NREL
Transforming ENERGY

Global trends in research and modelling

Future of the Grid

13-14 September 2023; Johannesburg, South Africa

Jarrad **WRIGHT** jarrad.wright@nrel.gov

NREL at-a-Glance

World-class facilities

One of the Department of Energy’s 17 national laboratories

>3000

Workforce

219 postdoctoral researchers

60 graduate students

81 undergraduate students

More than 900

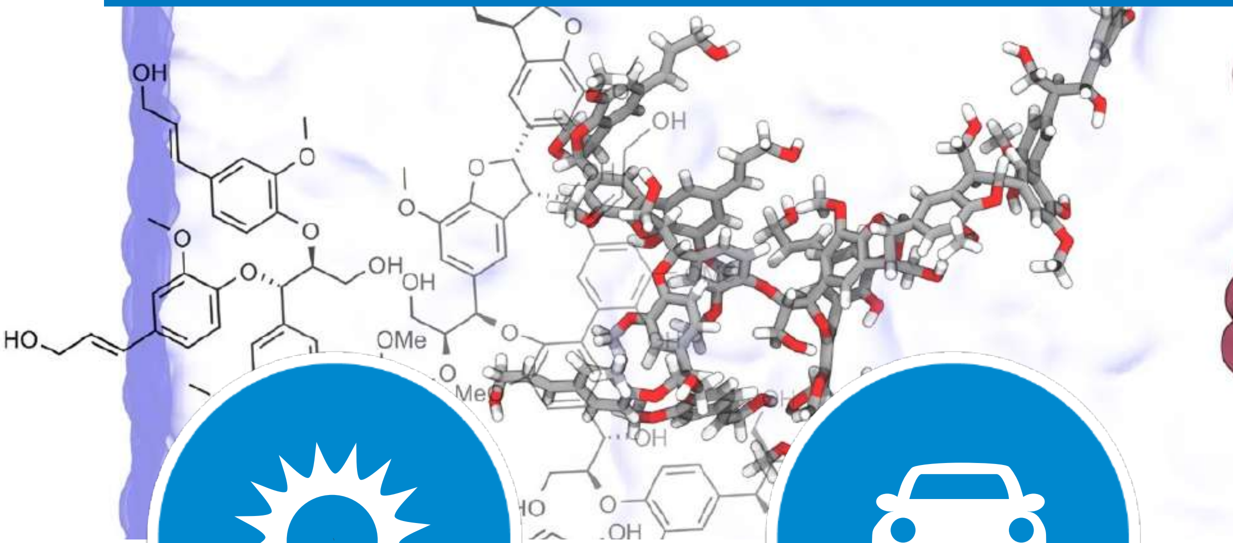
Partnerships

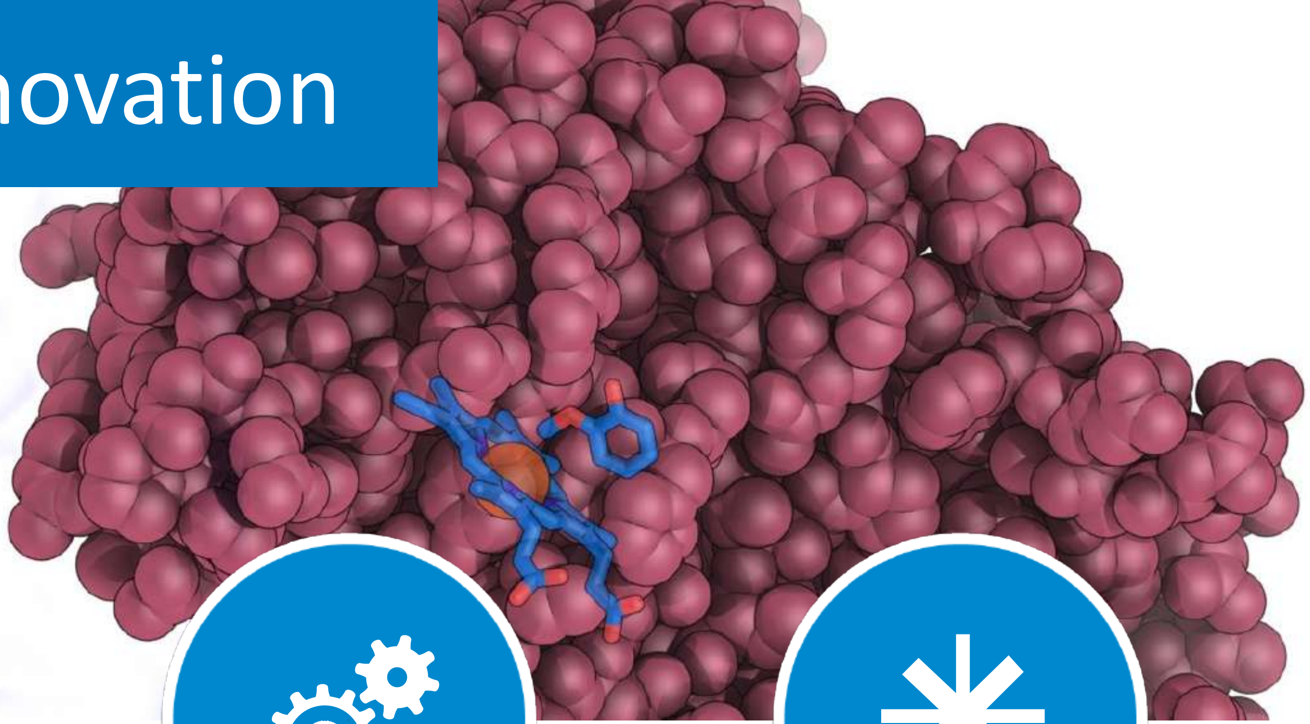
with industry, academia, and government

Campus

operates as a living laboratory

NREL Science Drives Innovation





Renewable Power

Solar

Wind

Water

Geothermal

Sustainable Transportation

Bioenergy

Vehicle Technologies

Hydrogen

Energy Efficiency

Buildings

Advanced Manufacturing

Government Energy Management

Energy Systems Integration

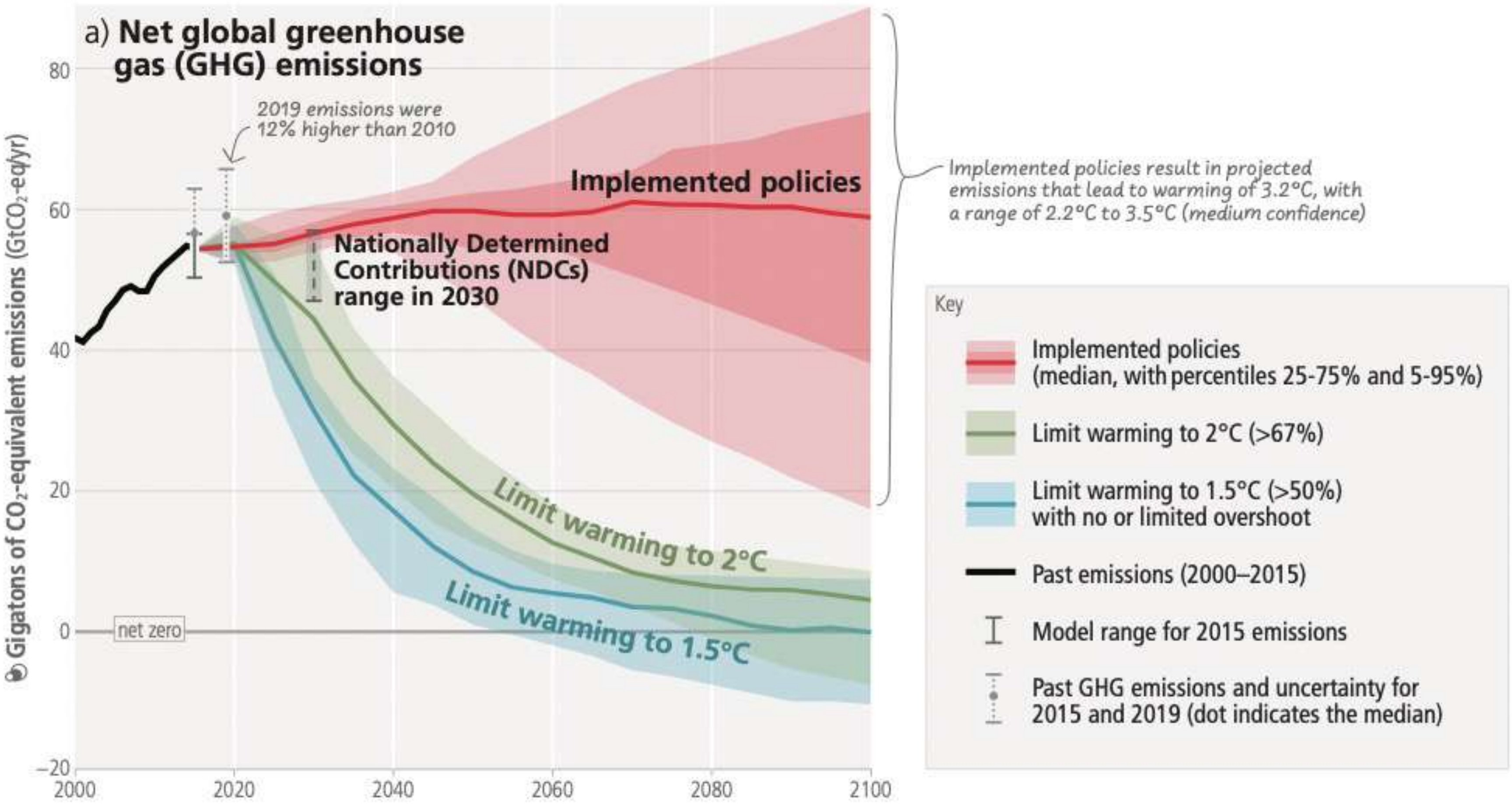
Grid Integration

Hybrid Systems

Security and Resilience

Global decarbonization is lagging behind

Per UN Climate Action Report and UN Sustainable Development Goals, emissions need to peak before 2025, decline by ~45% by 2030 and reach net zero by 2050



