LA100

The Los Angeles 100% Renewable Energy Study

Advisory Group Meeting #13

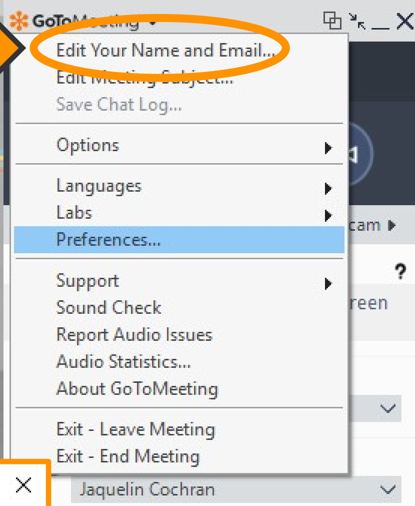
Virtual Meeting #4

Los Angeles Department of Water & Power

NREL Transforming ENERGY

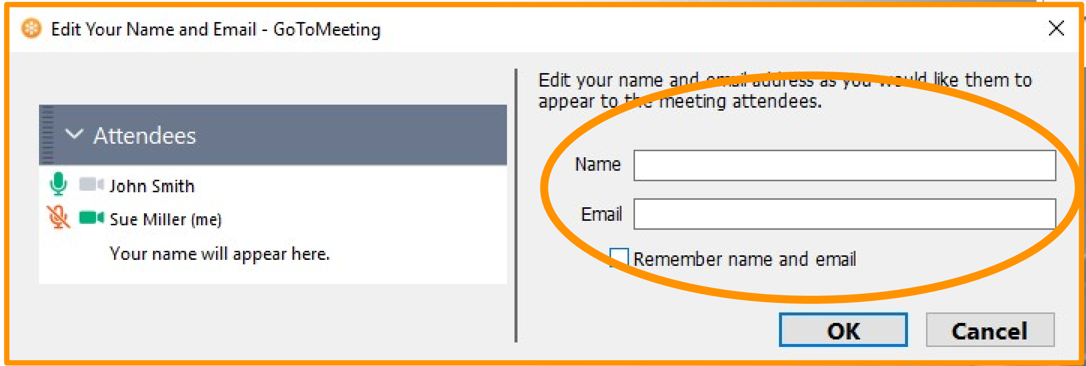
The Los Angeles 100% Renewable Energy Study

Welcome to the LA100 Advisory Group meeting!
Please consider adding your affiliation to your name identification.



Advisory Group Meeting #13

Virtual Meeting #4



Los Angeles Department of Water & Power

NREL Transforming ENERGY

Tips for Productive Discussions

Let one person speak at a time

Keep phone/computer on mute until ready to speak

Help ensure everyone gets equal time to give input

Type “Hand” in Chat Function to raise hand

Keep input concise so others have time to participate

Also make use of Chat function

Actively listen to others, seek to understand perspectives

Offer ideas to address questions and concerns raised by others

Hold questions until after presentations

Advisory Group #13 Agenda

October 1

- Community outreach and engagement – LA100 and more broadly (LADWP, NREL)
- Demonstration of Interactive Website (NREL)
- Discussion/Q&A

October 8

- 100% RE Investment Pathways, Part 1: Technology and Cost Sensitivity Analysis
- Discussion/Q&A

October 22

- Welcome
- Greenhouse Gas Emissions, Power & Non-Power Sectors
- Update to Air Quality Modeling Methods
- Discussion/Q&A

Today (October 29)

- 100% RE Investment Pathways, Part 2: Reliability
- Discussion/Q&A

Looking Ahead: Advisory Group Meeting #14

Final Results for LA100

- Distribution
- Jobs and Economic Impacts
- General Q&A

Distribution of completed chapters of the draft report (to be posted on the website)

Updates to website (bulk power layer to be added to data viewer; figure updates elsewhere on the site)

Looking Ahead: Advisory Group Meeting #15

Final Results for LA100

- Air quality
- Health
- Environmental justice
- Monetization of benefits

Distribution of remaining chapters of draft report

Remaining updates to the website

The Los Angeles 100% Renewable Energy Study

100% RE Investment Pathways, Part 2

Advisory Group Meeting #13, Virtual Meeting #4

Paul Denholm, Himanshu Jain & Bulk Power Team

National Renewable Energy Laboratory

October 29, 2020

Los Angeles Department of Water & Power | NREL Transforming ENERGY

Feedback

Feedback goal

- What questions of yours can we answer?
- How can we improve the communication of results?
- How can we make the study more relevant to the public?

Three Weeks Ago: Reviewed Sensitivity Analyses

- What happens when the 100% RE definition changes (e.g., basis on sales vs. generation, technology or REC eligibility)?
- How does the speed of the transition affect costs?
- What is the impact of different load levels (moderate vs high vs stress)?
- What happens if transmission is more or less available?
- What happens if RE technology costs change?

Context for today: Will we keep the lights on?

- One of our AG members during our website walk-through summed up the driving questions of our study as:
  - How quickly can we get there?
  - How much will it cost?
  - Will we keep the lights on?

- Today we are focusing on that last question—how well does the power system hold up to different type of events?

Today: What have we learned about maintaining reliability in a 100% RE system?

What changes in terms of:

- **Day-to-day operations**
  a. Balancing
  b. Ramping
  c. Operating reserves
- **Planning for extreme events and contingencies**
  a. Sufficiency of supply to meet demand all times of the year (resource adequacy)
  b. Sufficiency of supply under different weather years
  c. Extended outages
  d. Unexpected, rapid outages (contingencies)

Day-to-Day Operations

Balancing

Ramping

Operating Reserves

Changes in 100% Systems: Balancing

Traditional and Low RE Systems

Three types of operations:

- Baseload
- Intermediate
- Peaking

Resources like coal were supplemented by faster moving hydro or natural gas plants

As more RE is added, a diversity of wind/solar locations and RE forecasting grows more important

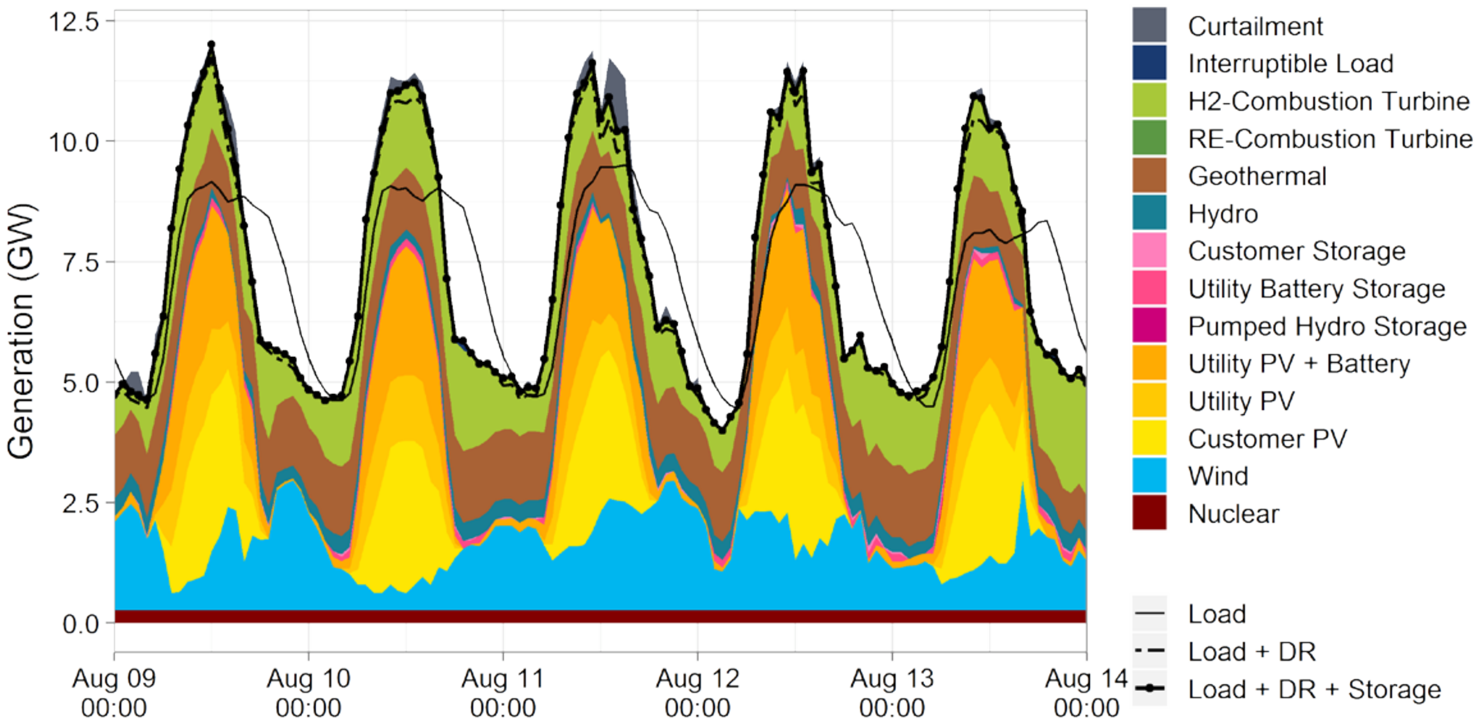
100% RE Systems

Weird net load shapes that system operators need to adjust to.

Very significant role of storage to balance supply and demand

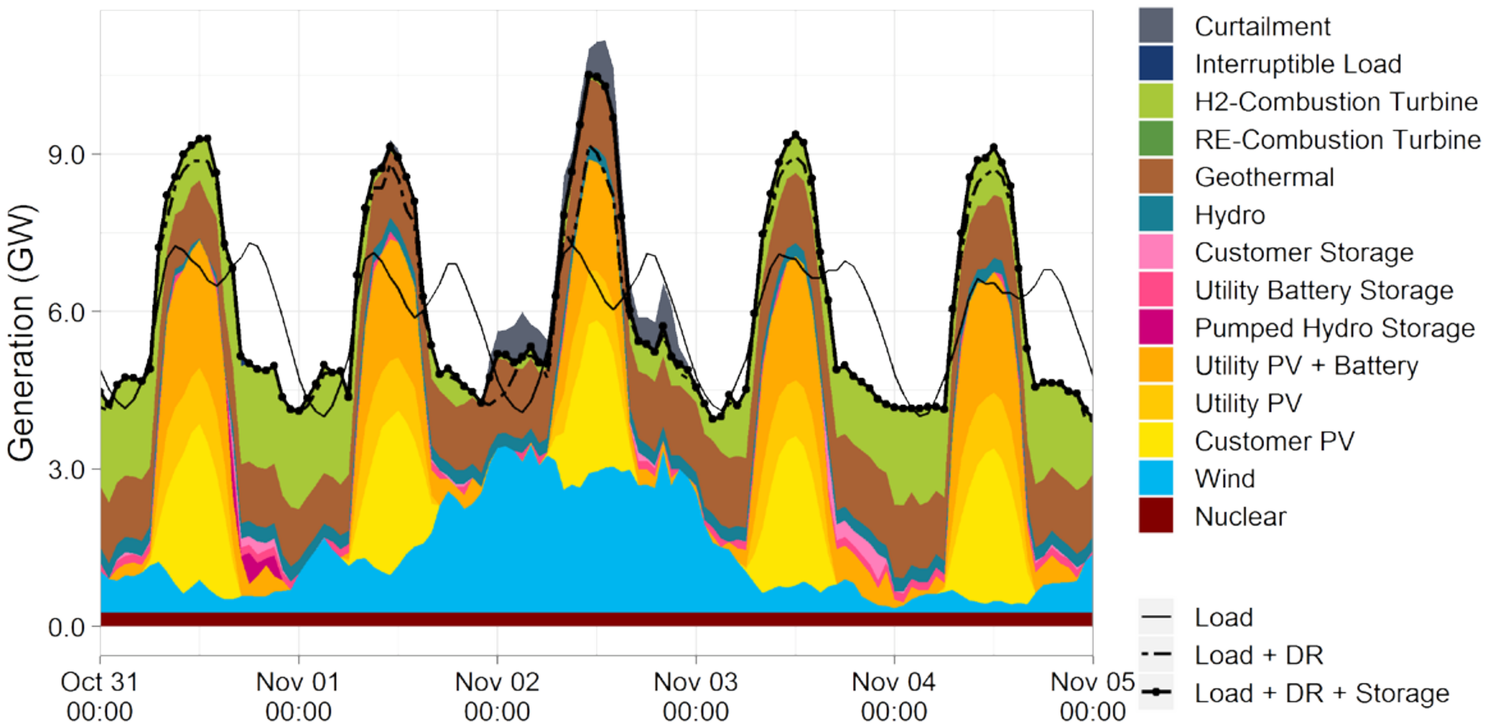
Careful scheduling of resources to ensure stored energy is available when needed.

