LA100

The Los Angeles 100% Renewable Energy Study

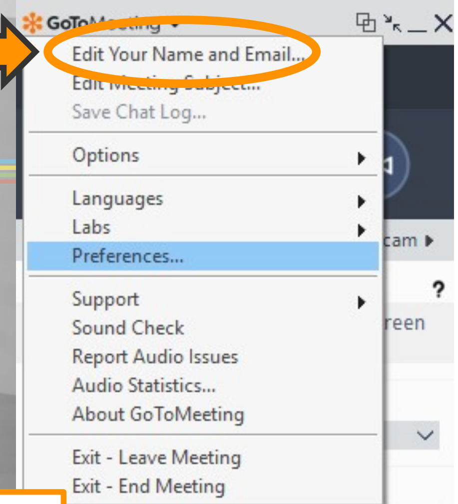
Advisory Group Meeting #12

Virtual Meeting #1

LA DWP 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 #12

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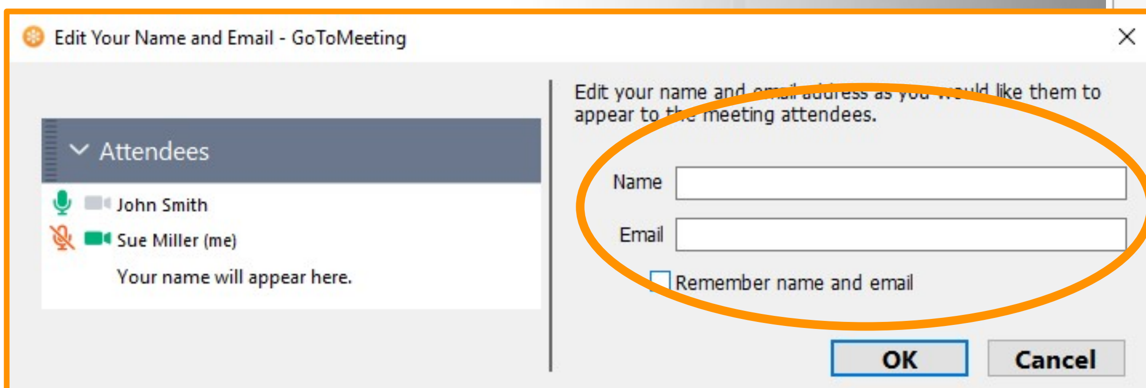


Los Angeles Department of Water & Power

NREL Transforming ENERGY

Agenda

Today (July 9)
- Welcome
- LA100 Scenarios—Pathways to 100% RE
- Discussion/Q&A

July 16
- Jobs and Economic Analysis
- Discussion/Q&A

July 23
- Environmental Analyses
- Discussion/Q&A

July 30
- Distribution Grid Analysis
- Discussion/Q&A

August 6
- Follow-up Q&A

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

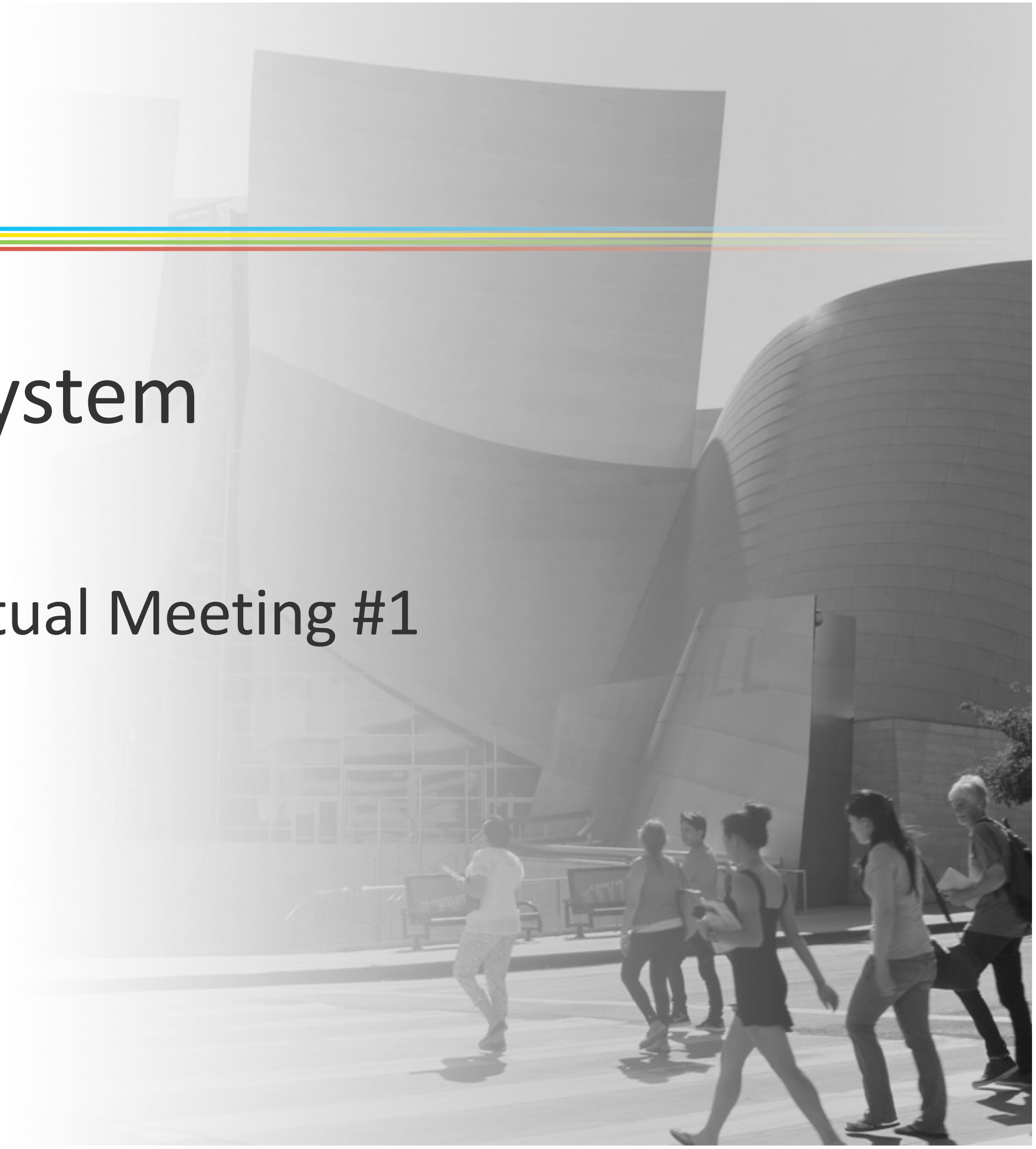
Hold questions until after presentations

LA100

The Los Angeles 100% Renewable Energy Study

LA100: Evaluating Bulk-System Pathways to 100% RE

Advisory Group Meeting #12, Virtual Meeting #1



Dan Steinberg & Bulk Power Team

National Renewable Energy Laboratory

July 9, 2020

Los Angeles Department of Water & Power | NREL Transforming ENERGY

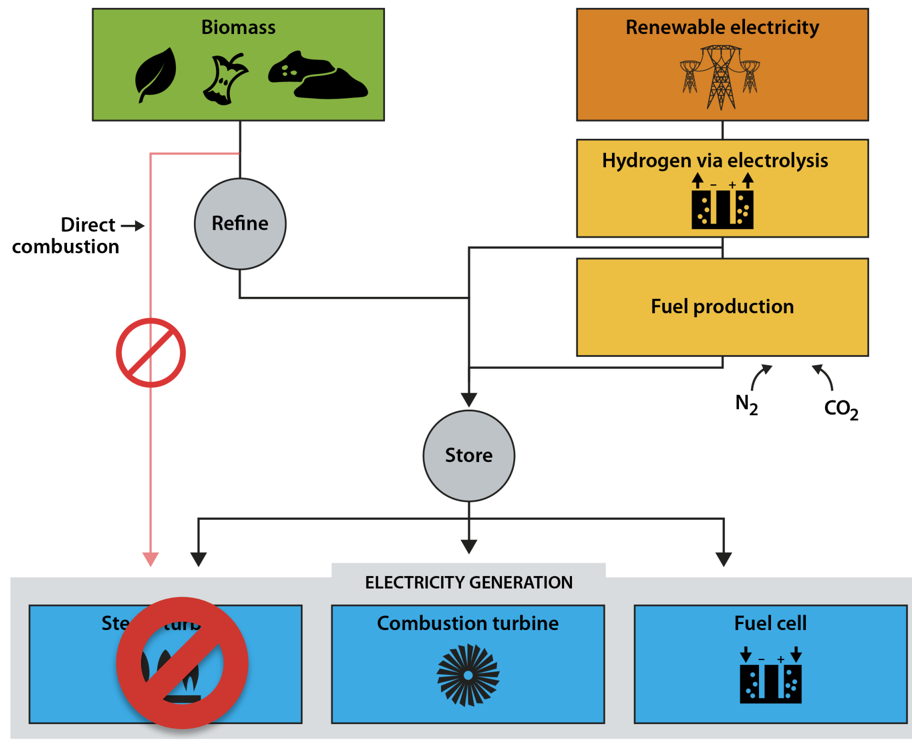
Feedback

We have modeled pathways that are reliable and 100% RE, but we need the Advisory Group to provide guidance on priorities that could shape the final analysis.

- What is your vision for this transition to 100% RE?
- How can we enable your vision and values to be considered in decision-making that emerges from this study?
- What additional analysis can we do to inform decisions?

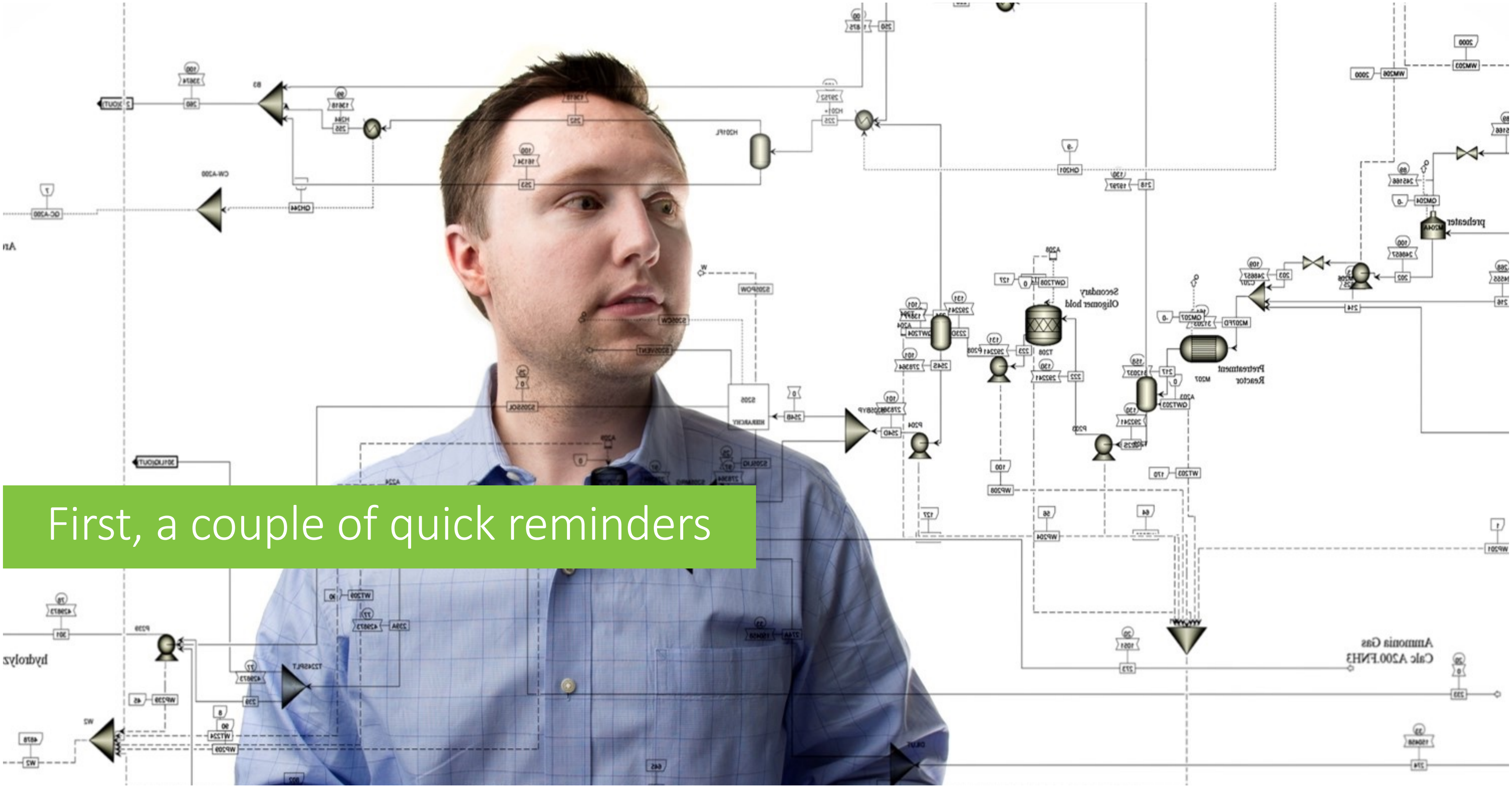
Where we left off after AG Meeting #11

1. Wind and solar resources are crucial *energy* resources in both the near and long term
2. Short-duration storage is key to increasing the utilization of wind and solar, but wind, photovoltaics (PV), and short-duration storage are insufficient to achieve 100% RE
3. In-basin capacity is highly valuable; there are several options to provide it, which vary in their costs, feasibility, emissions, infrastructure requirements, community impacts, and interdependence with economy-wide decarbonization



In this session, we will review

1. Options to provide firm ("peaking") capacity
   - What pipeline, transmission, and fuel storage infrastructure is required for different technologies?
2. Common results (to date) across all scenarios
3. Results (to date) by scenario
   - Assumptions about infrastructure
   - Evolution of capacity and generation mix
   - Sensitivity of results to changes in assumptions
4. Costs



First, a couple of quick reminders

LA100 Scenarios (revised June 2020)

		LA100 Scenarios								
		Moderate Load Electrification				High Load Electrification (Load Modernization)				High Load Stress
		SB100	LA-Leads, Emissions Free (No Biofuels)	Transmission Renaissance	High Distributed Energy Future	SB100	LA-Leads, Emissions Free (No Biofuels)	Transmission Renaissance	High Distributed Energy Future	SB100
	RE Target in 2030 with RECs	60%	100%	100%	100%	60%	100%	100%	100%	60%
	Compliance Year for 100% RE	2045	2035	2045	2045	2045	2035	2045	2045	2045
Technologies that <u>do not</u> vary in eligibility across scenarios	Solid Biomass	N	N	N	N	N	N	N	N	N
	Fuel Cells	Y	Y	Y	Y	Y	Y	Y	Y	Y
	RE-derived Hydrogen Combustion	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
	Nuclear - New	N	N	N	N	N	N	N	N	N
	Wind, Solar, Geothermal	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Storage	Y	Y	Y	Y	Y	Y	Y	Y	Y
Technologies that <u>do</u> vary	Biofuel Combustion	Y	No	Y	Y	Y	No	Y	Y	Y
	Natural Gas	Y	No	No	No	Y	No	No	No	Y
	Nuclear - Existing	Y	Y	No	No	Y	Y	No	No	Y
Repowering OTC	Haynes, Scattergood, Harbor	N	N	N	N	N	N	N	N	N
RECS	Financial Mechanisms (RECS/Allowances)	Yes	N	N	N	Yes	N	N	N	Yes
DG	Distributed Adoption	Moderate	High	Moderate	High	Moderate	High	Moderate	High	Moderate
Load	Energy Efficiency	Moderate	Moderate	Moderate	Moderate	High	High	High	High	Reference
	Demand Response	Moderate	Moderate	Moderate	Moderate	High	High	High	High	Reference
	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

Note, the study also includes a reference case (2017 IRP with minor updates). This case extends through 2036.