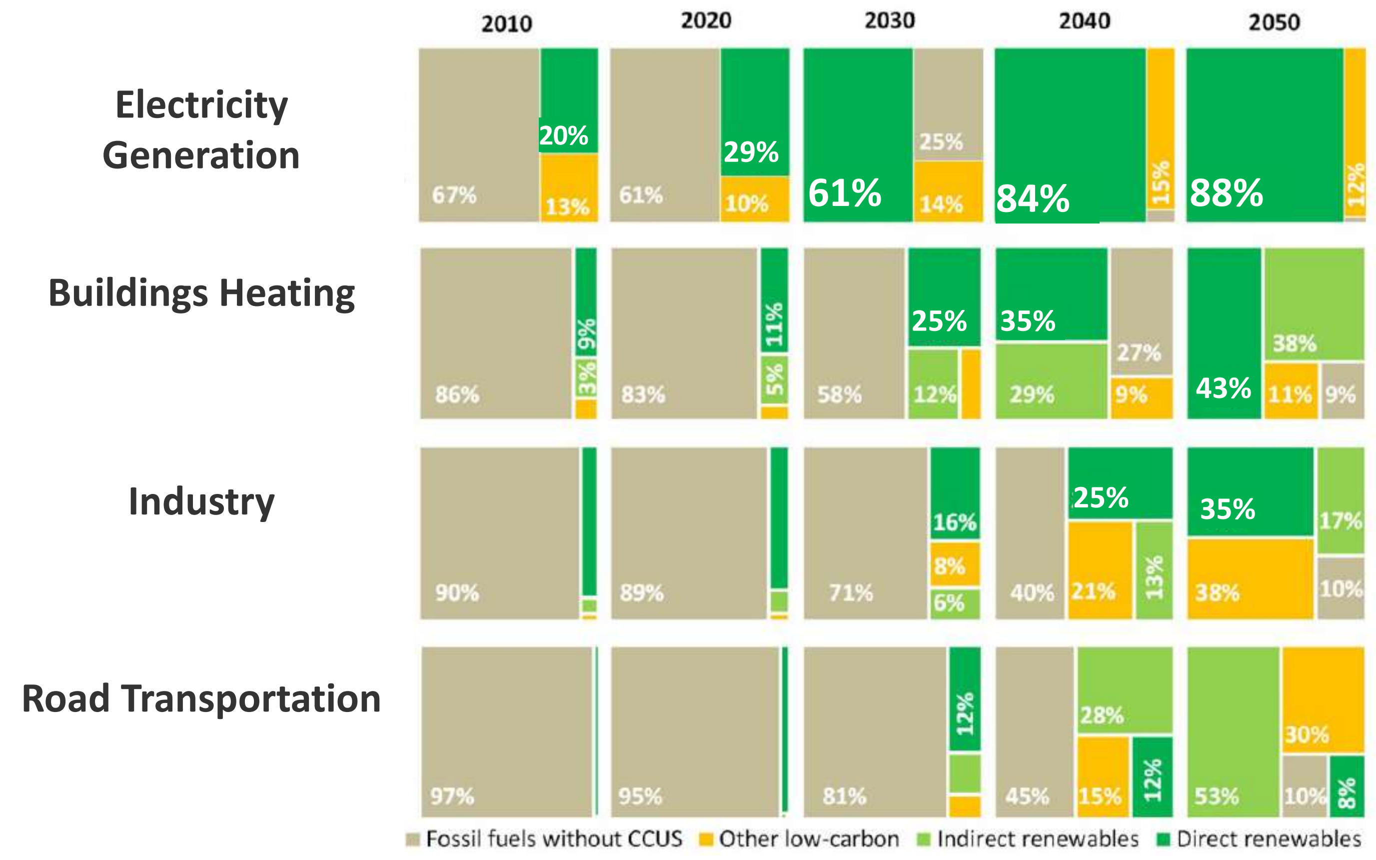
~25% of global GHG emissions are from power generation

Source: [IPCC AR6 Report]

Renewables and the power sector must lead decarbonization

*IEA's net zero pathway highlights a need to **accelerate renewable energy** to drive decarbonization of the power sector and **lead the way** for other sectors like heating, industry, and transportation*

Figure 2.18 ▷ Fuel shares in total energy use in selected applications in the NZE

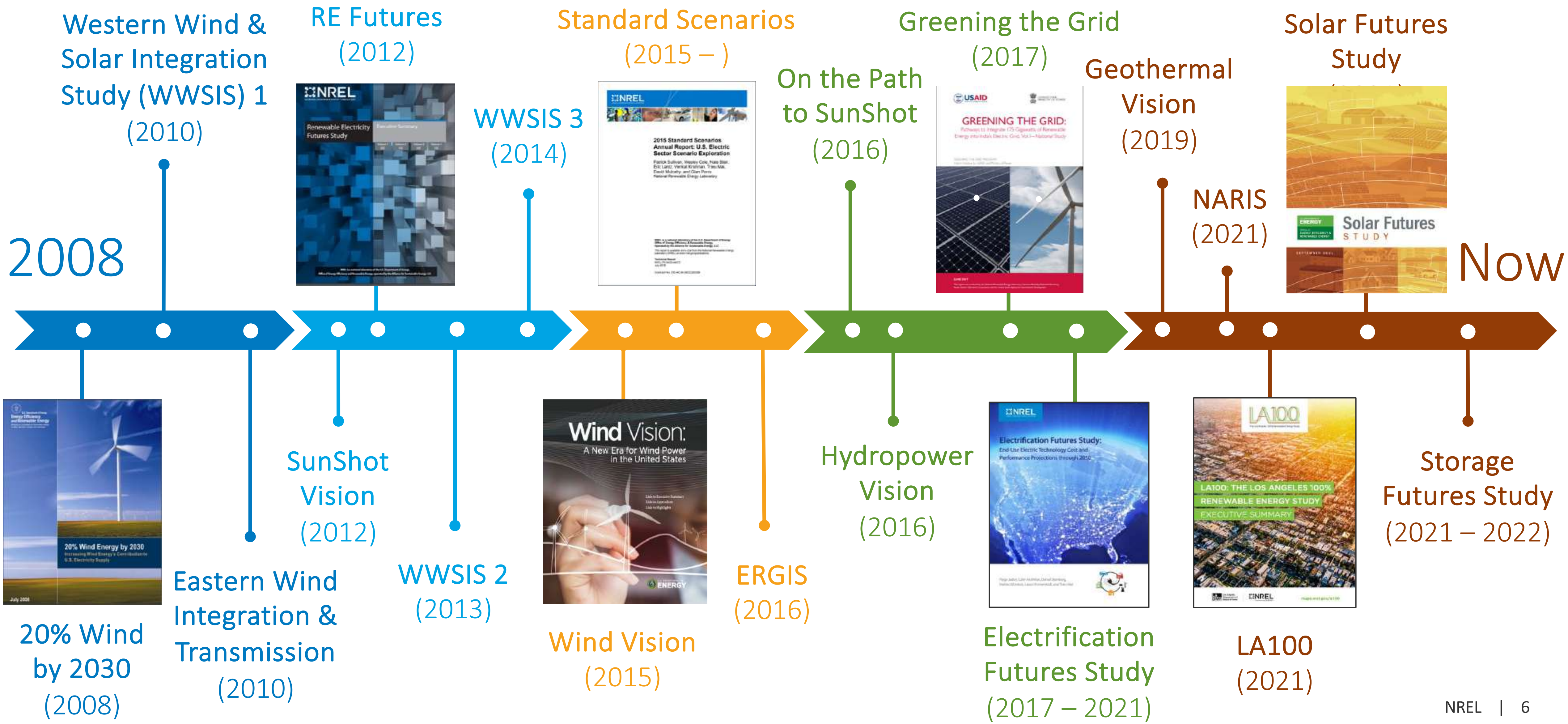


Source: IEA Net Zero by 2050

By 2030, at least ~60% direct renewable energy in the global power sector is needed to support decarbonization pathways.

Solar PV and wind will need to make up nearly 70% of renewable energy.

Long History of Clean Grid… exciting to now be serious about 100%

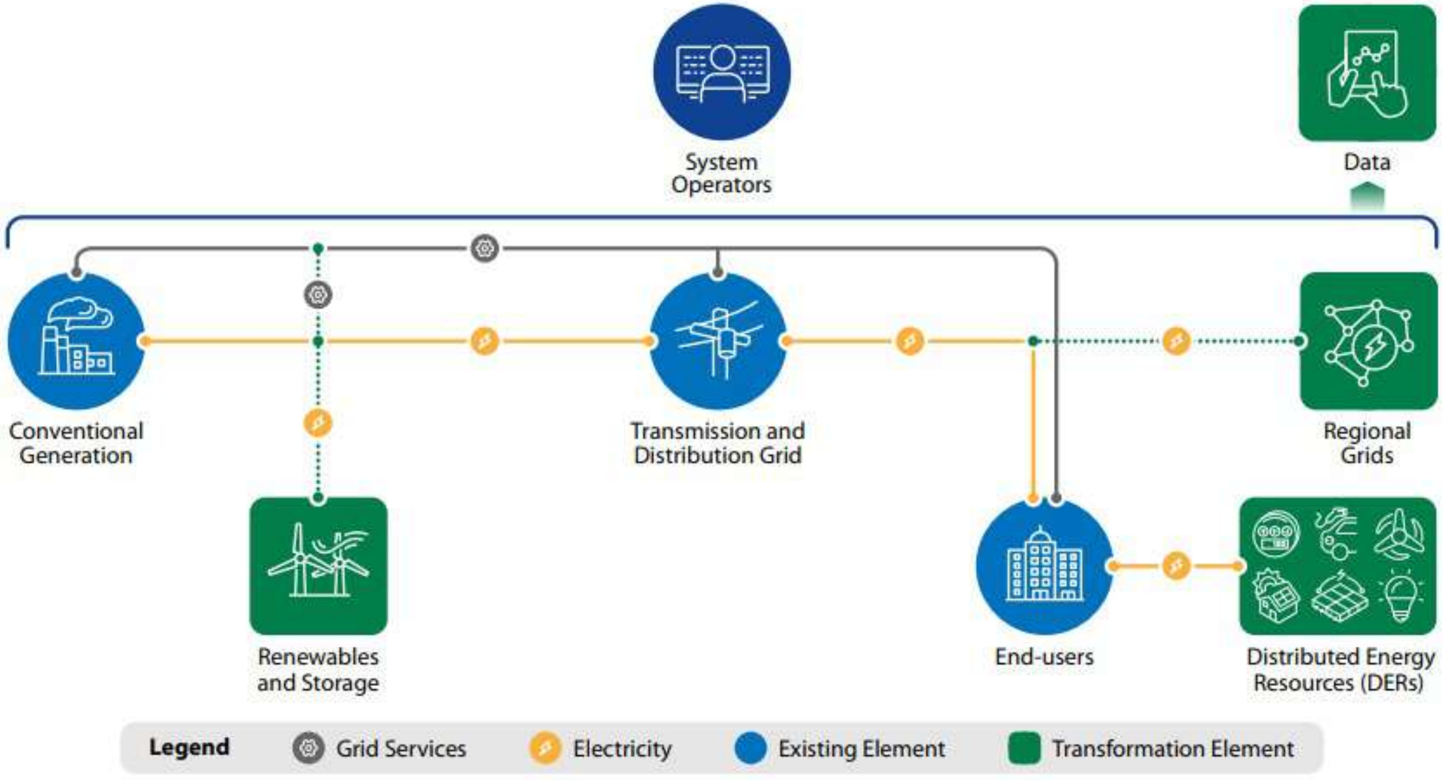


Key bottlenecks for renewables are looming over the energy transition

As renewables increase, significant challenges must be addressed to ensure systems can integrate and utilize renewables while still maintaining reliability of the grid

Renewables need to not only replace the electric power from traditional generation, but also services and functions that provide **reliability** and **stability** for the grid (e.g. operating reserves, voltage control, frequency, etc.)