Example—LA Leads (High Load) – Peak Demand Period



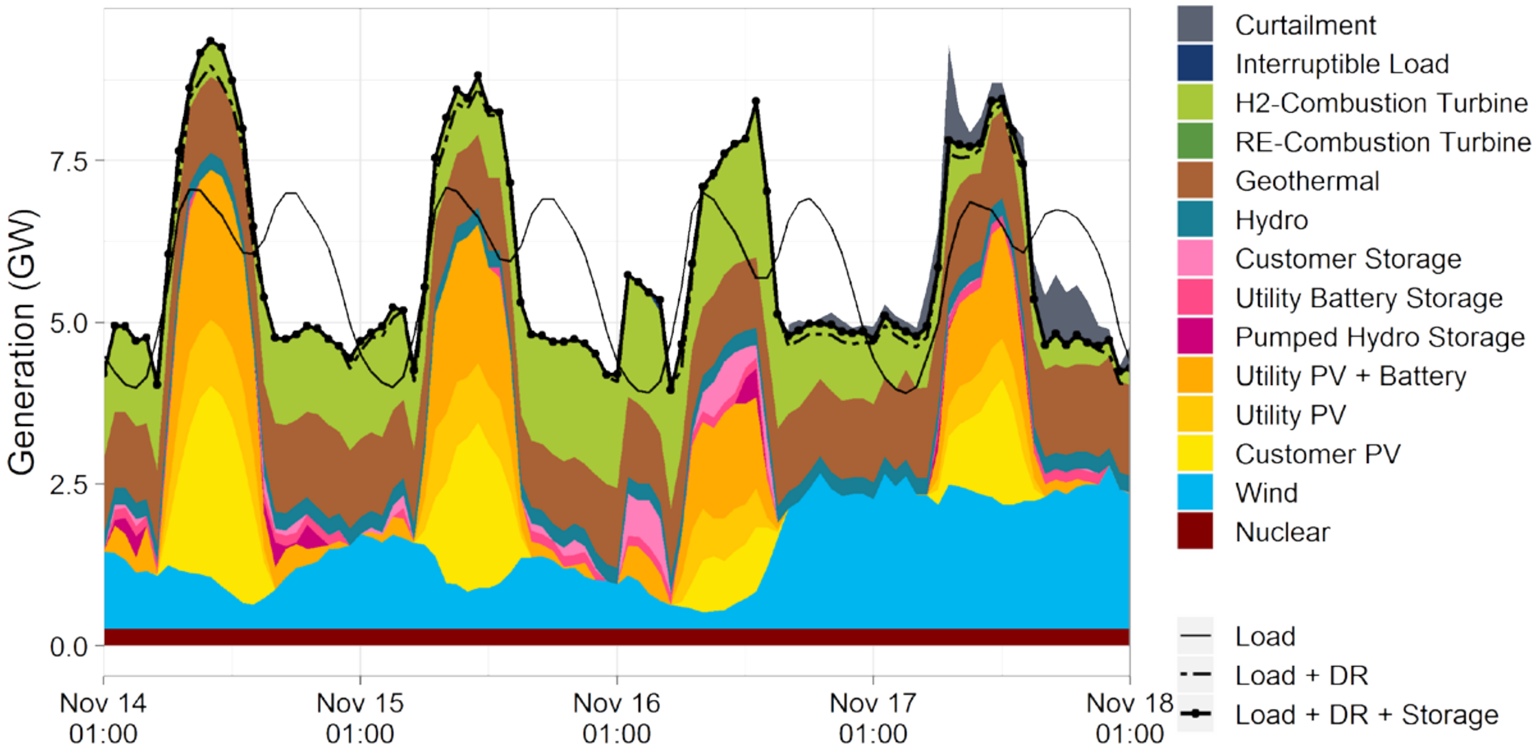
LA Leads – High Load scenario in 2045

Example—LA Leads (High Load) – Low Wind Period



LA Leads – High Load scenario in 2045

Example—LA Leads (High Load) – Low Wind & Solar Period



LA Leads – High Load scenario in 2045

Day-to-Day Operations

Balancing

Ramping

Operating Reserves

Changes in 100% Systems: Ramping

Traditional and Low RE Systems

Ramping (change in generator output) needed to follow changes in demand

As more RE added, a key concern has been capability of the rest of the system to ramp quickly enough to respond to RE

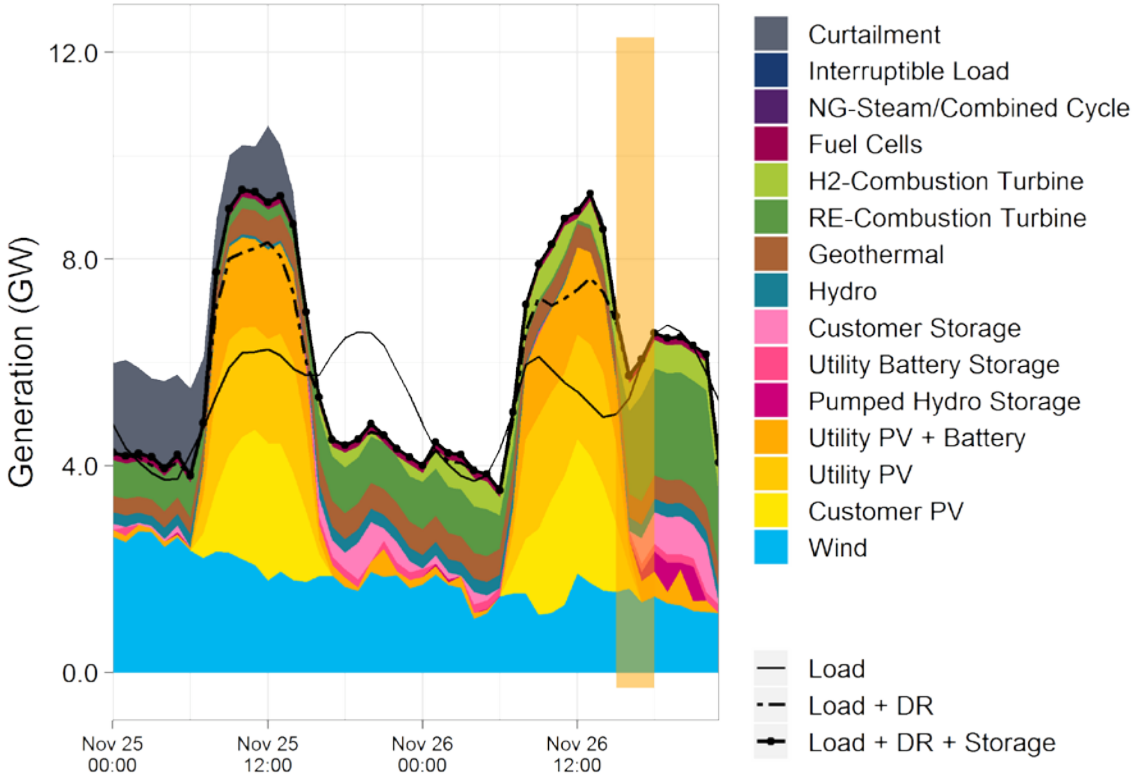
100% RE Systems

Supply ramps > demand ramps due to wind and solar variability

But ramping capability of power system increases too

- Down ramps (reducing supply) are easy (just turn down wind, solar)
- Up ramps are fast too and typically met by curtailed wind/solar (if exists) and storage, and if those are insufficient, by RE-CTs

Maximum Three-Hour Net Load Up Ramp: Ramping that Must be Met by Generation Not Wind or Solar



High Distributed Energy Future – High Load scenario in 2045

Day-to-Day Operations

Balancing

Ramping

Operating Reserves

Changes in 100% Systems: Operating Reserves

Traditional and Low RE Systems

Carry contingency reserves against large power plant and transmission line failures

Carry regulation reserves against small random variations in demand

Reserves derived from partially-loaded gas plants, pumped storage and hydro

100% RE Systems

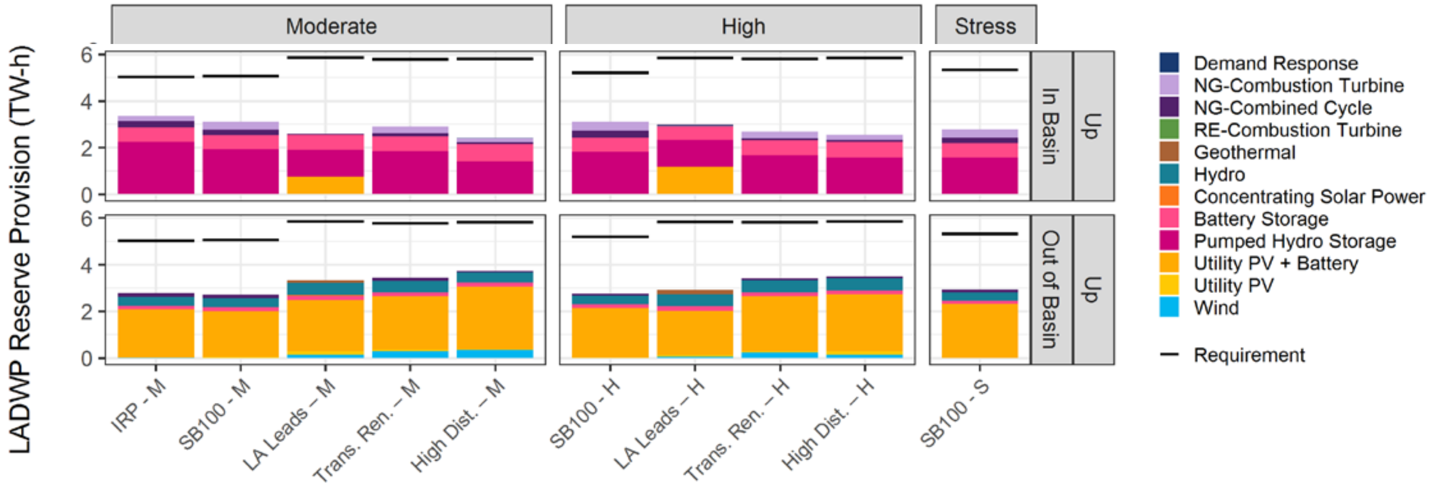
No change in LADWP system, where contingencies are driven by large transmission

Small increase in regulating reserves due to increased short-term variability of wind and solar

Additional flexibility reserves to address sub-hourly variability

Reserves derived increasingly from batteries and downward dispatched wind and solar

Annual Operating Reserve Provision



Planning for Extremes

Sufficiency of supply to meet demand all times of the year (resource adequacy)

Sufficiency of supply under different weather years

Extended transmission outages

Unexpected failures

Changes in 100% Systems: Resource Adequacy (1)

Traditional and Low RE Systems

Simple “planning reserve margin” approach. Build conventional capacity or pumped storage to your expected peak (hot summer afternoon). The build an extra 15%-20% of capacity to ensure reliability against outages, unexpected events

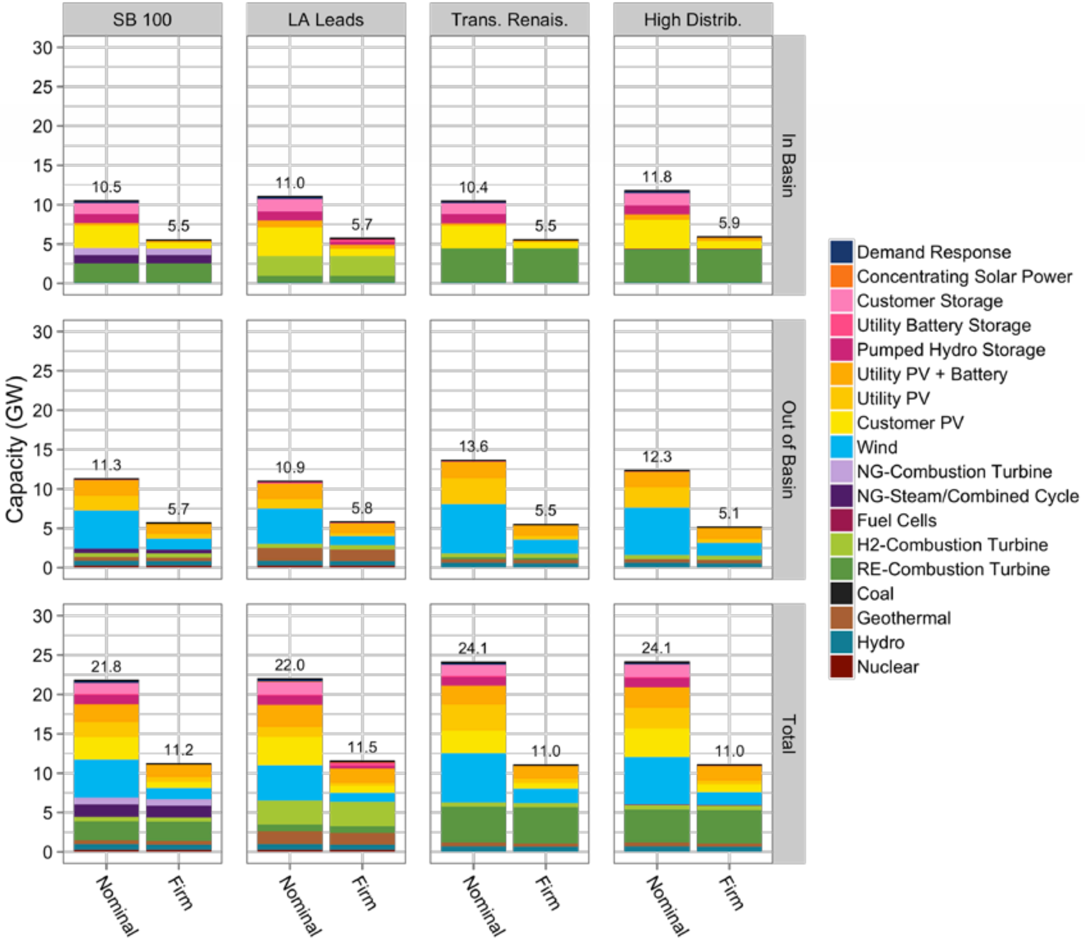
100% RE Systems

Need to consider availability of wind and solar, limited capacity of shorter-duration storage.

Need to consider all hours, not just the hottest summer afternoon.

