LA100

The Los Angeles 100% Renewable Energy Study

Highlights and Learnings from Additional Pathways, Initial Run Results of LA100 Scenarios

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Los Angeles Department of Water & Power

NREL Transforming ENERGY

Agenda for This Session

Review results and initial insights from the full set of LA100 scenarios

- Investment pathways
- Operations
- Distribution analysis
- Environment analysis

Initial Run (Today) vs. Final Run (June AG Presentation)

What's Included in Initial Run

Electricity Demand: **Initial** Run

Evaluation of the impacts of **short-duration** outages of generation and transmission on resource adequacy

Single weather year

Initial cost and performance assumptions; **initial** constraints on in-basin resources

What's Not Included Today but Will Be in Final Run

Electricity Demand: **Final** Run

Evaluation of **long-duration** outages of generation and transmission on resource adequacy and system operations

Multiple weather-years

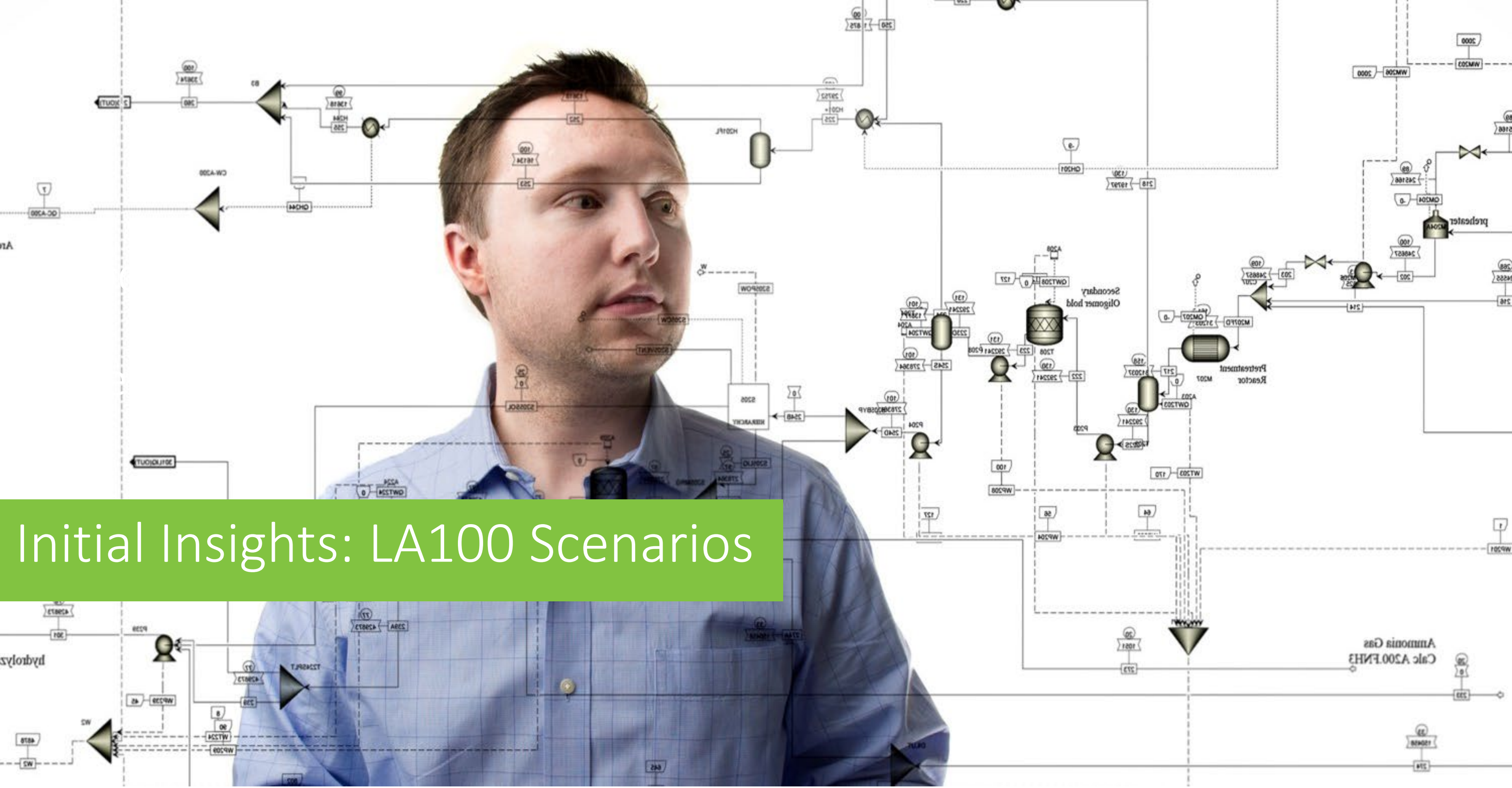
Final cost and performance assumptions; **revised** constraints on in-basin resources

Limits on transmission upgrades and new builds

Evaluation of power flow under steady-state and transient conditions

Today’s Focus

		LA100 Scenarios								
		Moderate Load Electrification				High Load Electrification (Load Modernization)				High Load
		SB100	LA-Leads, Emissions Free (No Biomass)	Transmission Renaissance	High Distributed Energy Future	SB100	LA-Leads, Emissions Free (No Biomass)	Transmission Renaissance	High Distributed Energy Future	High Load Stress
	2030 RE Target	60%	100% Net RE	100% Net RE	100% Net RE	60%	100% Net RE	100% Net RE	100% Net RE	60%
	Compliance Year for 100%	2045	2035/2040	2045	2045	2045	2035/2040	2045	2045	2045
Technologies Eligible in the Compliance Year	Biomass	Y	No	Y	Y	Y	No	Y	Y	Y
	Biogas	Y	No	Y	Y	Y	No	Y	Y	Y
	Electricity to Fuel (e.g. H2)	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Fuel Cells	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Hydro - Existing	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Hydro - New	N	N	N	N	N	N	N	N	N
	Hydro - Upgrades	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Natural Gas	Yes	N	N	N	Yes	N	N	N	Yes
	Nuclear - Existing	Y	Y	No	No	Y	Y	No	No	Y
	Nuclear - New	N	N	N	N	N	N	N	N	N
	Wind, Solar, Geo	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Storage	Y	Y	Y	Y	Y	Y	Y	Y	Y
Repowering OTC	Haynes, Scattergood, Harbor	N	N	N	N	N	N	N	N	N
DG	Distributed Adoption	Moderate	High	Moderate	High	Moderate	High	Moderate	High	Moderate
RECS	Financial Mechanisms (RECS/Allowances)	Yes	N	N	N	Yes	N	N	N	Yes
Load	Energy Efficiency	Moderate	Moderate	Moderate	Moderate	High	High	High	High	Moderate
	Demand Response	Moderate	Moderate	Moderate	Moderate	High	High	High	High	Moderate
	Electrification	Moderate	Moderate	Moderate	Moderate	High	High	High	High	High
Transmission	New or Upgraded Transmission Allowed?	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	New Corridors Allowed	No New Transmission	Only Along Existing or Planned Corridors
WECC	WECC VRE Penetration	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate



Initial Insights: LA100 Scenarios

Preliminary Insights

1. Substantial renewable energy additions both within and outside of the LA basin are required to achieve the 100% target, irrespective of the pathway
2. Associated with high penetrations of variable generation are high rates of *economic* curtailment
3. Storage plays a critical role in shifting variable generation diurnally
4. In the absence of eligibility of RECs (and associated natural gas generation), capacity that does not rely on variable resources (bio, geo, mid- to long-duration storage) is highly valuable
5. Although substantial transmission capacity is available to carry energy into the basin, in the absence of mitigating options, longer-duration transmission outages (both in- and out-of-basin) could be challenging
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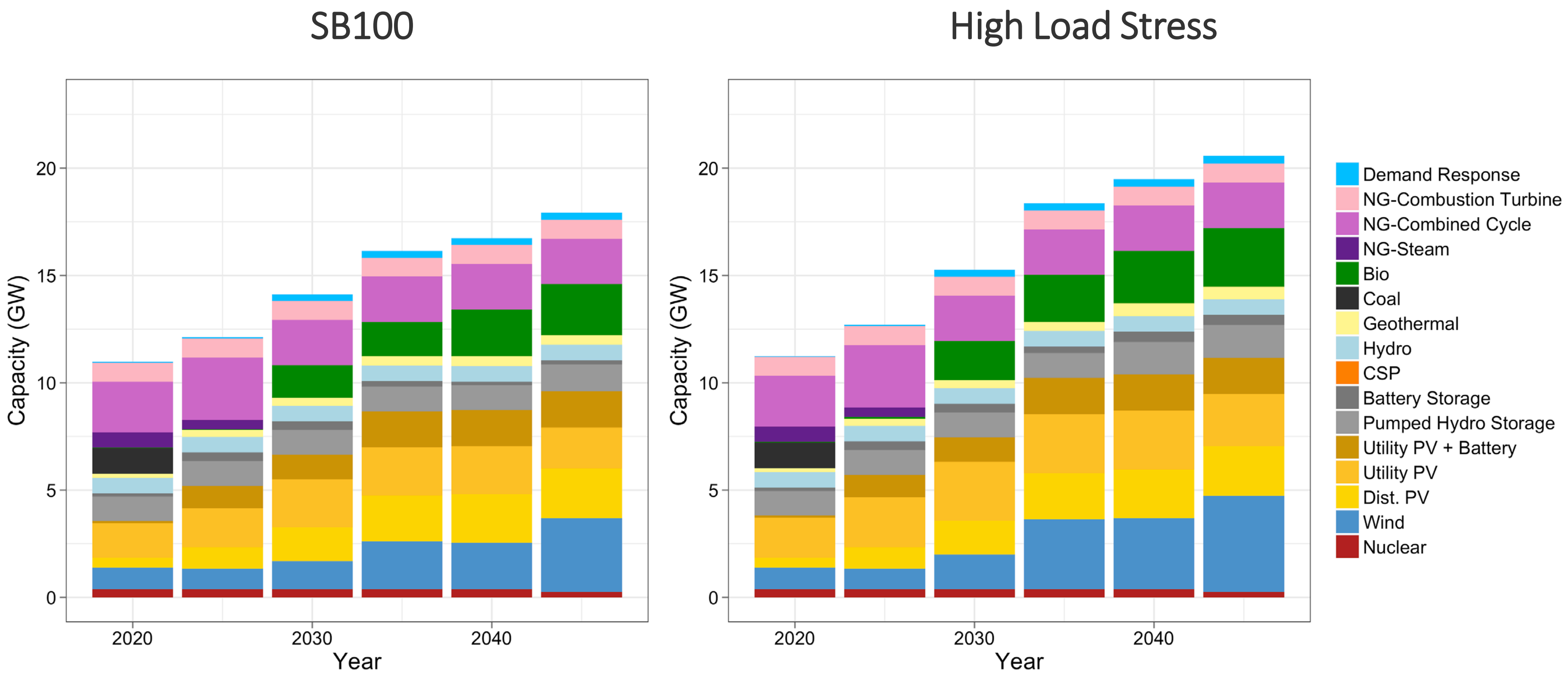
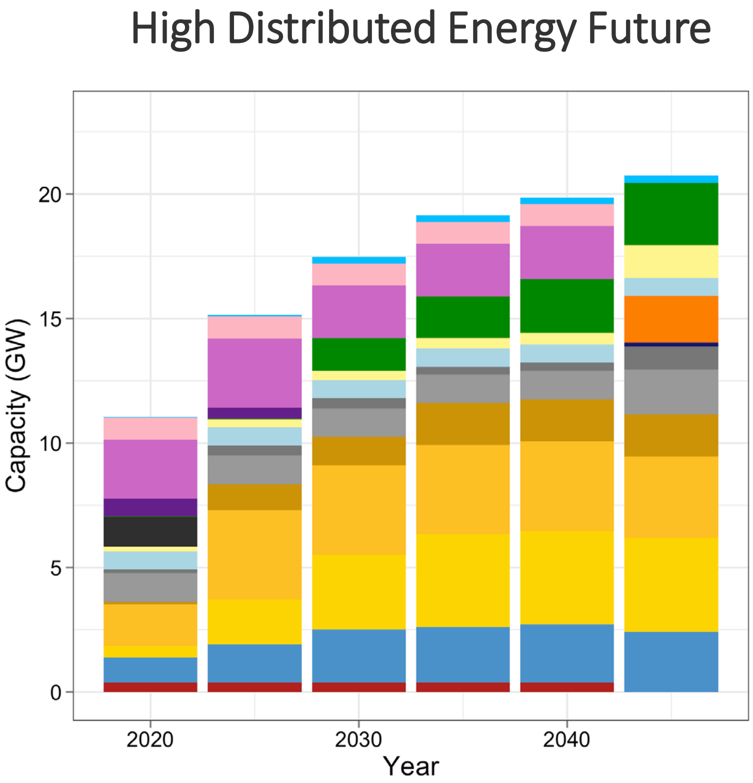
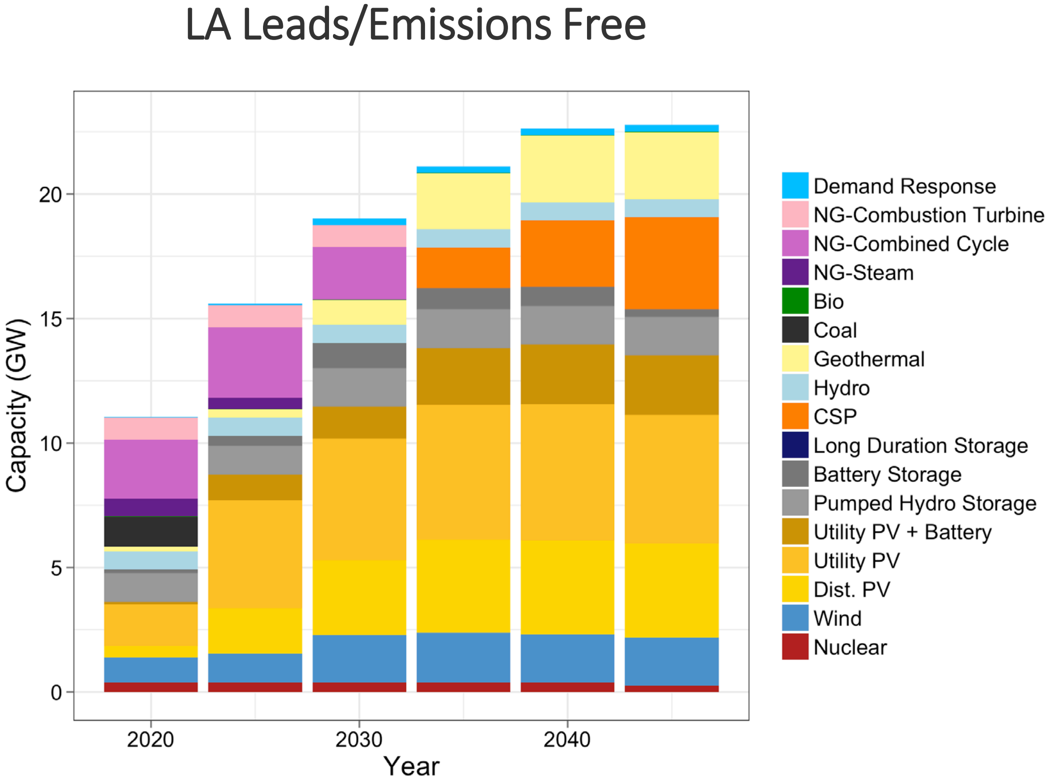
Initial Run, Capacity: **SB100** and **High Load Stress**