LA100 Scenarios: LA Leads allows hydrogen combustion

		LA100 Scenarios								
		Moderate Load Electrification				High Load Electrification (Load Modernization)				High Load Stress
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Technologies that <u>do not</u> vary in eligibility across scenarios	Solid Biomass	N	N	N	N	N	N	N	N	N
	Fuel Cells	Y	Y	Y	Y	Y	Y	Y	Y	Y
	RE-derived Hydrogen Combustion	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
	Nuclear - New	N	N	N	N	N	N	N	N	N
	Wind, Solar, Geothermal	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Storage	Y	Y	Y	Y	Y	Y	Y	Y	Y
Technologies that <u>do</u> vary	Biofuel Combustion	Y	No	Y	Y	Y	No	Y	Y	Y
	Natural Gas	Y	No	No	No	Y	No	No	No	Y
	Nuclear - Existing	Y	Y	No	No	Y	Y	No	No	Y
Repowering OTC	Haynes, Scattergood, Harbor	N	N	N	N	N	N	N	N	N
RECS	Financial Mechanisms (RECS/Allowances)	Yes	N	N	N	Yes	N	N	N	Yes
DG	Distributed Adoption	Moderate	High	Moderate	High	Moderate	High	Moderate	High	Moderate
Load	Energy Efficiency	Moderate	Moderate	Moderate	Moderate	High	High	High	High	Reference
	Demand Response	Moderate	Moderate	Moderate	Moderate	High	High	High	High	Reference
	Electrification	Moderate	Moderate	Moderate	Moderate	High	High	High	High	High
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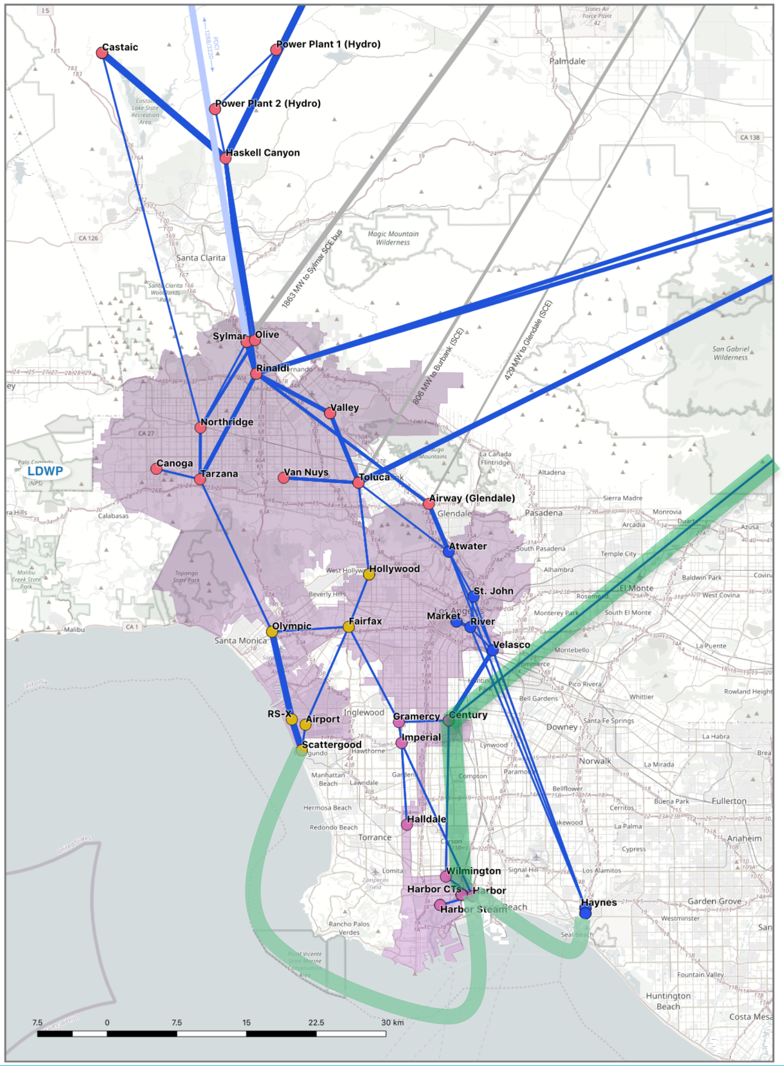
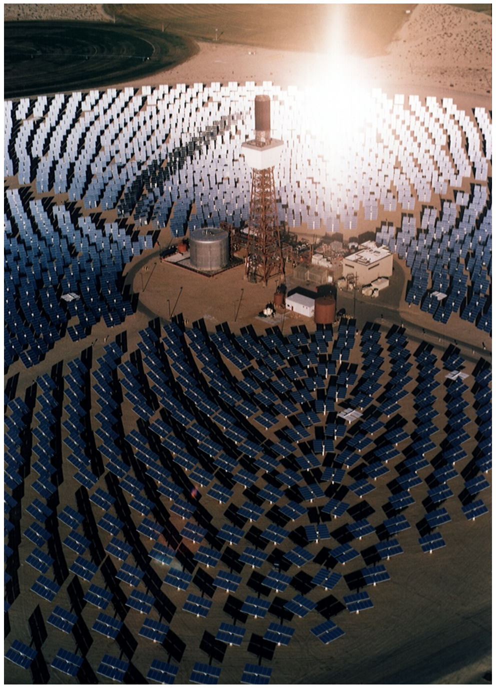
WECC	WECC VRE Penetration	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate

Note, the study also includes a reference case (2017 IRP with minor updates). This case extends through 2036.

Transmission Renaissance: the DC-backbone option



Every generation, storage, and transmission asset has varying space requirements, takes time to construct, and ultimately has different impacts on communities



Options for Peaking Capacity and Associated Infrastructure Requirements

New Options for Firm “Peaking” Capacity

Technology	Fuel	Storage Options	Can be sited in basin?	Net Emissions (fuel production & combustion/use)
Combustion Turbine	Biofuel (liquid)	Tank	Yes	NO_x SO_x—low GHG – net positive
	Biogas	Pipeline Network and/or Cavern	Yes	NO_x SO_x—low GHG – net positive
	RE-Derived Methane	Pipeline Network and/or Cavern	Yes	NO_x GHG – net zero/negative
	Hydrogen	<u>New</u> Pipeline Network and/or Cavern	Yes, <u>if</u> either pipeline is developed, or fuel is stored temporarily as ammonia before converting back to hydrogen	NO_x
	RE-Derived Ammonia (liquid)	Tank	Yes	NO_x
Fuel Cell	Hydrogen	<u>New</u> Pipeline Network and/or Cavern	Yes, <u>if</u> either pipeline is developed, or fuel is stored temporarily as ammonia before converting back to hydrogen	--
	RE-Derived Methane	Pipeline Network	Yes	GHG – net zero/negative
Geothermal	Hydrothermal Energy	Naturally Occurring	No	--

Current: Valley Generating Station

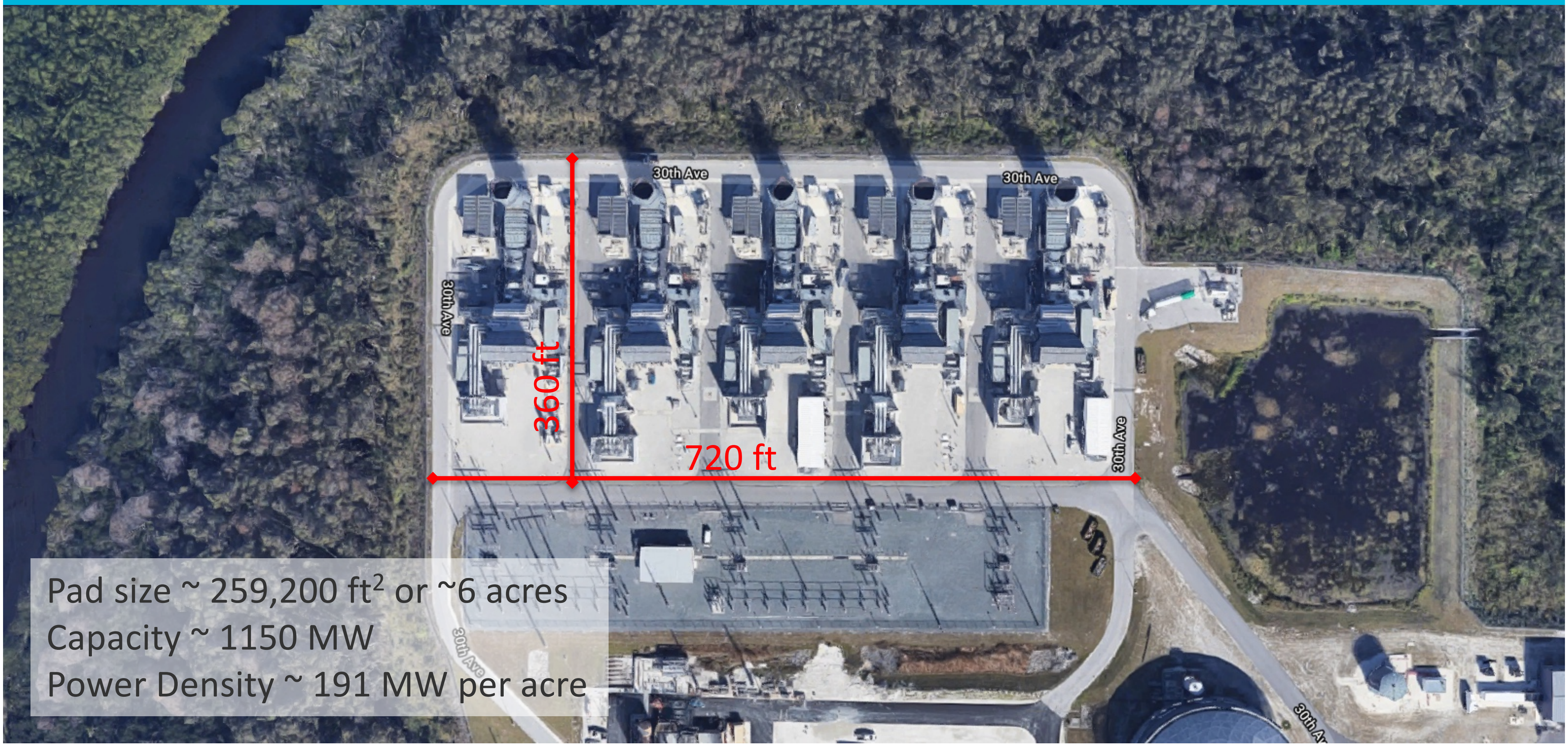
Valley Generating Station

Pad size ~ 1,000,000 ft^2 or ~23 acres
Capacity ~ 550 MW
Power Density ~ 24 MW/acre

Combustion Turbines

Dedicated combustion turbine facility could achieve the same capacity over a smaller footprint, lower stacks, less infrastructure

Potential future: Dedicated combustion turbine facility could achieve the same capacity over a smaller footprint, lower stacks, less infrastructure



Pad size ~ 259,200 ft^2 or ~6 acres
Capacity ~ 1150 MW
Power Density ~ 191 MW per acre

Fuel Cells

Fuel cells could provide capacity, but at lower density

Fuel cells could provide capacity, but at lower density

Fuel cells could provide capacity, but at lower density

Additional Firm Capacity Options with Transmission

New transmission requires construction and siting in densely populated areas

How are we capturing these options in our modeling?

- **Renewable Combustion Turbine (RE-CT)**: CT coupled with market-purchased renewable fuel (e.g., biogas, biofuel, hydrogen, RE-ammonia, RE-methane)
  - Unless otherwise specified, assumed to use either biogas or synthetic gas prior to 2045; in 2045 assumed to convert to H_2
  - Gas fuels assumed to be provided through a pipeline; liquid fuels through rail with local storage
- **Hydrogen Combustion Turbine (H2-CT):** CT fueled with self-produced hydrogen (with an electrolyzer)
- **Fuel Cell:** fuel cell using self-produced hydrogen (with an electrolyzer)

Both dedicated hydrogen technologies are treated similar to a battery, with increase in generation to produce the fuel, to be stored for later use

Questions?