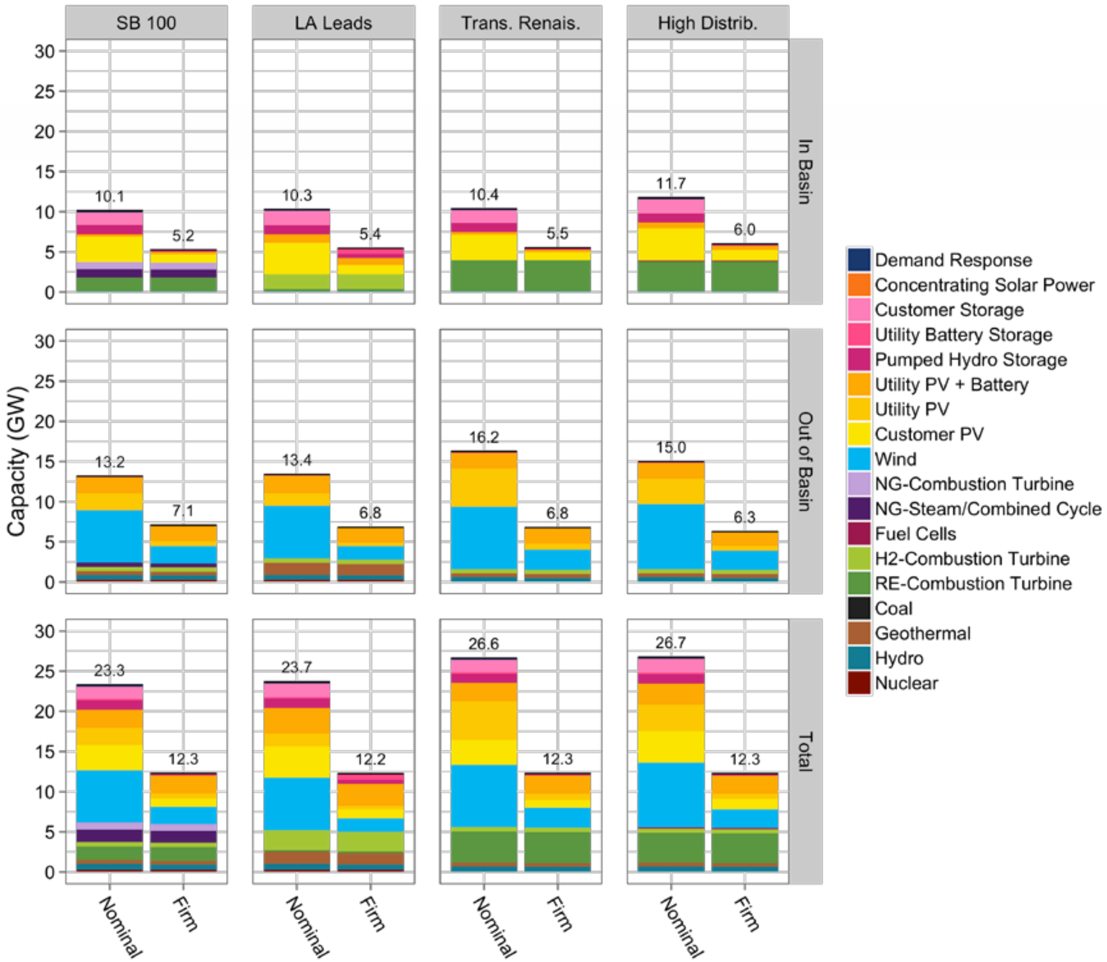
How much can we depend on wind, solar, and batteries?

2045- Moderate Load



How much can we depend on wind, solar, and batteries?

2045- Moderate Load



Changes in 100% Systems: Resource Adequacy (2)

Traditional and Low RE Systems

Resource adequacy challenges in transmission constrained regions solved with traditional dispatchable capacity.

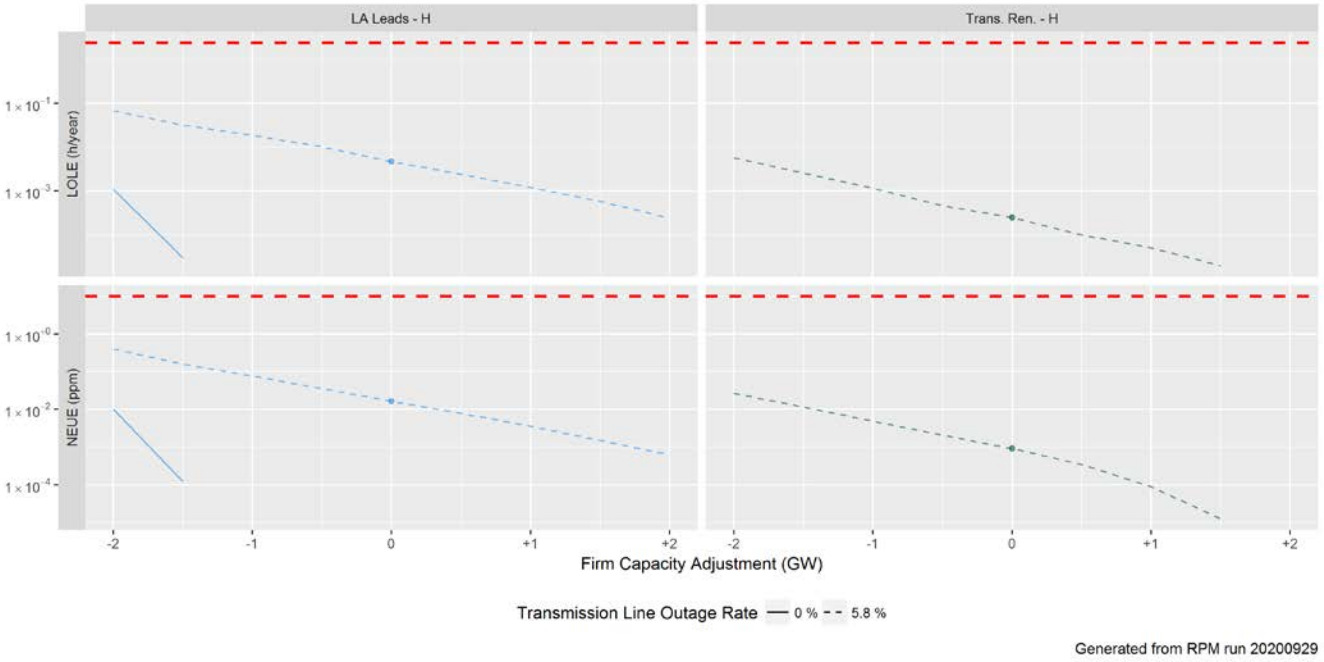
Standard probabilistic resource adequacy tools don’t need to model transmission in incredible detail (so they don’t).

100% RE Systems

Need to consider availability of in-basin resources and transmission in greater detail.

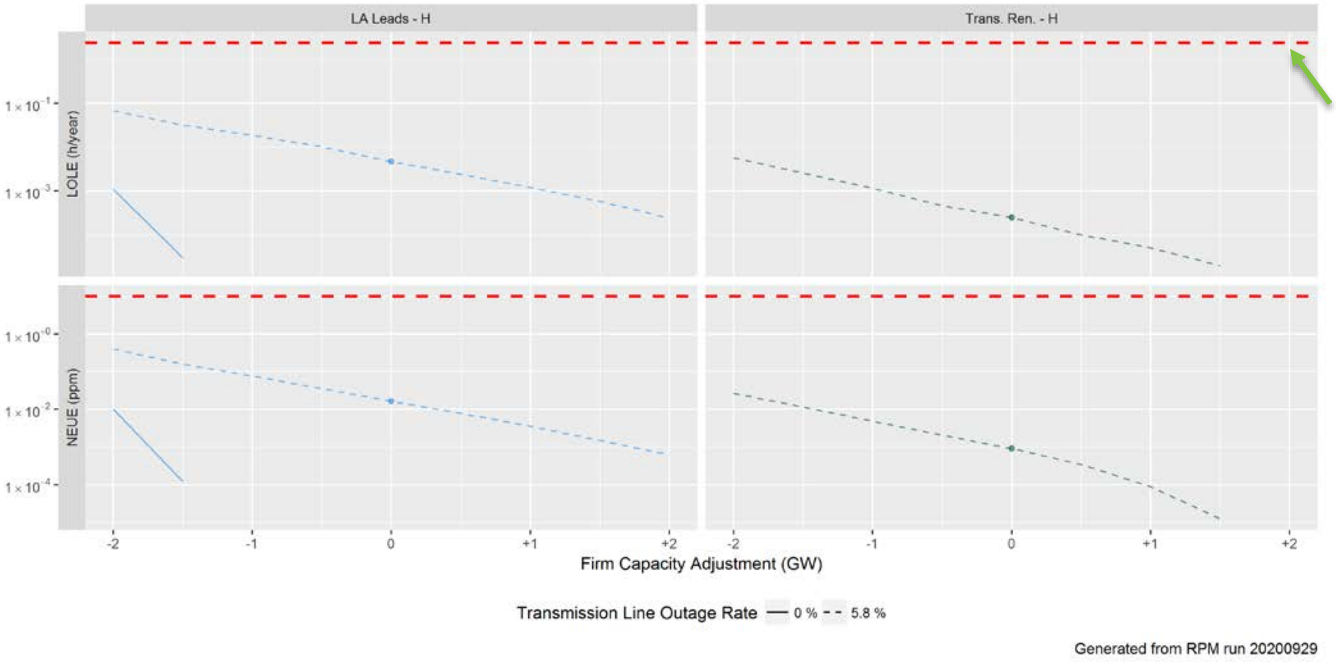
Need to consider energy dispatch in detail.

Example: Resource adequacy using a state-of-the-art tool



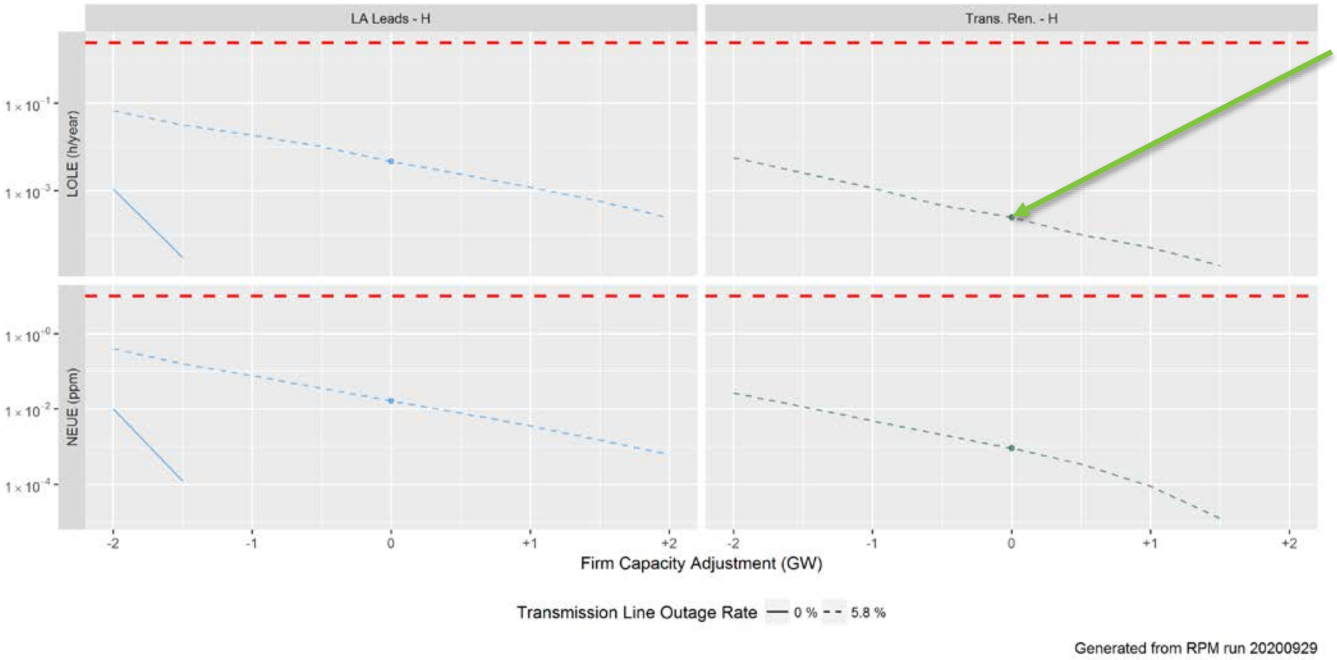
Thousands of probability scenarios, with a basic transmission representation – at least as good as the best commercial tool available

Example: Resource adequacy using a state-of-the-art tool



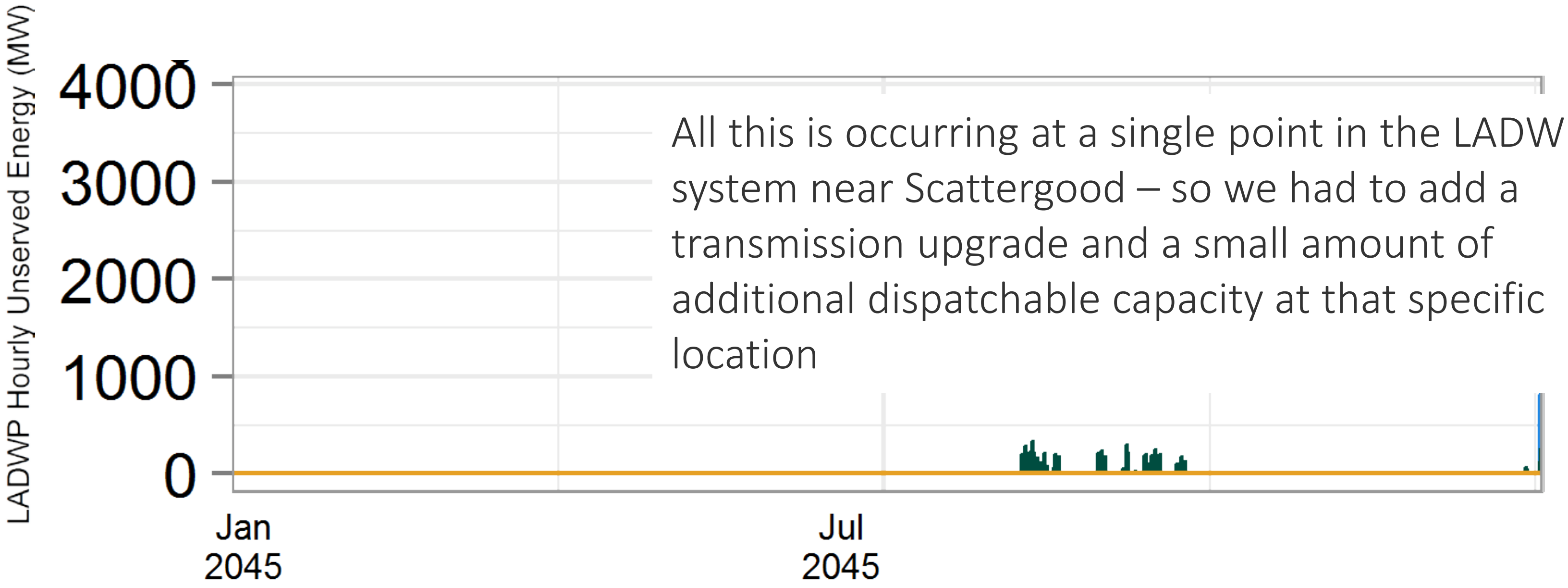
Reliability target, about 2.4 hours of outages per year

