenario Matrix

		LADWP 2017 IRP *Recommended Case*	100% RE Reference	LA-Leads	Transmission Renaissance	Limited Transmission	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

*All scenarios achieve net 100% renewable by 2030

Revised Scenarios—Comment Mapping

	Scenarios								
Comment	**LADWP 2017 IRP *Recommended Case***	**100% Renewable Reference Case**	**LA-Leads**	**Transmission Renaissance**	**Limited Transmission**	**Emissions Free**	**Net 100%**	**Load Modernization**	**Western Initiatives**
Accelerated Compliance			√						
Interim Targets	√	√	√	√	√	√	√	√	√
Financial vs Physical Compliance		√					√		
Current Policies, Plans, and Intiatives	√	√	√	√	√	√	√	√	√
Detailed Reporting	√	√	√	√	√	√	√	√	√
Current Policies, Plans, and Intiatives	√	√	√	√	√	√	√	√	√
Equity Implications	√	√	√	√	√	√	√	√	√
Environmental Impacts Beyond CO2	√	√	√	√	√	√	√	√	√
Regionalization, EIM, CAISO									√

*All scenarios achieve net 100% renewable by 2030

Scenario Descriptions

Scenario Name	Scenario Abbreviation	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	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	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	New-Trans	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.
Limited Transmission	No-Trans	2045	Identical to the 100-RE case, but only planned transmission upgrades (from the LADWP IRP) are allowed; adoption of distributed generation is substantially higher than the 100-RE case 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	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	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	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	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

Summary

- Revised scenarios address the spectrum of comments and perspectives from the Advisory Group.
- There are a broad set of pathways that could be pursued to achieve 100% renewable power system.
- All pathways will impact the investment and operational costs, emissions, air quality, jobs and economic development, and electricity rates in different ways.
- The revised suite of scenarios explore a broad set of pathways to 100% that will enable NREL, LADWP, and the AG to understand the tradeoffs between costs and the environmental, economic, equity outcomes.

Thank you!

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NATIONAL RENEWABLE ENERGY LABORATORY

Discussion

Advisory Group Schedule

LA DWP

■ COMPLETED MEETINGS/TASKS
■ PLANNED MEETINGS/TASKS

QUARTER	Phase 1 | 2017 LAUNCH AND ORGANIZATION		Phase 2 | 2018 SCENARIOS		Phase 3 | 2019 ANALYSIS AND MODELING	Phase 4 | 2020 FINAL REPORT
Q1			• Advisory Group Meeting Plan • Preliminary Scenarios and Sensitivities • Field Trip Itinerary • Power Strategic Long-Term Power Resources Plan • Once-Through Cooling Study Update	FEBRUARY 15	• Capacity Value • Electricity Operations Modeling II • Jobs & Economic Analysis II	• White Papers on Electricity Modeling Results • Final Results 1) Jobs & Economic Analysis and 2) Environmental Analysis • Final Visualization of Electricity Operations
Q2	• Advisory Group Launch • City Council Motion: 100% Renewable Energy Study	JUNE 23	FIELD TRIP April 26 • Draft 100% Papers: Framing, Data, Methods • Final Scenarios and Sensitivities • Once-Through Cooling Study Update	JUNE 7	• Planning Reserves • Operating Reserves • Load Modernization • Environmental Analysis II • Publication Plan	• Final Report • Final Presentation
Q3	• Advisory Group Charge and Operating Protocols • Introduction to NREL and 100% Renewable Energy Study	AUGUST 3	• Final 100% Papers • Electricity Operations Modeling I • Jobs & Economic Analysis I • Environmental Modeling I • Once-Through Cooling Study Update	AUGUST 16	• Final Scenarios and Sensitivities Results • Final Visualization of Scenarios • Initial Electricity Operations Modeling Results	
Q4	• Defining Clean Energy and Renewable Energy • Considerations for Study • Once-Through Cooling Study Overview • Public Outreach Overview	NOVEMBER 16	• Initial Scenario Results • Draft Visualizations of Scenarios • Once-Through Cooling Study Results	NOVEMBER 15	• Final Electricity Operations Modeling Results and Draft Visualizations • Draft results on Jobs and Economic Development • Draft results on Environmental Analysis	

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As of June 2018

Wrap up and next steps

- Next Advisory Group Meeting
  - August 16
- Meeting Summary Posted online:
  - July 9th
- Owens Valley Tour
  - Fri., Jun. 22 – Sat., Jun. 23
  - Fri., Sep. 21 – Sat., Sep. 22
  - Fri., Oct. 19 – Sat., Oct. 20
  - Fri., Nov. 2 – Sat., Nov. 3
  - RSVP: owensvalleytour@ladwp.com