OPA Review of NREL LA100 Study

Frederick H. Pickel, Ph.D.
Office of Public Accountability / Ratepayer Advocate
City of Los Angeles
opa@LAcity.org
tel. 213-978-0220

LADWP SLTRP
Advisory Group Meeting
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OPA/RPA Review of NREL's LA100 Study

- The OPA commissioned the Brattle Group to assist in monitoring and developing a review of the NREL LA100 study.
  - The following slides summarize the costs, potential rates, and risks from discussion draft of this review.
  - The final, full version of this review will be presented to the DWP Board. The full draft is available at http://opa.lacity.org.
- Background on the LA100 study:
  - The focus was on impacts from 2020 to 2045. The OPA review looks at 5 year steps 2025-45.
  - The LA100 cost estimates are for the power sector. While LA100 included the cost of providing power for transportation and building electrification, the cost of electrifying transportation and buildings is not included.

Power Industry Investment Timeline

- You need to be building now what you expect to need by the end of the 5 years, or be contracted with others to do so.
  - Pandemic supply chain issues might stretch this timing out.
- You need to be finalizing plans now for what you hope to build or contract in 5 to 10 years.
- You plan for the period beyond 10 years, but recognize the uncertainties in those plans.

Review of the LA100 Study - Digest

PRELIMINARY DRAFT – FOR DISCUSSION PURPOSES

PRESENTED BY

T. Bruce Tsuchida

Sylvia Tang

PRESENTED TO

City of Los Angeles

Office of Public Accountability / Ratepayer Advocate

AUGUST 19, 2021

LA100

The Los Angeles 100% Renewable Energy Study

Brattle

LA 100 Study and Nine Pathways

- **Pathways = 4 scenarios and 3 demand projections (and electrification levels)**
  - All pathways can achieve 100% clean energy by 2045 while maintaining reliability.

INTRODUCTION – OVERVIEW OF THE LA100 STUDY

LA100 Study - Pathways (Scenario – Load)

Modest scenario →

Aggressive scenario →

Scenarios	
SB100: Complies with existing California law *Senate Bill 100*. Clean energy targets 100% retail sales by 2045, as opposed to total generation, while allowing unbundled renewable electricity certificates to meet up to 10% of the target.	SB100 Moderate* SB100 High *SB100 Stress*
Early & No Biofuels: Meets the 100% clean energy goal in *2035*, prohibits biofuels in all years, and assumes higher levels of customer rooftop solar adoption.	Early & No Biofuels Moderate Early & No Biofuels High
Transmission Focus: Achieves the 100% target by *2045*, assumes lower barriers to new transmission and upgrades, and eliminates nuclear energy generation by 2045.	Transmission Moderate Transmission High
Limited New Transmission: Achieves the 100% target by *2045*, assumes no new transmission capacity that is not already planned, and higher levels of customer rooftop solar adoption.	Ltd. Transmission Moderate Ltd. Transmission High

Demand Projection and Electrification

Moderate Load: Moderate (above-code) improvements to energy efficiency and moderate electricity demand growth due to electrification of consumer products (e.g., transportation and heating). ← Modest electrification

* SB100 Moderate is very close to the 2017 SLTRP after adjusting for load projections, OTC units retirement, and IPP coal replacement.

High Load: Assumes a more widespread effort to decarbonizing buildings and transportation. The higher energy-efficiency target leads customers to almost exclusively select (when purchasing) the most efficient building materials and appliances. ← Higher electrification

Stress Load (only applicable to SB100 scenario): Aggressive electrification assumptions (same as High Load) but with lower efficiency and demand response improvements (compared to Moderate Load), leading to a even higher load.