Example: Resource adequacy using a state-of-the-art tool



So a traditional analysis shows that we are more reliable than we need to be (meaning an over built and too costly system)

Transmission Constraints Show a Different Result



All this is occurring at a single point in the LADWP system near Scattergood – so we had to add a transmission upgrade and a small amount of additional dispatchable capacity at that specific location

2045 Transmission Renaissance case (high load)

Planning for Extremes

Sufficiency of supply to meet demand all times of the year (resource adequacy)

Sufficiency of supply under different weather years

Extended transmission outages

Unexpected failures

Changes in 100% Systems: Multiple Weather Years

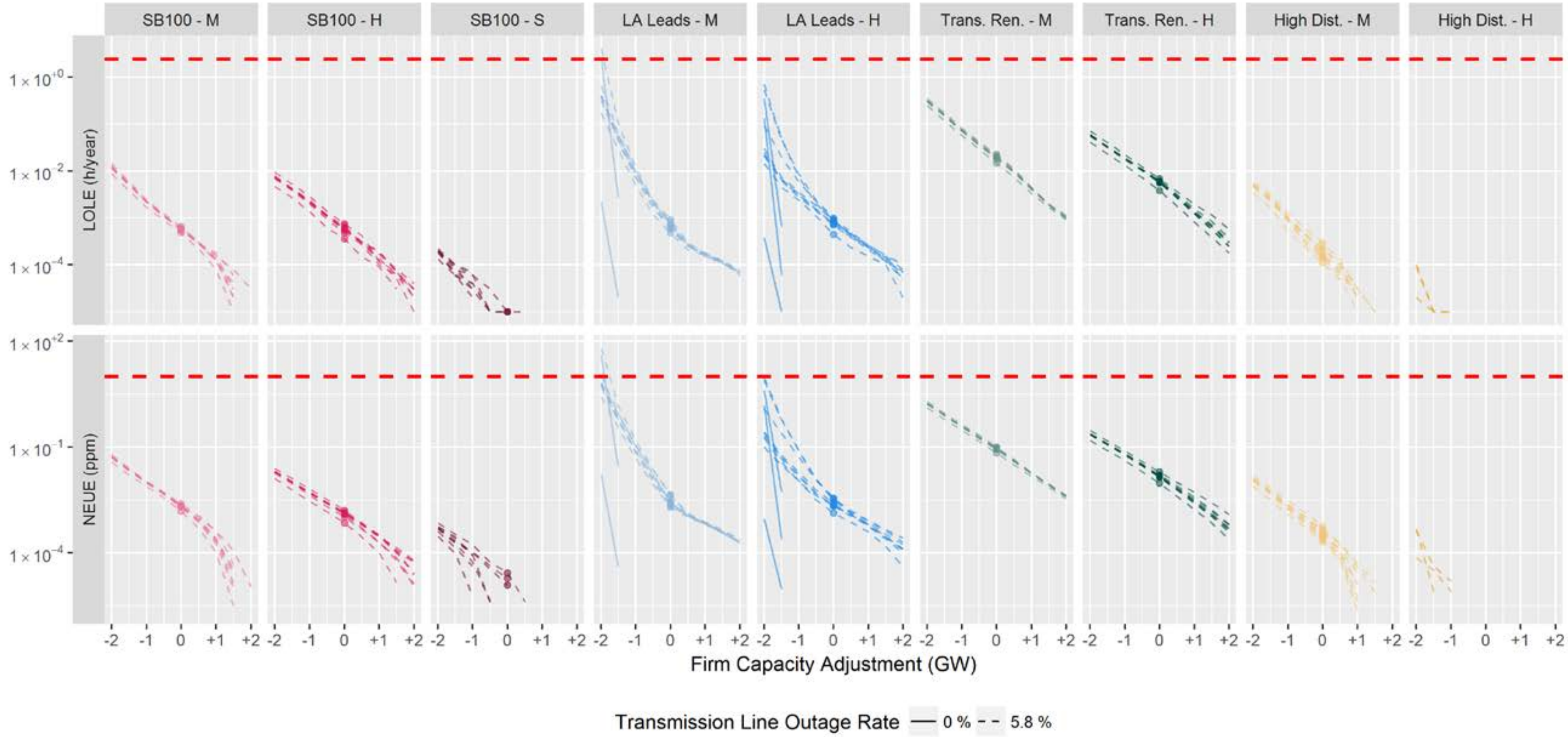
Traditional and Low RE Systems

Plan around expected hottest day, considering hydro availability

100% RE Systems

Plan around every day, and consider longer term variability of wind and solar

We Do Not See a Significant Impact of Multiple Weather Years in Our Base Resource Adequacy Calculation



Generated from RPM run 20200805

Planning for Extremes

Sufficiency of supply to meet demand all times of the year (resource adequacy)

Sufficiency of supply under different weather years

Extended transmission outages

Unexpected failures

Changes in 100% Systems: Extended Outages

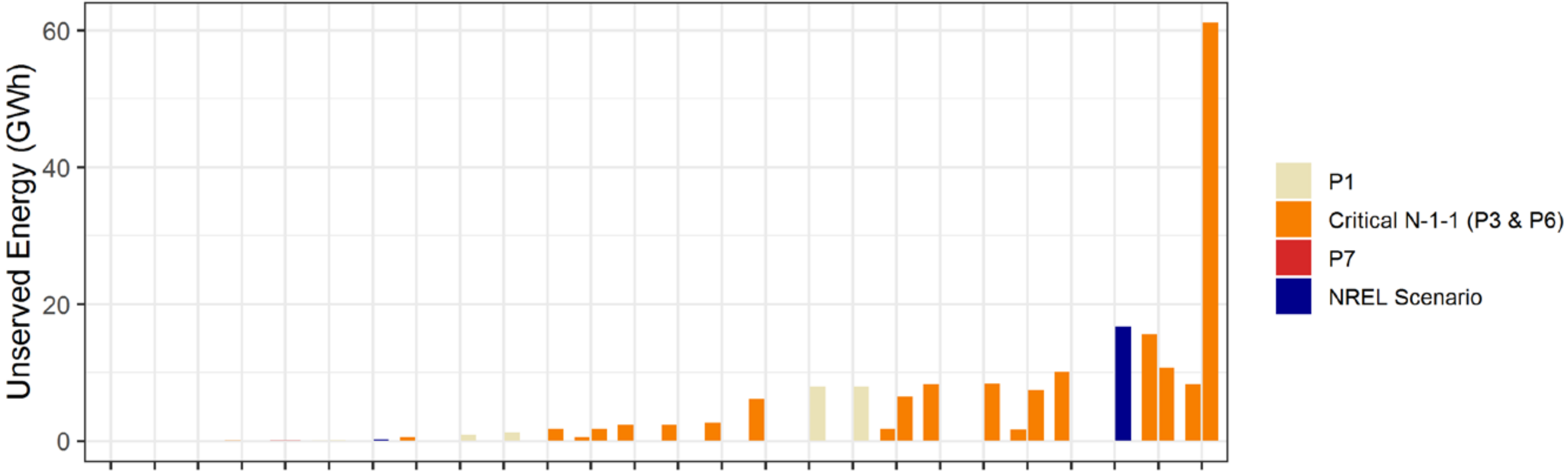
Traditional and Low RE Systems

Maintain replacement reserves that can operate for days or longer while plant or transmission line is being fixed. Currently this is provided by in-basin gas-fired units.

100% RE Systems

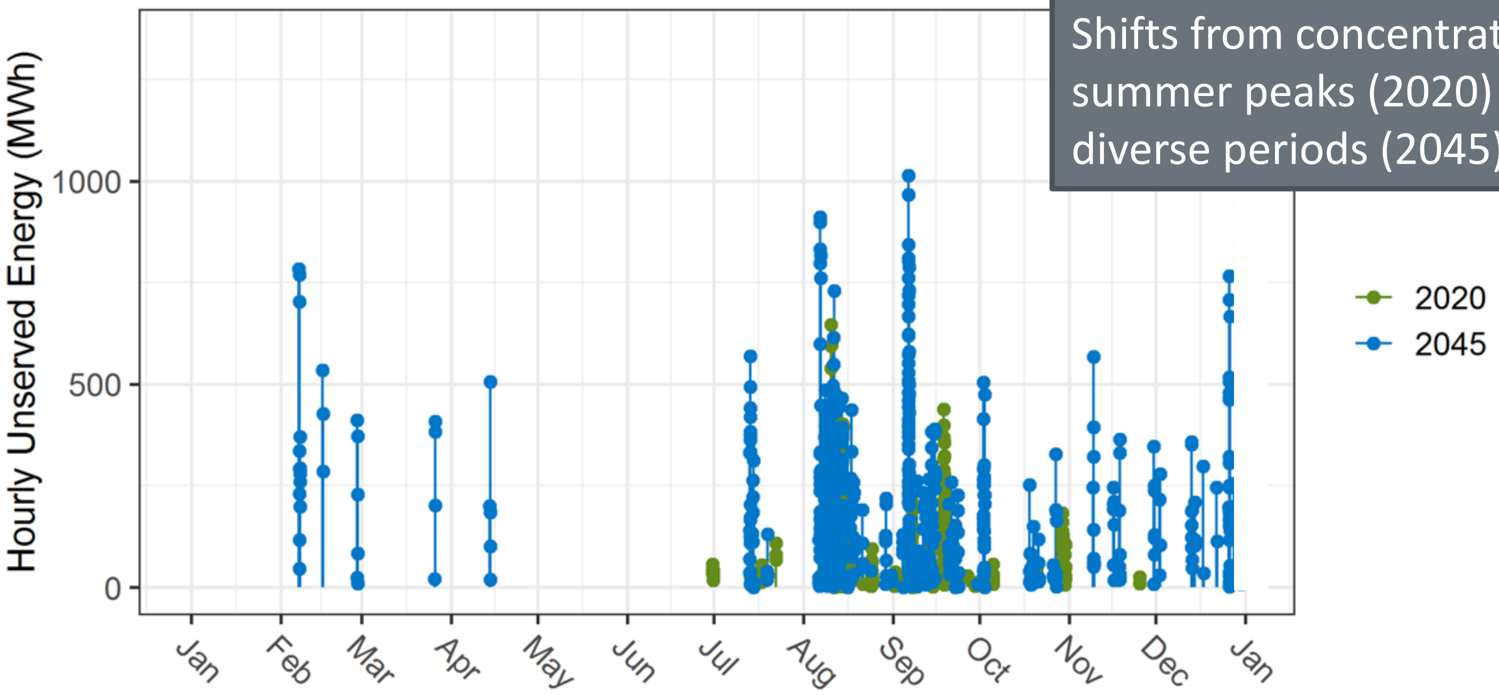
Evaluate the continued need for replacement reserves. Need to evaluate for the entire year instead of just a few times of the year. Now consider impact of wind and solar.

Managing long-duration outages



Outage Scenario – Names Redacted

Managing long-duration outages



Timing of Outages:
Shifts from concentration in summer peaks (2020) to more diverse periods (2045)

Planning for Extremes

Sufficiency of supply to meet demand all times of the year (resource adequacy)

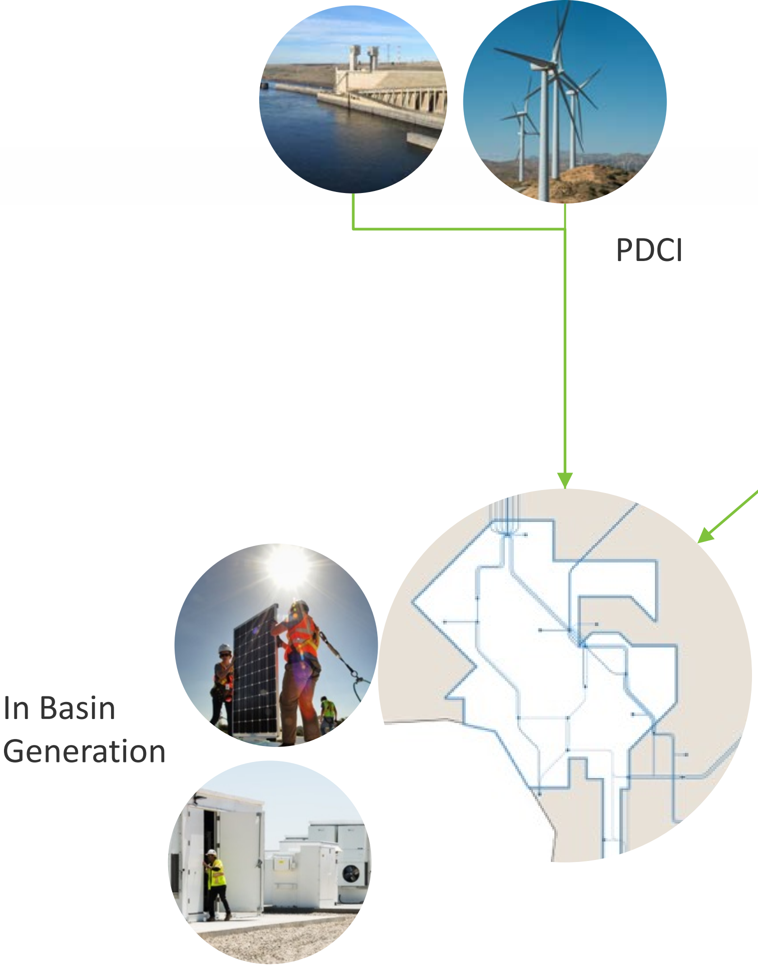
Sufficiency of supply under different weather years

Extended transmission outages

Unexpected failures

Lets back up a bit and talk about LADWP's three sources of generation…

In Basin Generation



LADWP's DC Transmission Network

Controllable power lines. There are only 5 in the entire country and LA owns part of 2 of them.