Initial Run – For Discussion Purposes Only; Subject to Change

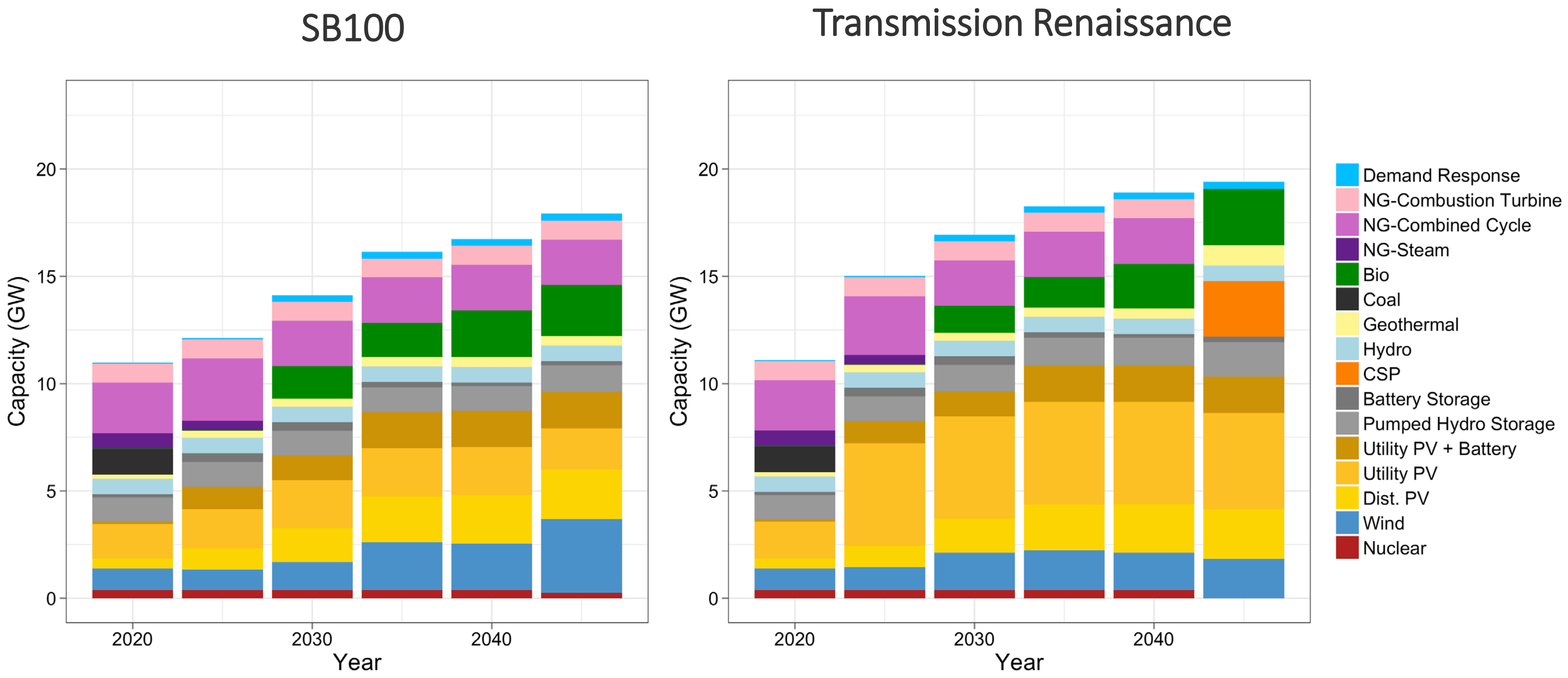
Initial Run, Capacity: **High Distributed Energy Future** and **LA Leads**



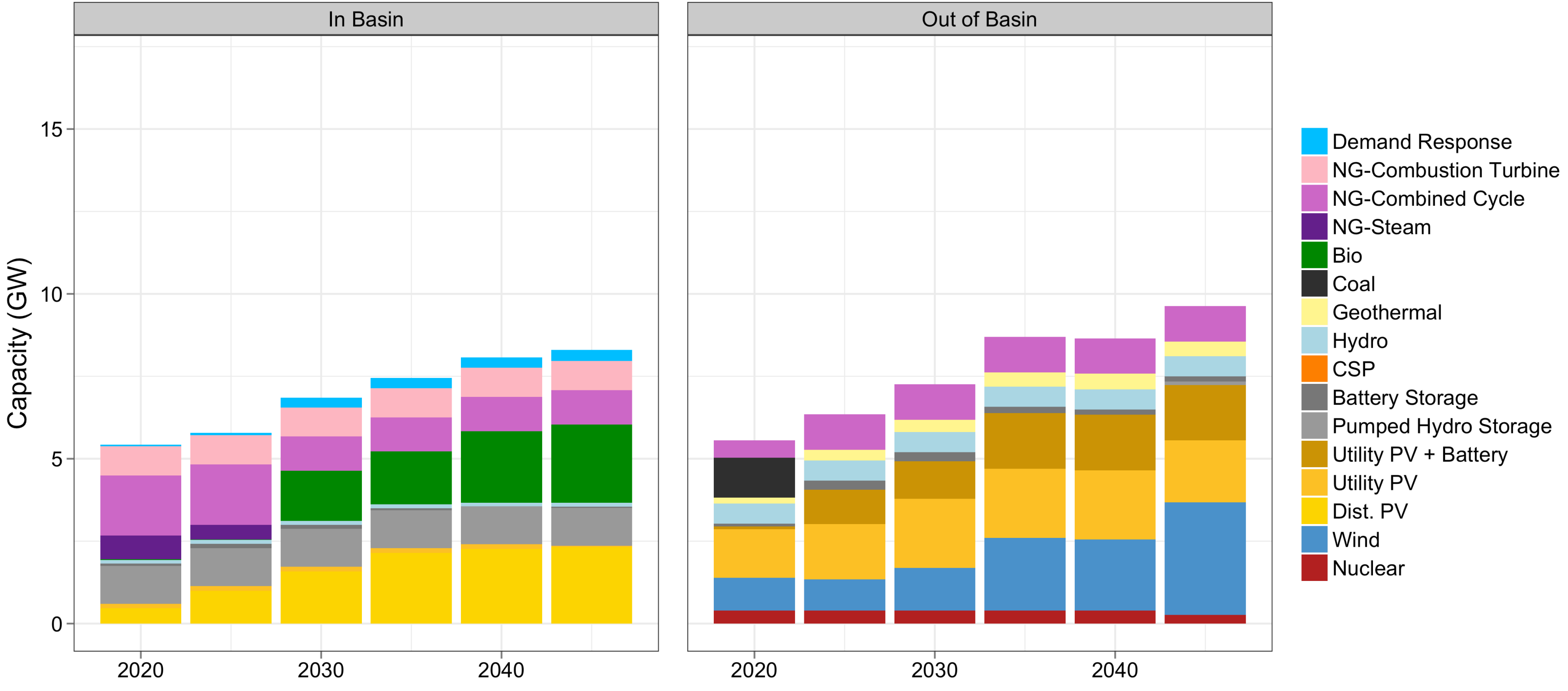


Initial Run – For Discussion Purposes Only; Subject to Change

Initial Run, Capacity: SB100 and Transmission Renaissance

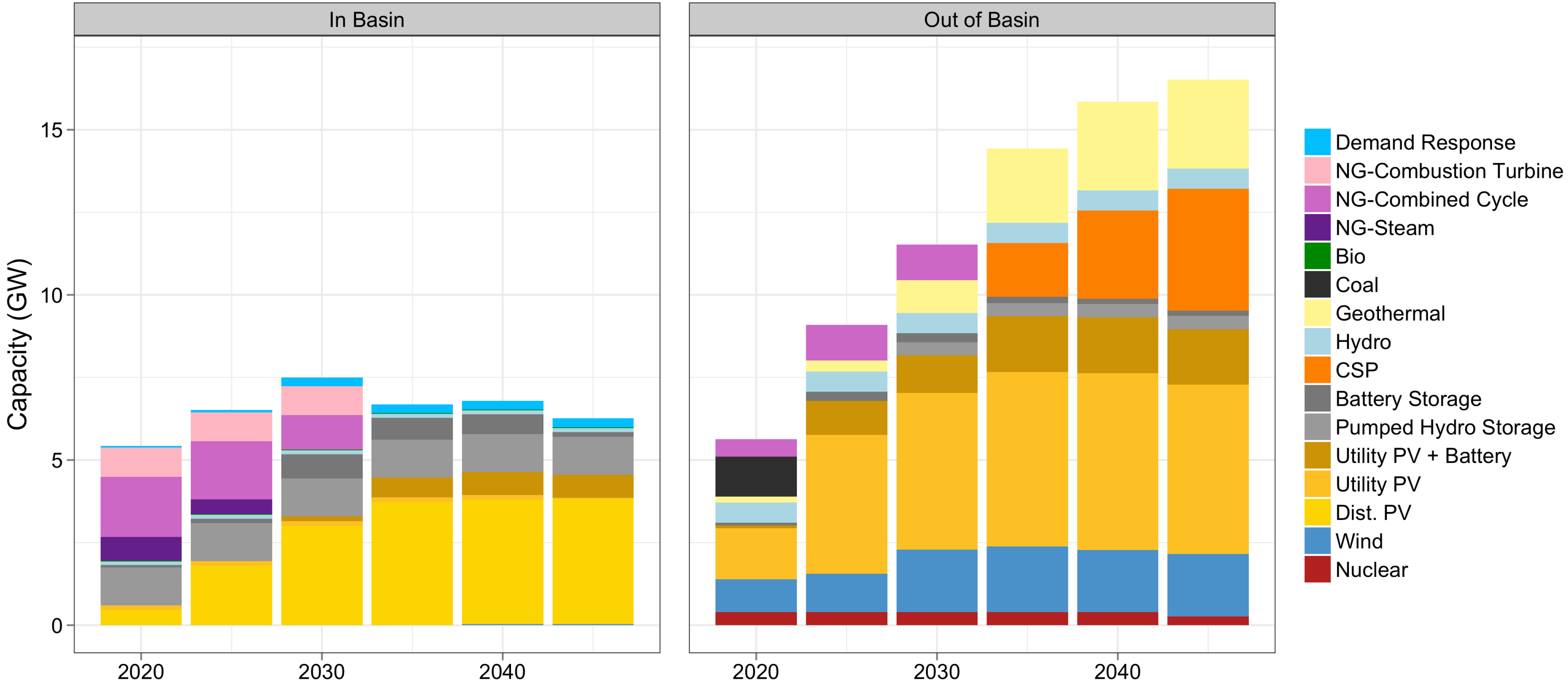


Initial Run Insights: **High Stress**, Basin-Level Capacity



Initial Run – For Discussion Purposes Only; Subject to Change

Initial Run Insights: **LA Leads**, Basin-Level Capacity



Initial Run – For Discussion Purposes Only; Subject to Change

Summary: Renewable Resources

- **Substantial investment in new renewable resources** will be required to meet the target
- **Wind and PV are built across all scenarios**
- Scenarios that do not allow generation from natural gas and/or biofuel require either **non-variable renewable generation** (such as geothermal) or **longer-duration storage**