Up Next:

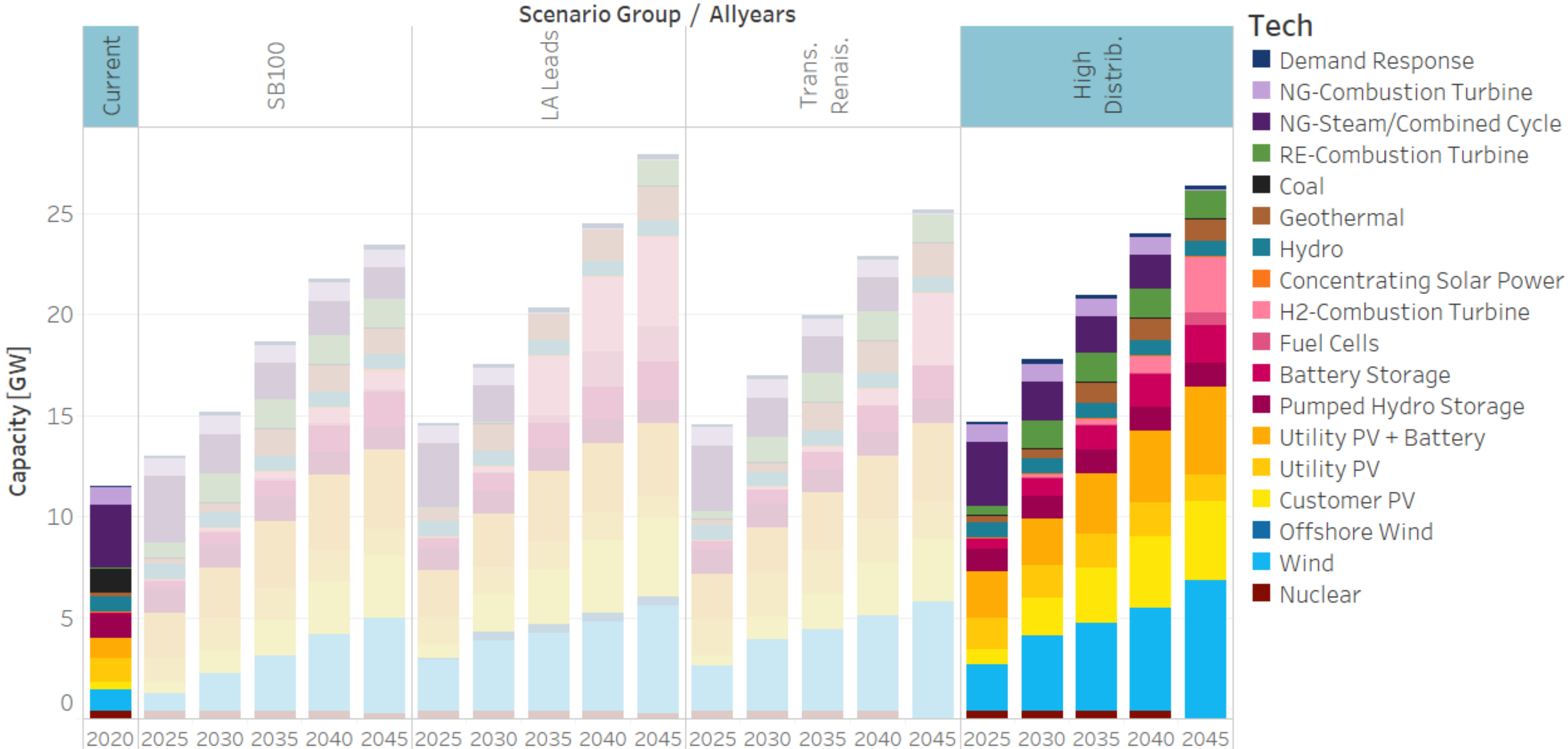
Results (To-Date) Across Scenarios

Results by Scenario

Costs

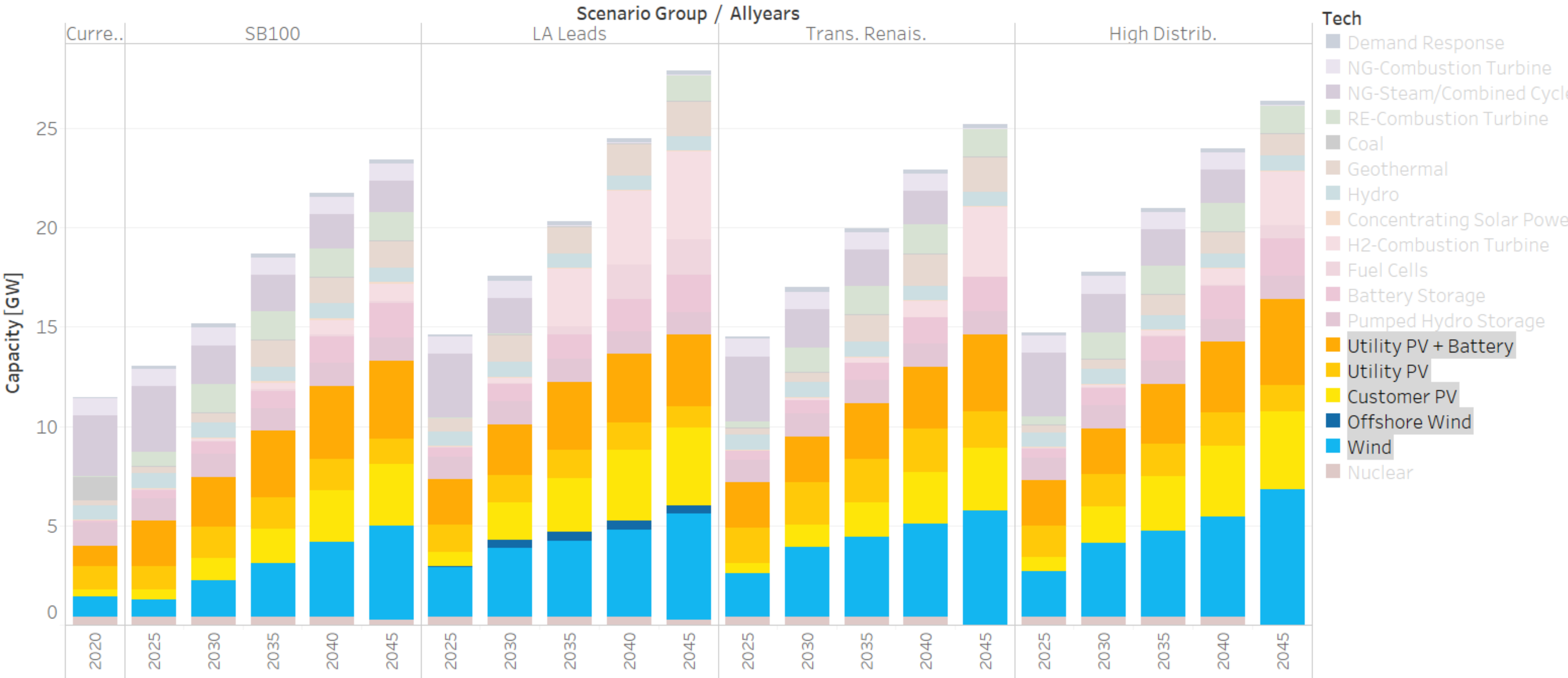
Draft results and findings

Capacity—understanding figures



Draft Results for Discussion Only; Subject to Change

Capacity [High Load Scenarios]—wind & solar are a crucial source of energy across all scenarios



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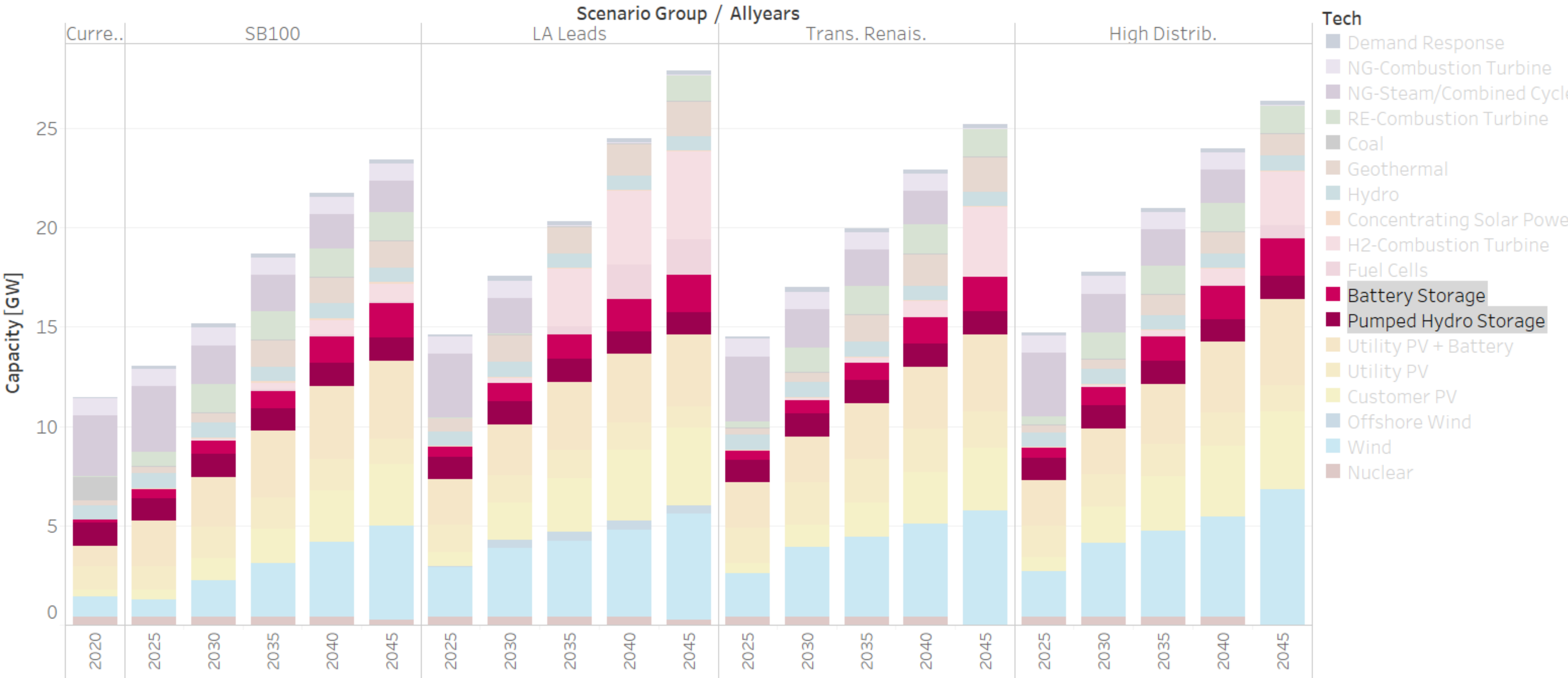
Capacity [High Load Scenarios]—short-duration storage capacity is built to increase utilization of wind & solar



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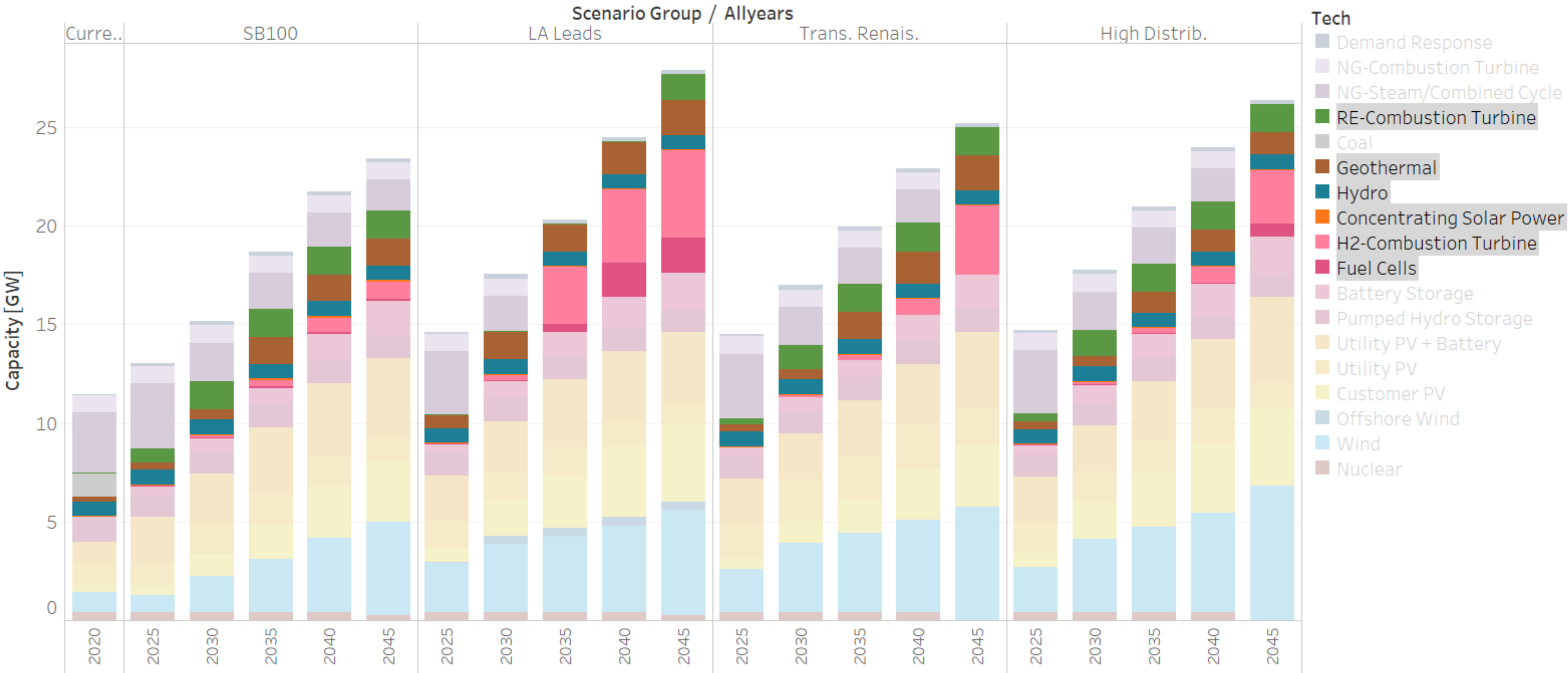
Capacity [High Load Scenarios]—firm "peaking" capacity is deployed across all scenarios