Because renewables operate fundamentally differently from traditional generation, system operators **need new tools, methodologies, technologies, and research** to build confidence for renewables and storage to be able to meet all these needs.



As grids across the globe add more renewables and other advanced energy technologies, system operators must adopt novel approaches to adapt to the changes and overcome key barriers to power system transformation.

Bottlenecks for integrating renewables arise from many factors

Integration challenges for renewables stem from a variety of factors from current technology limitations, limited codes and standards, underdeveloped market frameworks, policy restrictions, and operator confidence

Technology

Certain technologies supporting renewables are still emerging and solutions need to be developed and piloted to enable renewables to deliver stability and reliability services (e.g., grid forming technologies, energy storage, GETs)

Standards and Frameworks

Definitions of services, market products, and technologies for supporting renewables and energy storage are underdeveloped or don't exist, limiting what renewables are able to do (e.g., meeting requirements for system stability, frequency, and voltage)

Operational Policy

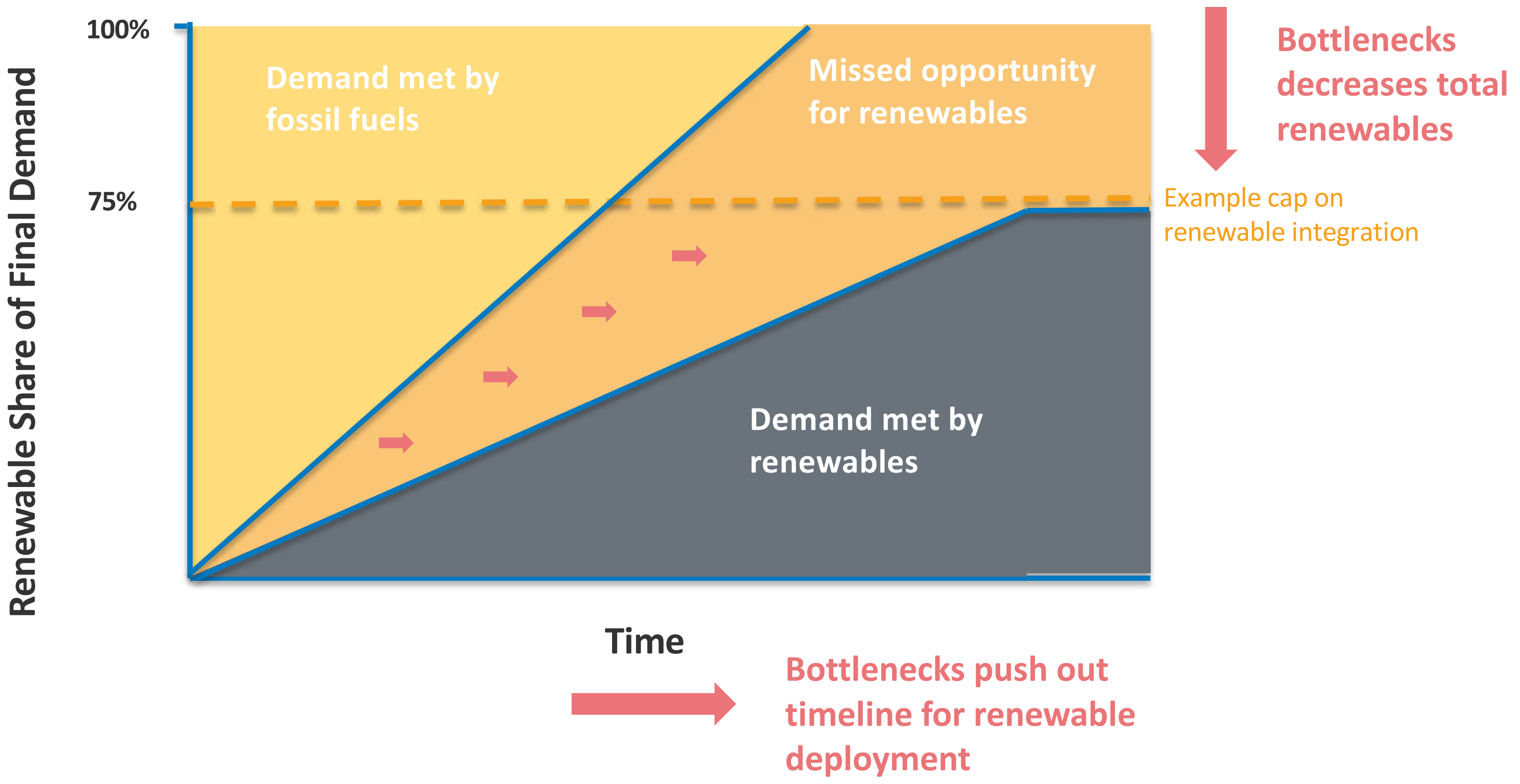
Operational policies for system operators limit the services that renewables can provide (e.g., total VRE limits, minimum generation from synchronous fossil generators, imports/exports limitations)

Confidence

System operators haven't seen renewable energy solutions provide needed services before and renewable energy functions very differently from what they are used to (e.g., default to fossil fuel systems that are more familiar)

Bottlenecks will limit and slow growth of renewables

It does not matter how many megawatts are built - if they cannot be used ***the world will miss net zero by 2050***



If bottlenecks aren't addressed, leading system operators will lack confidence in renewables for their systems and will limit what services renewables can provide and slow integration of renewables to ensure stability and reliability.

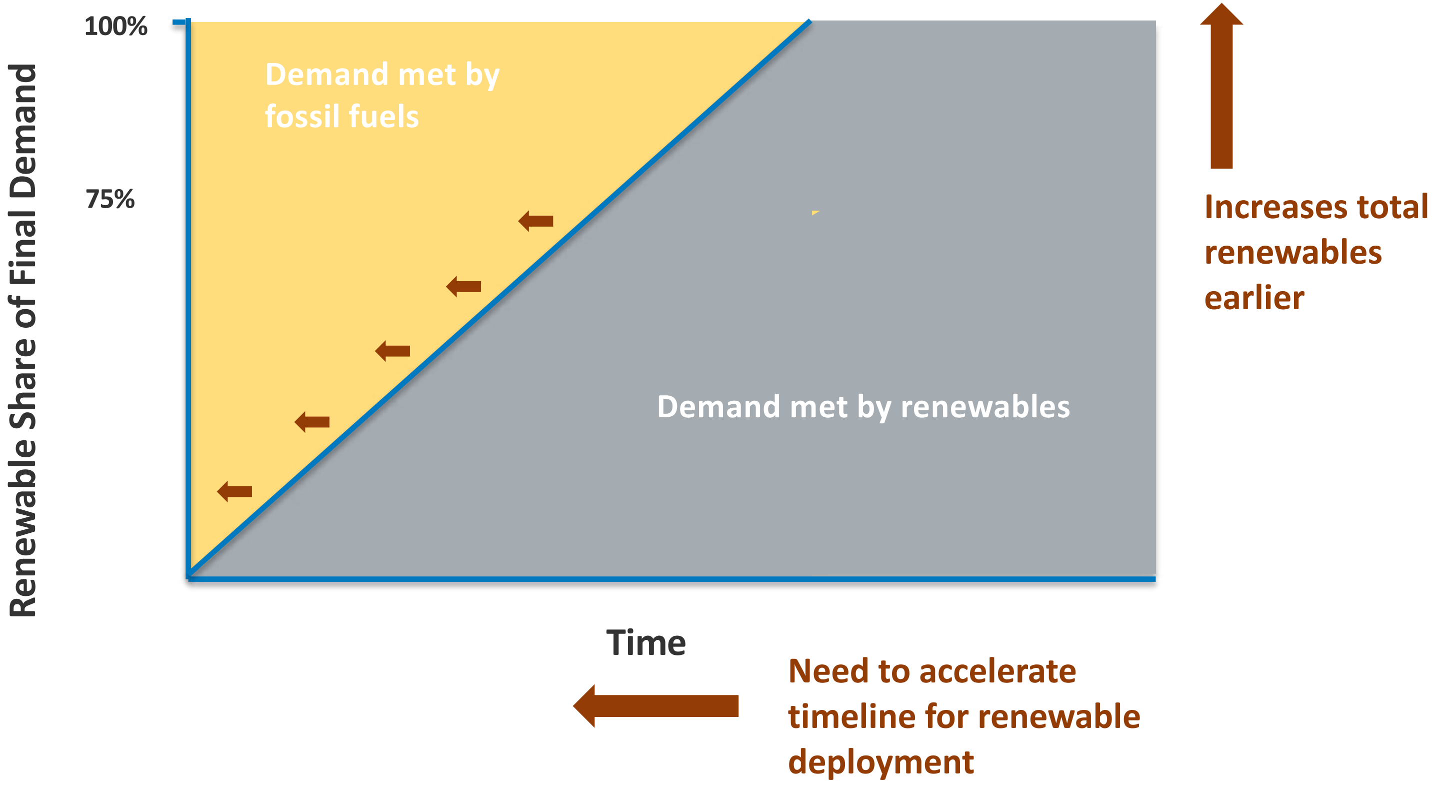
This has cascading effects and will cause other system operators to follow similar practices.