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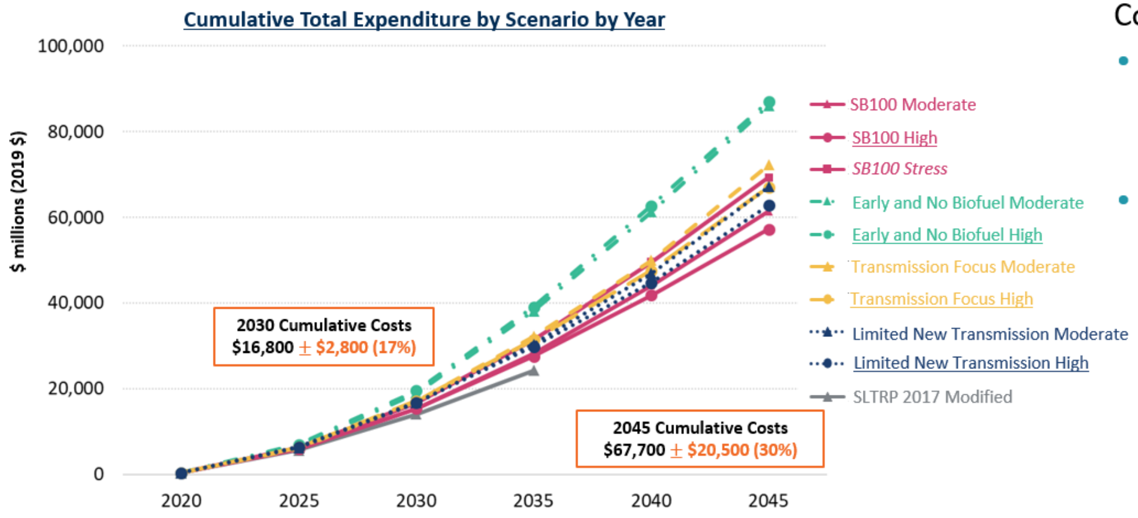
See slide 5 of full presentation.

Costs by Pathways - 1/2

- **Costs grow exponentially in future years (after 2030).**
  - <25% through 2030, <50% (2x of costs through 2030) through 2035. More than half of all costs in the last ten years (2035-2045).

LA100 COSTS AND GHG REDUCTION - COSTS

Estimated Total Costs by Pathway - 3/4



Mean	$6,200	$16,800	$31,300	$48,400	$67,700
Range - Dollar	± $700	± $2,800	± $7,400	± $13,800	± $20,500
Percent	(± 10%)	(± 17%)	(± 24%)	(± 28%)	(± 30%)

Cost Breakdown

- Cumulative costs through 2030 do not vary much by pathway and are at a similar level assessed in the SLTRP 2017 (**grey line**).
- Costs tend to diverge afterwards by Scenarios rather than by Load levels.
  - Early and No Biofuel Scenarios show highest costs, followed by Transmission Focus Scenarios, Limited Transmission Scenarios, and SB100 Scenarios.
  - With the exception of the Early and No Biofuel Scenarios where the costs are roughly the same, total costs with High Load (with electrification) are slightly more (7 to 8%) than that with Moderate Load.

Sources and notes: SLTPR 2017 Modified extends only through 2036. Values in table above are rounded to the nearest $100 million. Data from NREL Study website, https://maps.nrel.gov/la100/data-viewer?Theme=system-costs&Resolution=lc&LoadScenario=moderate&RpmScenario=sb100&LayerId=xmission.cost&Year=2045&Variable=dlrs_millions.
Cost do not include debt payments on asset installed prior to 2021, distribution maintenance costs, or costs associated with energy efficiency or demand response program.