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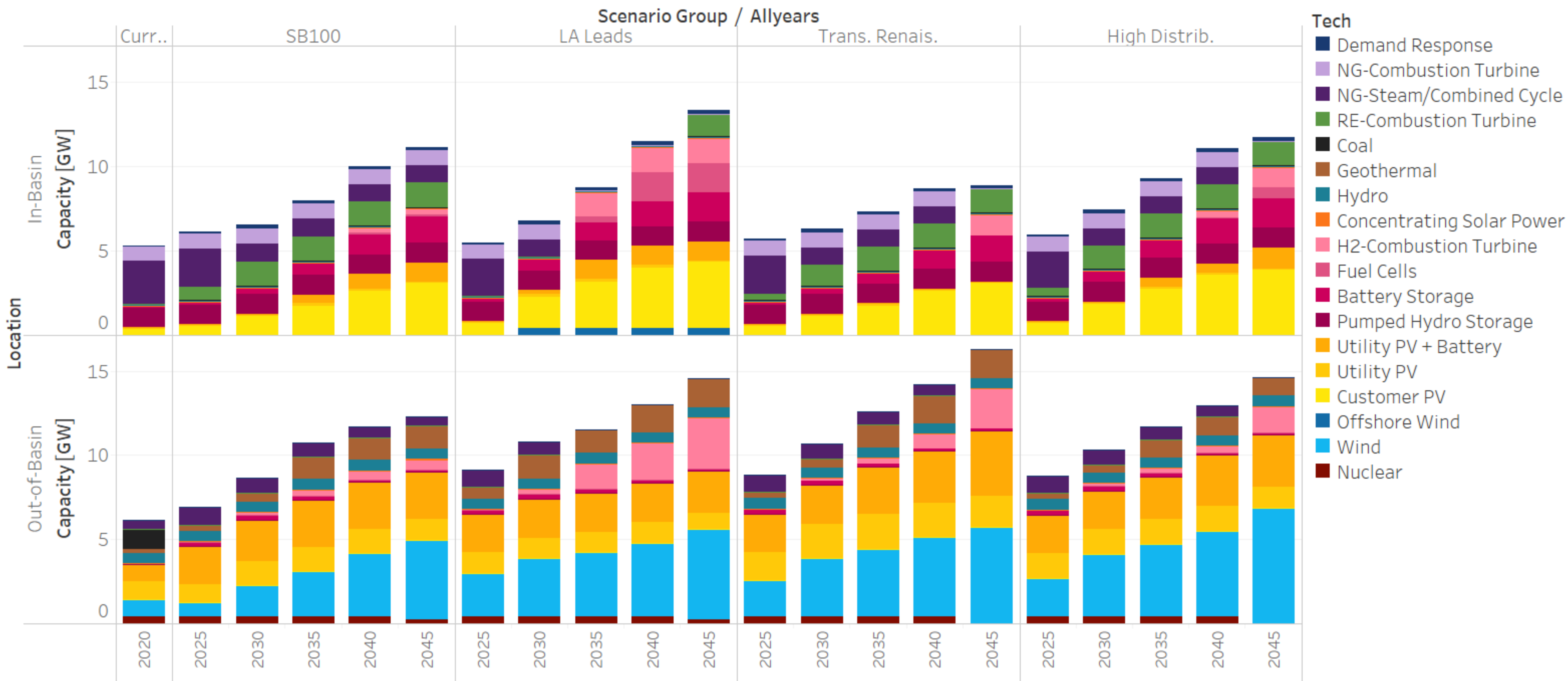
Capacity deployed in and out of basin [High Load Scenarios]



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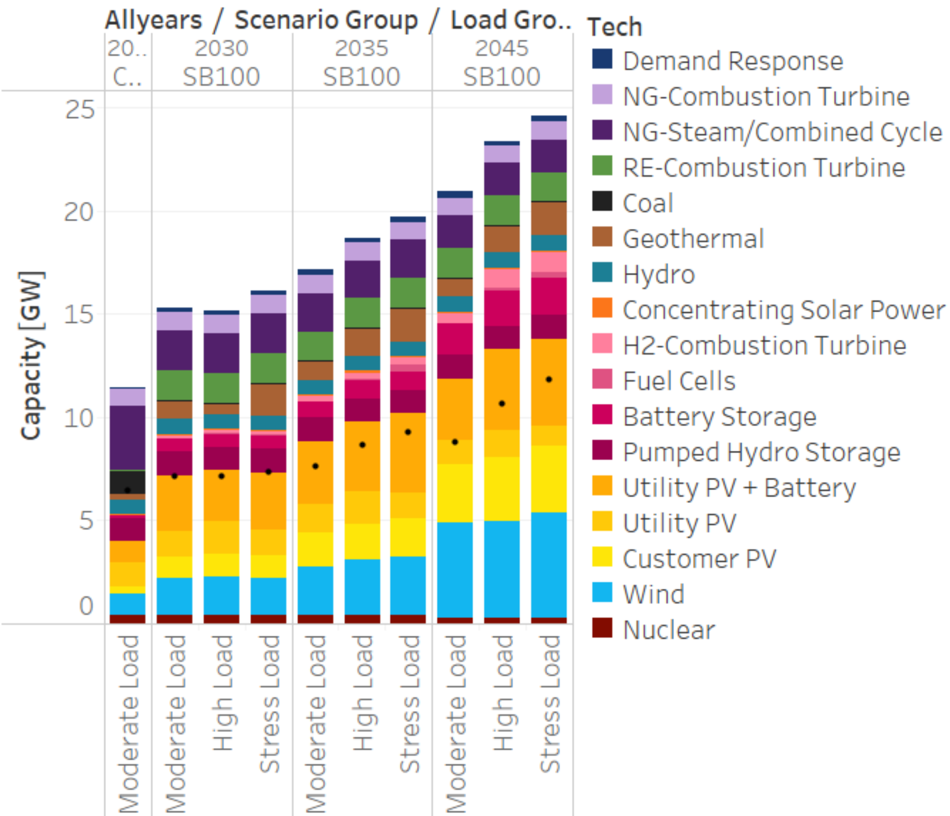
Scenario Deep Dives

SB100 Assumptions

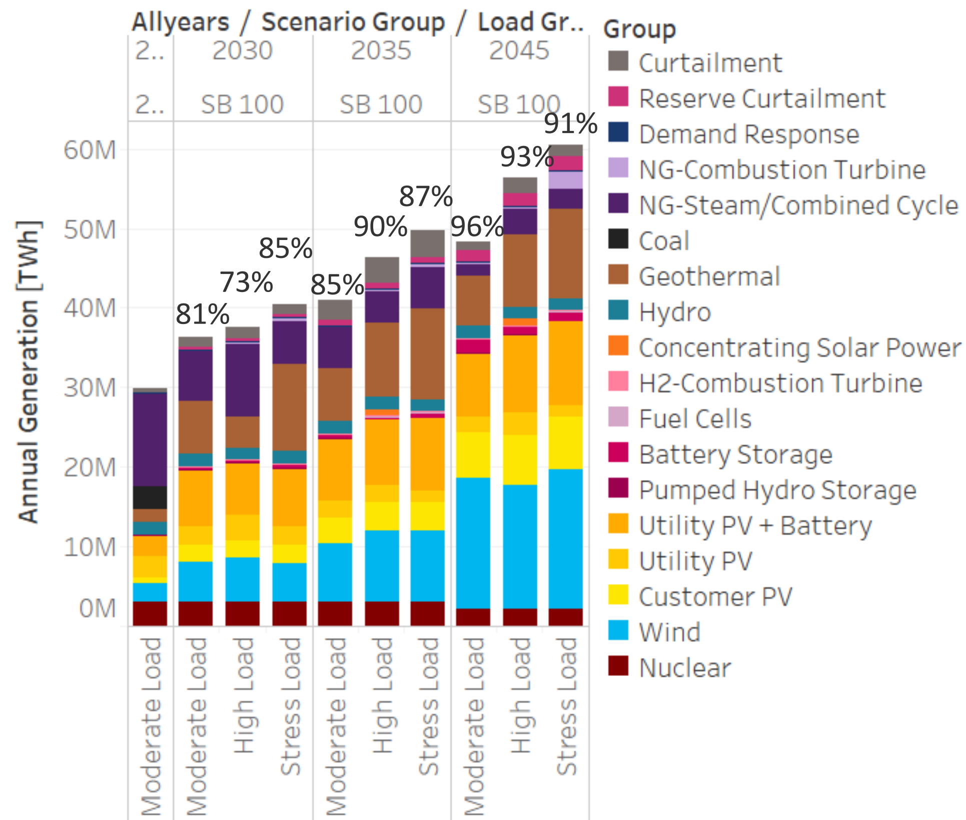
- 100% clean target is based on fraction of load
- RECs allowed for a portion of compliance
- Nuclear and biofuel qualify as clean
- Natural gas generation
  - OTC units retire by 2030
  - Non-OTC natural gas units remain online through 2045—approximately 2.4 GW of capacity
- RE-Combustion Turbines (RE-CT) allowed in all years
- Transmission is very challenging to build in and around the basin, particularly through 2035

SB100 Capacity and Generation Mix

Capacity Mix



Annual Generation



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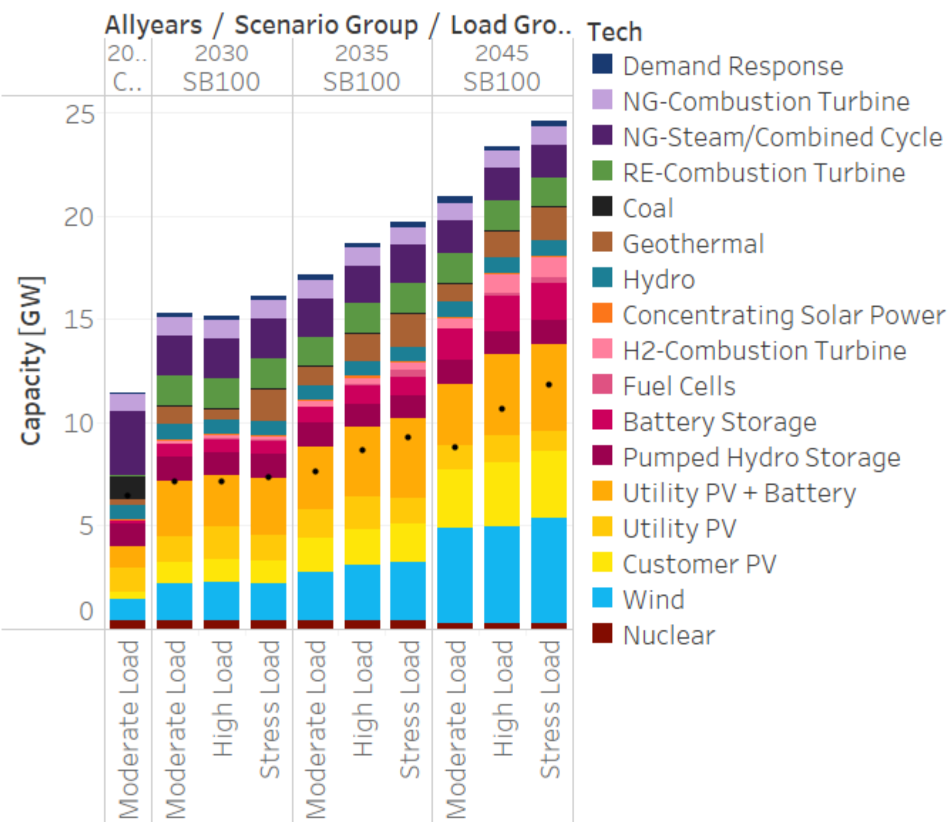
SB100 Capacity and Generation Mix

Capacity Mix



Annual Generation

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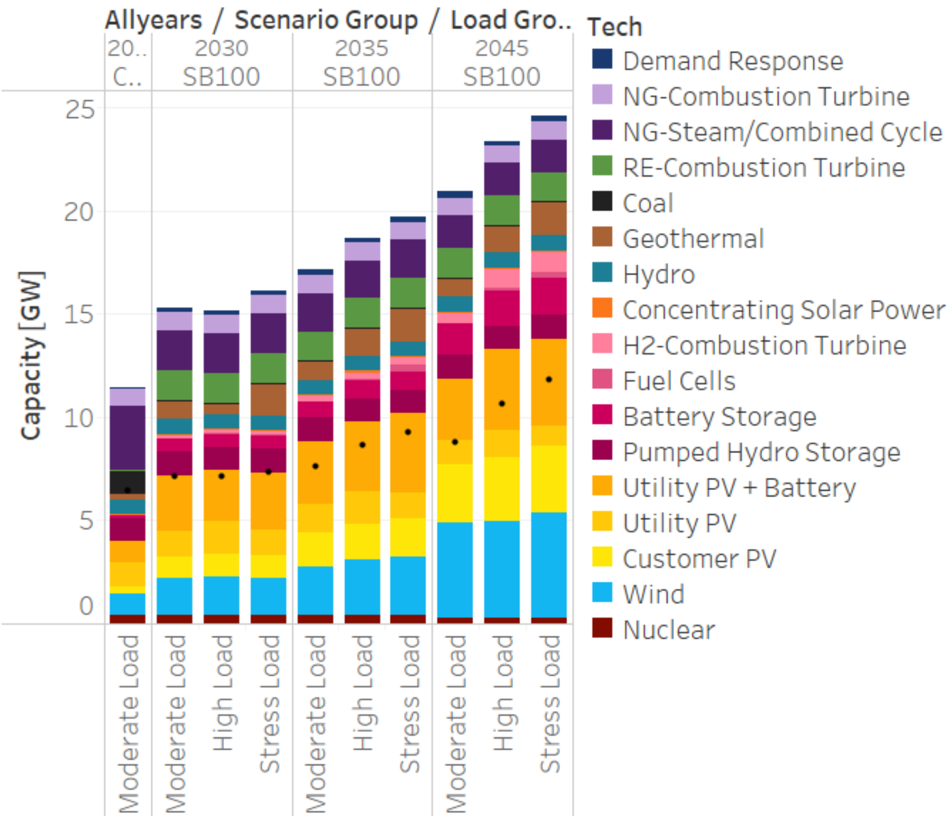
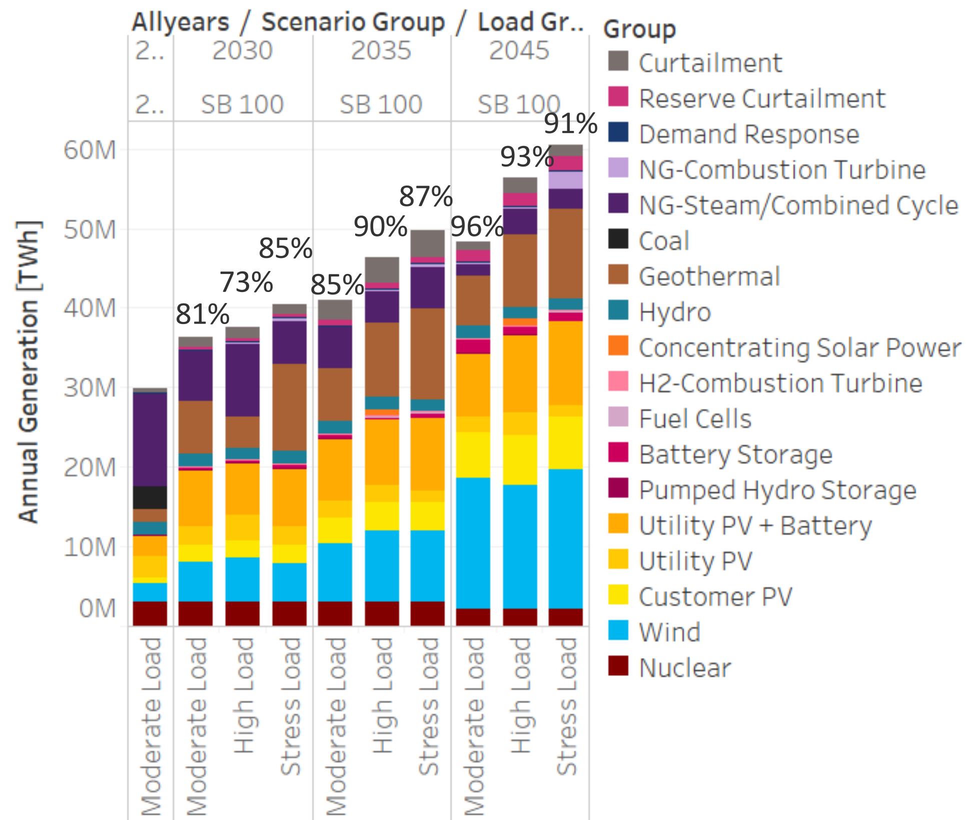
SB100 Capacity and Generation Mix