Need to proactively address bottlenecks and delivers global solutions

Need to develop the critical solutions to solve bottlenecks for renewable energy – increasing system operator confidence to operate high renewable systems and accelerating the clean energy transition

Key solutions addressing bottlenecks identified by selected system operators

- System needs and services
- Grid forming resources
- Stability assessment
- Resource adequacy
- Control room of the future
- Distributed energy resources



Advanced modelling for 100%

LA100

The Los Angeles 100% Renewable Energy Study

The most comprehensive study ever done to model a grid this large and complex

LA set a bold goal: transition to 100% renewable electricity supply by 2045

But even in LA’s sunny sprawl

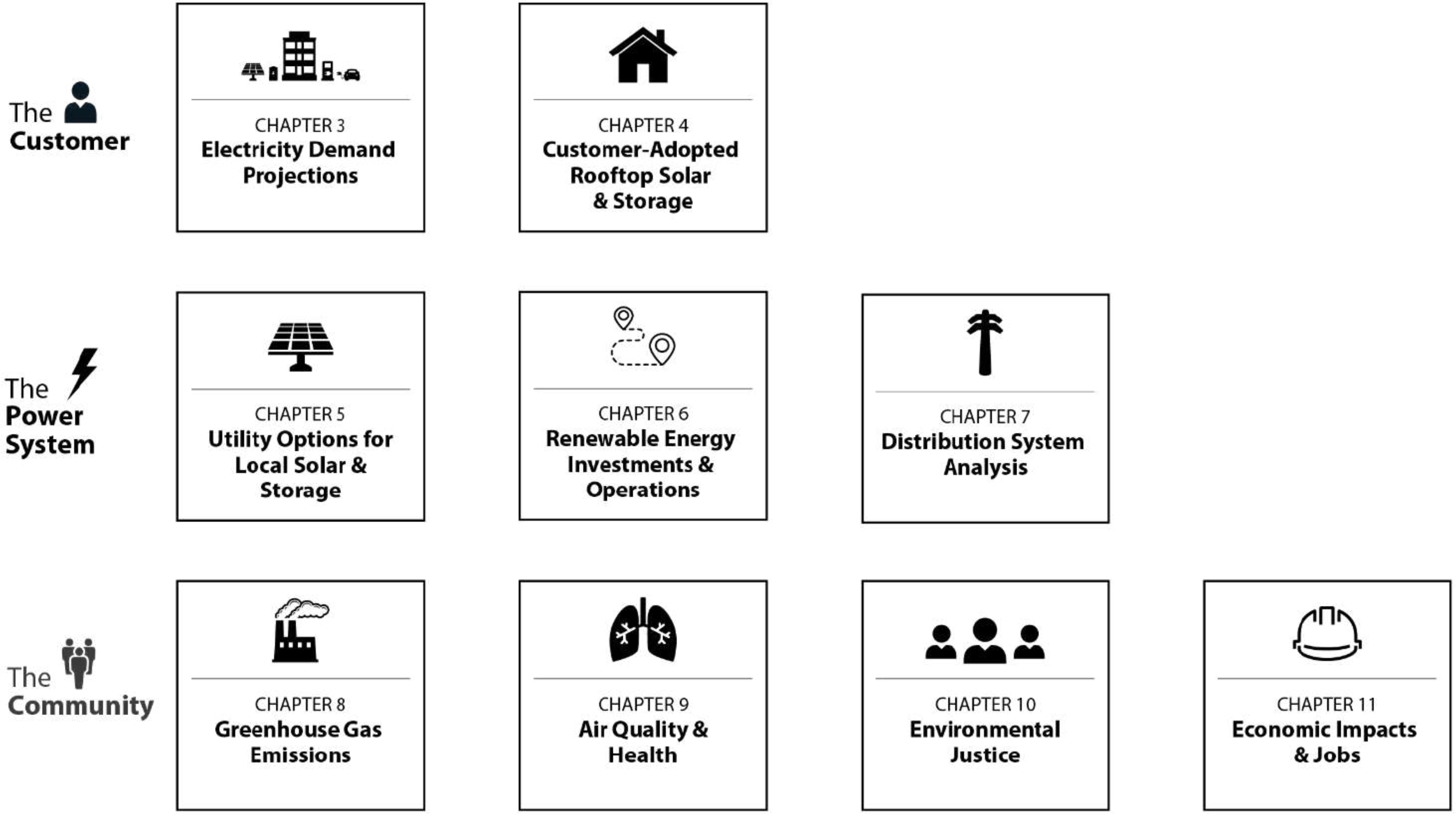
100% is not as simple as building lots of solar

Los Angeles Department of Water and Power (LADWP)

L.A.'s Current Power Grid

7,880 MW of Generation Capacity
Peak Load: 6,502 MW (Aug. 31, 2017)
4 million residents

LA100: More than just the Power System



LA100 Scenarios

Each Scenario Evaluated Under Different Customer Demand Projections
(different levels of energy efficiency, electrification, and demand response)

Moderate

High

Stress

SB100

Evaluated under Moderate, High, and Stress Load Electrification

- 100% clean energy by **2045**
- Only scenario with a target based on retail sales, not generation
- Only scenario that allows up to 10% of the target to be natural gas offset by renewable electricity credits
- Allows existing nuclear and upgrades to transmission

Early & No Biofuels

Evaluated under Moderate and High Load Electrification

- 100% clean energy by **2035**, 10 years sooner than other scenarios
- No natural gas generation or biofuels
- Allows existing nuclear and upgrades to transmission

Transmission Focus

Evaluated under Moderate and High Load Electrification

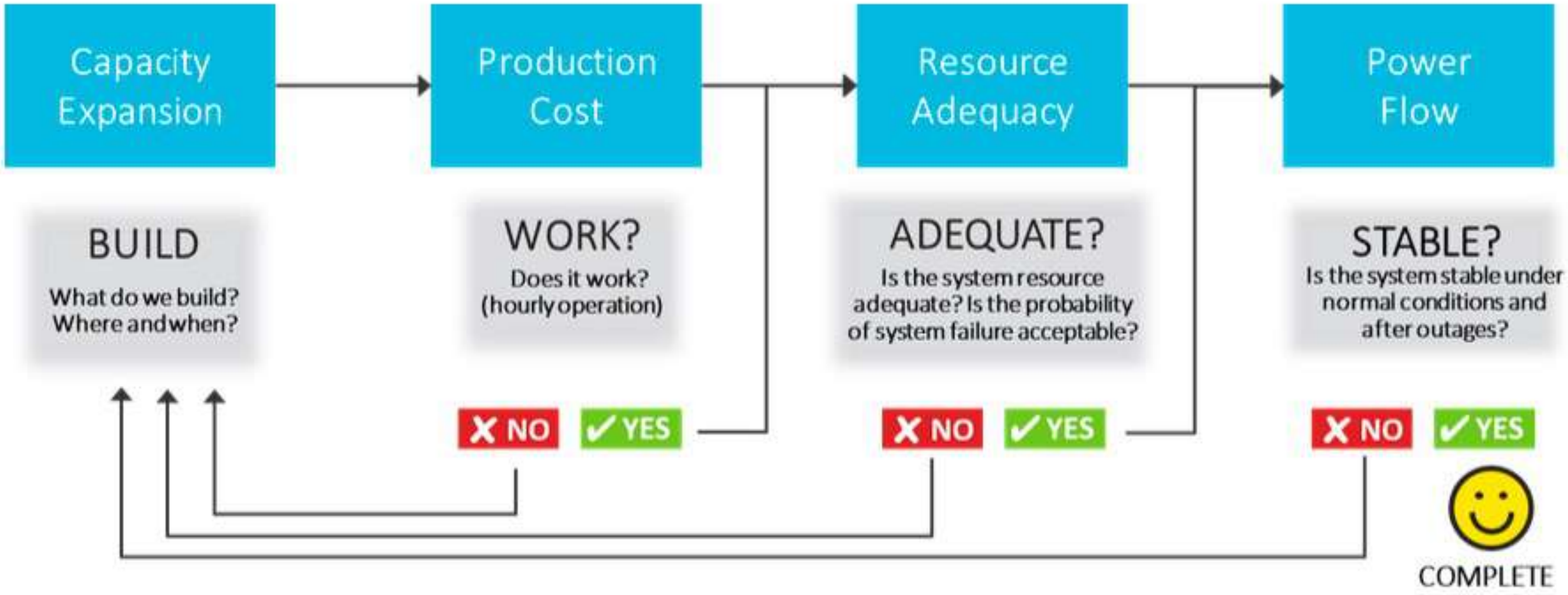
- 100% clean energy by **2045**
- Only scenario that builds new transmission corridors
- No natural gas or nuclear generation

Limited New Transmission

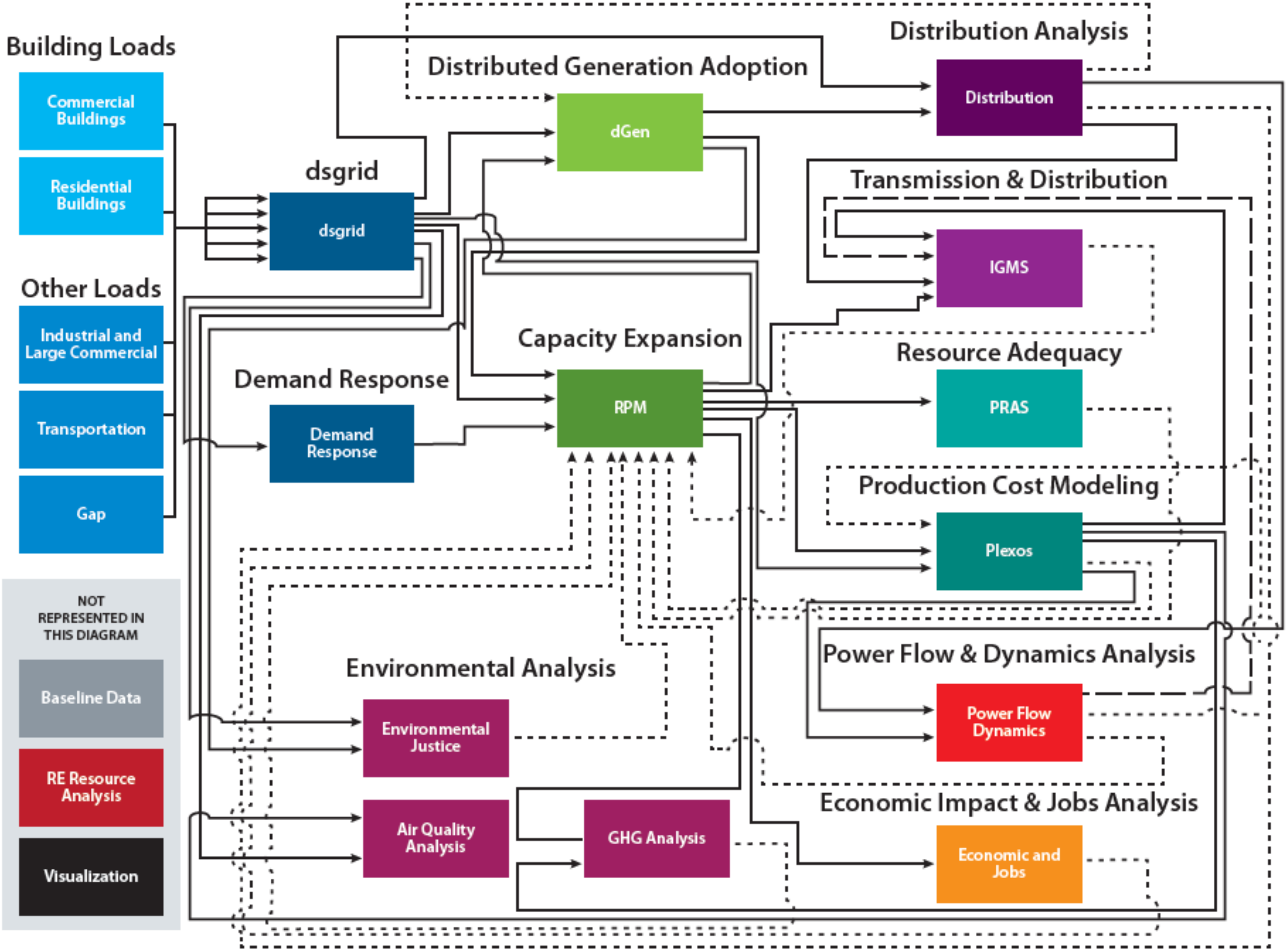
Evaluated under Moderate and High Load Electrification