Preliminary Insights

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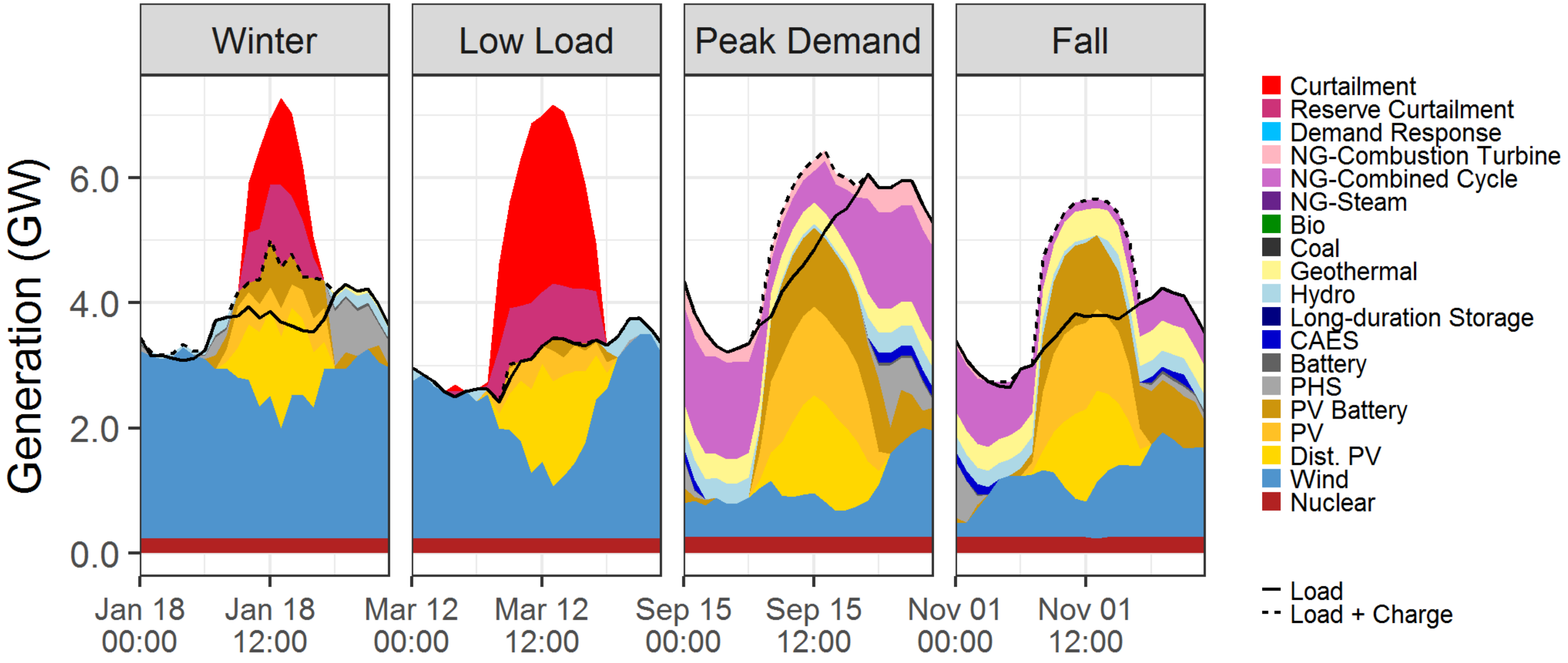
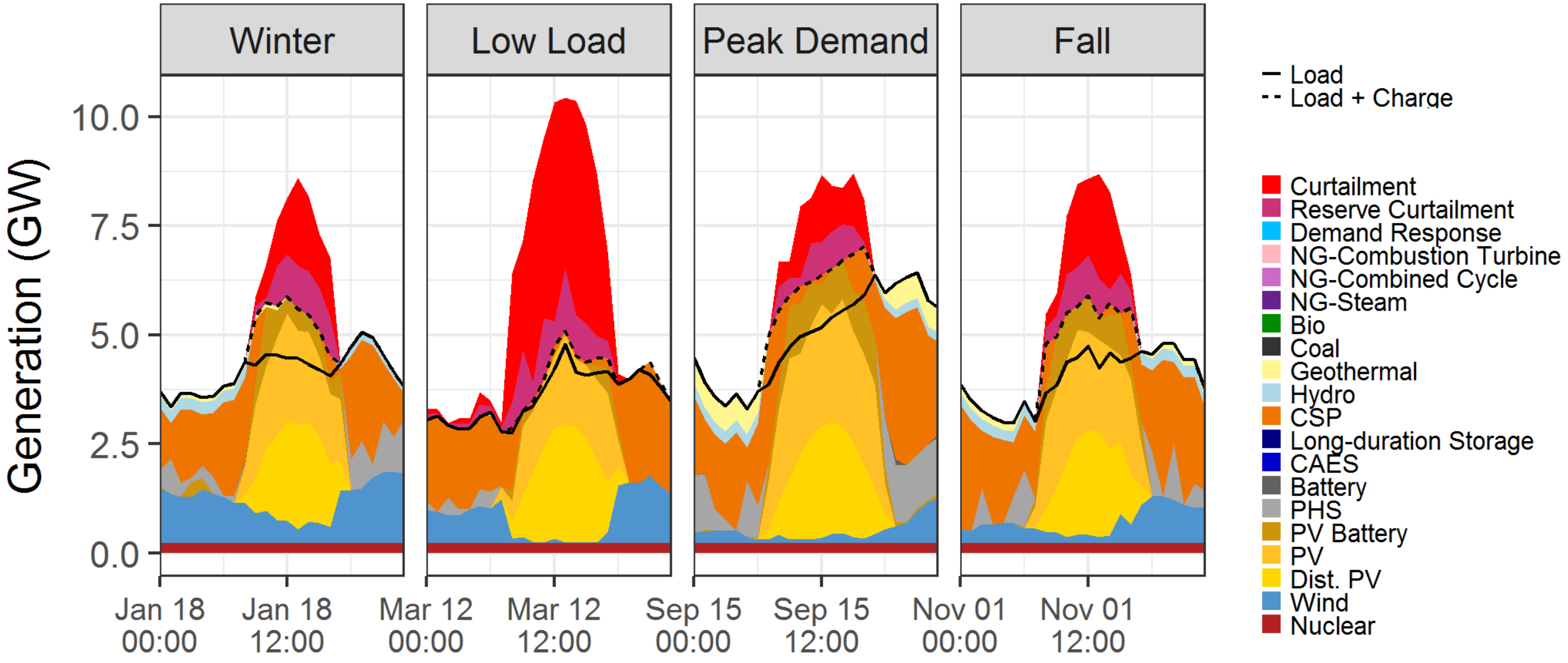
Initial Run, **SB100**: Curtailment largely during low-load and high resource quality days



Initial Run – For Discussion Purposes Only; Subject to Change

Initial Run, **LA Leads**: Higher penetrations of solar capacity leads to substantially greater levels of curtailment



Initial Run – For Discussion Purposes Only; Subject to Change

Summary: Curtailment

- In cases that do not allow contributions from natural gas or biofuel, further “overbuilding” of solar photovoltaic capacity leads to **higher rates of curtailment**
- Trade-offs between:
  - Overbuilding and curtailing variable generation
  - Storage
  - Non-variable renewable resources
  - Transmission

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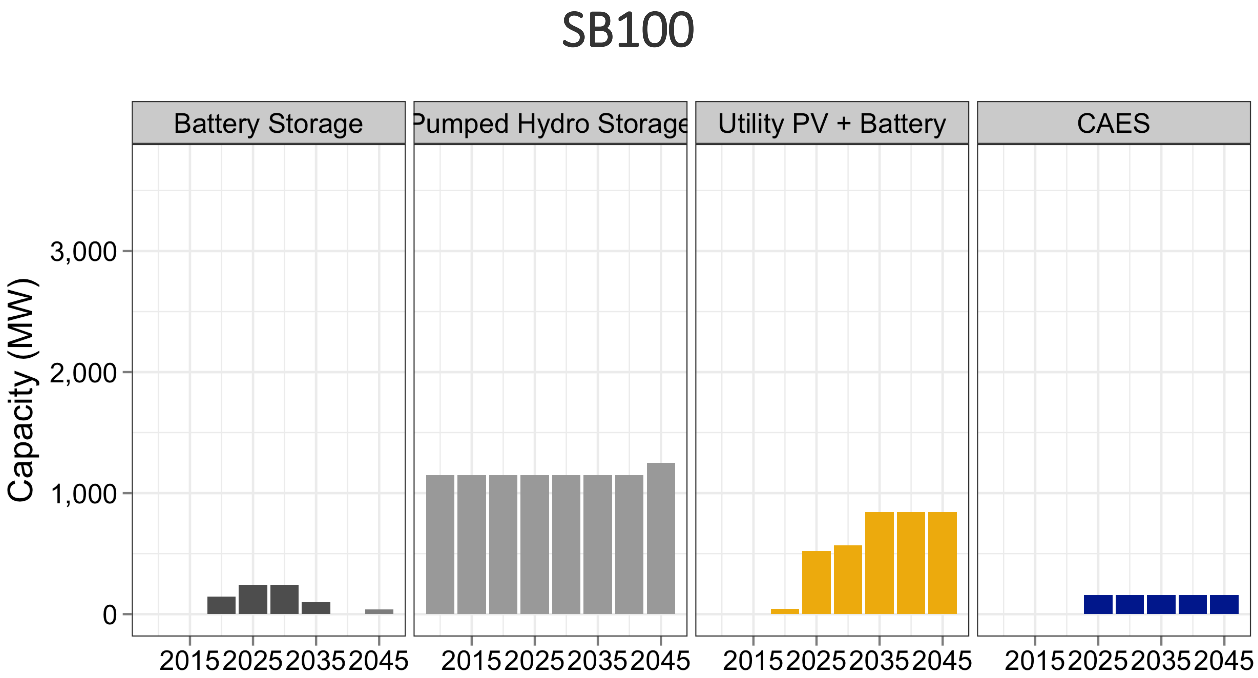
Storage is crucial to all scenarios



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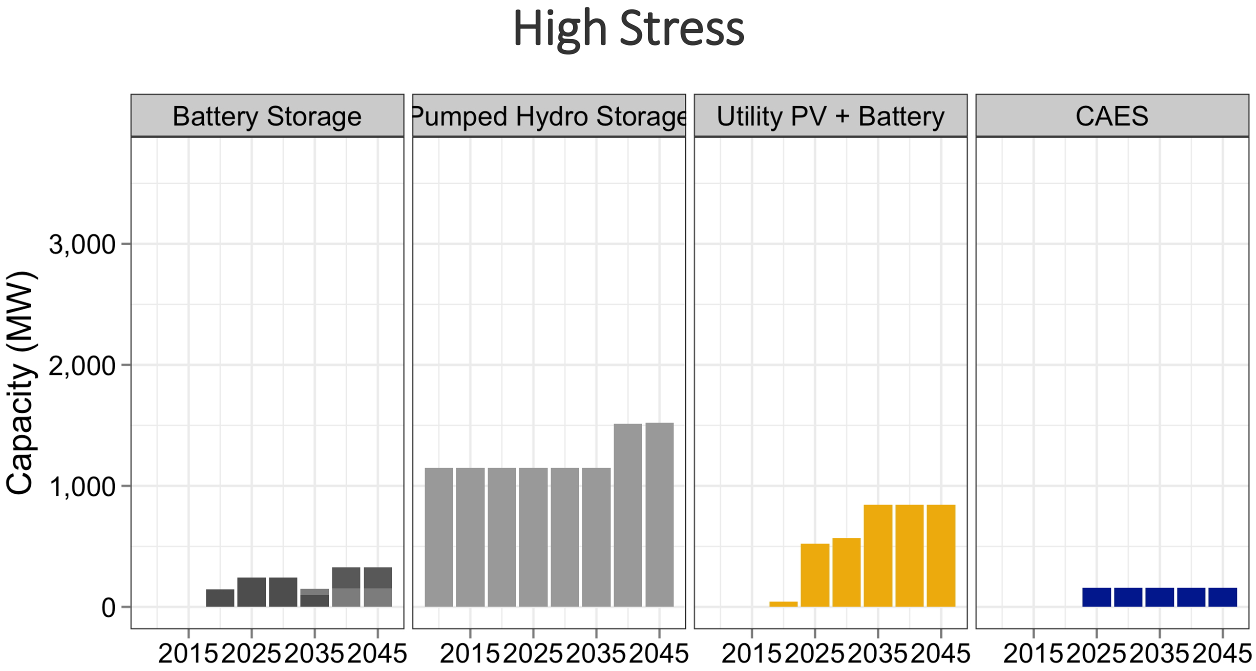