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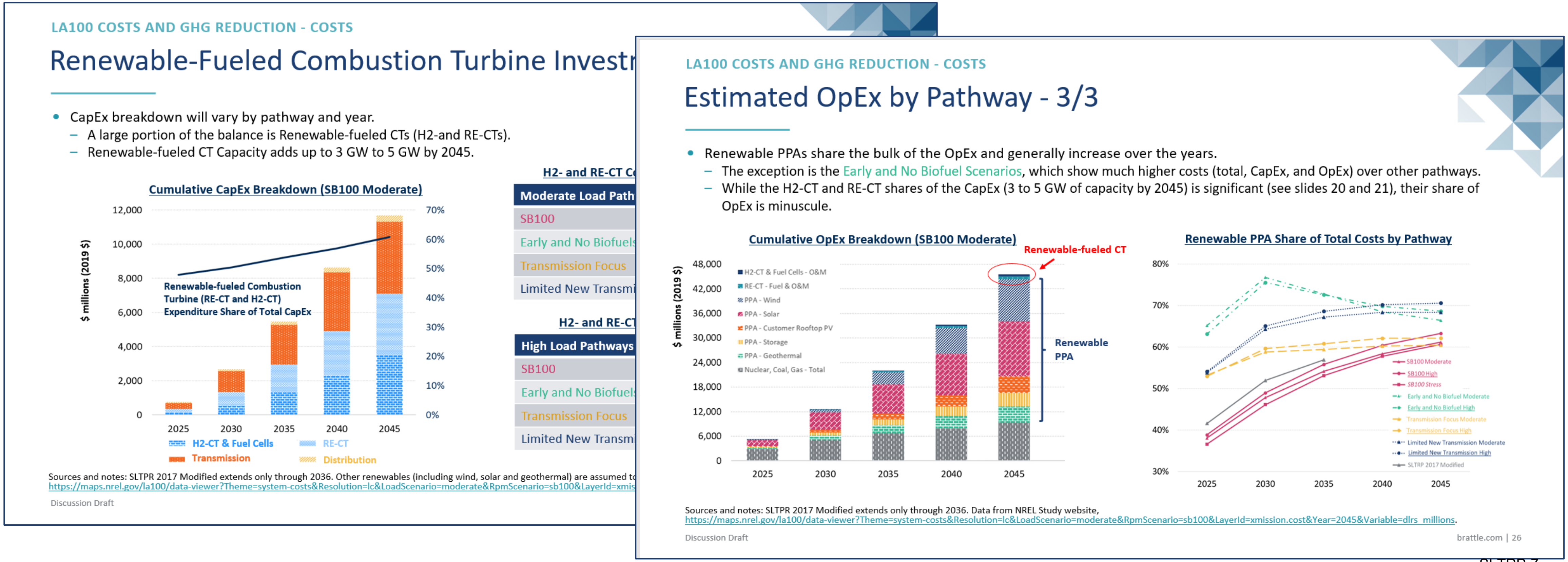
See slide 16 of full presentation.

Costs by Pathways - 2/2

- **CapEx/OpEx split is roughly 20% CapEx and 80% OpEx.**
  - 2/3 of OpEx is renewable PPAs.
  - Renewable-fueled CTs: ~60% of CapEx (investment amounts vary between ~$6 - $19 billion by pathway), and 1-6% of OpEx
  - Transmission: ~40% of CapEx (investment amounts are constant among pathway—with the exception of Transmission Focus pathways).



See slides 20 and 26 of full presentation.

GHG Emissions by Pathways

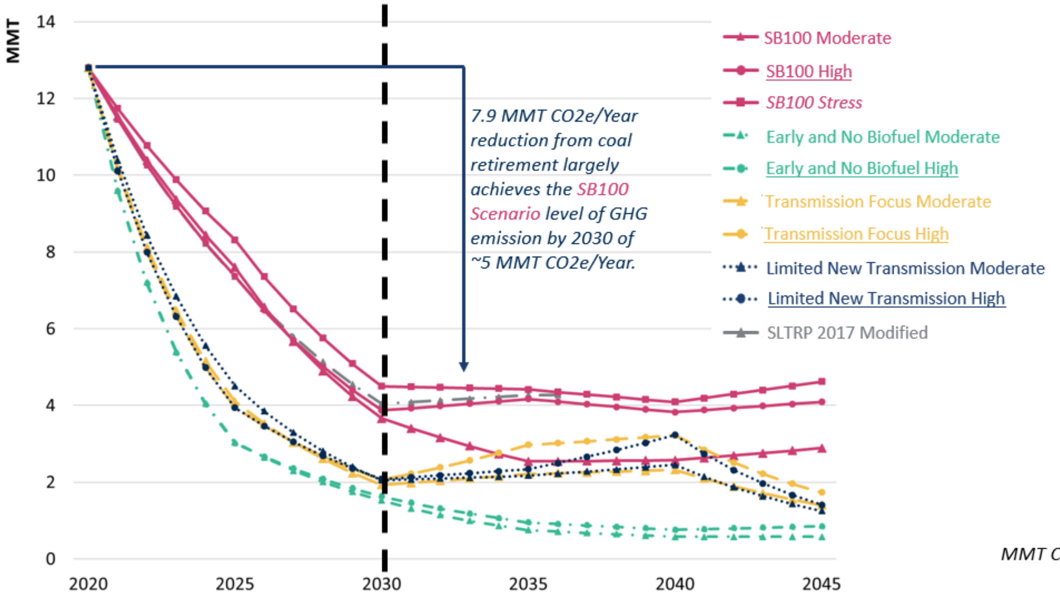
- **Significant GHG reduction occurs in the first ten years (through 2030).**
  - Largest reduction is from eliminating coal-fueled generation.