- 100% clean energy by **2045**
- Only scenario that does not allow upgrades to transmission beyond currently planned projects
- No natural gas or nuclear generation

LA100 bulk system workflow



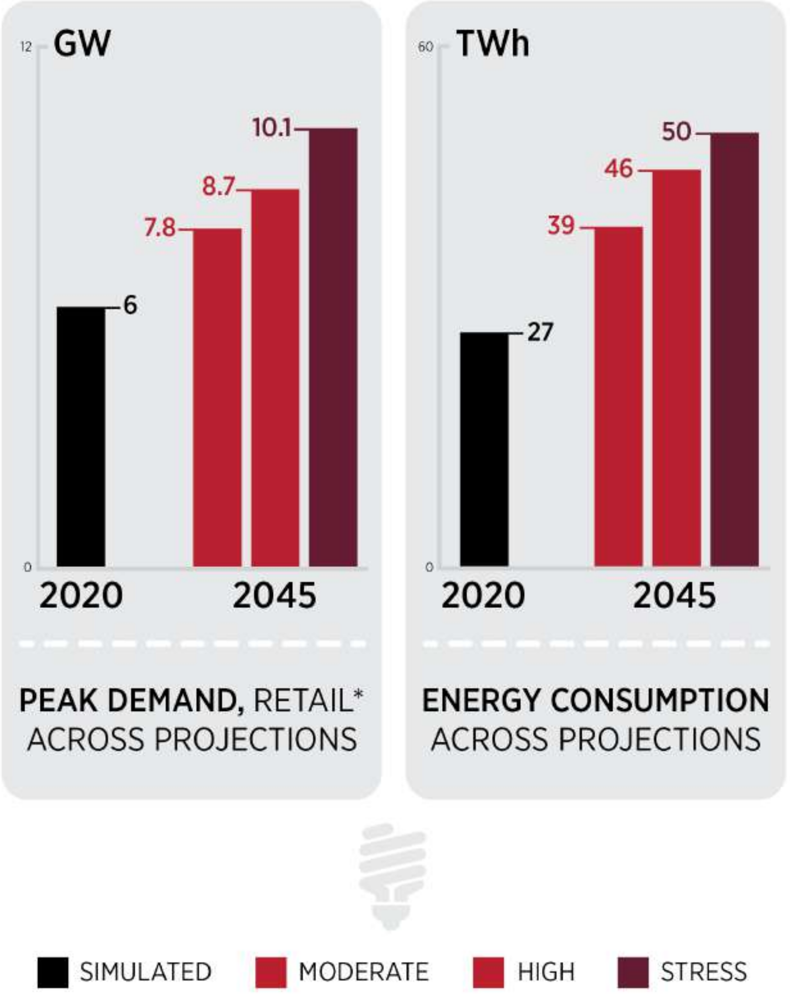
LA100 leveraged substantive expertise and High-Performance Computing



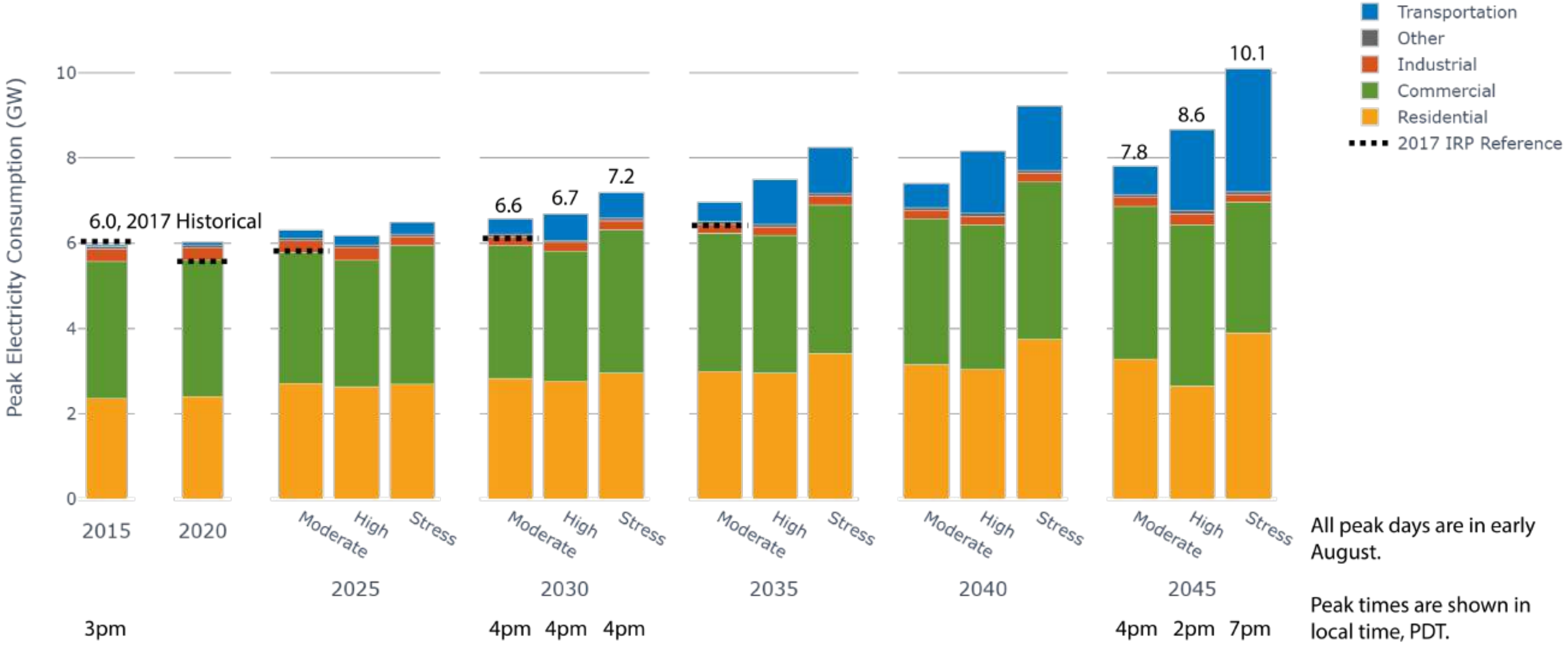
Over 100 million simulations

What did we find?

High levels of energy efficiency help offset load growth due to building electrification; transportation drives load growth



*Based on customer demand at the meter and not including losses.
Totals are also prior to shifts in timing due to customer demand flexibility.



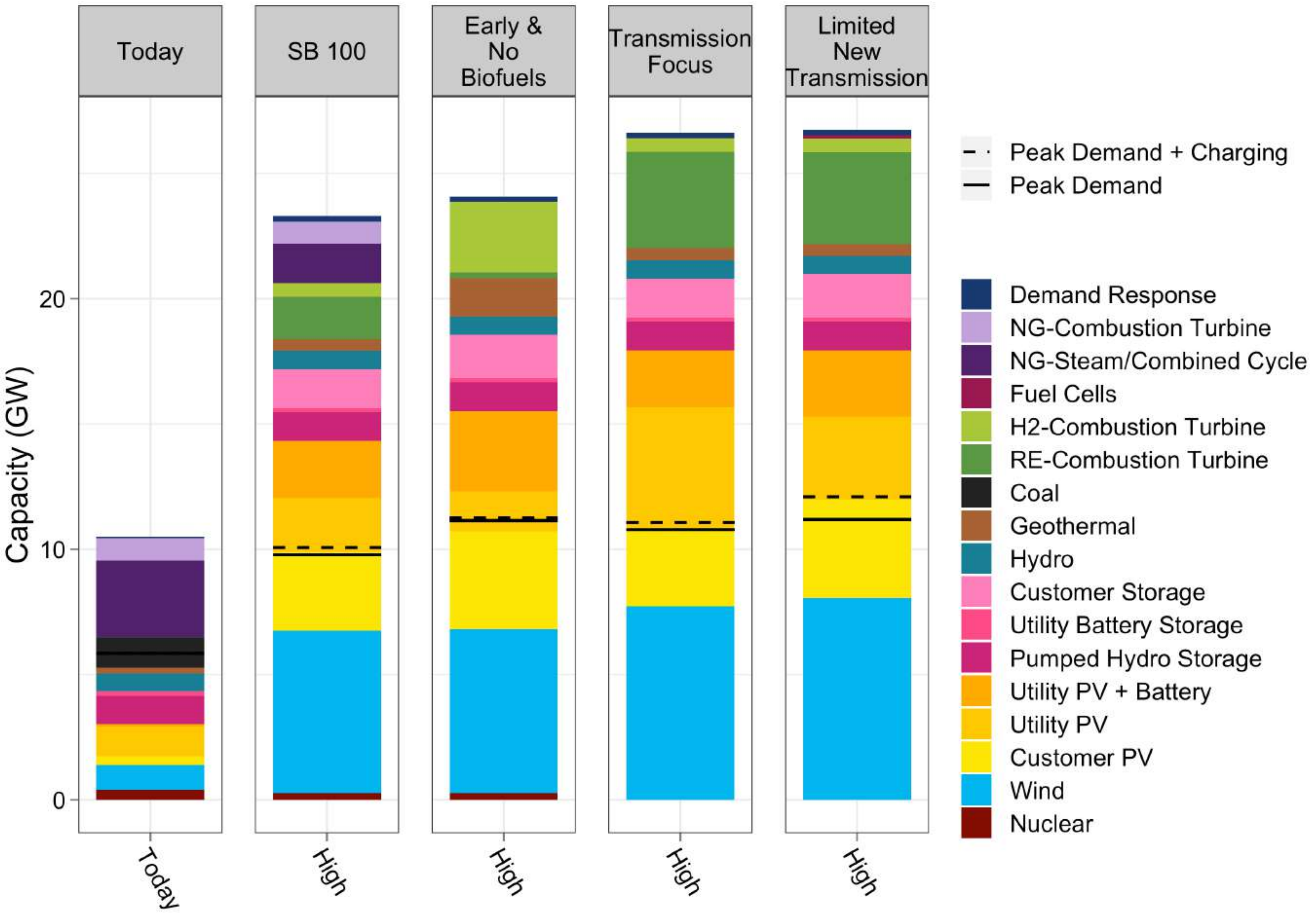
In all scenarios, wind and solar provide 69%–87% of future load, and new renewable firm capacity is built in the LA basin to maintain reliability.