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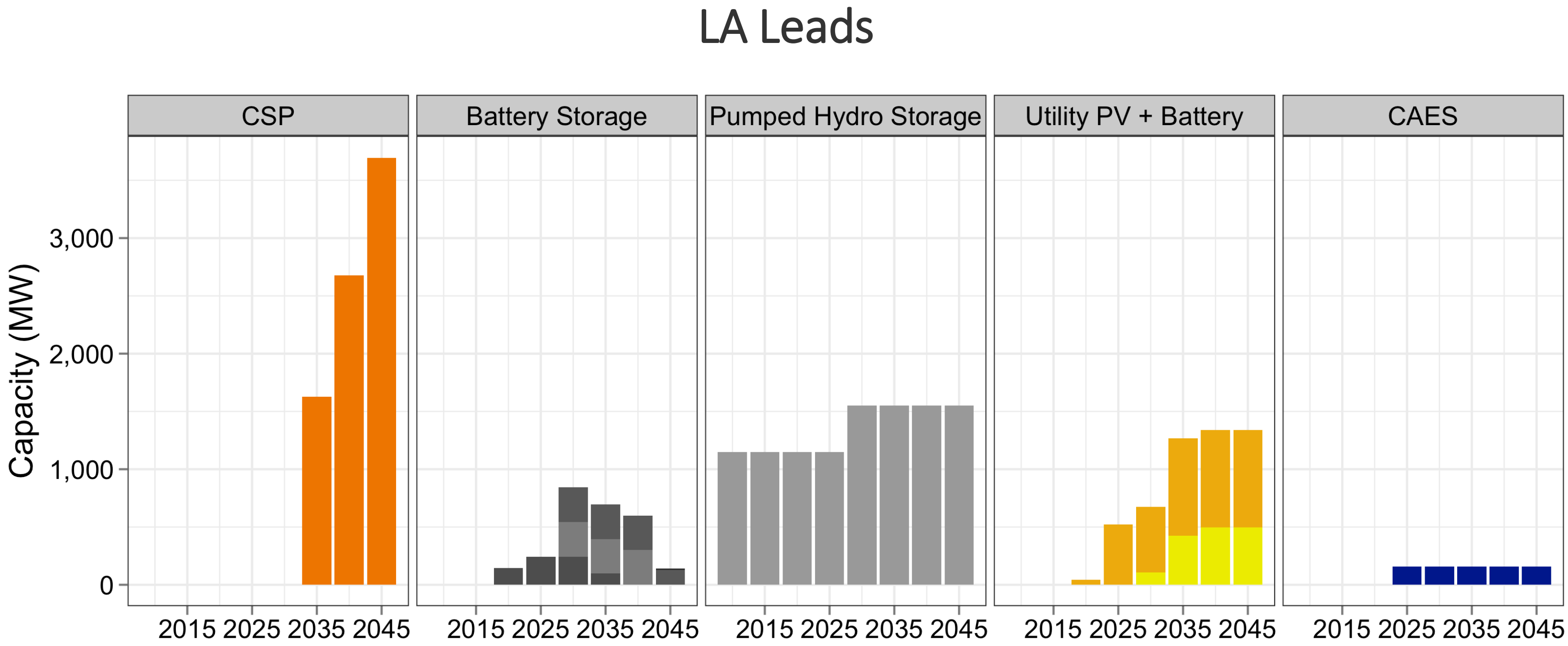
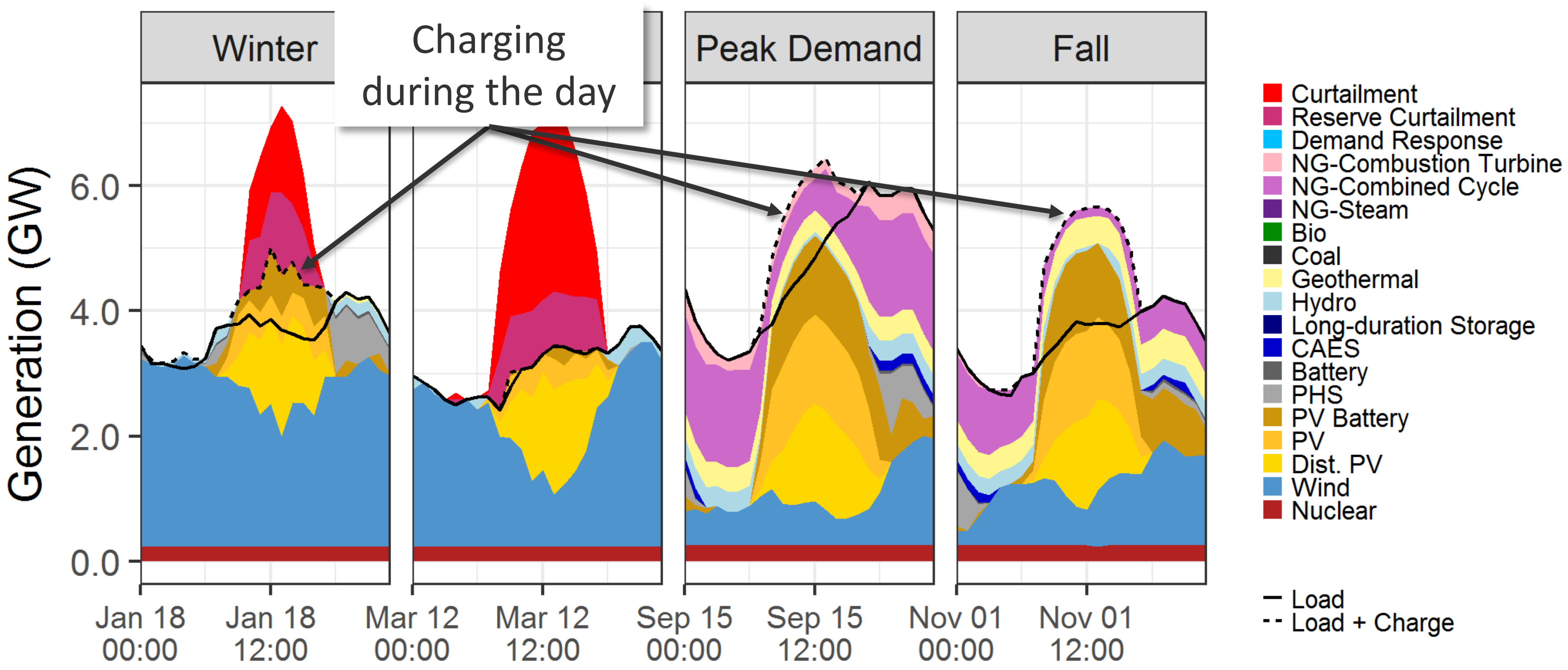


Initial Run – For Discussion Purposes Only; Subject to Change

Initial Run, **SB100**: Storage—Battery, PV+battery, pumped storage, CAES used to shift excess renewable generation



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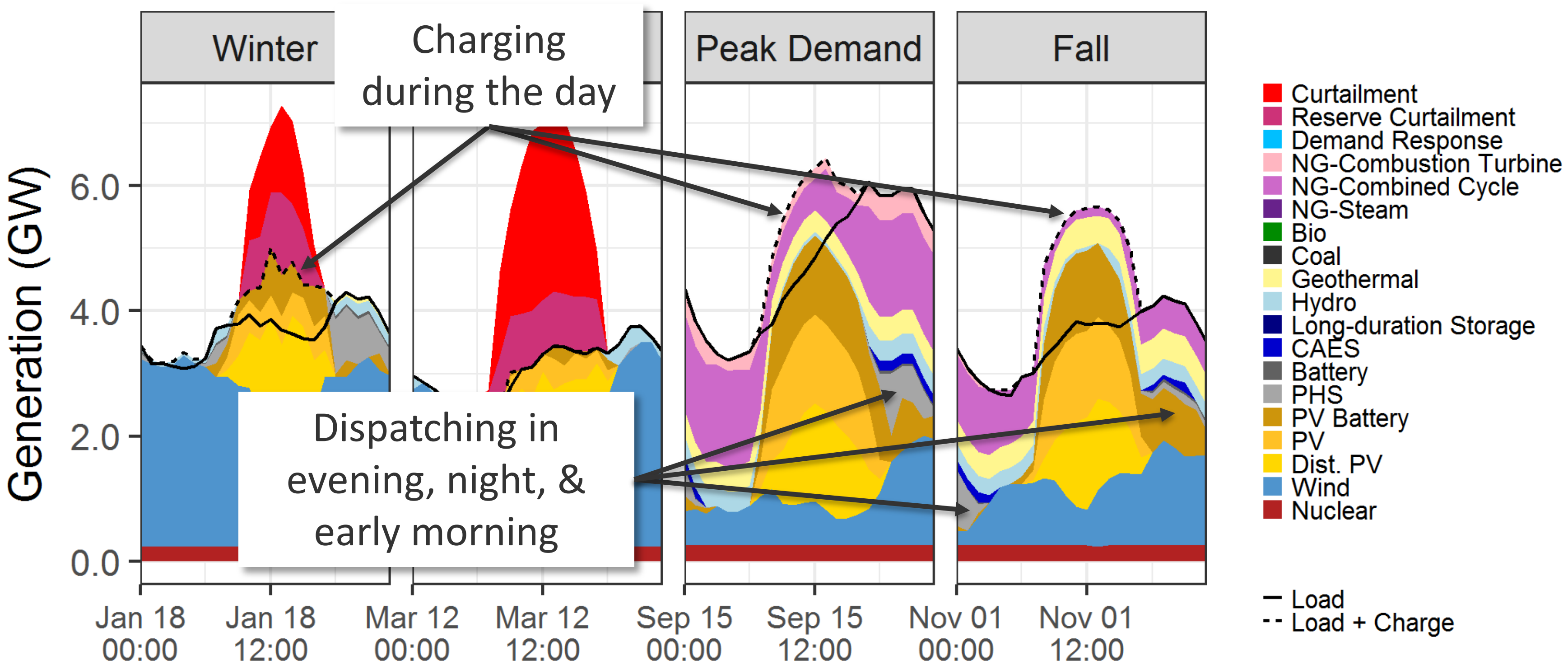
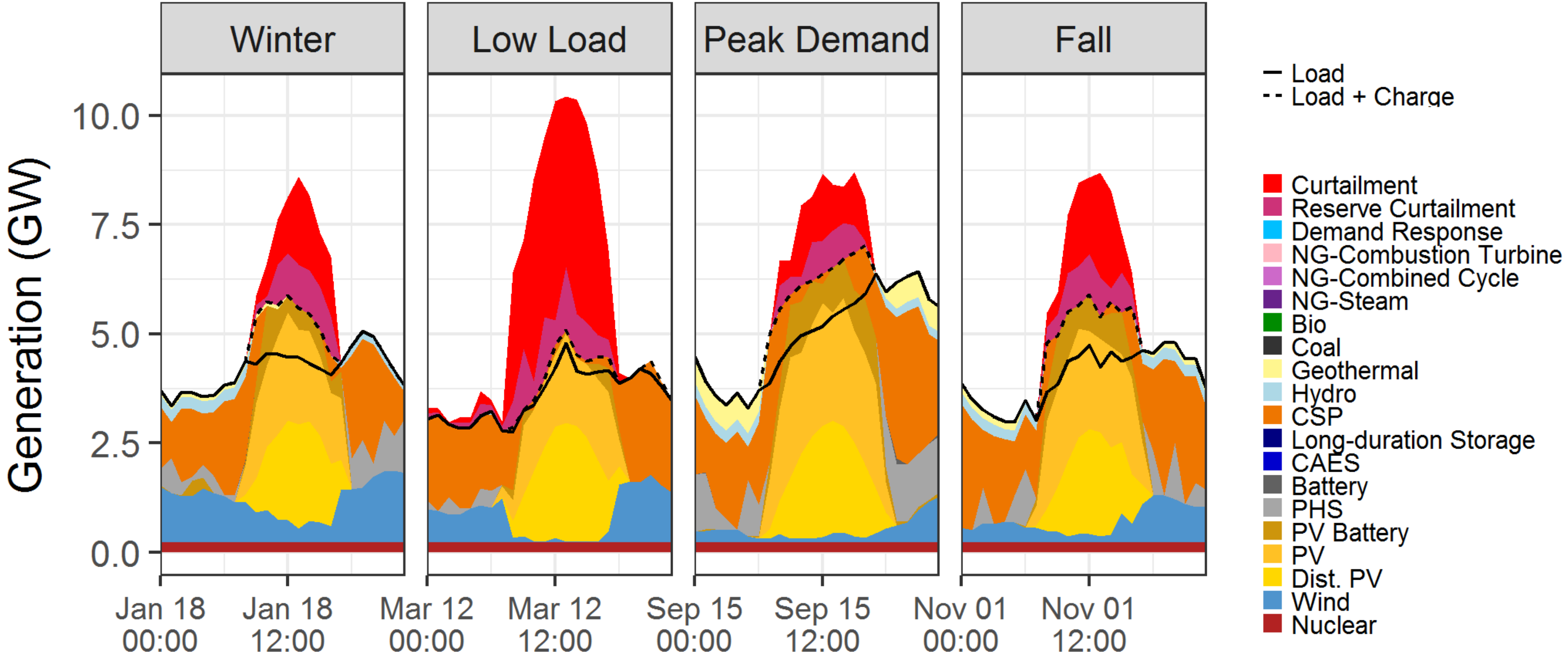


Initial Run – For Discussion Purposes Only; Subject to Change

Initial Run, **LA Leads**: CSP with 8-hour storage is used to serve a substantial portion of energy during night hours



Battery siting within the city could pose challenges

Summary: Storage

- The **lowest-cost** options (on a levelized basis) to produce renewable energy are **wind and PV technologies**
- These technologies have **variable resources** and therefore do not always produce energy when it is needed
- **Storage allows re-dispatch** of the variable energy
- Under scenarios that do not allow contributions from natural gas or biofuel, **longer-duration storage becomes more valuable**
- **Storage siting in-basin** could present challenges