17.9 MMT
in 1990

LA100 COSTS AND GHG REDUCTION - REDUCTION OF GHG EMISSIONS

Power Sector Estimated Annual GHG Emissions

Total GHG Emissions for Power Sector by Pathway (2020-2045)



Total GHG Emission

- Total GHG emissions include both combustion and non-combustion related GHG emissions.
- All pathways show power sector total GHG emissions to decrease sharply from 2020 through 2030.
- In 2020:
  - Nearly 90% of total emission (11.1 out of 12.8 MMT CO_2e/Year) is from direct combustion.
  - Over 70% (7.9 out of 11.1 MMT CO_2e/Year) of direct combustion emission is from coal-fueled generation.

MMT CO2e/Year is million metric tons of CO2 equivalent

Sources and notes: SLTPR 2017 Modified extends only through 2036. Data from NREL study report, Chapter 8, Appendix A, https://www.nrel.gov/docs/fy21osti/79444-8.pdf.
Assume power sector GHG emission changes in linear CAGR for each five-year interval.

Discussion Draft

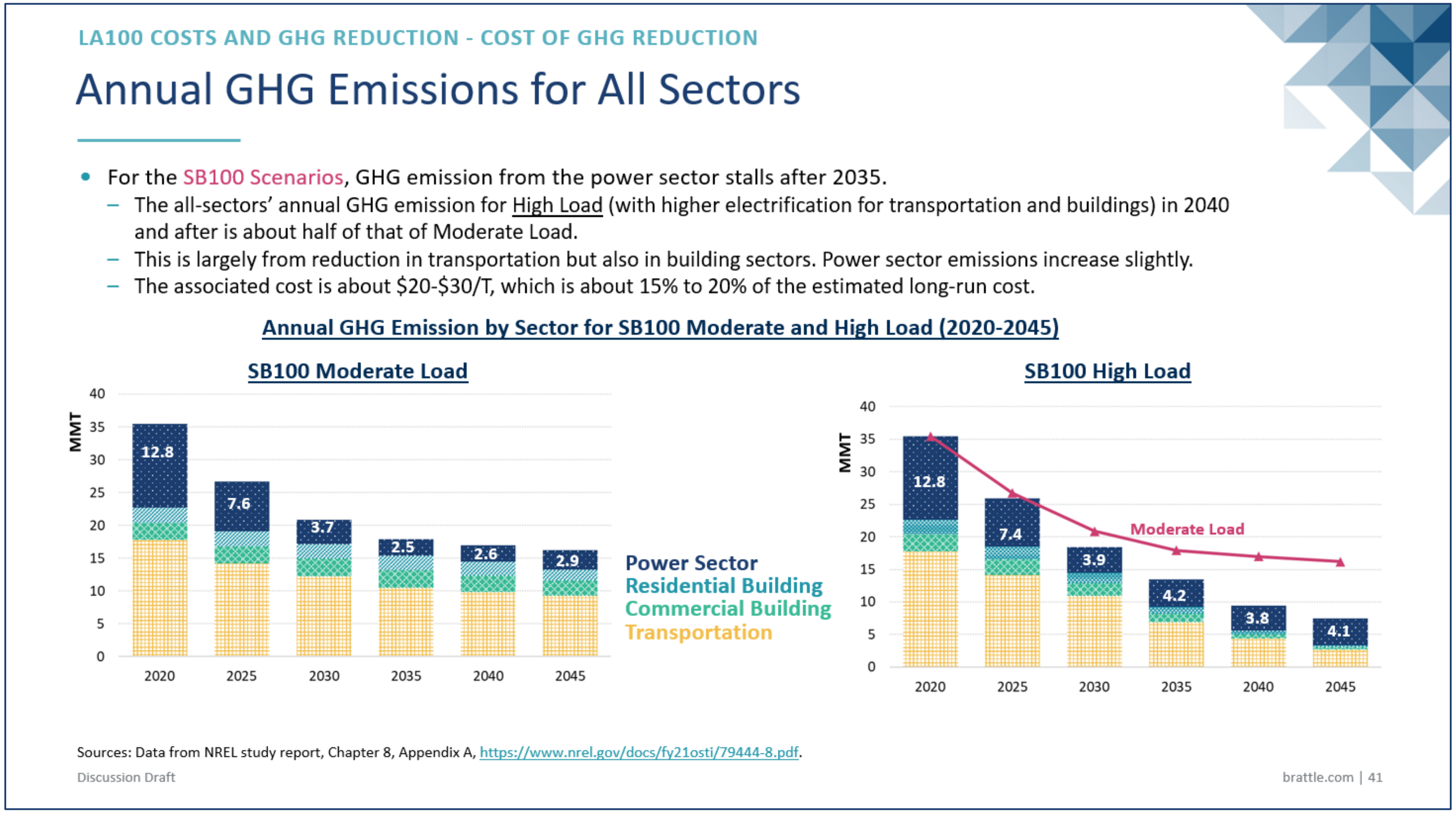
LA 100 Study looks at:

- Direct combustion related GHG emission from power sector
- Indirect GHG emission from power sector
- Total GHG emission from power and other sectors (buildings and transportation sectors of electrified load)

See slide 27 of full presentation.

Benefits of Electrification - 1/2

- **Electrification of other sectors reduce more GHG for lower incremental costs.**
  - Study does not account for the cost of electrification but includes the cost of serving the newly electrified load.



See slides 41 through 44 of full presentation. Slide 41 is shown above.

Benefits of Electrification - 2/2

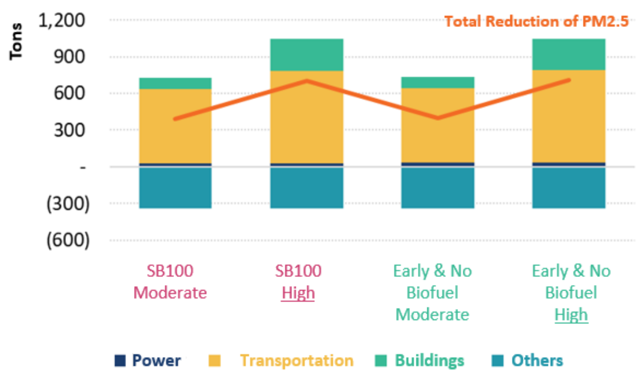
- **Health benefits are correlated more with electrification levels than scenarios.**
  - Higher electrification increases health benefits by more than 50% (and is consistent among scenarios).

INTRODUCTION – STUDY RESULTS AND SUMMARY OF FINDINGS

LA100 Study Summary of Findings - 3/3

- Electrification contributes significantly to monetized health benefits (values shown below are compared to 2012).
  - The annual benefits of Moderate load pathways (SB100 and Early & No Biofuel) for 2045 is ~$900 million.
  - The additional annual benefits of High load over Moderate load for 2045 is ~$500 million regardless of the scenario (SB100 and Early & No Biofuel).
  - The annual benefits of High load pathways (SB100 and Early & No Biofuel) for 2045 is ~$1,400 million.

Total Annual Emissions Reduction of PM2.5 by Scenario (2045)



Observations from the LA100 Study

- Health benefits are largely due to reduction in fine particulate matters ($PM_{2.5}$) and nitrogen oxides (NO_x).
- NO_x, combined with other pollutants, forms ozone (O_3) and $PM_{2.5}$ in the atmosphere.
- O_3 and $PM_{2.5}$ are major contributors to air pollutant-caused human health impacts.
- While NO_x emission is reduced, there is a time-lag before O_3 also decreases (and the LA100 Study shows O_3 increasing but more than offset by reduction in $PM_{2.5}$).
- The power sector contributes very little to the reduction of these pollutants.

Sources and notes: The baseline PM2.5 emission in 2012 is estimated at 7,342 Tons. Some representative contributors to "Other" include cooking, road dust, wood and paper, and mineral processes for the four future scenarios.
The monetized Data from NREL study website, https://maps.nrel.gov/la100/data-viewer?Theme=aqh&Resolution=dst&LoadScenario=moderate&RpmScenario=sb100&LayerId=aqh.health-monetization&Variable=mean and NREL report Chapter 9, https://www.nrel.gov/docs/fy21osti/79444-9.pdf, p.p 60.