So.
Cal.Edison

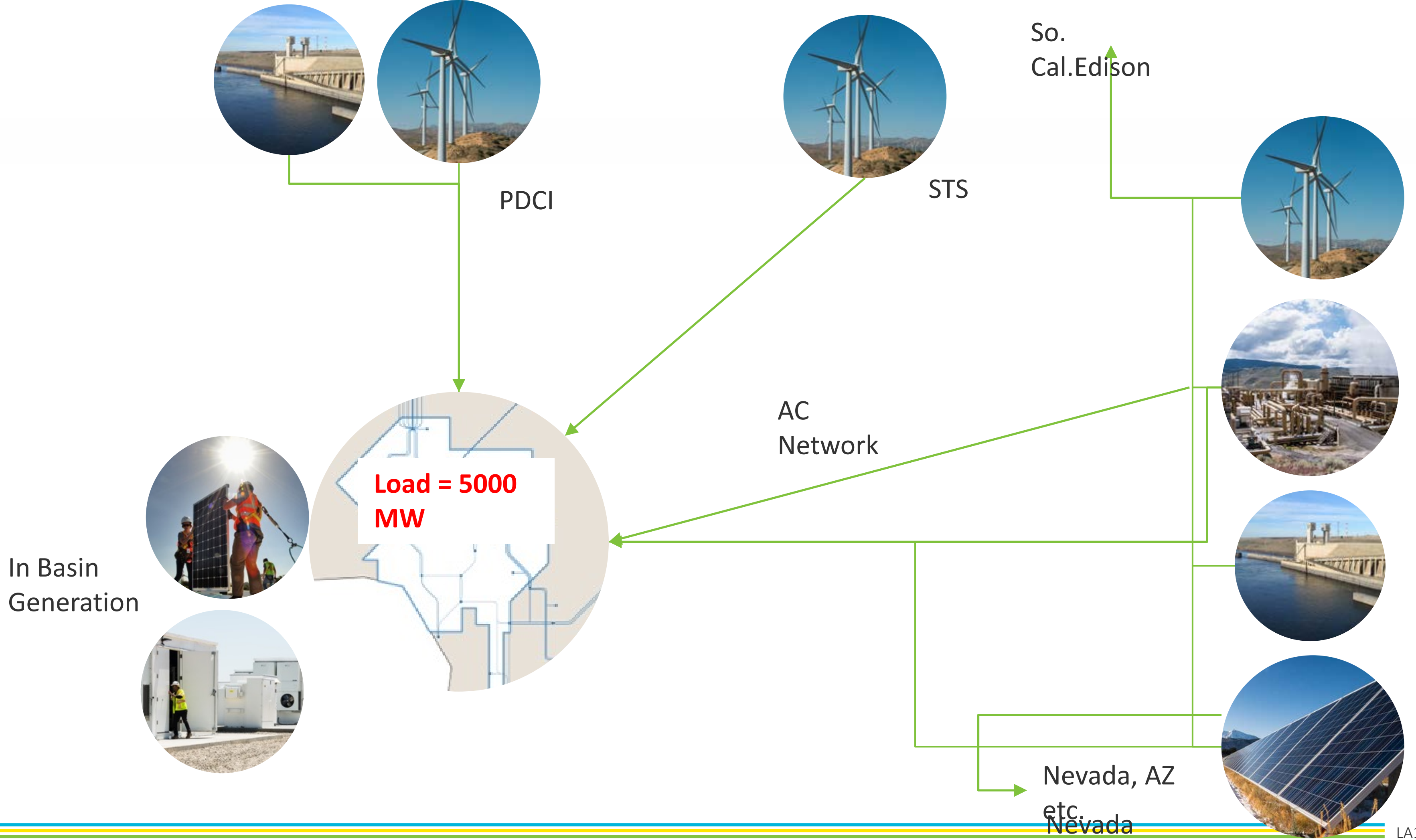
LADWP's AC Network

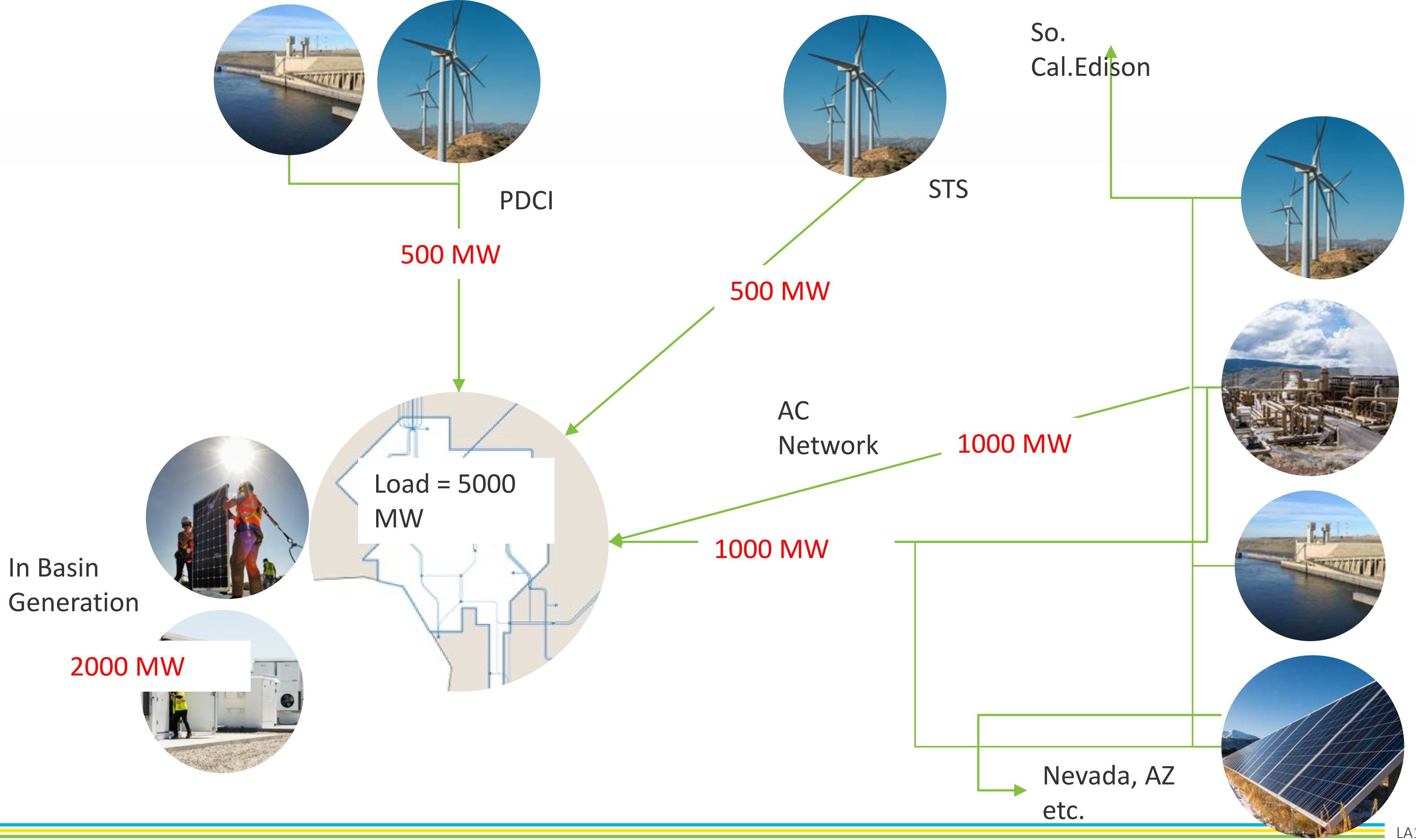
Non-controllable power lines. Linked to multiple points throughout the southwest. This is a very simplified representation.

LADWP's AC Transmission Network

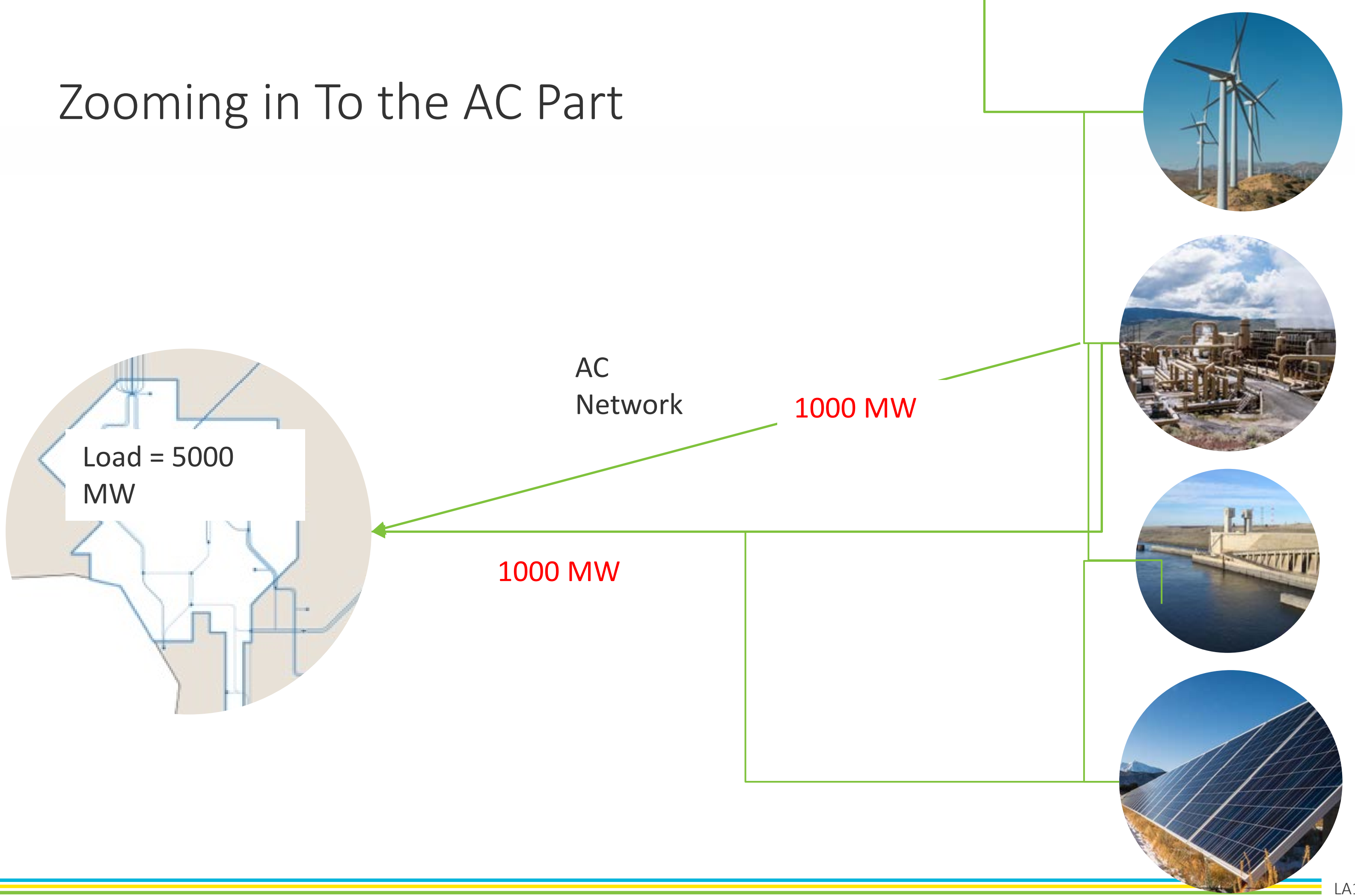
In Basin Generation

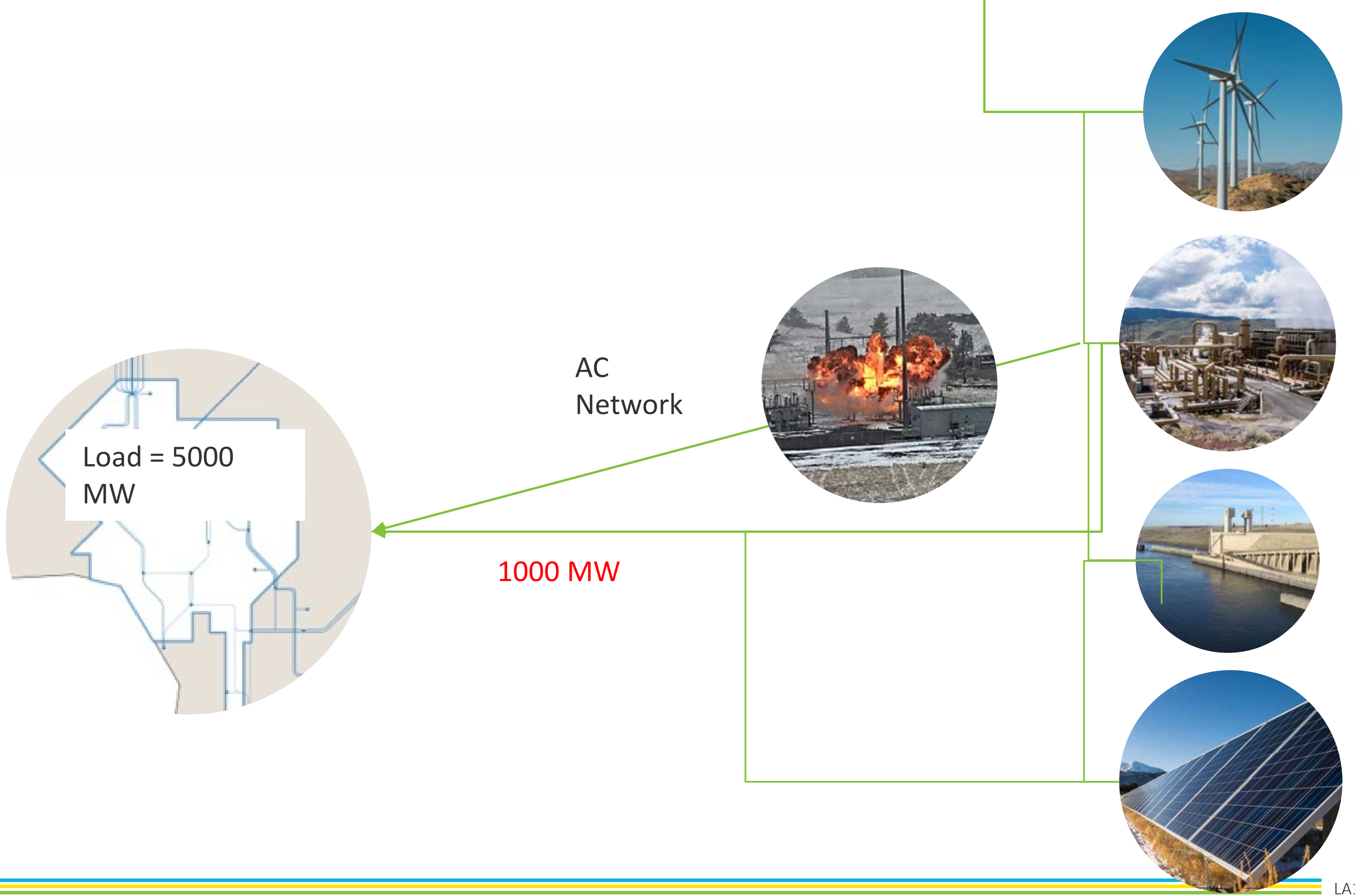
Nevada, AZ etc.