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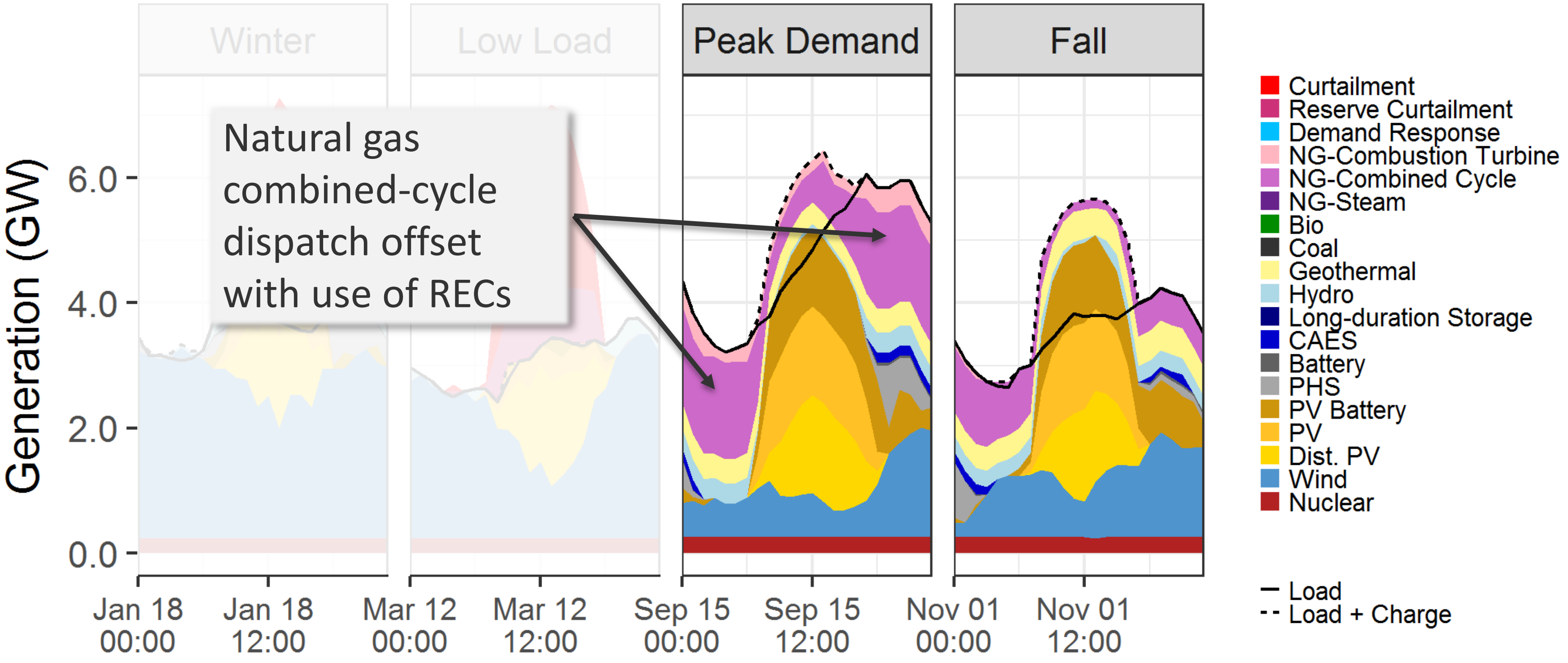
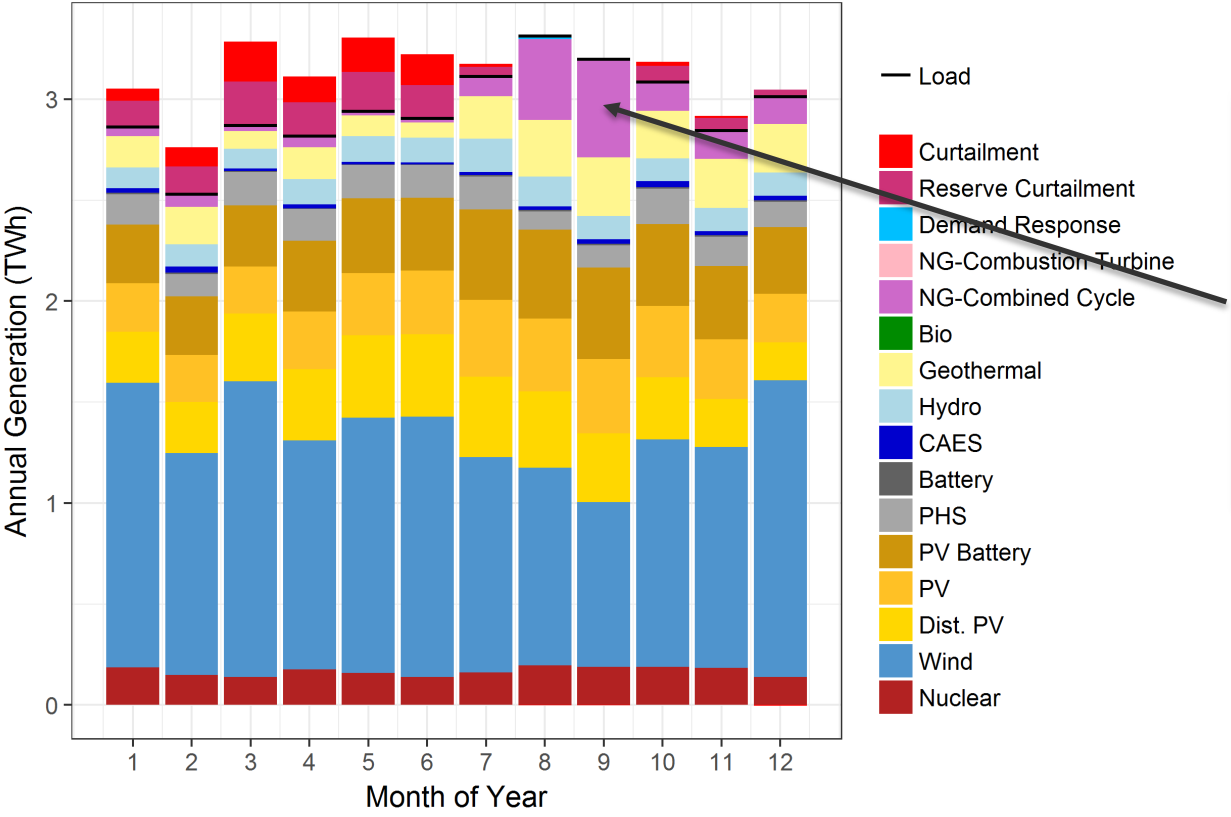
Initial Run: Eligibility of RECs allows use of existing in-basin natural gas generation during times stress or low renewable resource



Initial Run – For Discussion Purposes Only; Subject to Change

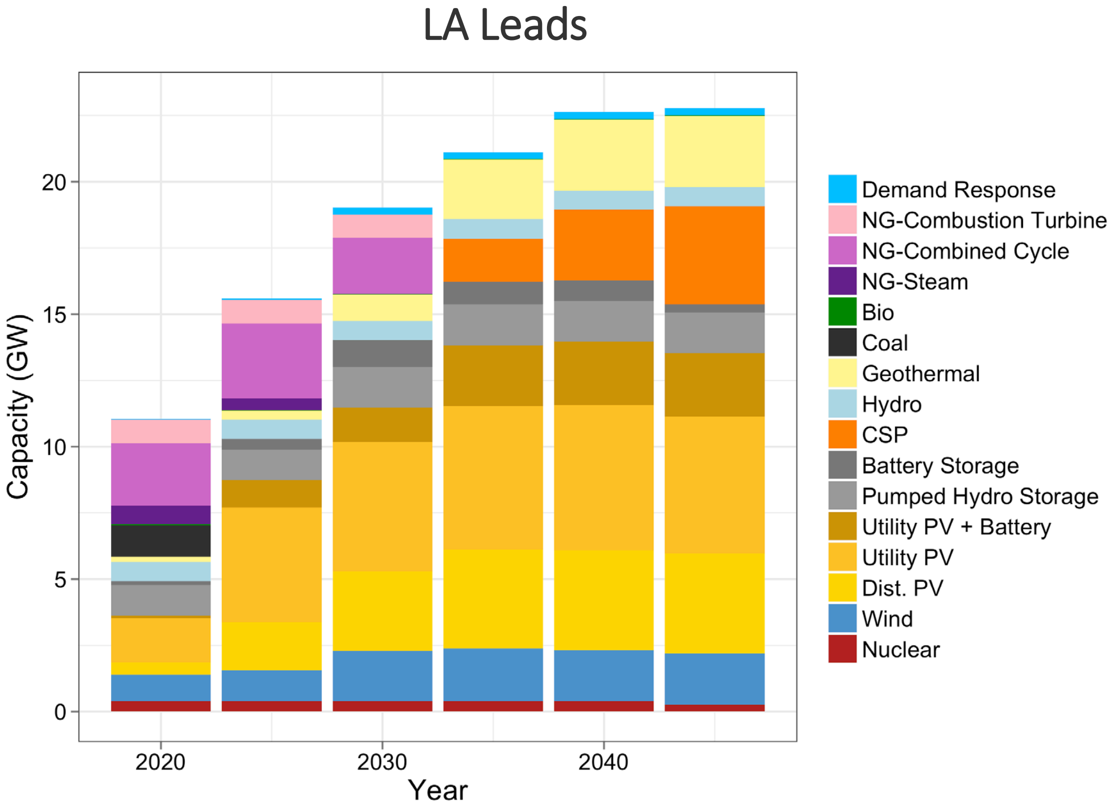
Initial Run, **SB100**: Natural gas combined-cycle accounts for ~6% of total generation



Substantial contributions during peak months, but overall usage is minimal over the year

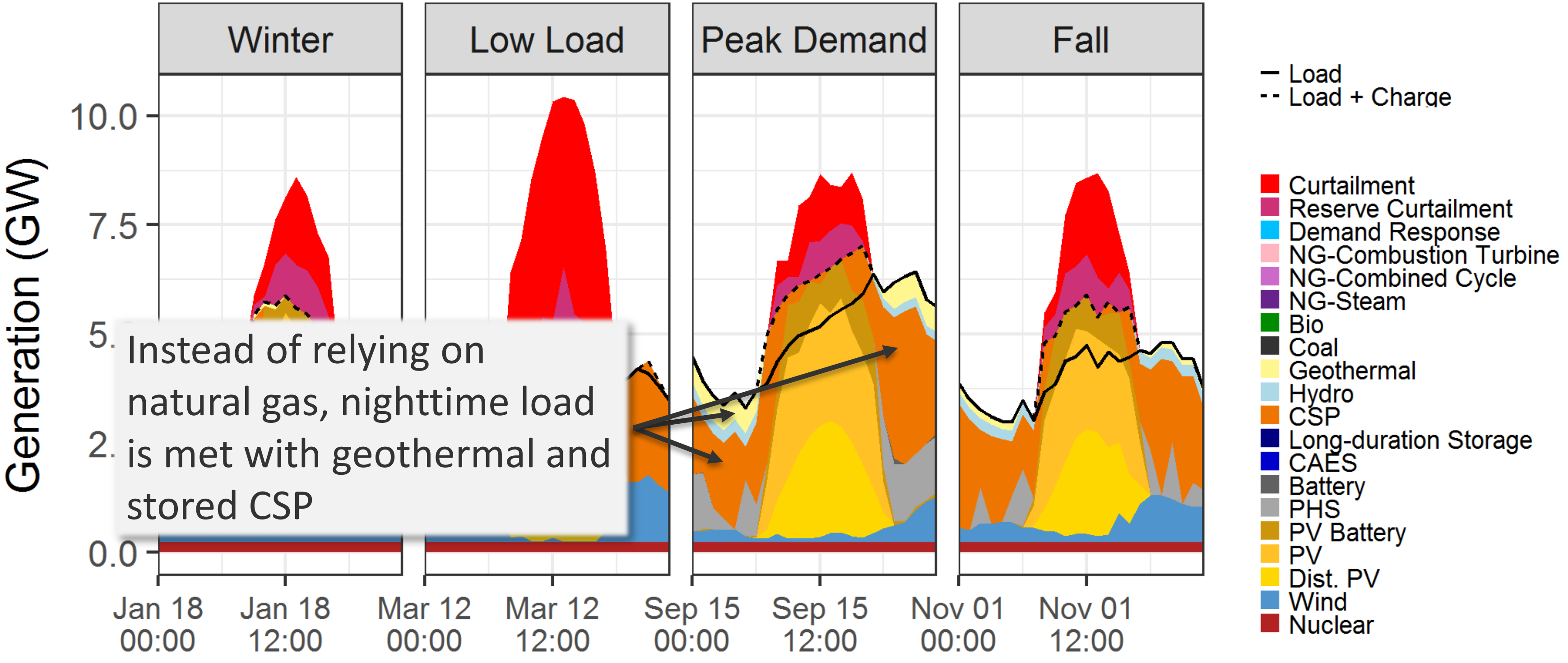
Initial Run – For Discussion Purposes Only; Subject to Change

Restricting the eligibility of natural gas and biomass requires reliance on storage and other dispatchable renewable generation



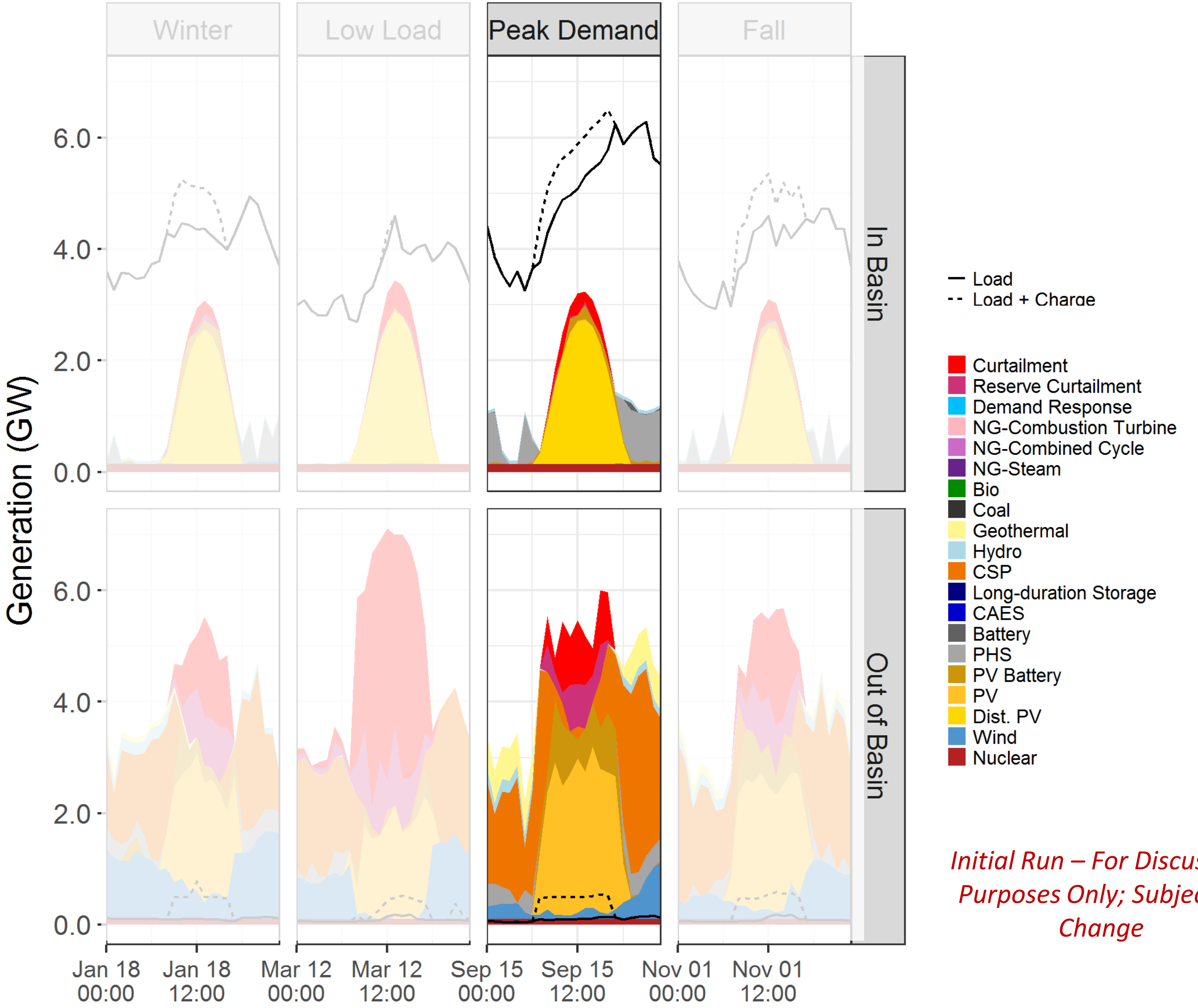
Initial Run – For Discussion Purposes Only; Subject to Change