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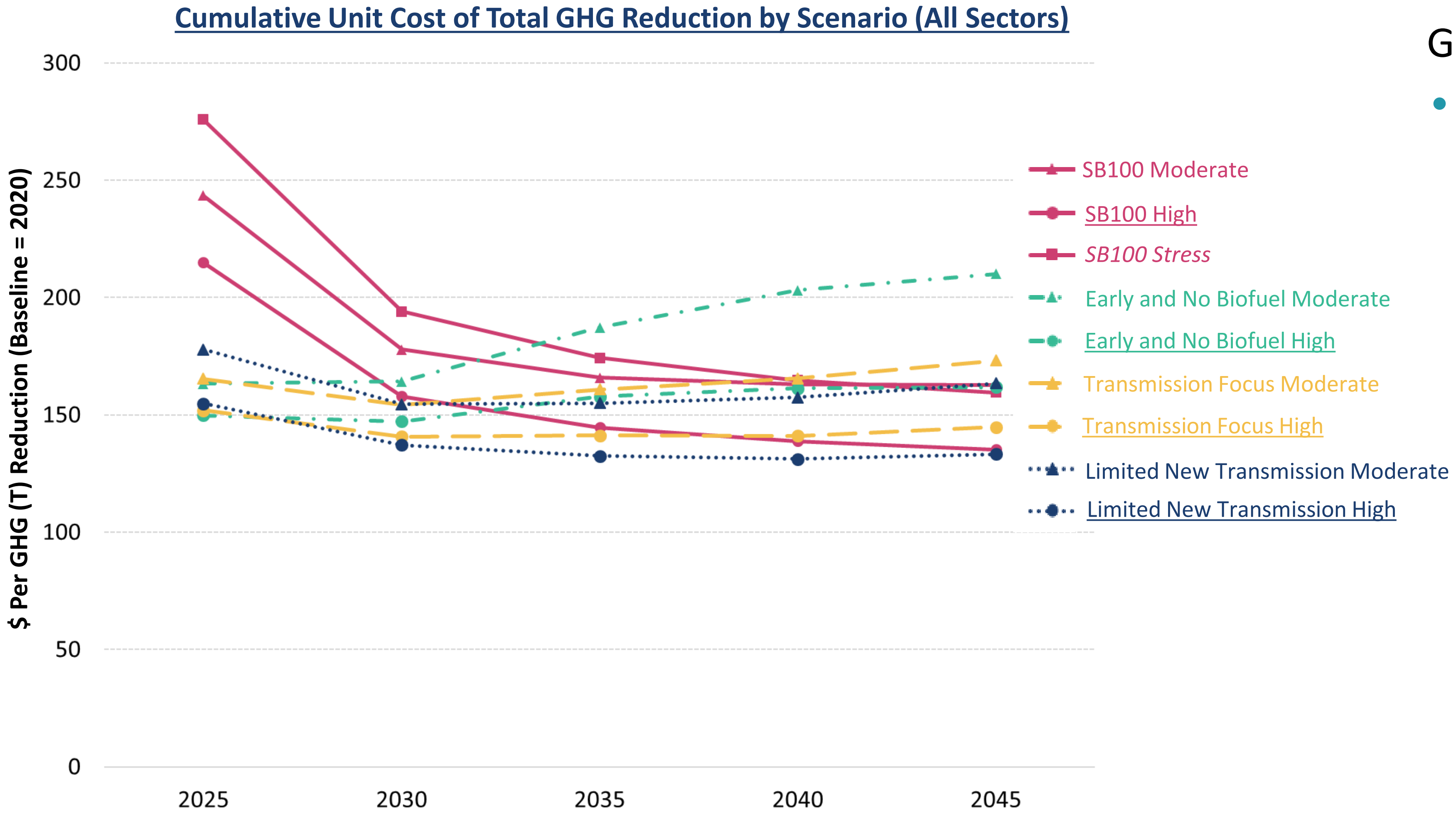
See slide 10 of full presentation.