Capacity Mix



Annual Generation



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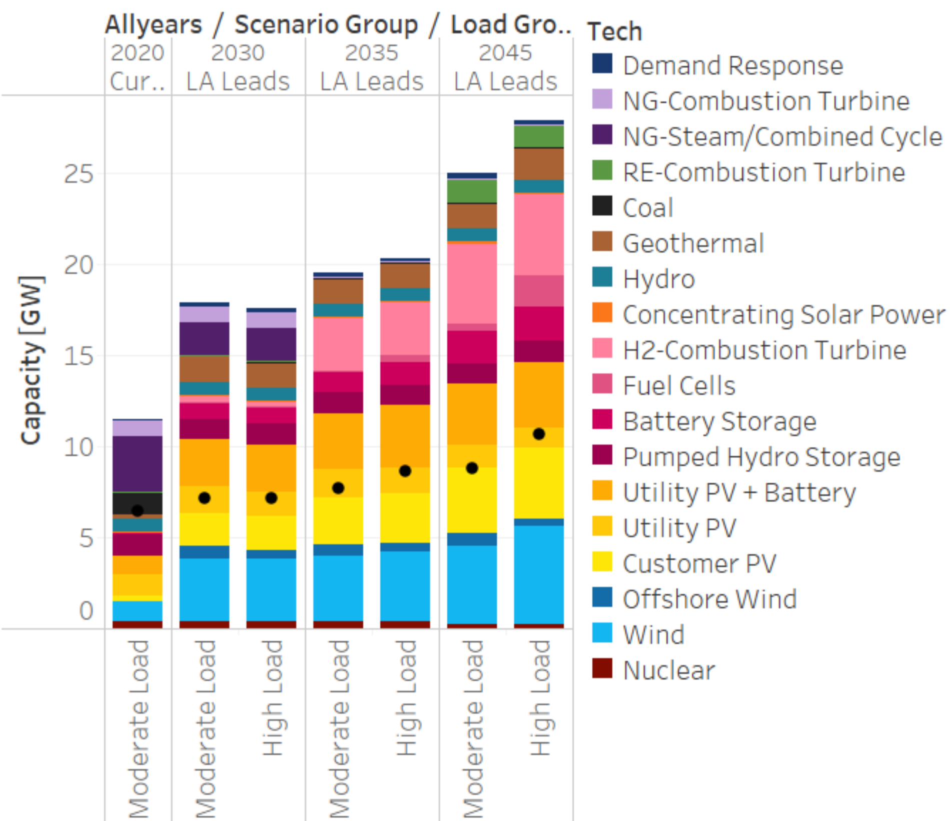
LA Leads Assumptions

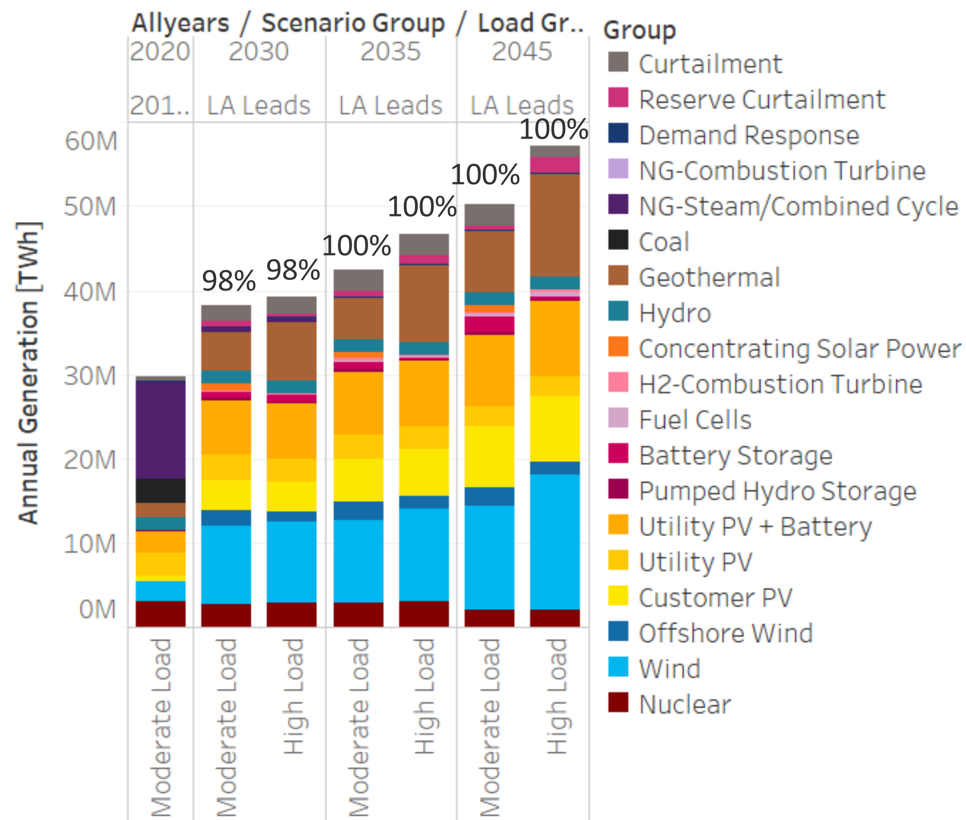
- 100% clean target is based on fraction of generation; compliance by 2035
- Biofuels/biogas builds not allowed
- RE-CTs
  - Because biofuels/gas not allowed, RE-CT is only available in 2045, when a hydrogen fuel market assumed
  - Hydrogen CTs allowed after 2030 (same for all scenarios)
- Existing nuclear allowed
- Natural gas
  - OTC units retire by 2030
  - All other natural gas units retire by 2035
- Transmission is very challenging to build in and around the basin, particularly through 2035

LA Leads Capacity and Generation Mix

Capacity Mix



Annual Generation



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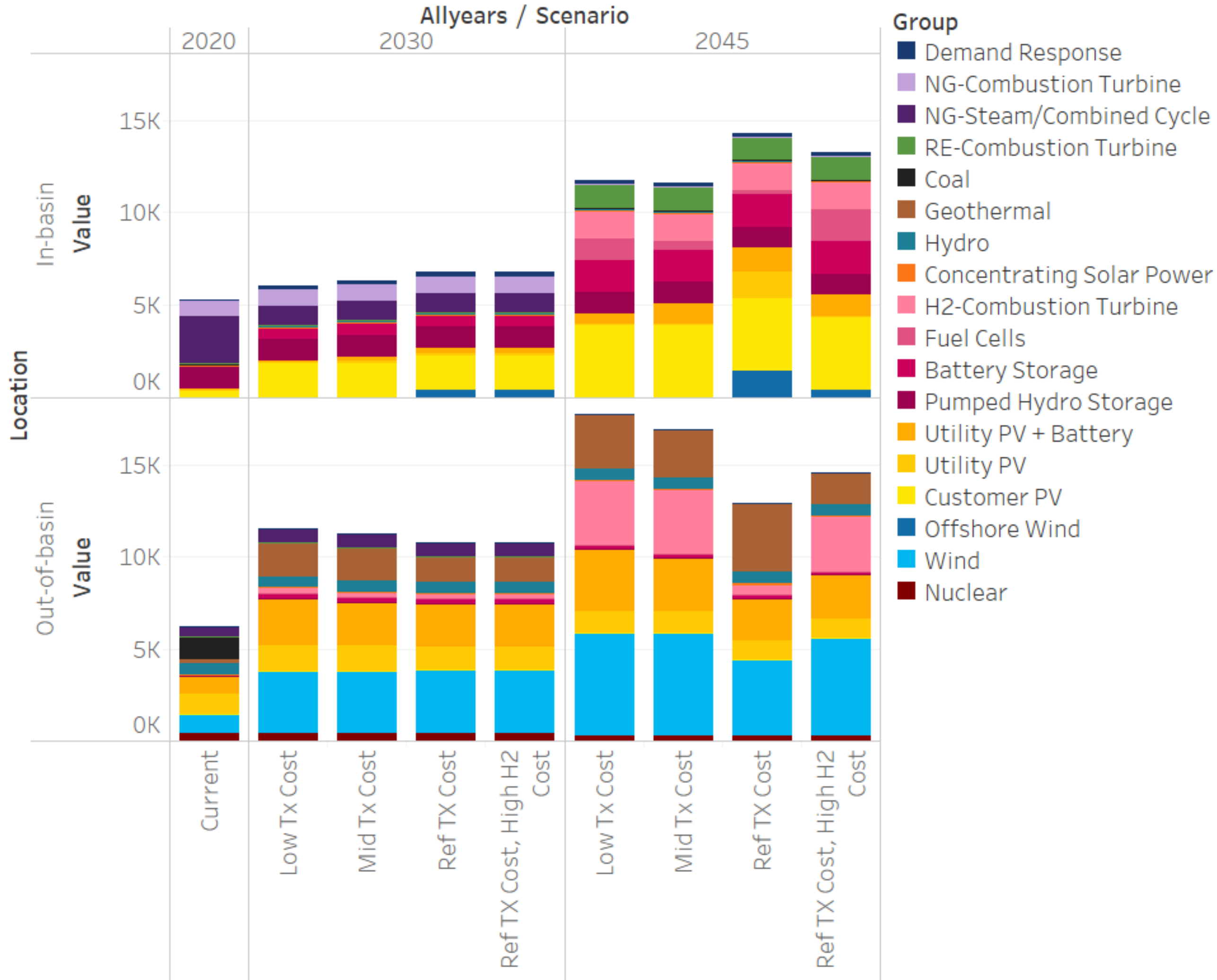
LA Leads Sensitivities

Increasing the feasibility of transmission builds shifts capacity out of basin

High hydrogen costs drive further deployment of in-basin connected offshore wind & PV



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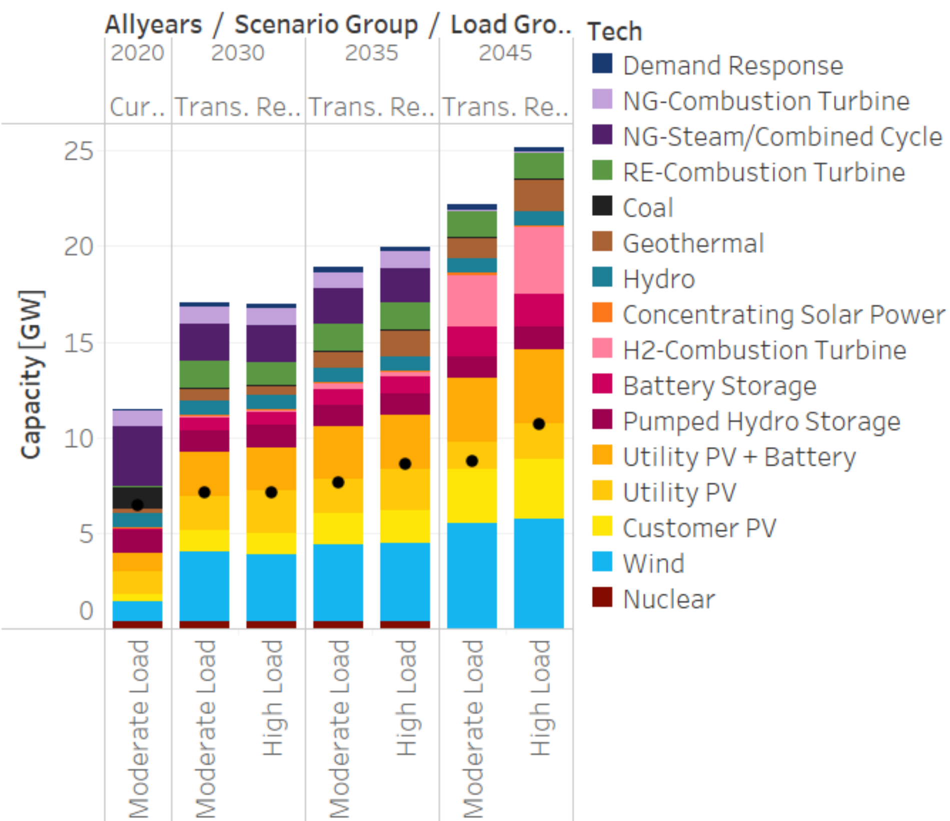
Transmission Renaissance Assumptions