Initial Run, **LA Leads**: Morning, evening, and night hours met with wind, storage, and geothermal



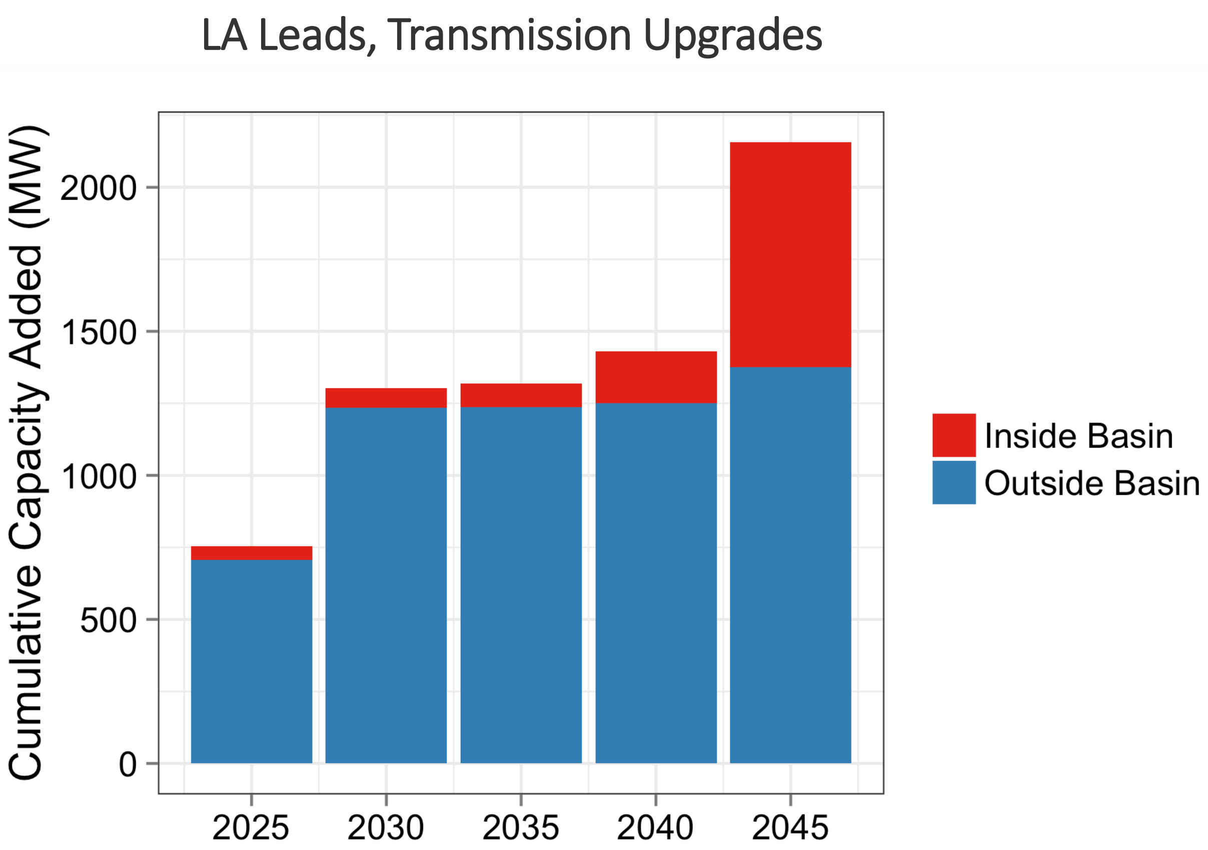
Initial Run – For Discussion Purposes Only; Subject to Change

Initial Run, **LA Leads**: Relying on a greater share of out-of-basin storage resources during morning, evening, night hours



Initial Run – For Discussion Purposes Only; Subject to Change

Initial Run, *LA Leads*: Greater reliance on out-of-basin resources requires more out- and in-basin transmission



Initial Run – For Discussion Purposes Only; Subject to Change

Summary: RECs

- RECs and associated natural gas generation:
  - Provide energy during times of **stress** (e.g., high load) and during times of **low renewable resource quality**
  - **Reduce the amount of higher-cost dispatchable renewable generation or storage** (e.g., bio, geothermal, 8-hour storage)

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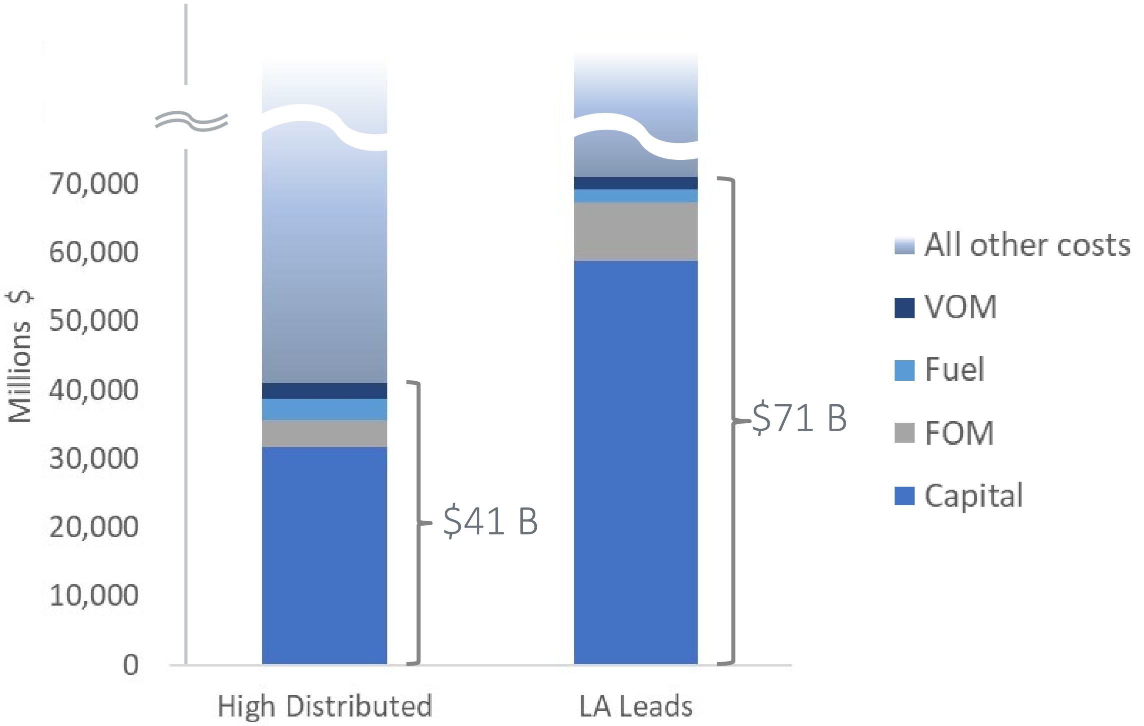
6. **Changes in the eligibility of compliance options can have substantial implications for total costs**

Initial Run Insights: Bulk system costs

Differences in technology eligibility and other scenario requirements lead to differences in bulk generation and transmission costs: **>30% increase in bulk system costs (2021–2045) from Highly Distributed to LA Leads**

Not including:
+ Debt-service on existing capacity
+ Distribution O&M
+ Distribution system upgrades
+ Distributed PV
+ Efficiency and DR program costs

2021-2045 Generation and Transmission Costs



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Summary

- **Substantial renewable energy additions** both within and outside of the LA basin are required to achieve the 100% target irrespective of the pathway
- **Storage plays a critical role** in shifting variable generation diurnally
- In the absence of eligibility of RECs (and associated natural gas generation), **dispatchable capacity** (bio, mid-to long duration storage) is highly valuable
- Although substantial transmission capacity is available to carry energy into the basin, in the absence of mitigating options, **longer-duration transmission outages** (both in- and out-of-basin) **could be challenging**
- Changes in the **eligibility of compliance options** can have substantial implications for total costs

Summary (continued)

- Results may change substantially
- Why?
  - Load will change substantially
  - Continuing to refine representation of the transmission system
  - Only have completed test runs of power flow
  - Will be further analyzing both short- and long-run duration outages
  - Continuing to refine resource constraints and cost assumptions

Questions?

The Los Angeles 100% Renewable Energy Study

Distribution Grid Analyses

All Scenarios

Preliminary 4.8kV Distribution Insights

1. Aggressive rooftop solar requires more widespread upgrades, but only for a minority of feeders
2. Rooftop solar adoption seems to have a larger impact than load difference on distribution upgrade needs

Caveats:

- *Modeled load data will change for Final Run*
- *Estimated rooftop solar adoption will change for Final Run*

DG and Load Are Key Differentiators for Distribution Analyses

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	Biogas	Y	No	Y	Y	Y	No	Y	Y	Y
	Electricity to Fuel (e.g. H2)	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Fuel Cells	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Hydro - Existing	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Hydro - New	N	N	N	N	N	N	N	N	N
	Hydro - Upgrades	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Natural Gas	Yes	N	N	N	Yes	N	N	N	Yes
	Nuclear - Existing	Y	Y	No	No	Y	Y	No	No	Y
	Nuclear - New	N	N	N	N	N	N	N	N	N
	Wind, Solar, Geo	Y	Y	Y	Y	Y	Y	Y	Y	Y
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Preliminary 4.8kV Distribution Insights

1. **Aggressive rooftop solar requires more widespread upgrades, but only for a minority of feeders**

2. Rooftop solar adoption seems to have a larger impact than load difference on distribution upgrade needs

Caveats:

- *Modeled load data will change for Final Run*
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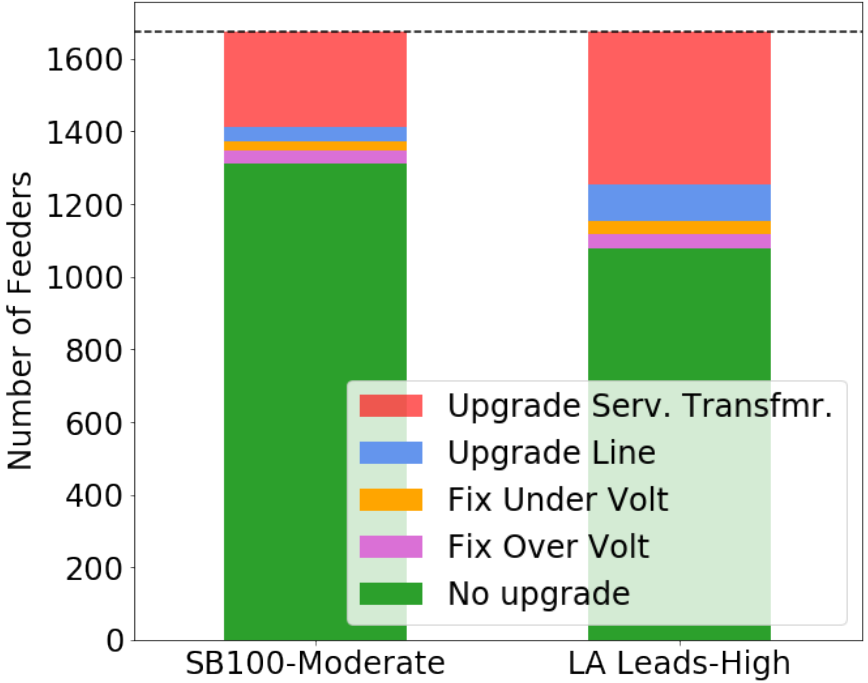
Aggressive DG requires more upgrades, but only for a minority of feeders

4.8kV-only, 2045

Most common upgrade needs with Load+Solar



Upgrades Required:

- SB100: **22%** of feeders
- LA Leads: **36%** (highest)