The pathways diverge going from 90% to 100% renewables.

This last 10% is what is needed for reliability during periods of very low wind and solar, extremely high demand, and unplanned events like transmission outages.

Meeting the last 10% on the road to 100%

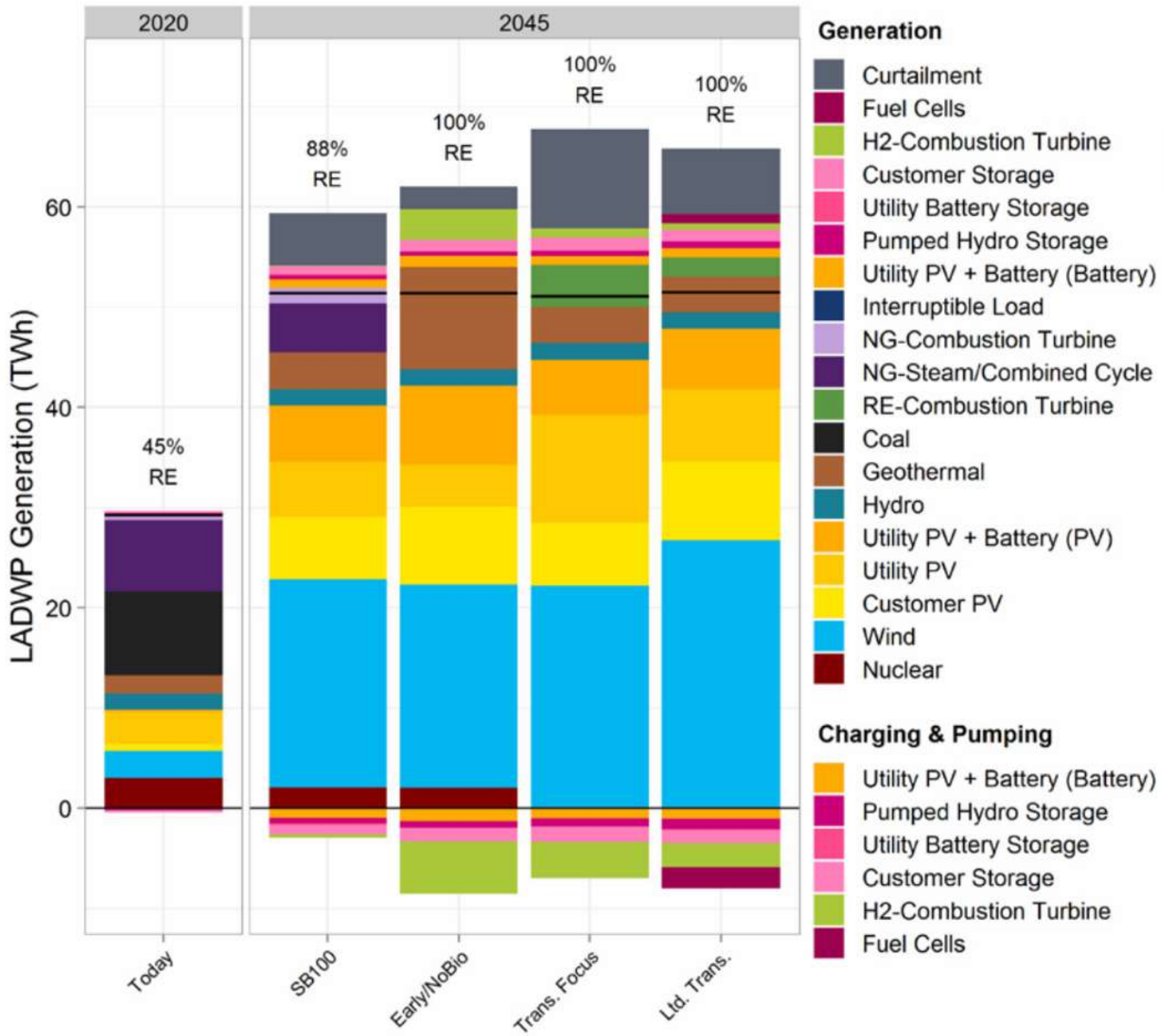
Producing hydrogen adds ~20% to cumulative costs (rather than buying commercially available RE fuels)



Capacity Mix in 2045 — High Load Scenarios, Compared to 2020

Very different operational regime (flexibility is key)

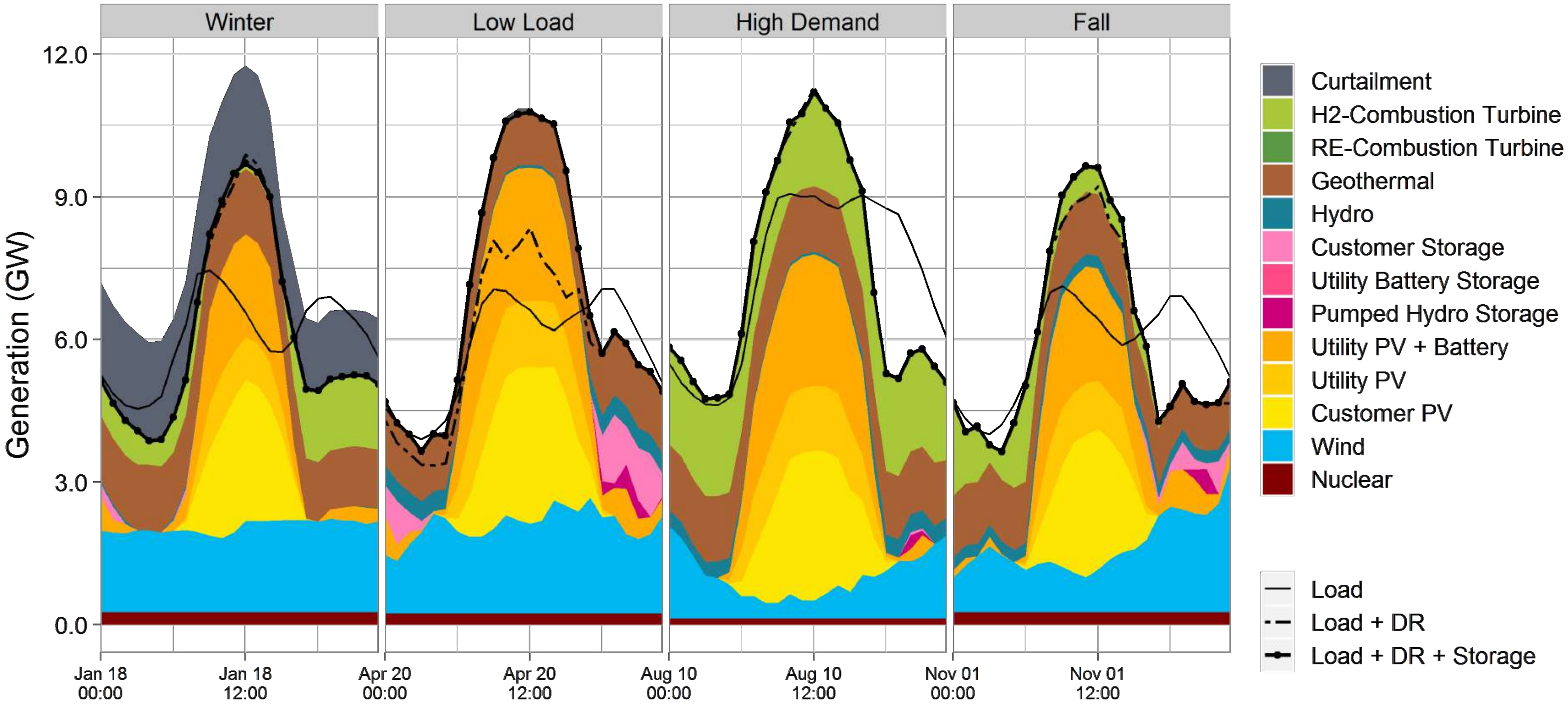
100% RE necessities some optimal level of curtailment
2x demand growth combined with a very different resource mix



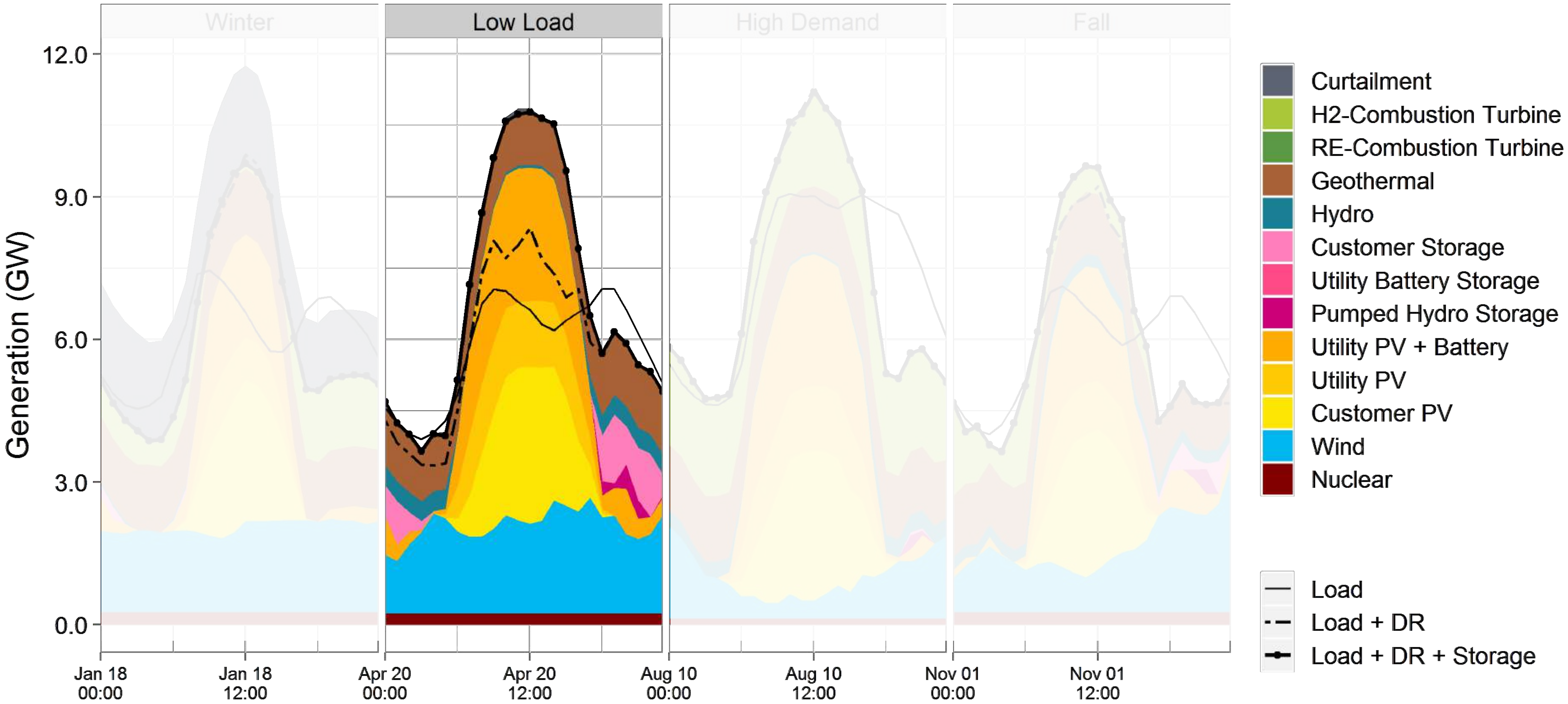
Energy Mix in 2045 — High Load Scenarios, Compared to 2020