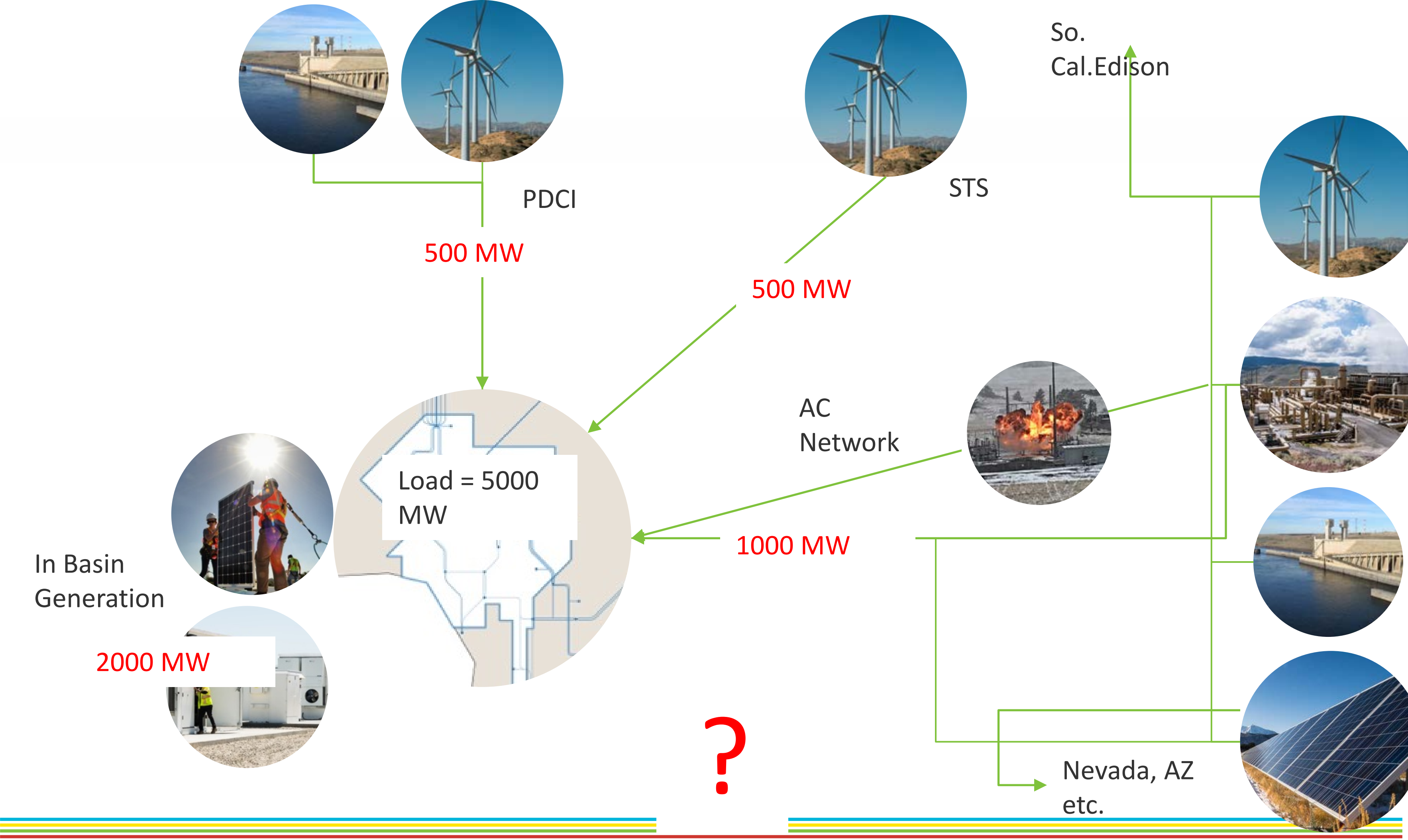

So.
Cal.Edison
PDCI
STS
AC
Network
Load = 5000
MW
In Basin
Generation
Nevada, AZ
etc.
Nevada

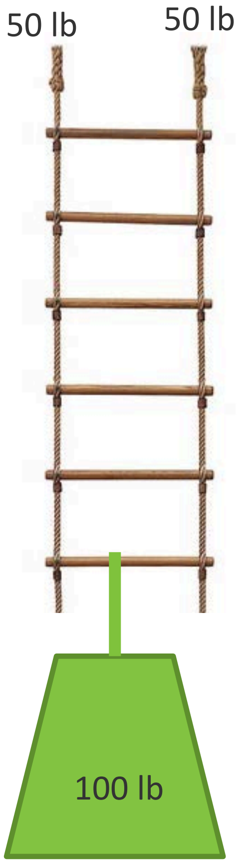

PDCI
500 MW
STS
500 MW
So. Cal.Edison
AC Network
1000 MW
1000 MW
Load = 5000 MW
In Basin Generation
2000 MW
Nevada, AZ etc.

Zooming in To the AC Part



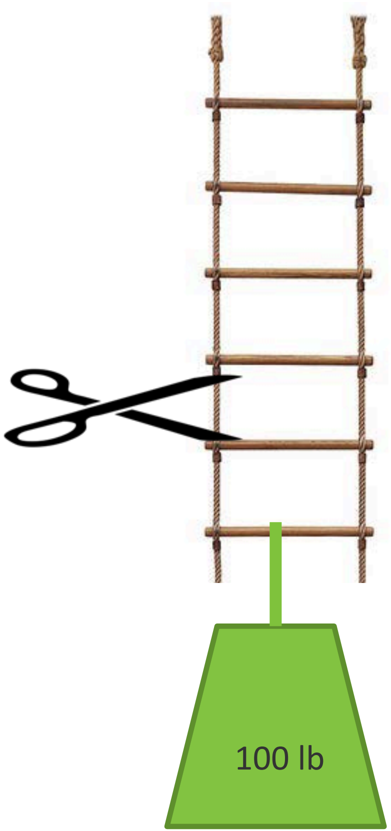

Load = 5000 MW
AC Network
1000 MW


PDCI
500 MW
STS
500 MW
So.
Cal.Edison
AC
Network
1000 MW
Load = 5000
MW
In Basin
Generation
2000 MW
?
Nevada, AZ
etc.

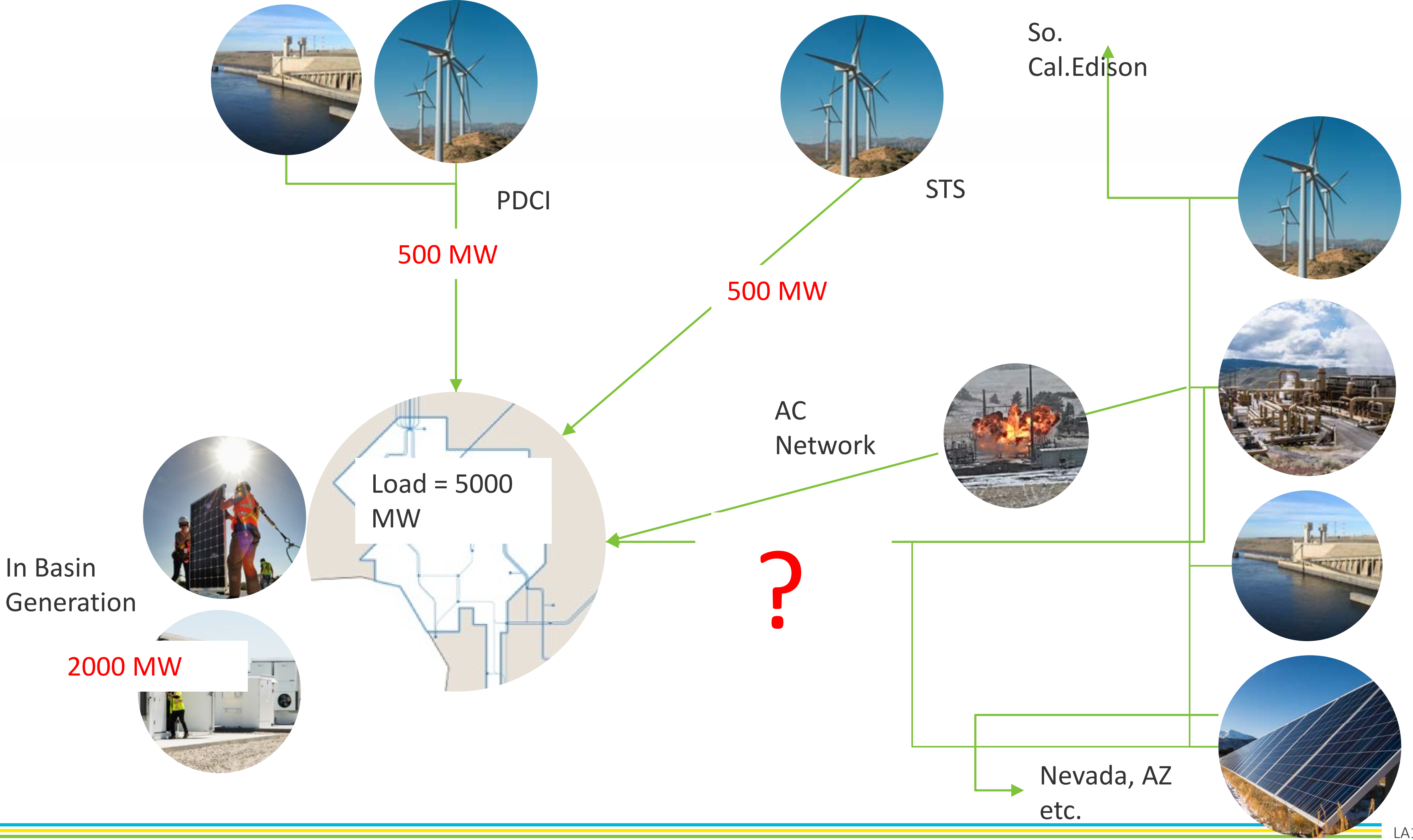

50 lb
50 lb
100 lb

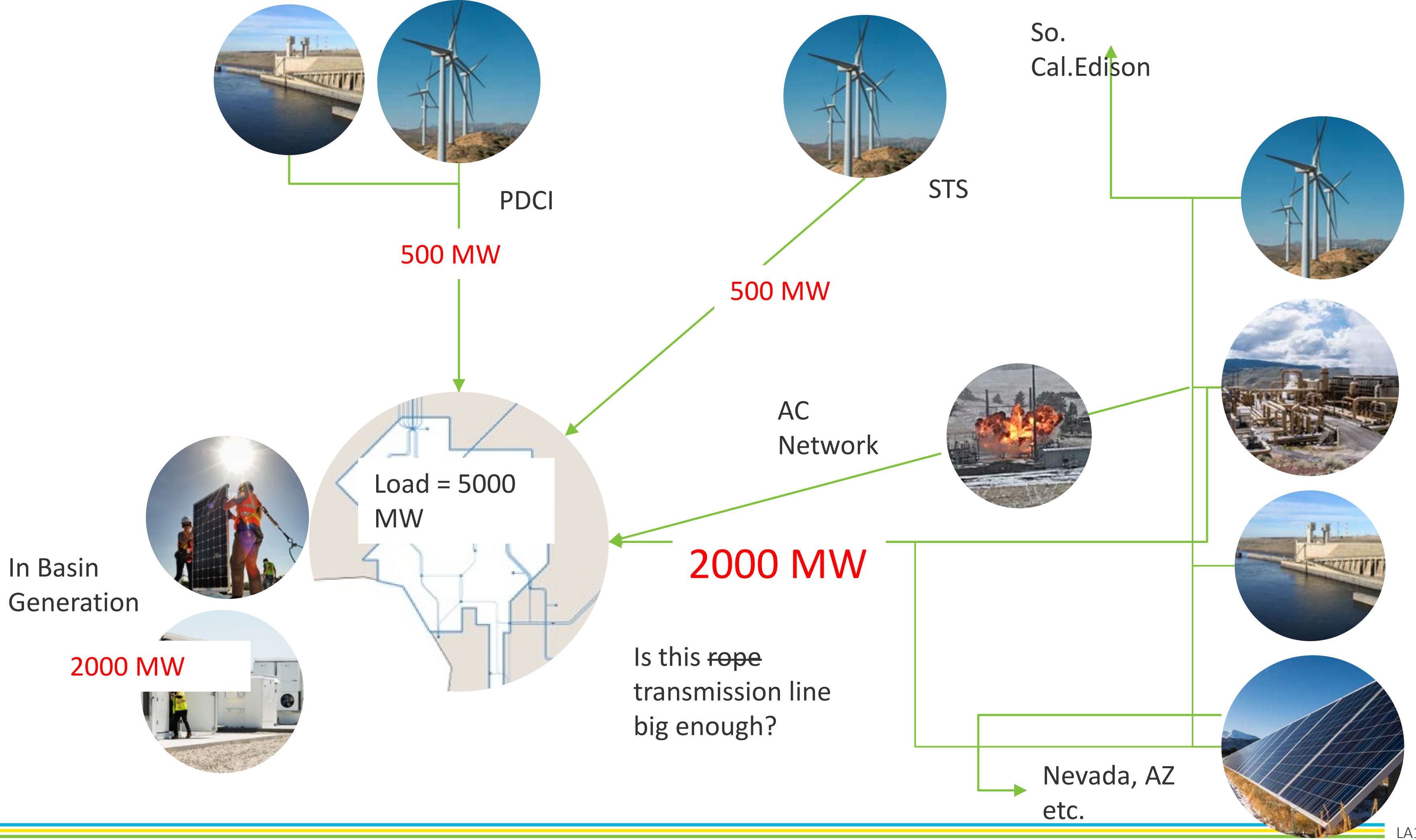
Good engineering
20% reserve margin!