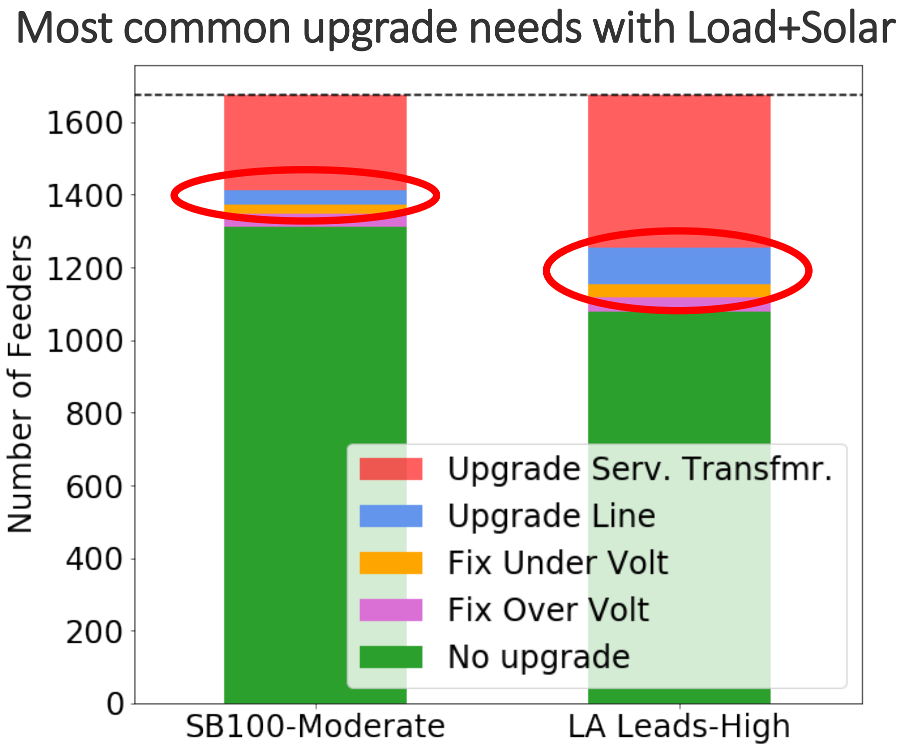
Most common upgrade (for both):

- Service transformer ($-$$)

Initial Run – For Discussion Purposes Only; Subject to Change

Aggressive DG requires more upgrades, but only for a minority of feeders

4.8kV-only, 2045



Upgrades Required:

- SB100: **22%** of feeders
- LA Leads: **36%** (highest)

Most common upgrade (for both):

- Service transformer ($-$$)

However, considerably more feeders need line upgrades ($$$+) with increased rooftop solar

Preliminary 4.8kV Distribution Insights

1. Aggressive rooftop solar requires more widespread upgrades, but still only for a minority of feeders

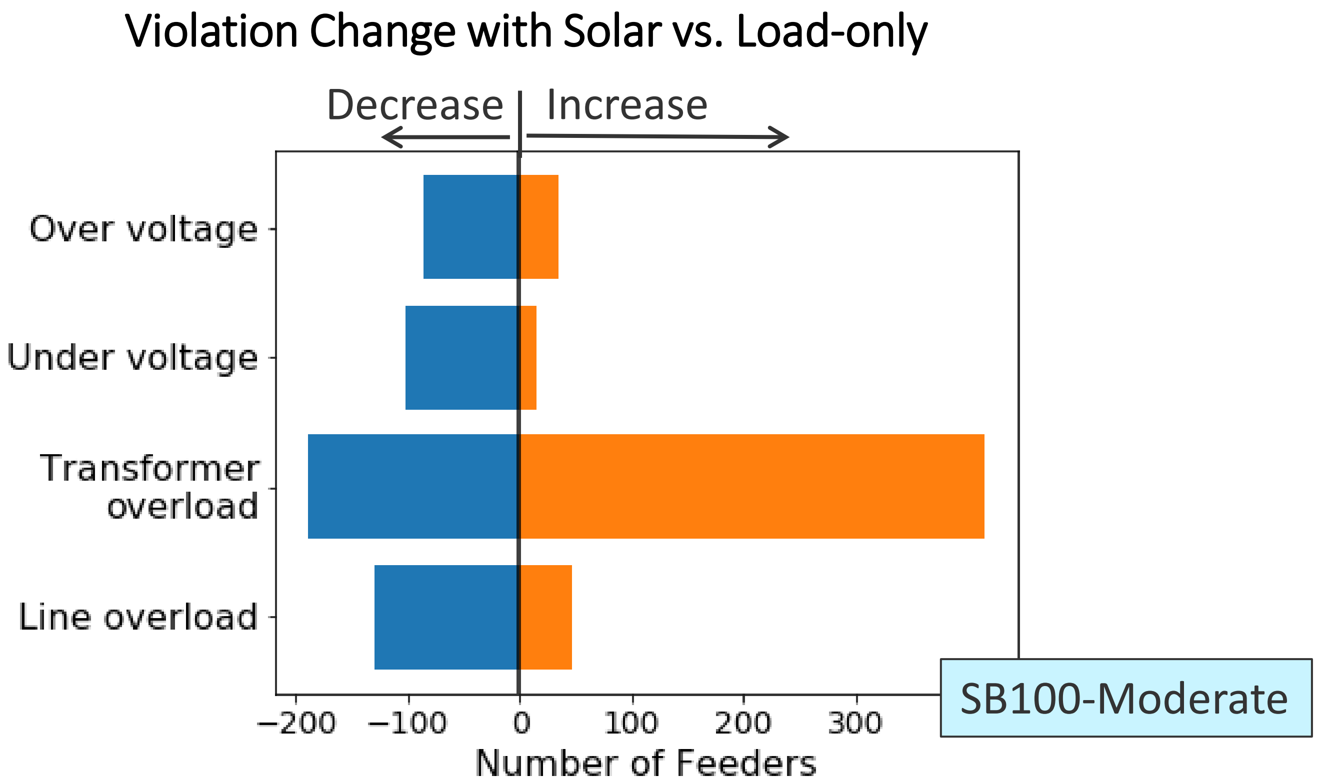
2. Rooftop solar adoption seems to have a larger impact than load difference on distribution upgrade needs

Caveats:

- *Modeled load data will change for Final Run*
- *Estimated rooftop solar adoption will change for Final Run*

Reminder: Solar may help or hurt distribution impacts compared to load alone

4.8kV-only, 2045



Initial Run – For Discussion Purposes Only; Subject to Change

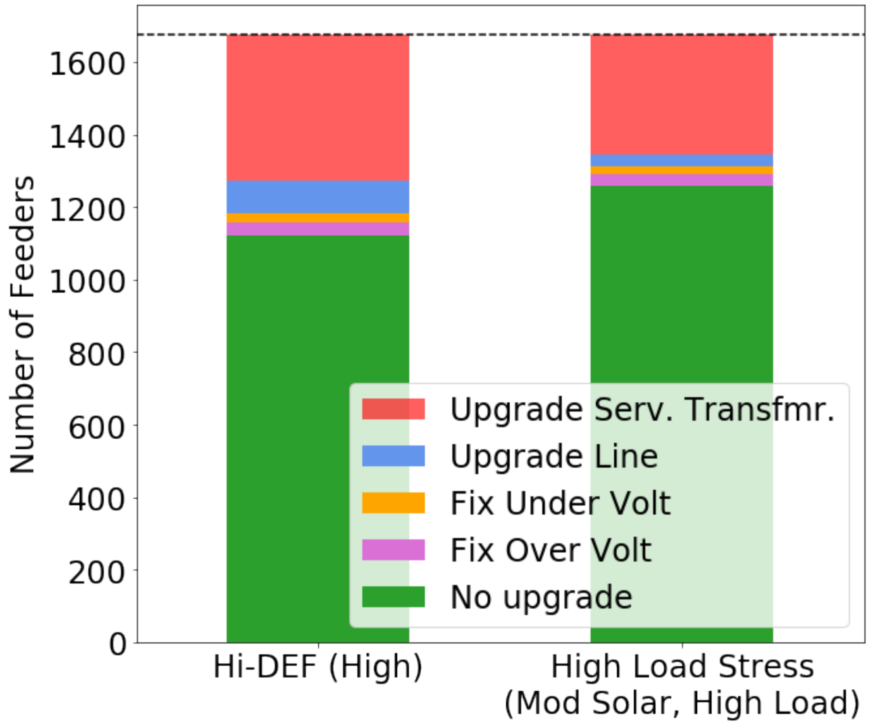
Not much difference in upgrades even with very high load levels

4.8kV-only, 2045

Upgrades Required:

- SB100: **22%** of feeders
  - Load: Mod., Solar: Mod.
- High Load Stress: **25%**
  - Load: Very High, Solar: Mod.

Most common upgrade needs with Load+Solar



Initial Run – For Discussion Purposes Only; Subject to Change

But even with (somewhat) lower loads, a switch to high rooftop solar makes a big difference

4.8kV-only, 2045

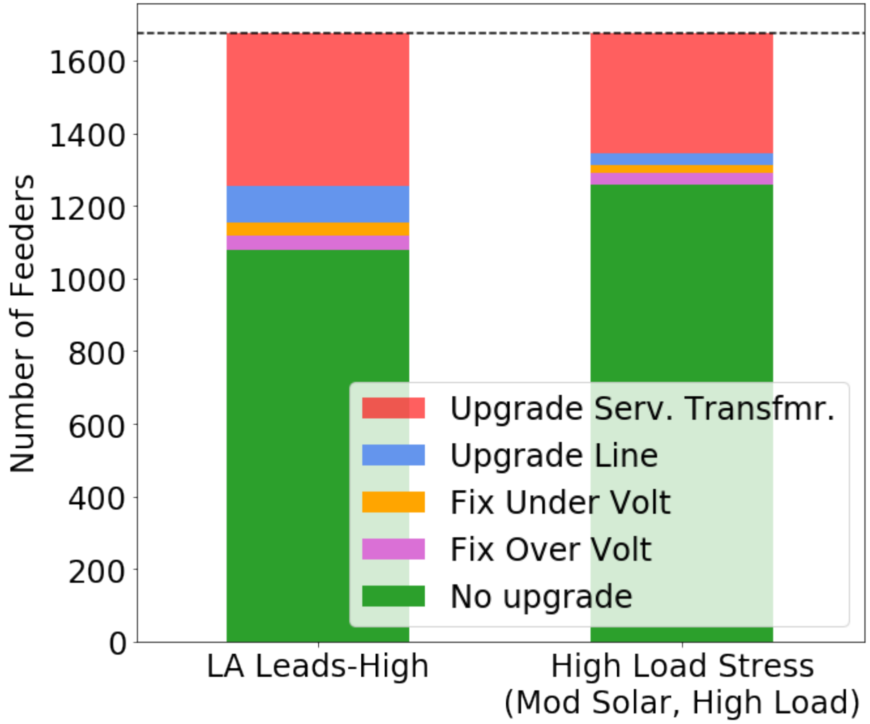
Upgrades Required:

- SB100: **22%** of feeders
  - Load: Mod., Solar: Mod.
- High Load Stress: **25%**
  - Load: Very High, Solar: Mod.
- Highly Distributed Energy Future (Hi-DEF): **33%**
  - Load: High, Solar: High

Line upgrades ($$$+) more common with increased solar (vs. load-only), but for fewer feeders than need transformer upgrades

- SB100: **2.2%**, High Load Stress: **1.8%**
- Hi-DEF: **5.3%**

Most common upgrade needs with Load+Solar



Initial Run – For Discussion Purposes Only; Subject to Change

Preliminary 4.8kV Distribution Insights

1. Aggressive rooftop solar requires more widespread upgrades, but still only for a minority of feeders

2. Rooftop solar adoption seems to have a larger impact than load difference on distribution upgrade needs

Caveats:

- *Modeled load data will change for Final Run*
- *Estimated rooftop solar adoption will change for Final Run*

Questions?

Initial Run: Impacts–Environment Analysis

Input models

What is electricity demand and customer-driven supply?

- Electricity demand
- Demand response
- RE resource analysis
- Customer-driven solar

Main scenario model

What should LADWP build?

- Generation
- Transmission
- Distribution upgrades

Output and validation models

How do we know it's right?

- Load balancing
- Resource adequacy
- Power flow and stability analysis
- Integrated distribution and transmission analysis

Impact models

What are the impacts?

- Economic and workforce analysis
- Environmental analysis

Greenhouse Gas (GHG) Emissions

Purpose within LA100

How do the scenarios compare in terms of lifecycle GHG emissions?

Greenhouse Gas Emissions Analysis

Methodology

- Life cycle GHG emissions from all four life cycle phases, not just combustion
- Literature-sourced, phase-specific emissions factors for each technology

Assumptions

- Electric sector only; does not consider other GHG emissions (e.g., vehicles, buildings)
- Does not consider GHG emissions from other electric infrastructure (e.g., transmission lines, distribution lines, substations)