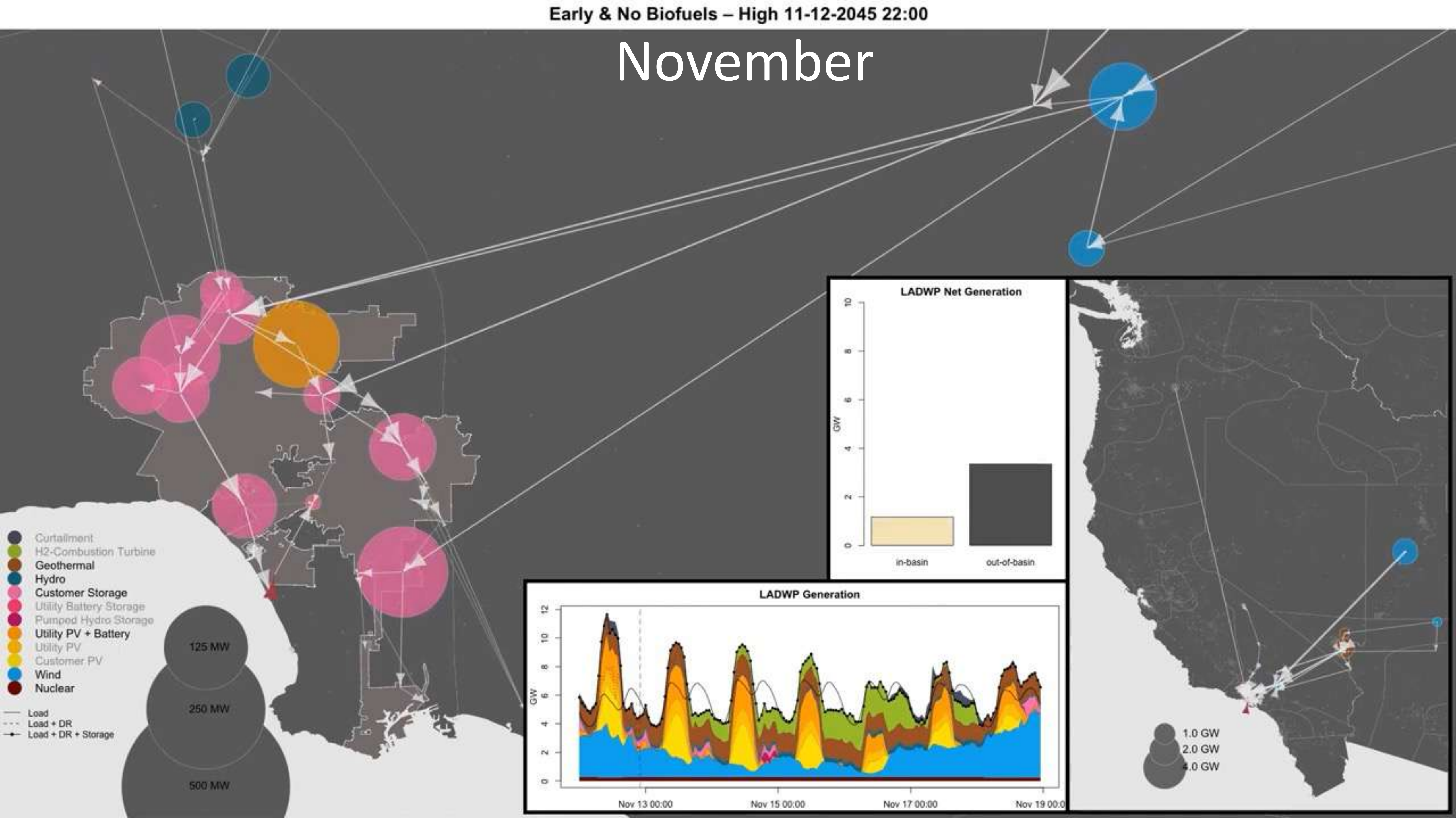
How does LADWP maintain balance in a 100% RE system?

System operation:
What resources are operating in every hour?



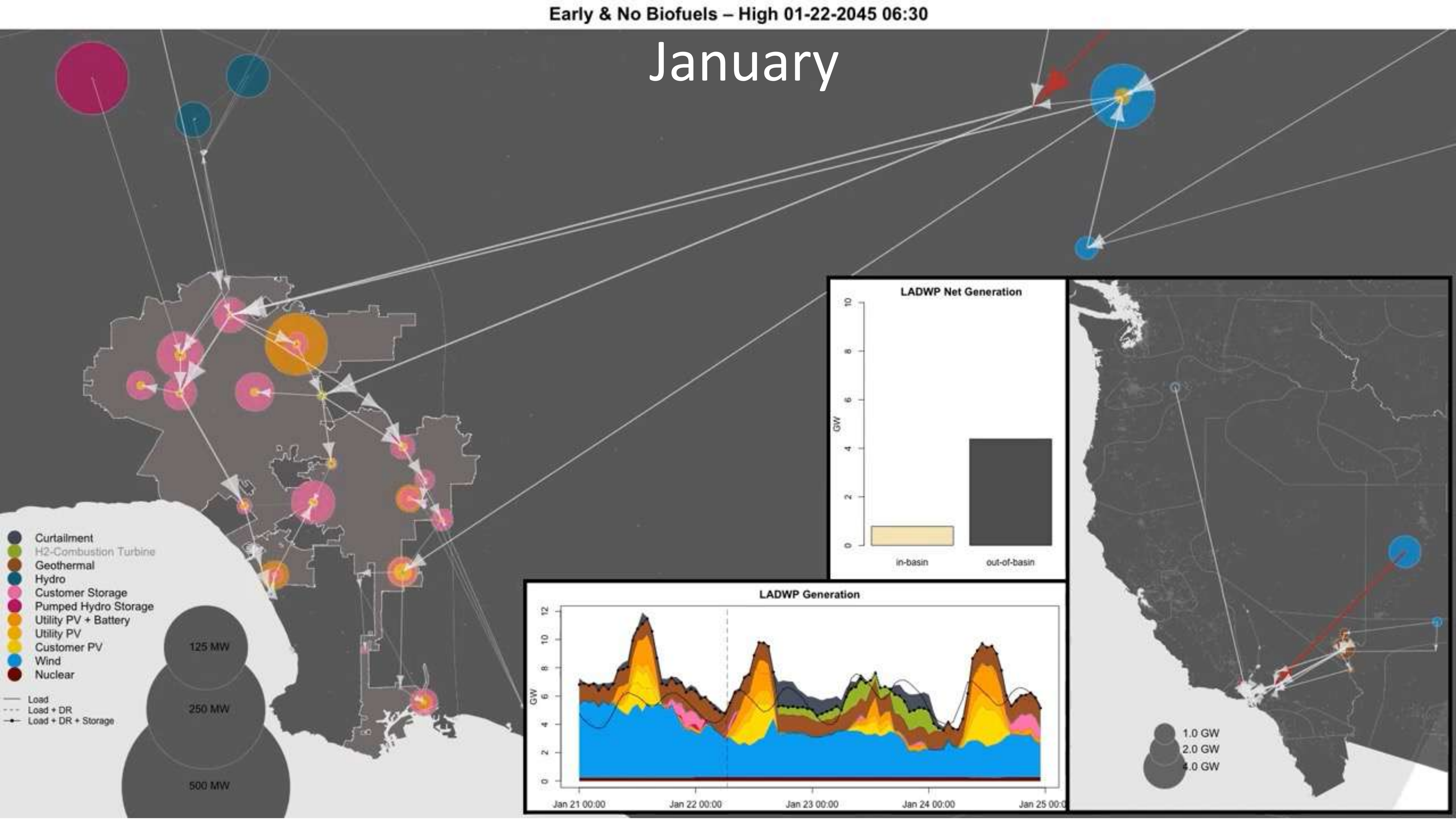
System operation:
What resources are operating in every hour?