Running with scissors?



How much weight is now on this rope?


So.
Cal.Edison
PDCI
STS
500 MW
500 MW
AC
Network
Load = 5000
MW
?
In Basin
Generation
2000 MW
Nevada, AZ
etc.


PDCI
500 MW
STS
500 MW
So. Cal.Edison
AC Network
2000 MW
Load = 5000 MW
In Basin Generation
2000 MW
Is this ~~rope~~ transmission line big enough?
Nevada, AZ etc.

This is why we do contingency analysis.

We see if we broke the rope

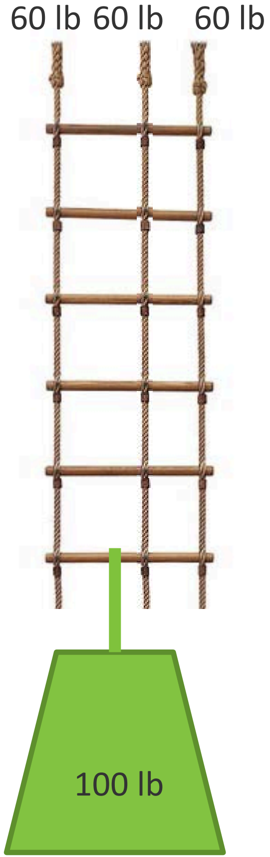
This is why we do contingency analysis.

We see if we broke the rope

Before we show you the results, the answer is yes, we did break the rope in a few places...

But we also need to talk about solutions.

More Wires

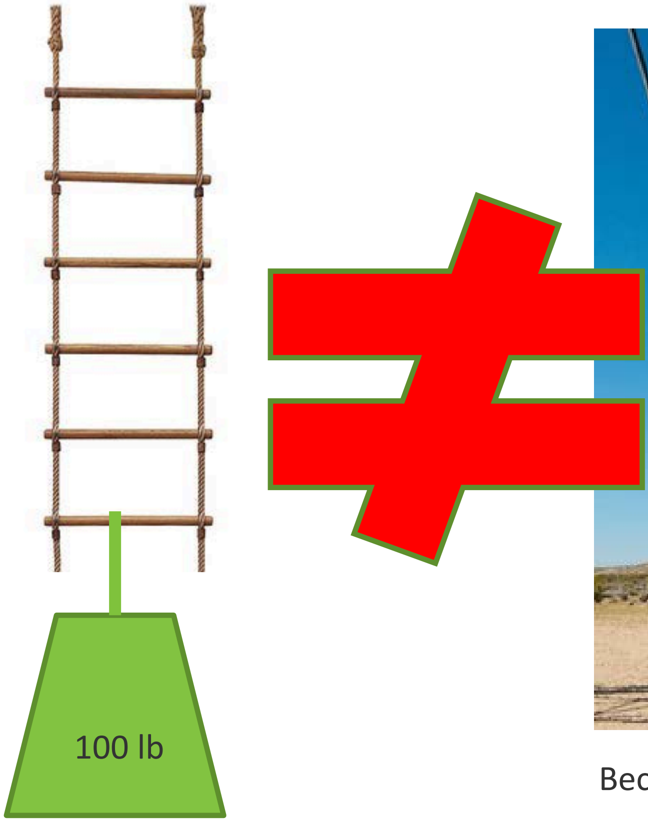


Bigger Wires

More In-Basin Generation*

*But it has to be running...(or does it?)

This analogy can only go so far….



Because this isn't really a rope, there are some things we can't show

Like flexible AC or additional DC transmission
Or the role of fast response under contingency conditions….

What is the role of fast responding technologies?

- How long do we have to correct the fault?
  - Which components will blow up right away?
  - Which components will be OK for a while?

- Does a transition to fast responding resources change anything?
  - Traditional generators might take minutes to respond
  - But batteries can respond quickly (seconds)

So with that, let’s break some rope…

Changes in 100% Systems: Contingency Analysis

Traditional and Low RE Systems

Plan for outages by maintaining spinning contingency reserves. Test reliability for a few snapshot conditions.

100% RE Systems

Still need to evaluate post-contingency events. Need to consider non-traditional sources of voltage control and frequency response (inverter-based resources)

Why is Power Flow and Stability Analysis Need

Don’t blow stuff up or melt the wires

- Power flow and stability analysis addresses the issue of **deliverability**
  - ✓ Deliverability – Can power be delivered to loads with acceptable power quality?
- Power flow analysis
  - ✓ Do the pre- and post-contingency states have acceptable voltages and thermal loadings?
  - ✓ Reactive power impacts voltages and thermal loadings of lines
- Stability analysis
  - ✓ Can a power system transition from one steady-state to the other?
  - ✓ Is the transition and the final steady-state acceptable?
  - ✓ Power flow and stability analysis models the reality of power systems most accurately – ac power flow and equipment dynamics

And of course, we need yet another model…

- Power flow and stability analysis models the reality of power systems most accurately – ac power flow and equipment dynamics

Scenarios and Sensitivities

Scenarios (Highest Bus Loading Hour)

2030 SB100 High Load Stress

2045 LA Leads High Load

Sensitivities

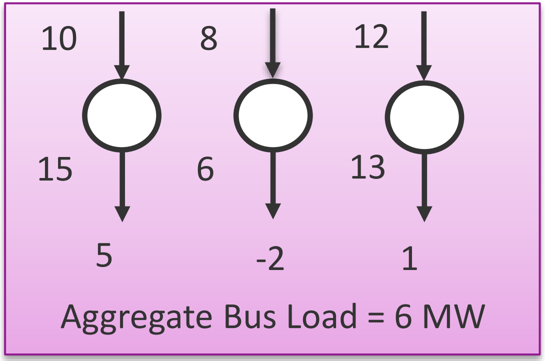
>26K power flow contingencies

>300 transient contingencies

High Northern Imports

Monsoon

High VIC-LA Flow



Scenarios and Sensitivities

Scenarios
(Highest Bus Loading Hour)

2030 SB100 High Load Stress

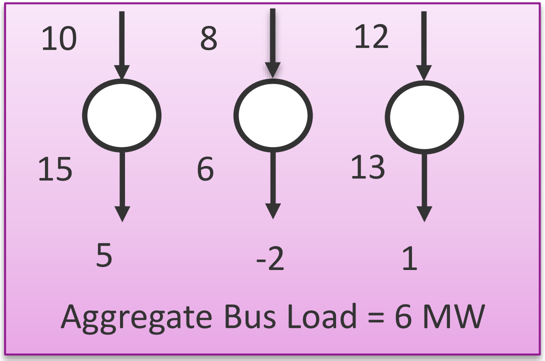
2045 LA Leads High Load

Sensitivities

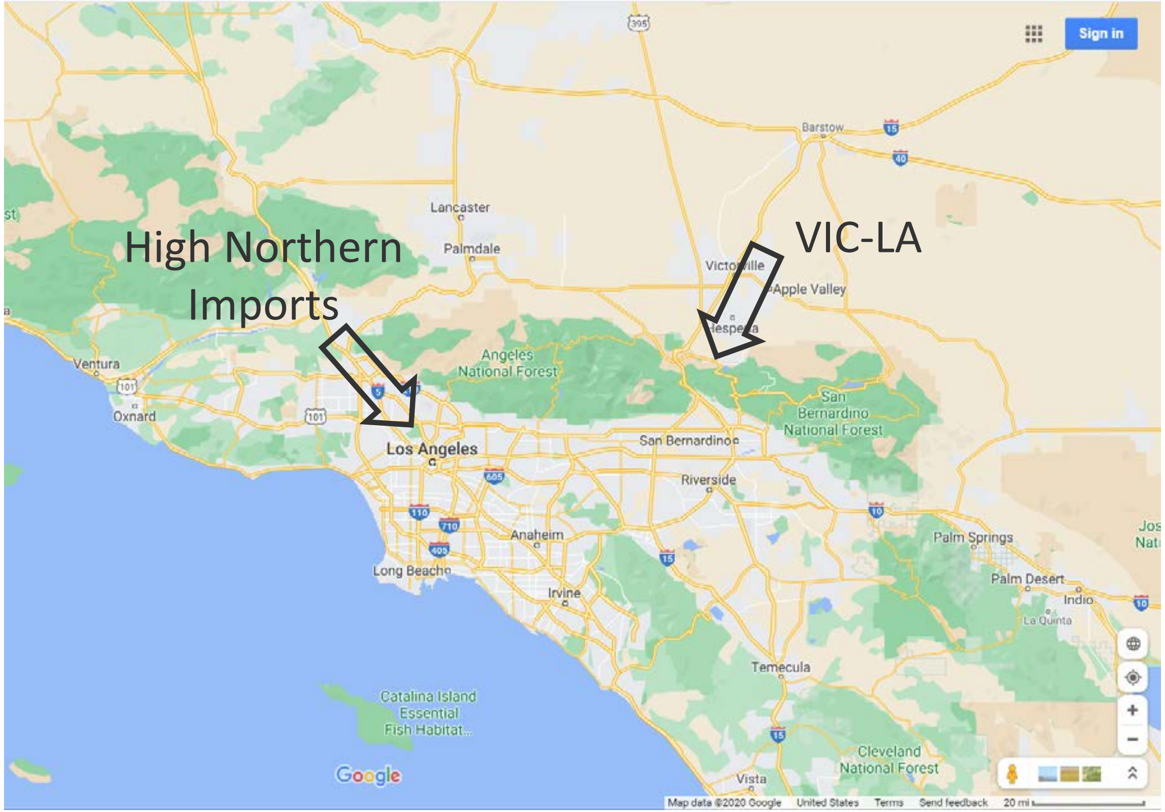
- High Northern Imports
- Monsoon
- High VIC-LA Flow

We cut the rope in 26 thousand locations

>300 transient contingencies



Transmission Stressed in the Sensitivities



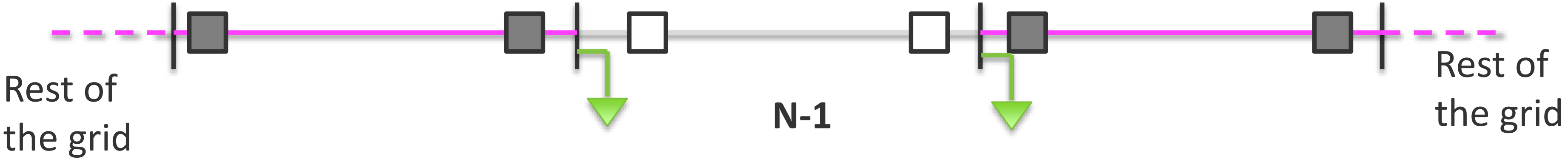
Power Flow Case Summary

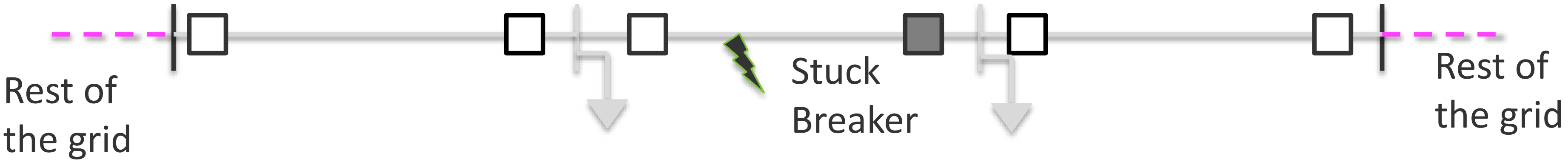
LADWP Balancing Authority			
	2028 HS	2030 SB100 Stress	2045 LA Leads High
LA-Basin Load (MW)	6,592	7,065	7,716
Out of Basin Load (MW)	629	601	703
Aux Load (MW)	[illegible]	[illegible]	163
AC Losses (MW)	[illegible]	[illegible]	457
Total Load (including loss, MW)	[illegible]	[illegible]	9,039
LA-Basin Generation (including DG, MW)	3,2[illegible]	[illegible]	[illegible] (-567 - 558)
Out of Basin Generation (MW)	3,810	4,712	7,418
Pacific DC Intertie (MW)	2,240 (loss 186)	1,600 (loss 94)	2,600 (loss 250)
Total Generation (MW)	8,170	6,794	7,593
LA-Basin Imports	3,352	5,783	8,841
AC System Reactive Power Demand (MVAr)	1,310	2,491	6,107

You can ignore most of this, but this is a really big change

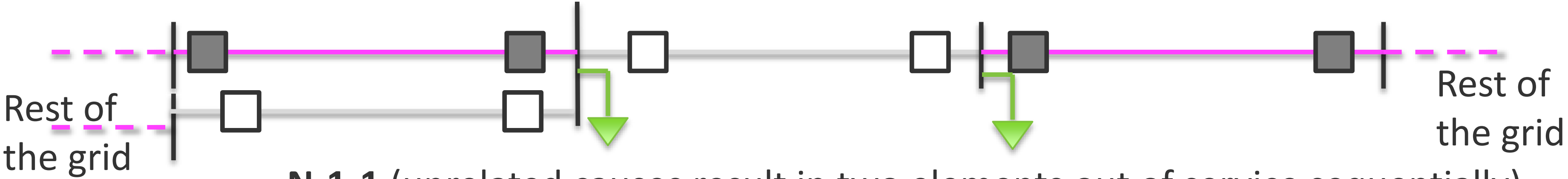
Locating most generation outside the LA-basin results in power flow over longer distances, larger reactive power demand, and higher losses

What are N-1, N-k, N-1-1 contingencies?