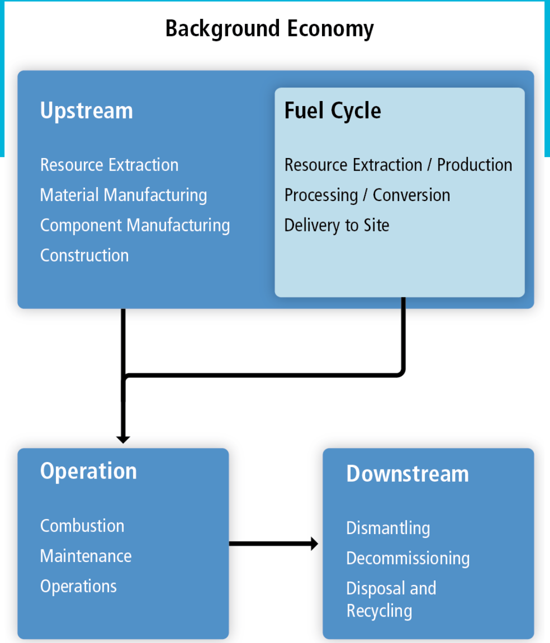
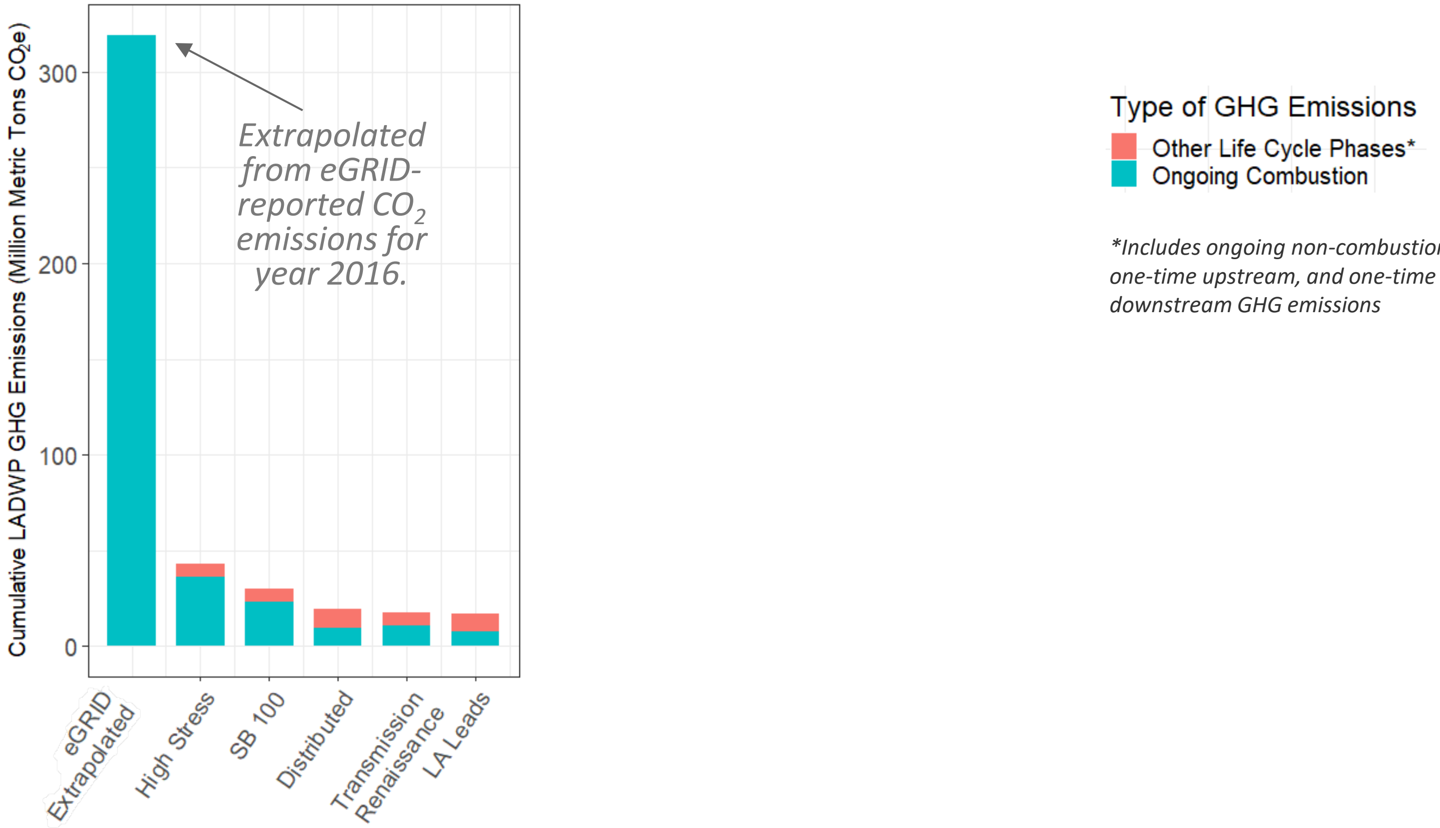


Figure from: Sathaye, J., Lucon, O., Rahman, A., Christensen, J., Denton, F., Fujino, J., ... & Shmakin, A. (2011). Renewable energy in the context of sustainable development.

Life Cycle GHG Emission Phase	Examples	Relevant Metric	Combustion-Only GHG Analysis	Full Life Cycle GHG Analysis
1) Ongoing **combustion**	CO_2 from fuel burned in a power plant	Fuel burn (BTU)	✓	✓
2) Ongoing **non-combustion**	Extraction of fossil fuel (e.g. NG); plant O&M	Generation (MWh)	X	✓
3) One-time **upstream**	Building a new power plant	Capacity (MW)	X	✓
4) One-time **downstream**	Decommissioning an old power plant	Capacity (MW)	X	✓

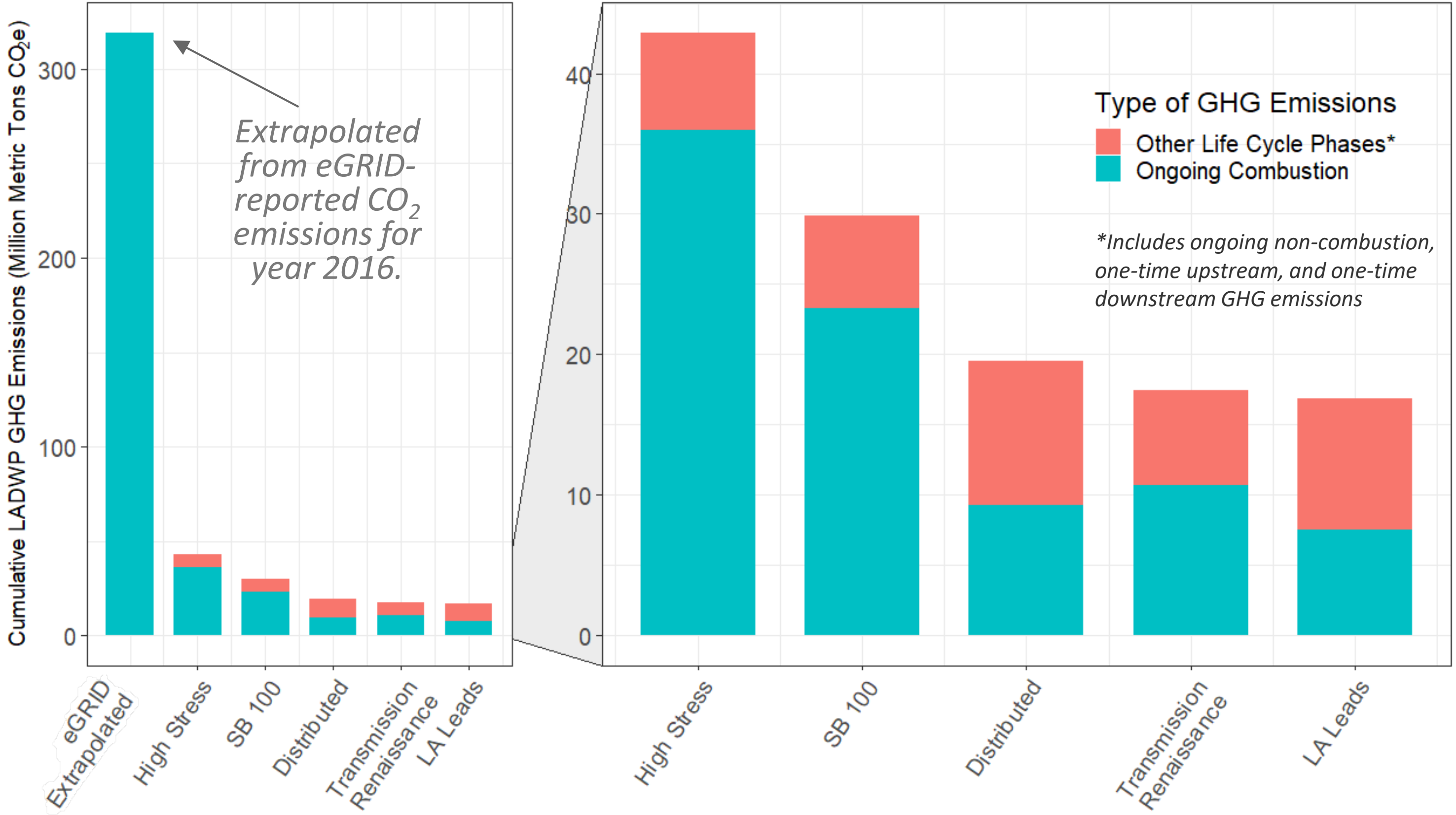
Initial Run: Cumulative LADWP Lifecycle GHG Emissions, 2020–2045



**Includes ongoing non-combustion, one-time upstream, and one-time downstream GHG emissions*

Initial Run – For Discussion Purposes Only; Subject to Change

Initial Run: Cumulative LADWP Lifecycle GHG Emissions, 2020–2045



Coming Soon:

- GHG breakdown for each lifecycle phase
- GHG breakdown by generator/ fuel type
- GHG impacts from increased part-loading / startup / shutdown

Initial Run – For Discussion Purposes Only; Subject to Change

Environmental Justice (EJ)—Technology Deployment

Rooftop Solar Deployment

Purpose within LA100

How much of rooftop solar is being adopted in disadvantaged communities?

We compare rooftop solar adoption levels (installed capacity, MW) in EJ and non-EJ tracts in LADWP service territory

Initial Run (Today) vs. Final Run (June – Dec AG)

What's Included in Initial Run

EJ deployment:
Rooftop solar

What's Not Included Today But Will be in Final Run

EJ analysis of:

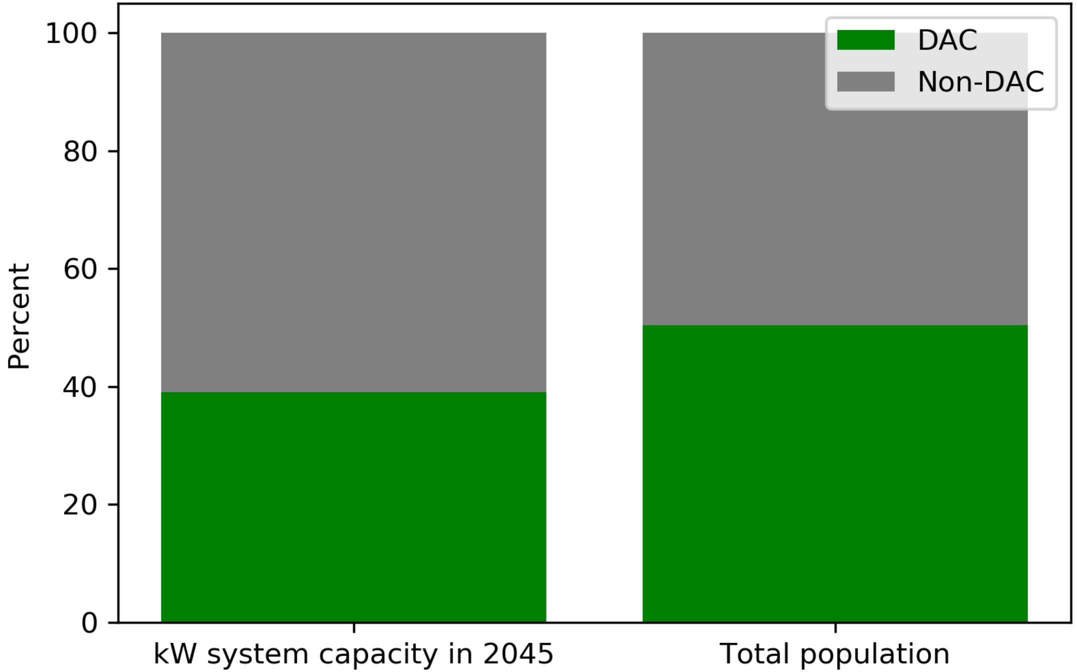
1. Air quality and public health
2. Deployment based on:
    - Energy use intensity in buildings
    - EV adoption and DC fast charging

Initial Run: EJ Deployment—Rooftop Solar by Population

39% of rooftop solar deployment is in Cal EnviroScreen-identified Disadvantaged Communities (DAC)

DAC represents **50%** of LADWP population

Share of rooftop solar in disadvantaged communities compared to share of population

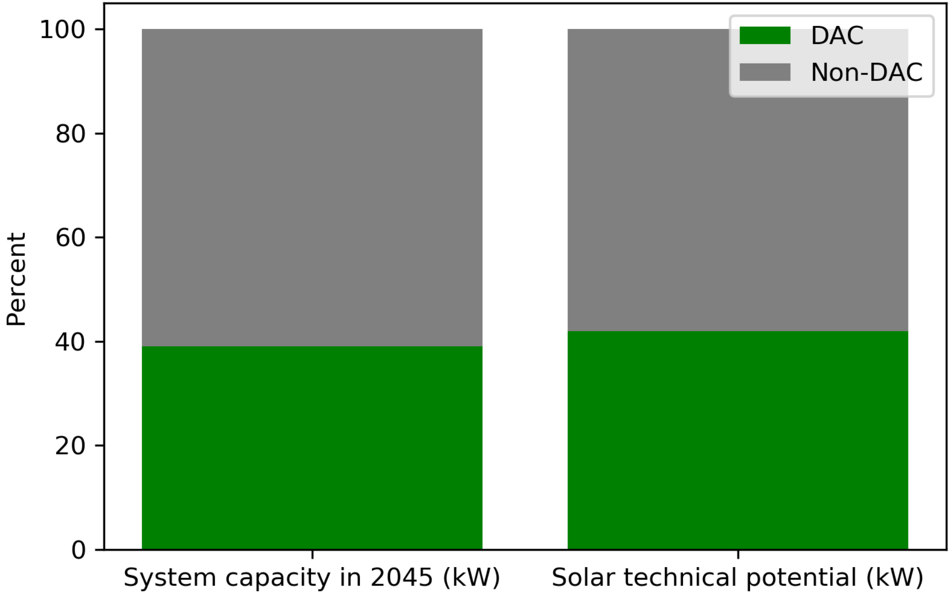


Initial Run – For Discussion Purposes Only; Subject to Change

Initial Run: EJ Deployment—Rooftop Solar by Technical Potential

39%: Share of **rooftop solar** in disadvantaged communities

42%: Share of **technical potential** in disadvantaged communities



Initial Run – For Discussion Purposes Only; Subject to Change

Upcoming AG Presentations

EJ analysis based on:

- Air quality
- Health improvements
- Deployment based on:
  - Energy use intensity in buildings
  - EV adoption and DC fast charging

Questions?

The Los Angeles 100% Renewable Energy Study