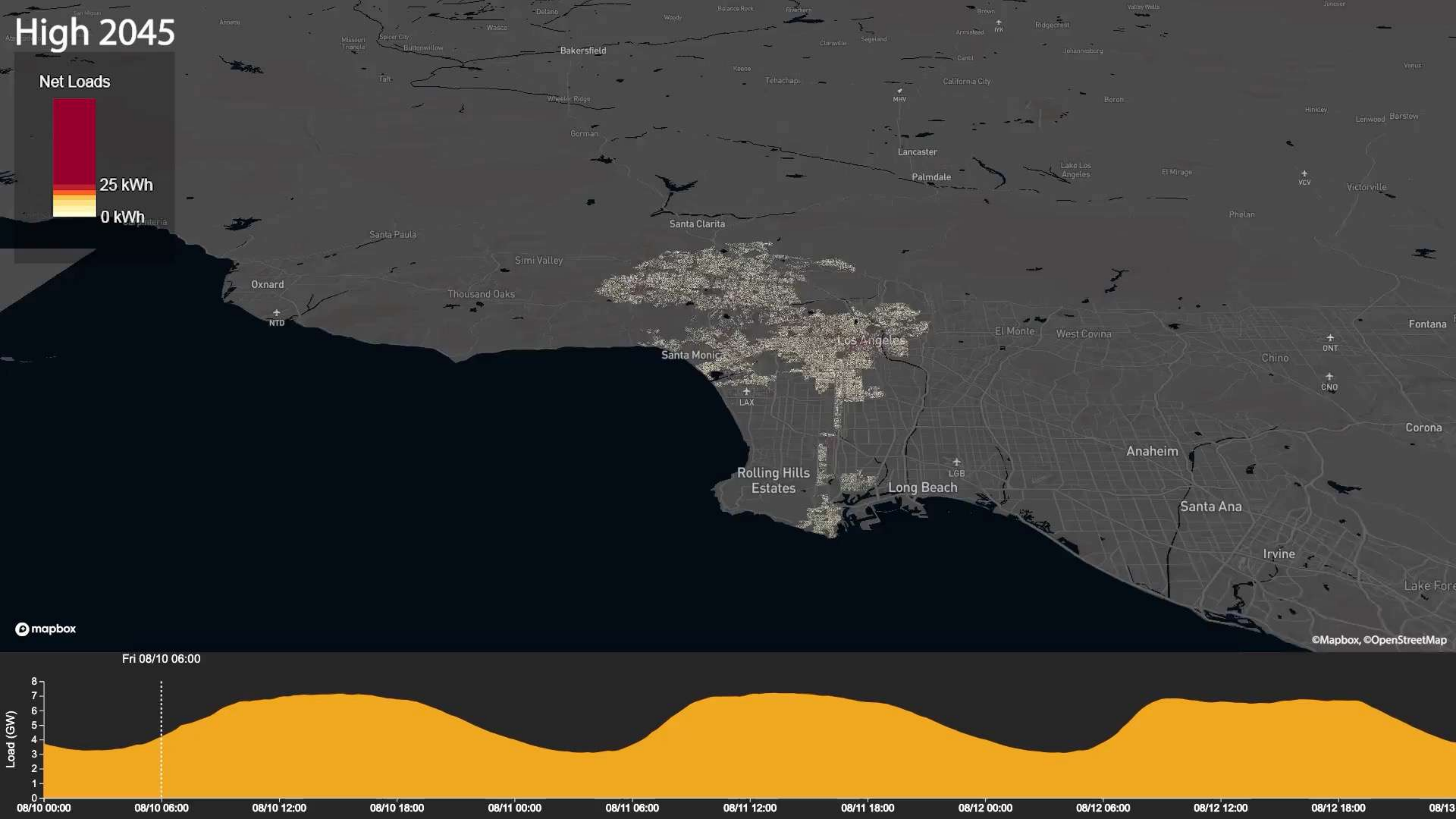




Early & No Biofuels – High 11-12-2045 22:00
November
Curtailment
H2-Combustion Turbine
Geothermal
Hydro
Customer Storage
Utility Battery Storage
Pumped Hydro Storage
Utility PV + Battery
Utility PV
Customer PV
Wind
Nuclear
125 MW
250 MW
500 MW
Load
Load + DR
Load + DR + Storage
LADWP Net Generation
GW
in-basin
out-of-basin
LADWP Generation
Nov 13 00:00
Nov 15 00:00
Nov 17 00:00
Nov 19 00:0
1.0 GW
2.0 GW
4.0 GW

January


Early & No Biofuels – High 01-22-2045 06:30
Curtailment
H2-Combustion Turbine
Geothermal
Hydro
Customer Storage
Pumped Hydro Storage
Utility PV + Battery
Utility PV
Customer PV
Wind
Nuclear
Load
Load + DR
Load + DR + Storage
125 MW
250 MW
500 MW
LADWP Net Generation
GW
in-basin
out-of-basin
LADWP Generation
GW
Jan 21 00:00
Jan 22 00:00
Jan 23 00:00
Jan 24 00:00
Jan 25 00:00
1.0 GW
2.0 GW
4.0 GW


High 2045
Net Loads
25 kWh
0 kWh
Bakersfield
Tehachapi
California City
Lancaster
Palmdale
Santa Clarita
Santa Paula
Simi Valley
Oxnard
Thousand Oaks
Santa Monica
Los Angeles
El Monte
West Covina
Fontana
Chino
Corona
Anaheim
Rolling Hills Estates
Long Beach
Santa Ana
Irvine
Victorville
Phelan
mapbox
©Mapbox, ©OpenStreetMap
Fri 08/10 06:00
Load (GW)
8
7
6
5
4
3
2
1
0
08/10 00:00
08/10 06:00
08/10 12:00
08/10 18:00
08/11 00:00
08/11 06:00
08/11 12:00
08/11 18:00
08/12 00:00
08/12 06:00
08/12 12:00
08/12 18:00
08/13

Across All Scenarios

Electrification
Efficiency
Flexible Load

Customer Rooftop Solar

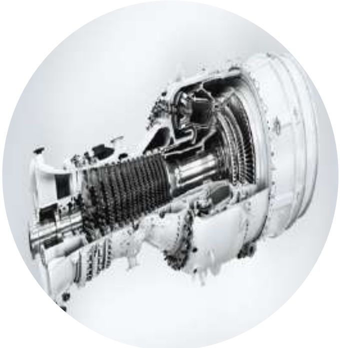
Renewable Energy

Solar: + >5,700 MW
Wind: + >4,300 MW

Storage
(including coupled with solar)

+ >2,700 MW

Distribution,
Transmission



Renewably Fueled Combustion Turbines

+>2,600 MW
(in basin)

Much More

New

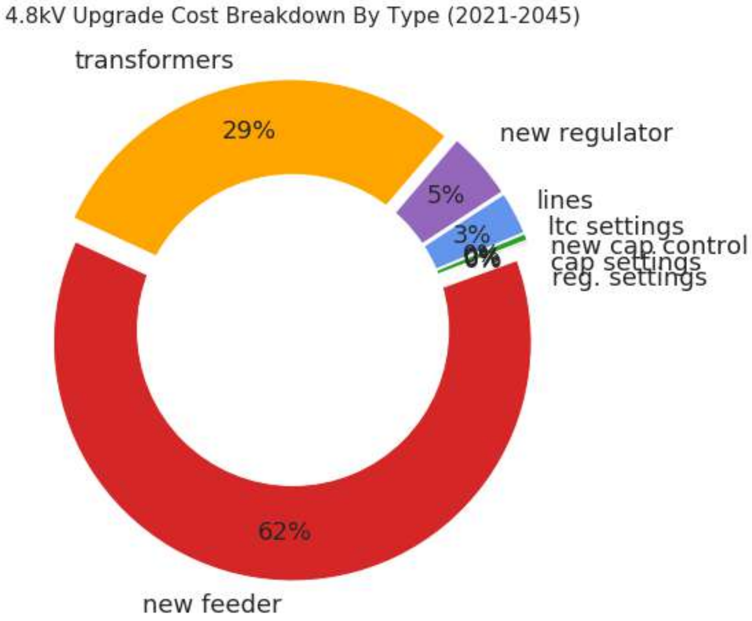
Natural gas → Biofuel/ hydrogen

Today:
Daily

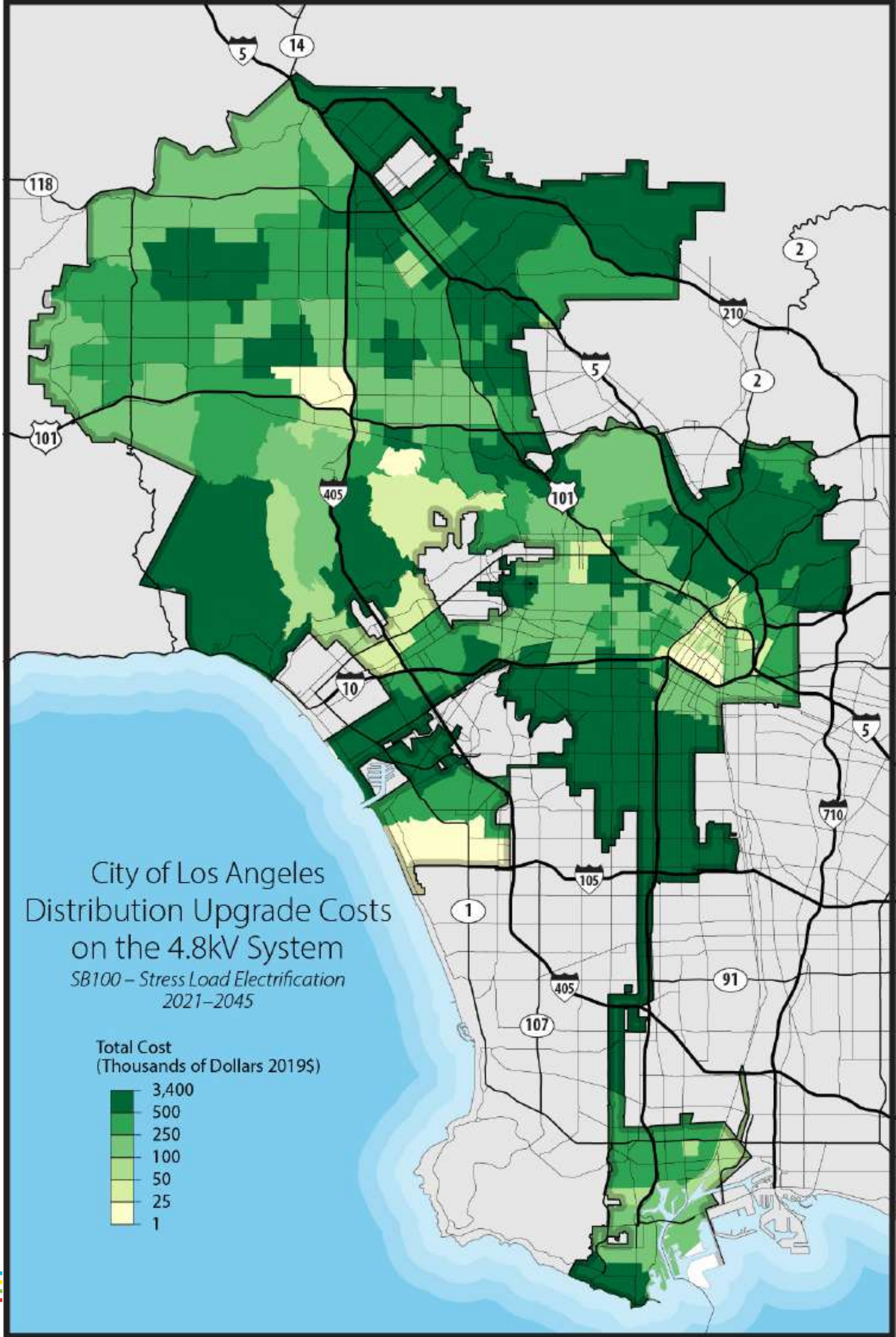
Future:
Infrequently

Identifying alternative options for firm, in-basin capacity likely represents the largest opportunity to reduce the costs of the transition and points to the highest priorities for R&D: hydrogen and extended demand response.

What type of distribution upgrades are needed and where?



Across all scenarios



LA100

The Los Angeles 100% Renewable Energy Study

LA100 Equity Strategies

THE CHALLENGE:

- How can Los Angeles ensure its transition to 100% clean energy with high levels of electrification improves energy justice?

OUR SOLUTION:

- Prioritize energy justice outcomes based on community input
- Analyze clean-energy transition pathways that maximize energy justice outcomes for all communities in LA

POTENTIAL IMPACT:

- Improved understanding of factors contributing to energy inequities
- Implementation-ready strategies to address energy justice in LA
- Replicable approaches for incorporating energy justice in future research

Questions?

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Web: https://www.nrel.gov/grid/