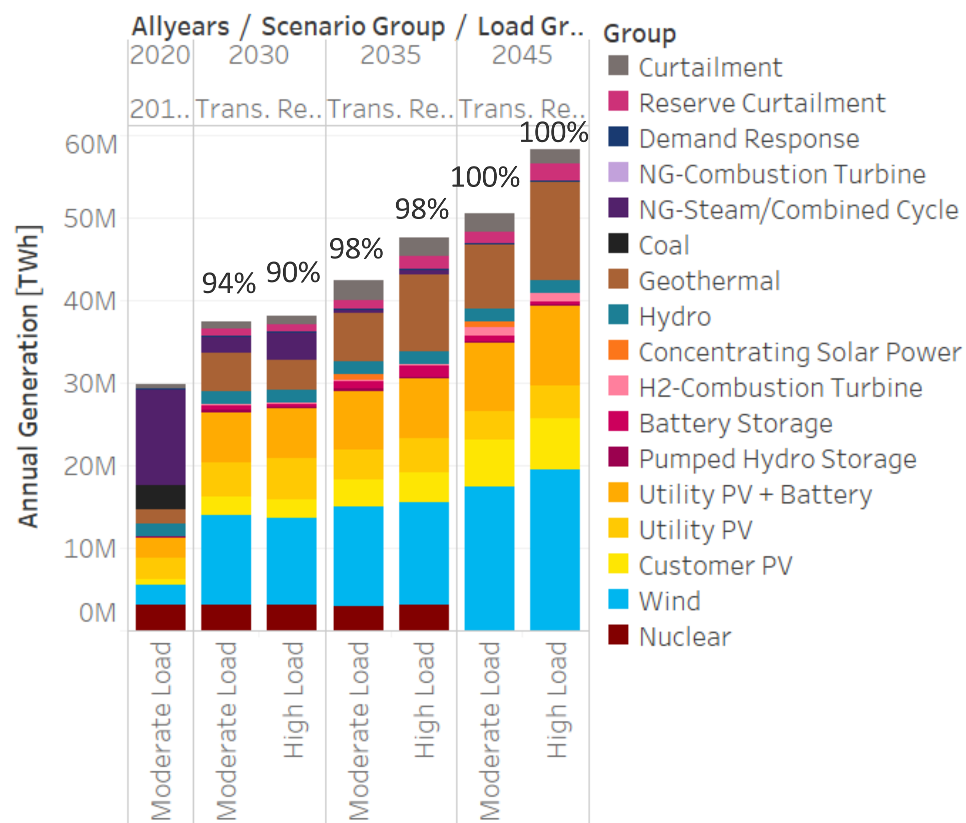
- 100% clean target is based on fraction of generation; compliance by 2045
- Biofuels/biogas allowed
- Existing nuclear not allowed starting 2045
- Natural gas
  - OTC units retire by 2030
  - All other natural gas units retire by 2045
- RE-CTs allowed, all years
- Transmission—more feasible and less costly to upgrade existing in-basin and out-to-in transmission; allows *option to construct DC-transmission backbone* to bring in out-of-basin capacity/energy, and distributed it throughout southern OTC sites

Transmission Renaissance Capacity and Generation Mix

Capacity Mix



Annual Generation



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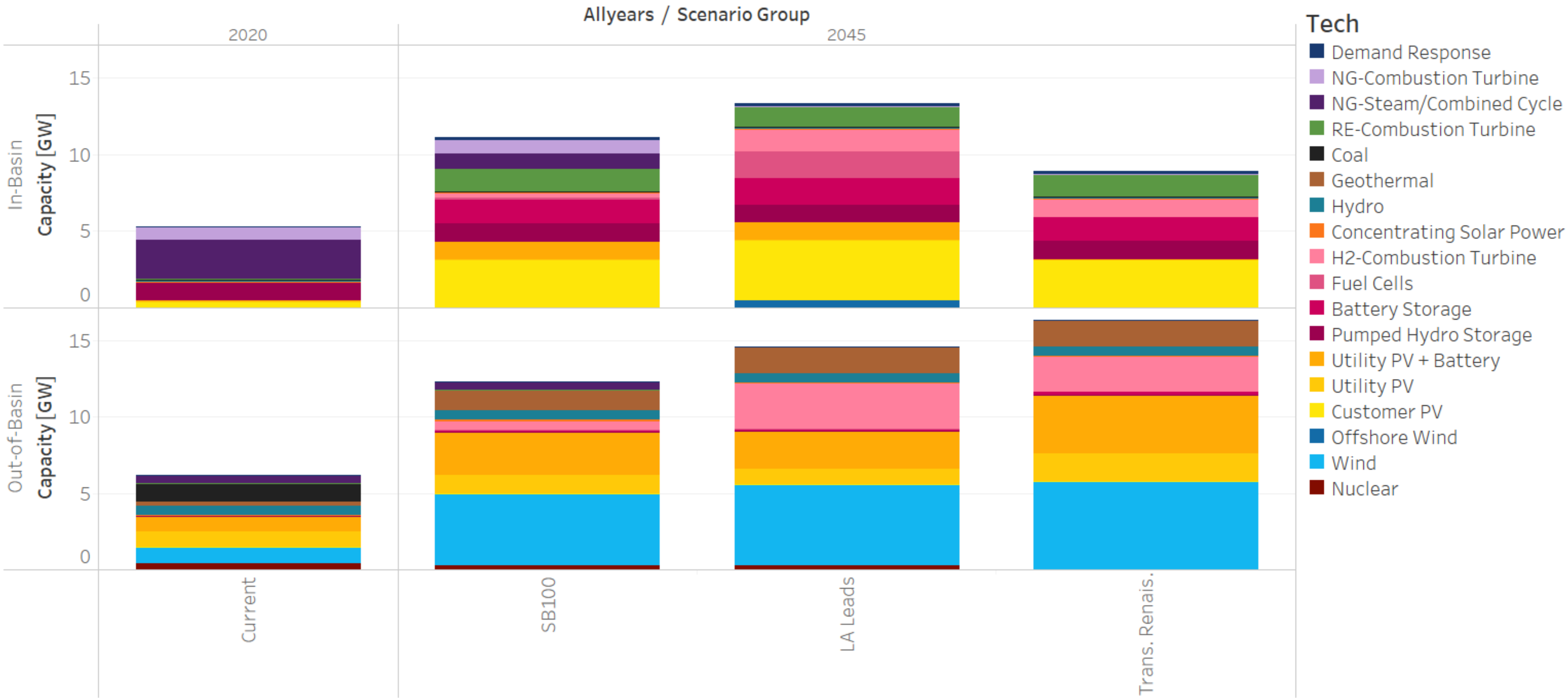
Transmission Renaissance leads to greater out-of-basin deployment [High Load Only]



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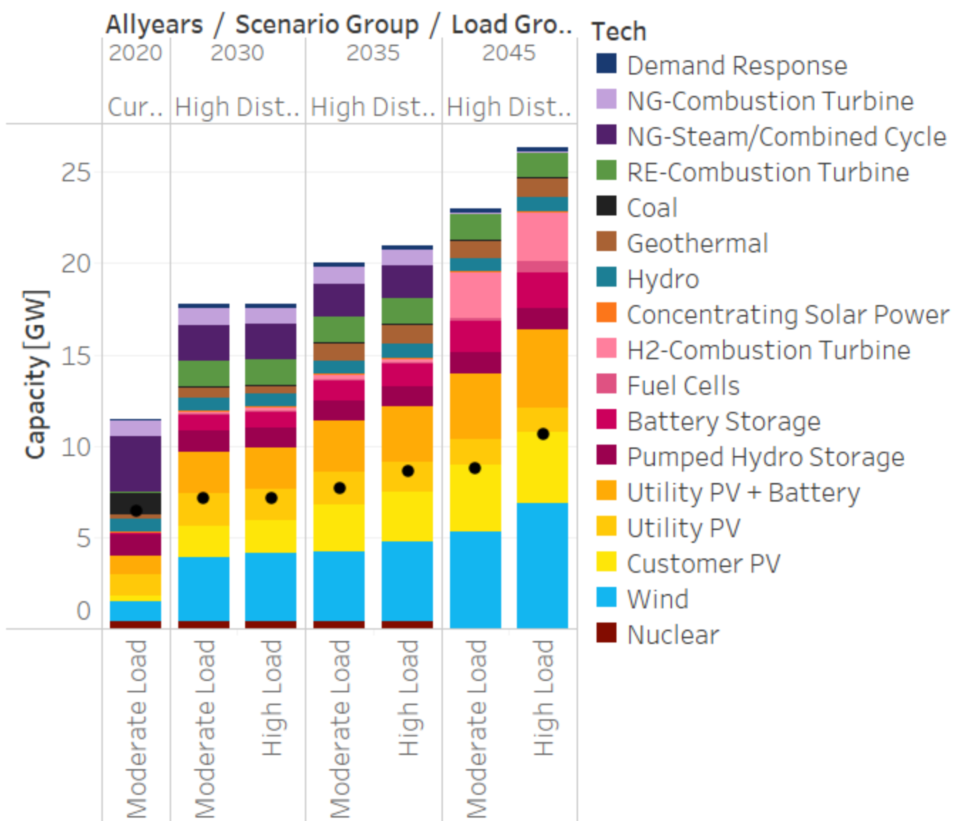
High Distributed Energy Future Assumptions

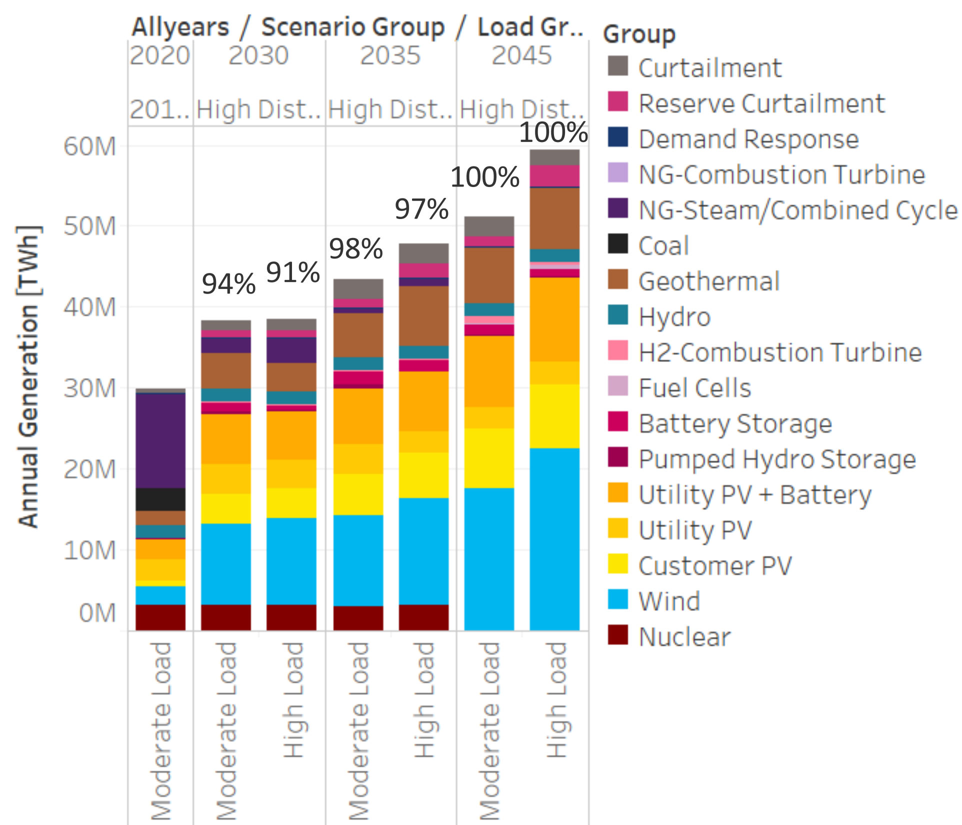
- 100% clean target is based on fraction of generation; compliance by 2045
- Biofuels/biogas allowed
- Existing nuclear not allowed starting 2045
- Natural gas
  - OTC units retire by 2030
  - All other natural gas units retire by 2045
- RE-CTs allowed in all years
- Transmission—new/upgraded transmission is <u>not</u> allowed