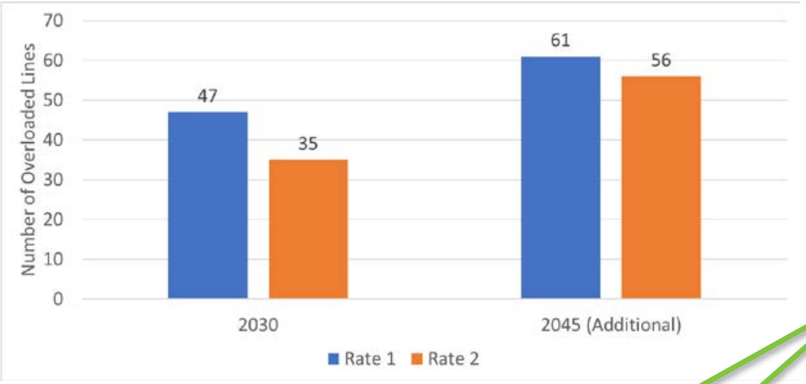


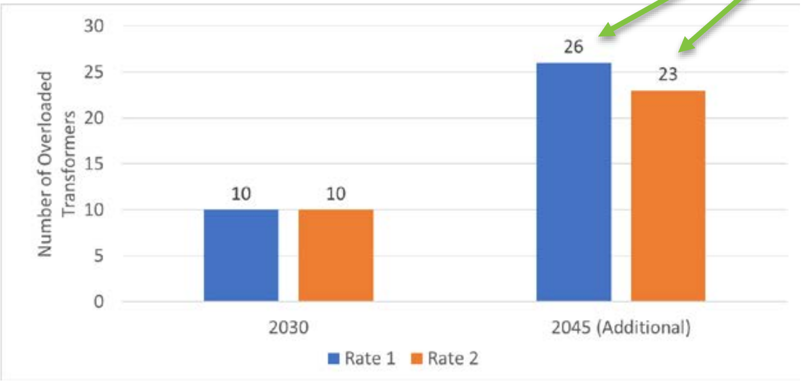
N-k (Common cause takes out multiple elements)



N-1-1 (unrelated causes result in two elements out of service sequentially)

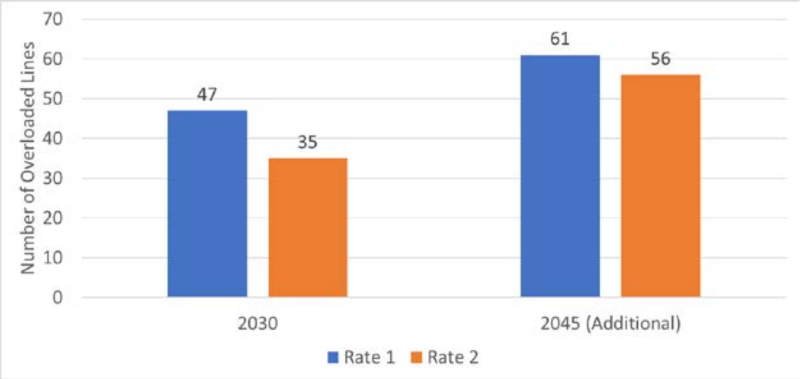
Summary (Base Case Overloads)

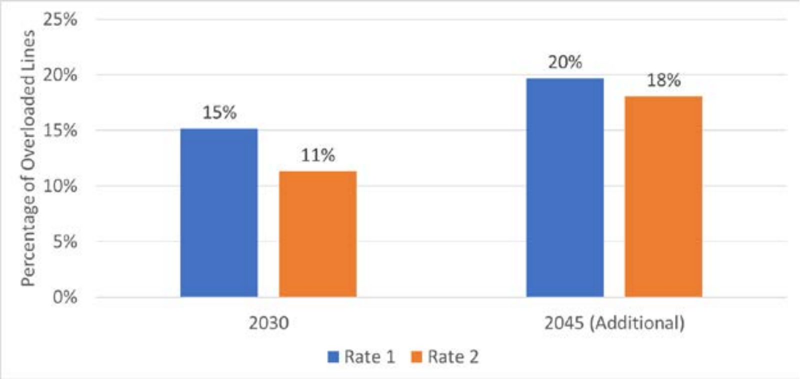


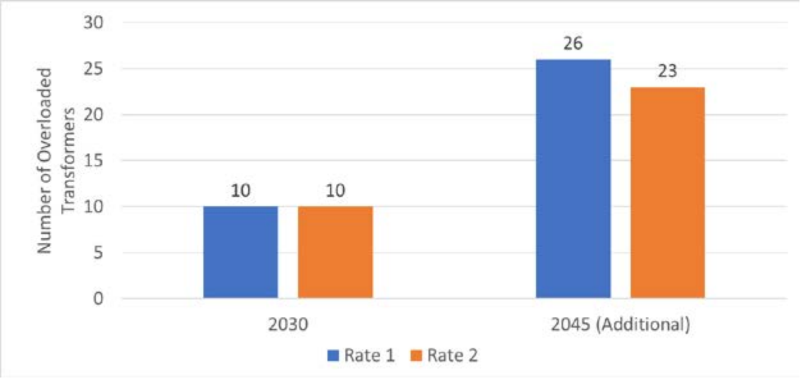


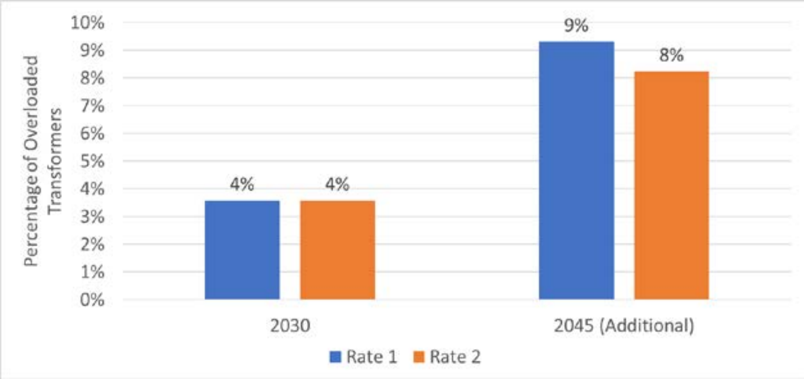
This is an indication of how long we have to fix the problem. If we can act reasonably quickly, we can tolerate short overloads on some of the components…

Summary (Base Case Overloads)

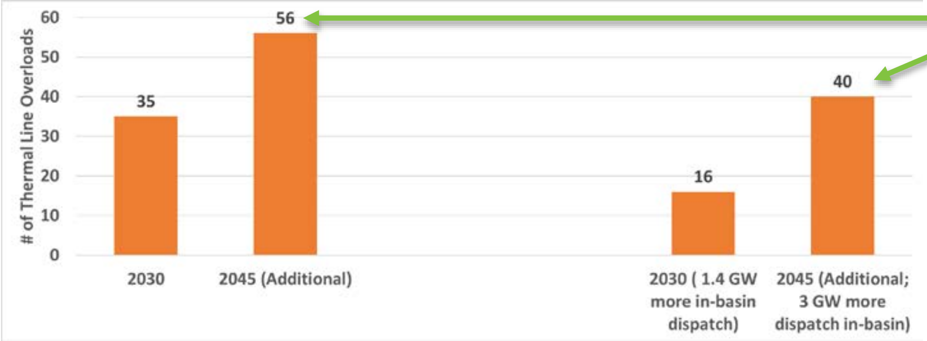




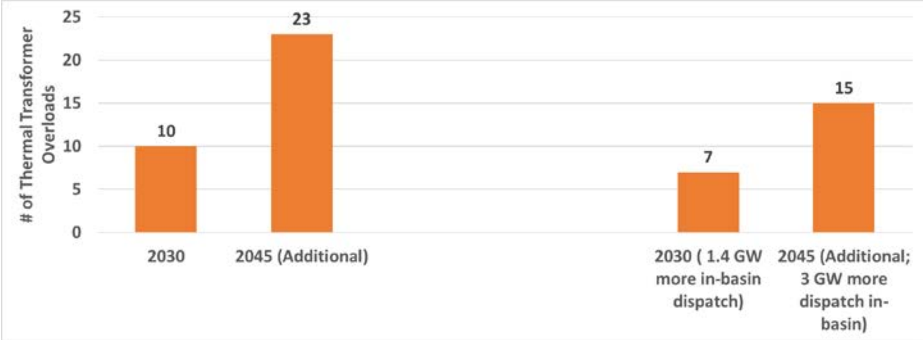




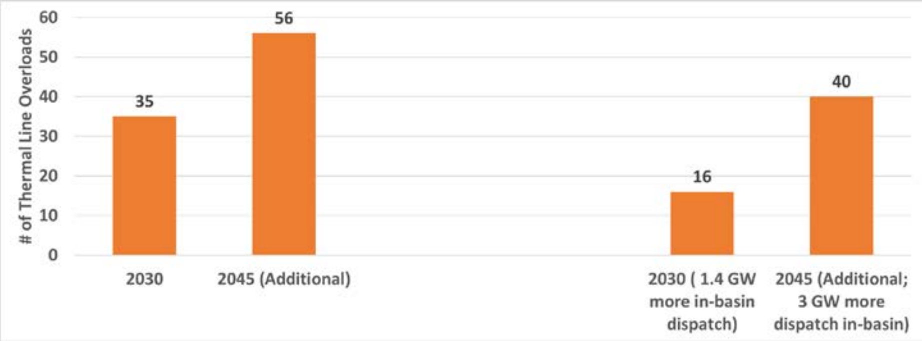
Summary - Base Case Overloads with more in-basin dispatch (rate 2)

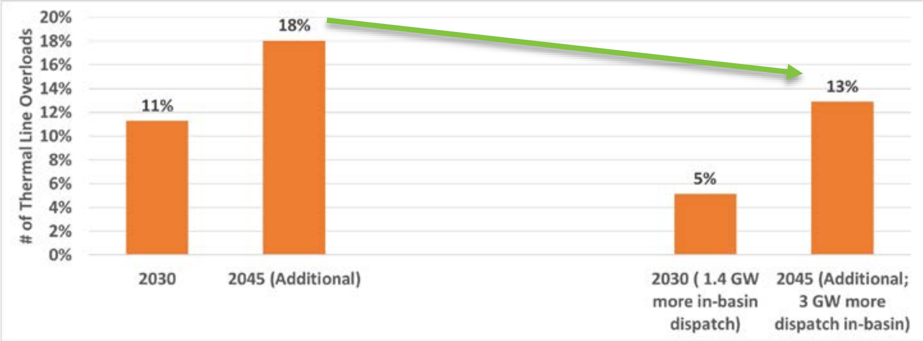


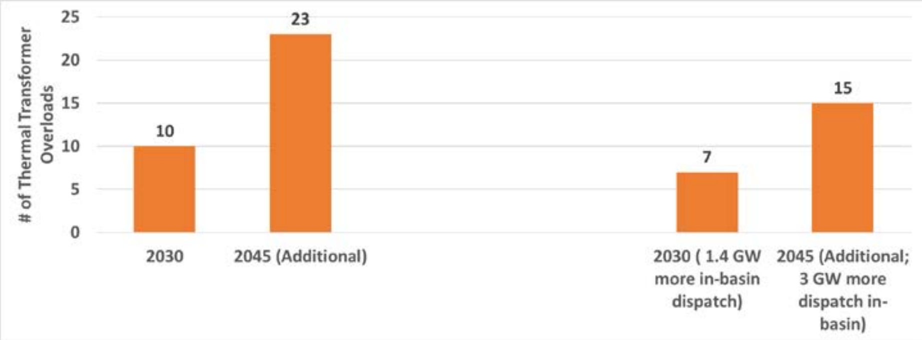
This is an indication of the benefits of increased use of our in- basin resources

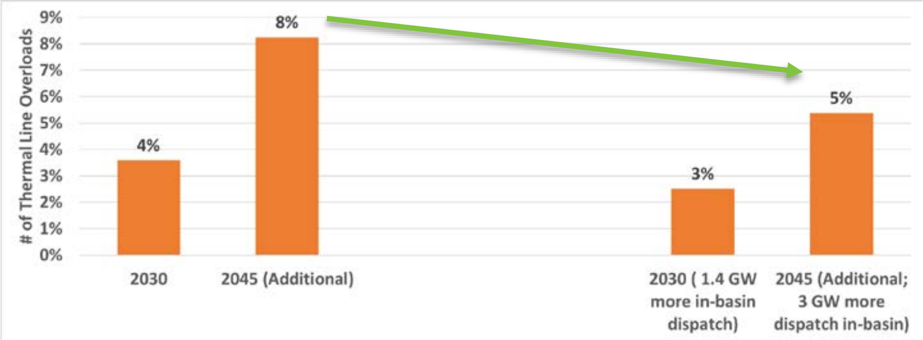


Summary - Base Case Overloads with more in-basin dispatch (rate 2)









Power Flow Takeaways

- **2030 SB100 High Stress**
  - ✓ Dispatching 1.4 GW more from in-basin generators reduces line overloads to **5%** of the total lines based on rating 2.
  - ✓ **3%** transformers are overloaded
- **2045 LA Leads High**
  - ✓ Dispatching 3.0 GW more from in-basin generators reduces additional overloads beyond 2030 overloads to **13%** of the total lines based on rating 2.
  - ✓ Additional **5%** transformers are overloaded
- There are additional radial transformer upgrades needed simply because of higher loads in 2030 and 2045 and the addition of new generators - **6%** in 2030 and **13%** in 2045.

A Few Closing Thoughts

- We can find solutions that provide reliable operation under normal operations and under many contingencies
- They depend on a mix of RE resources, in-basin dispatchable capacity and transmission upgrades
- But standard definitions and approaches of evaluating reliability that have taken decades to evaluate on classical system haven’t been sufficiently tested under 100% RE scenarios

Questions?

The Los Angeles 100% Renewable Energy Study