High Distributed Capacity and Generation Mix

Capacity Mix



Annual Generation



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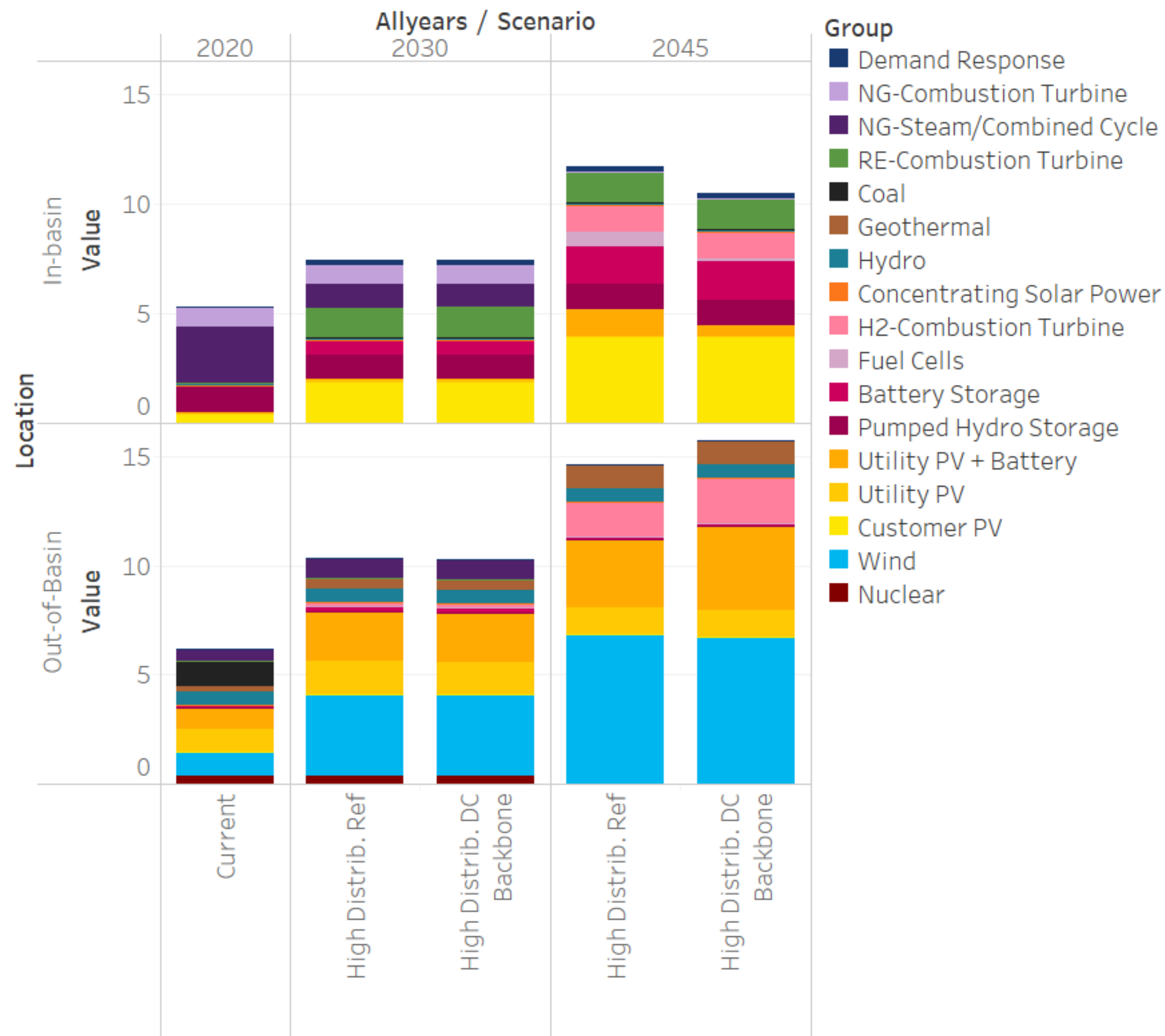
High Distributed Energy Future – Moderate

Sensitivity with DC backbone



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Questions?

Up Next:

Costs

System Costs

Cost Categories

- **Capital** – capital and associated financing costs* of new infrastructure
- **Fixed Operations and Maintenance (O&M)** – fixed costs of operating and maintaining assets
- **Fuel** – cost of fuel, including natural gas, uranium, coal, biofuel
- **Variable O&M** – non-fuel variable costs of operating and maintaining assets

**Financing terms are being revised to align with LADWP practices; will impact costs*

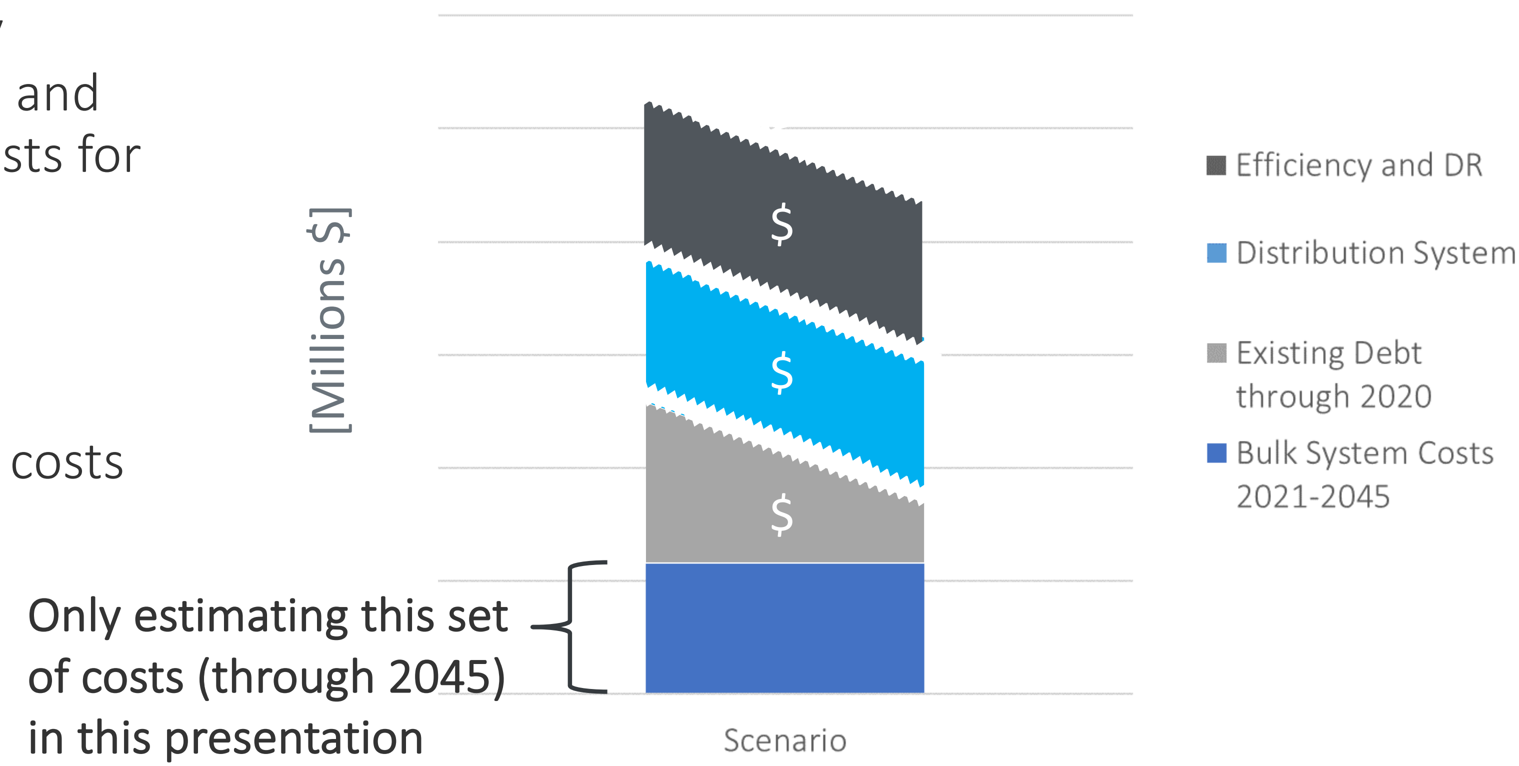
Cost Estimates

- Include:
  - Bulk system (generation, storage, and transmission):
    - Capital and financing costs for new investments (2021–2045)
    - Fuel, variable O&M, and fixed O&M for all assets
  - Distributed: Capital cost and fixed O&M for customer-owned distributed generation
- Exclude:
  - Existing debt on capital expenses (made before 2021)
  - Distribution system costs (upgrades* and O&M)
  - Costs of energy efficiency and demand response programs**

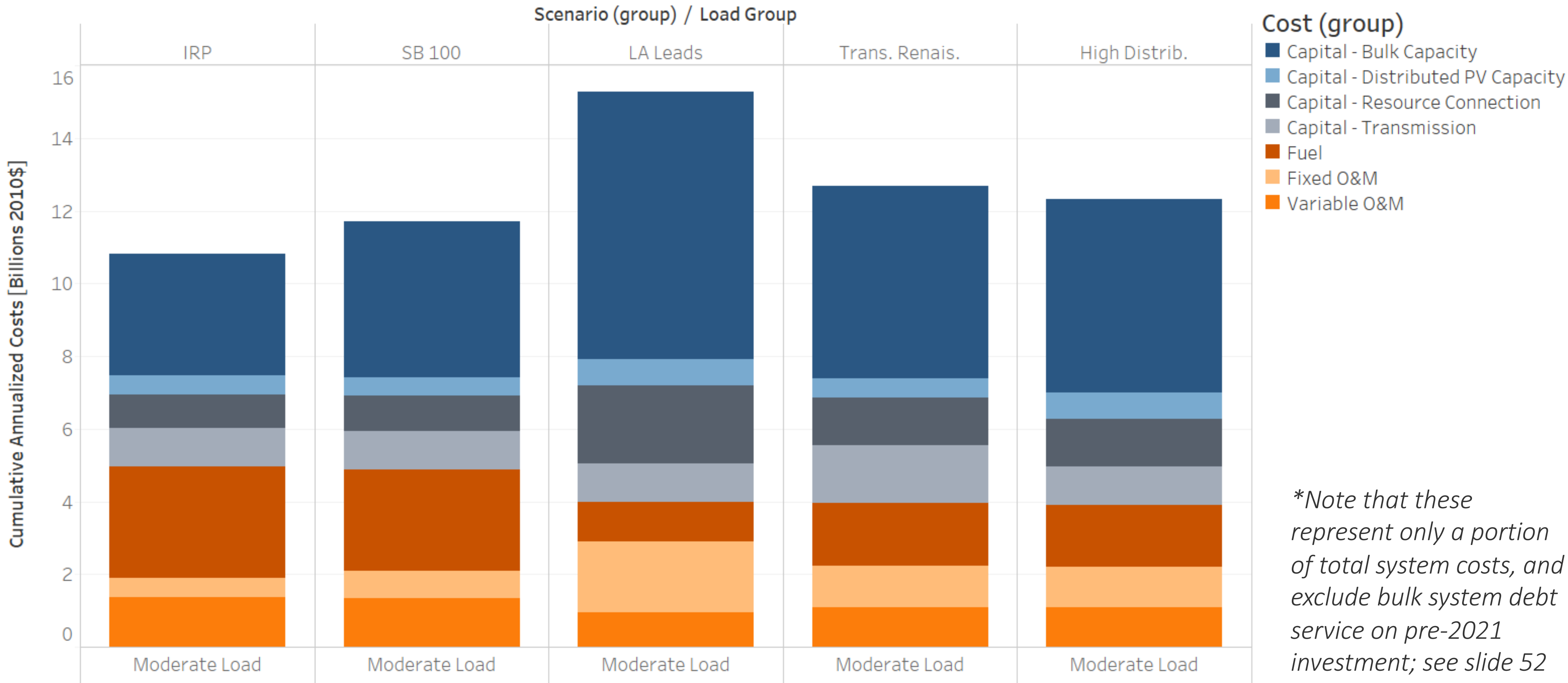
* Will be included in final results
** Will be estimated by LADWP

Illustrative Cost Stack

Estimates only include capital and operational costs for bulk system generation, transmission, storage, and distributed PV costs



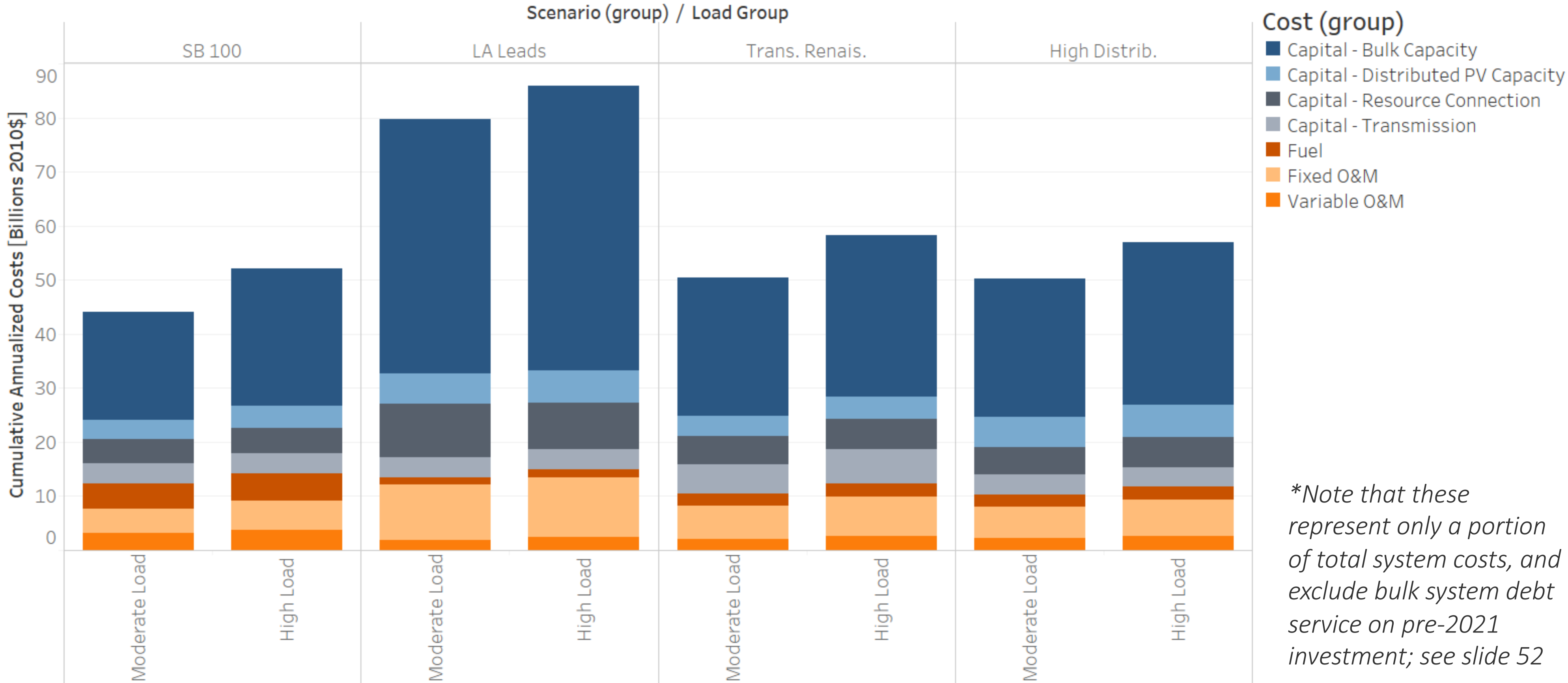
Cumulative Annualized Bulk System & Customer PV Costs: 2021–2030



**Note that these represent only a portion of total system costs, and exclude bulk system debt service on pre-2021 investment; see slide 52*

Draft Results for Discussion Only; Subject to Change

Cumulative Annualized Bulk System & Customer PV Costs: 2021–2045



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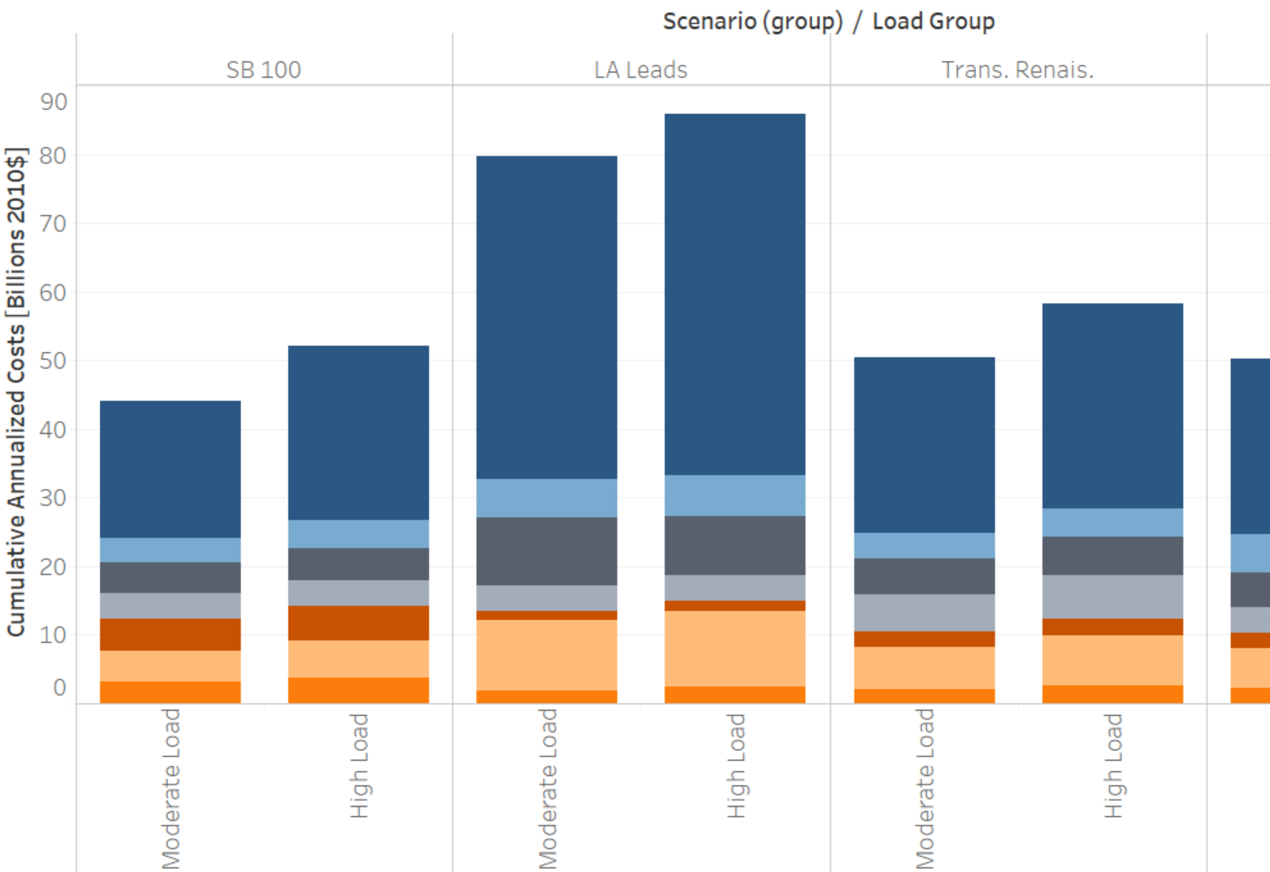
Cumulative Annualized Bulk System & Customer PV Costs: 2021–2045

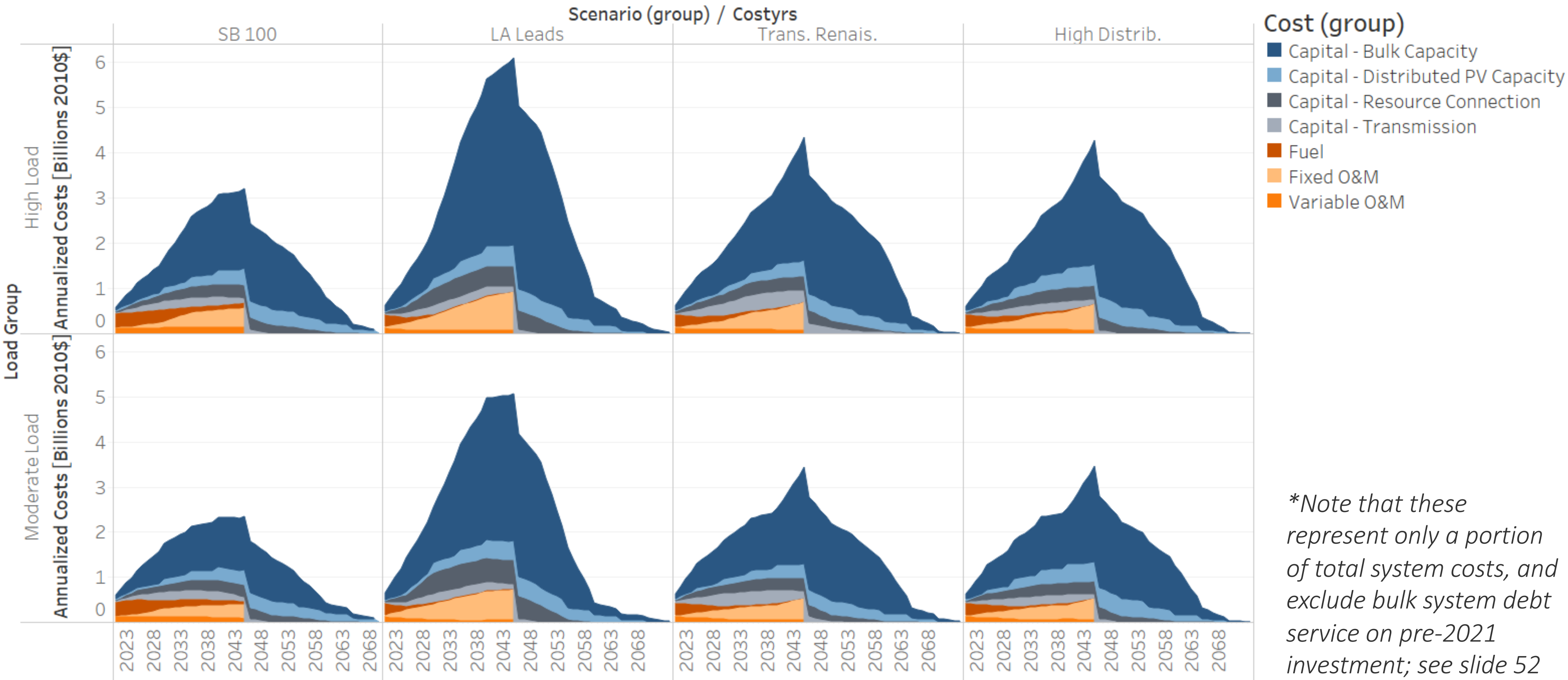


Reasons for Higher Costs for LA Leads:

- Earlier compliance (new capacity is needed earlier, which adds ten years of annualized costs)
- Reliance on developing technologies
- Rapidly developing technologies are more expensive in 2035 compared to 2045 based on cost trajectories

Draft Results for Discussion Only; Subject to Change

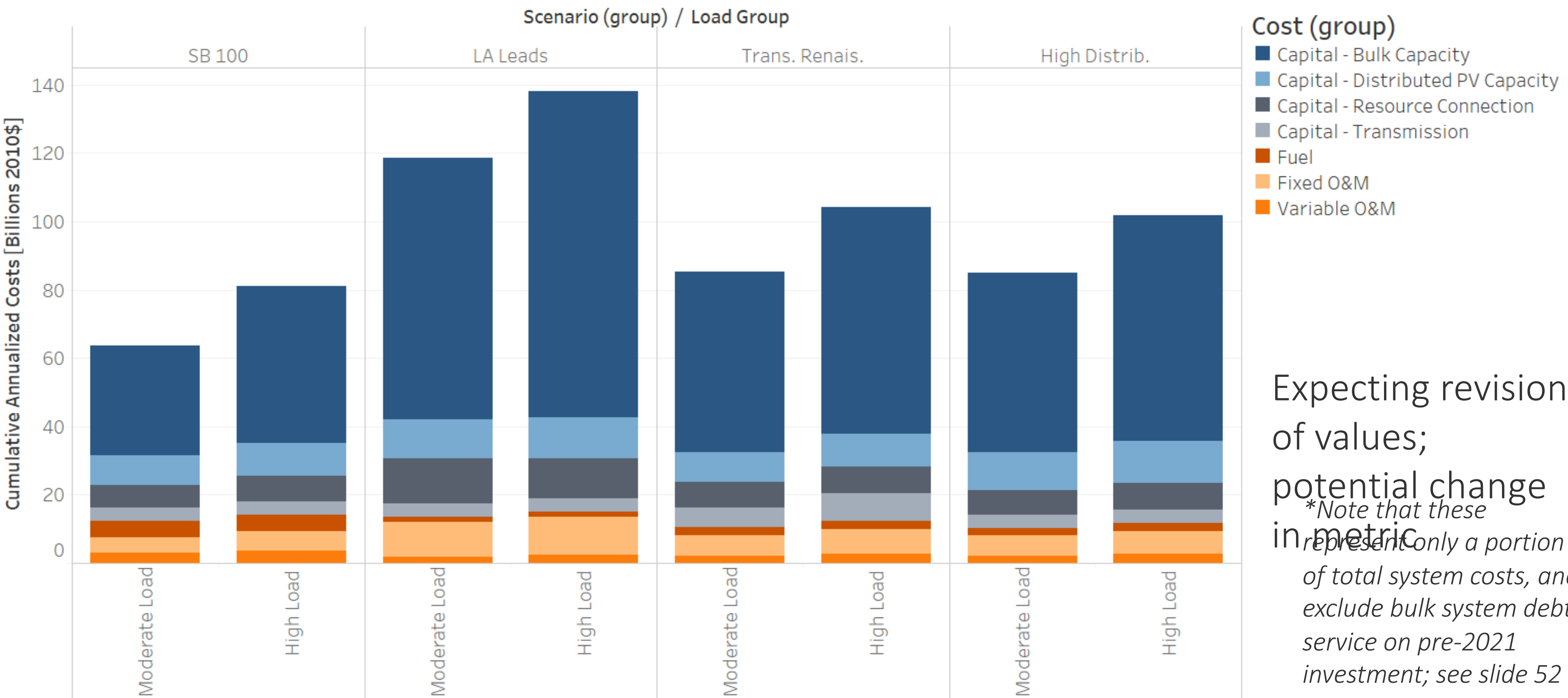
Annual Costs Bulk System & Customer PV



**Note that these represent only a portion of total system costs, and exclude bulk system debt service on pre-2021 investment; see slide 52*

Draft Results for Discussion Only; Subject to Change

Cumulative annualized capital costs through 2074 (debt fully paid off), all other costs through 2045



Expecting revision of values; potential change in metric

*Note that these represent only a portion of total system costs, and exclude bulk system debt service on pre-2021 investment; see slide 52

Thinking Creatively

- Our 100% RE study uses supply-side oriented engineering approaches
- This approach is driving some of the very high costs we see, particularly in the LA Leads scenario
- Exploring further options for compliance may allow for substantially reduced costs, greater community involvement, and equal if not greater environmental and social benefits

Three Examples

1. Truly revolutionary demand response (or responsive load) programs
   - Can we think creatively about options that maximize the value of price responsive demand while protecting lower income communities?
   - Can consumers be part of the solution with real-time pricing? Consumer choice on electricity products differentiated by reliability? Can we have customers bid in their willingness to pay and unleash the power of internet of things?
2. Cost optimal 100% decarbonization that extends beyond the electric sector?
   - Would it be acceptable to reach 95% RE and achieve additional emission reductions through direct air capture or in other parts of the economy?
3. Creative transmission
   - Can we think beyond traditional AC and DC power grids and deploy the latest steerable, dynamic transmission technologies to maximize use and value of existing difficult-to-site lines?

Wrap Up

Summary of findings to date

- Wind and solar are key energy assets in the near and long term
- Short-duration storage increases the utilization of wind and solar assets
- Firm "peaking" capacity sited in basin or firm capacity delivered to the basin (with transmission) is crucial to maintaining reliability and adequacy
  - In the absence of a hydrogen economy and associated delivery system, the challenges to storing hydrogen limits options for in-basin technologies; liquid fuels or fuels that can utilize the natural gas pipeline have fewer hurdles
  - Increasing transmission capacity can reduce the need for in-basin assets, but eliminating the need for in-basin capacity with transmission capacity would require close to comprehensive upgrades

Summary of insights

1. No-regrets infrastructure
2. Maintaining options
3. Costs of achieving 100%

Scattergood Generating Station

Areas that we are still exploring with our modeling:

- The ability to deploy (and constraints on) in-basin peaking technologies (RE-CT, H2-CT, and fuel cells) and their associated fuel supply options
- In the absence of a hydrogen pipeline or ability to store liquid fuels on-site, pathway to 100% is unclear
- Adequacy and reliability of the system: are we planning around too high of a resource adequacy and reliability level?
- Avenues for cost reduction based on today's discussion

Preview of September AG Meeting

- Bulk power considerations that we have not had time to address today but will at September AG meeting:
  - Many details for each scenario, including access to results through an interactive visualization
  - Details behind our models to assess reliability (how we know these investments will work)
  - Summary of data provided to assess rate impacts

Thank you!

The Los Angeles 100% Renewable Energy Study

Information that will be provided to assess impacts to rates:

- Cash flow data by year consisting of:
  - – Raw capital investment
  - – Fixed O&M
  - – Variable costs:
    - O&M
    - Fuel
    - All other bulk system operational costs (e.g., start & stop)