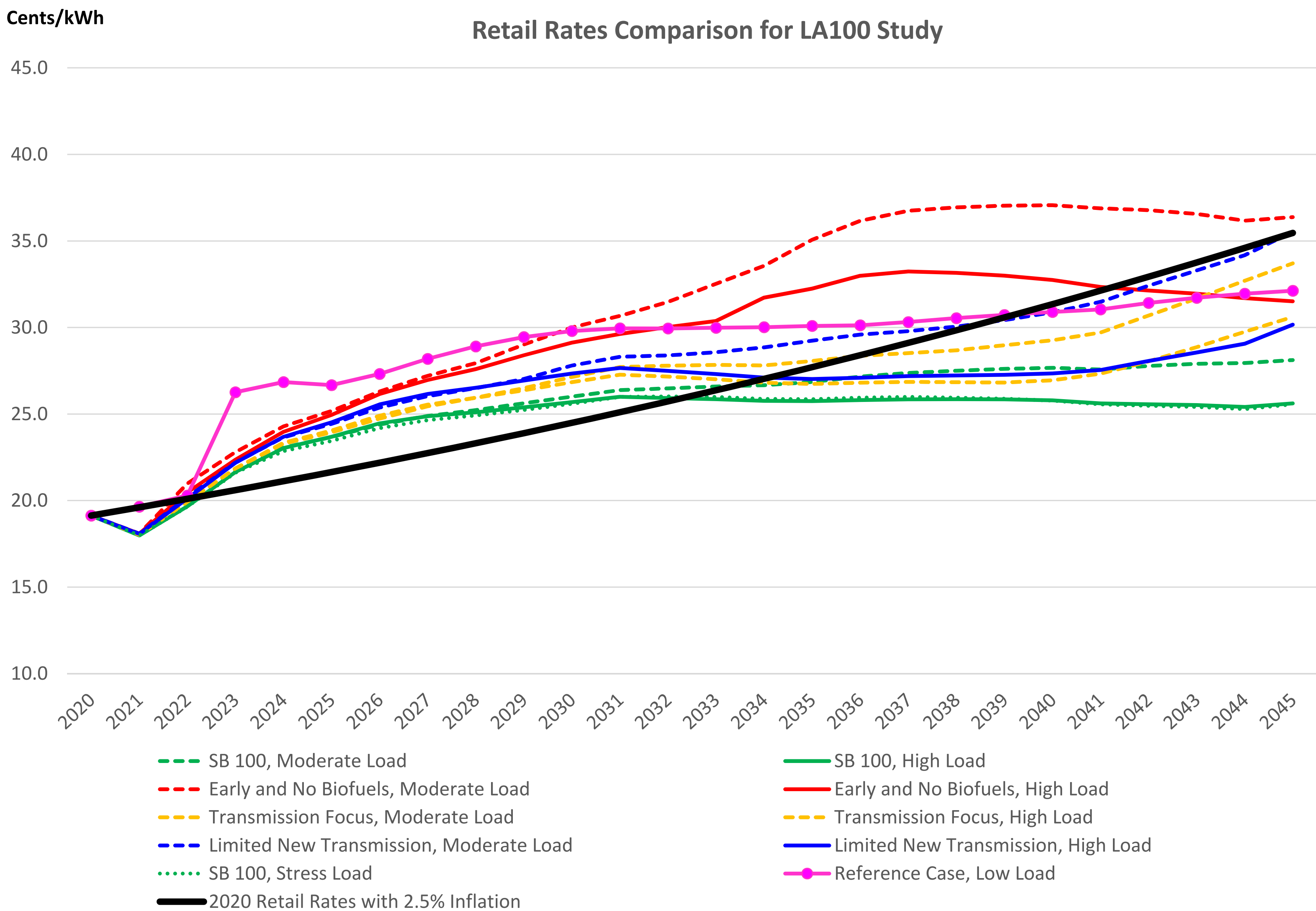
Cumulative Unit Cost of Total GHG Reduction - All Sectors



GHG Emission

- In all scenarios, High Load shows lower cost per tonne of GHG reduction than Moderate Load.
  - High Load assumes higher load electrification, suggesting it is a better way for reducing GHG.
  - Delta is $20 to $30/T, or 15% to 20% of the average cost of ~$150/T.
  - This delta is smaller than the growth seen in the previous slide that shows the power sector only, indicating spending money on load electrification is better than further decarbonizing the electric sector after 2030 where the marginal benefits decrease.

Sources and notes: SLTRP 2017 Modified is not included since it reports only power sector GHG emission. Data from NREL study website, https://maps.nrel.gov/la100/data-viewer?Theme=ghg&Resolution=rs&LoadScenario=moderate&RpmScenario=sb100&LayerId=ghg.power_and_nonpower&Variable=ann_ghg_mmt.
Assume combustion GHG emission changes in linear CAGR for each five-year interval.

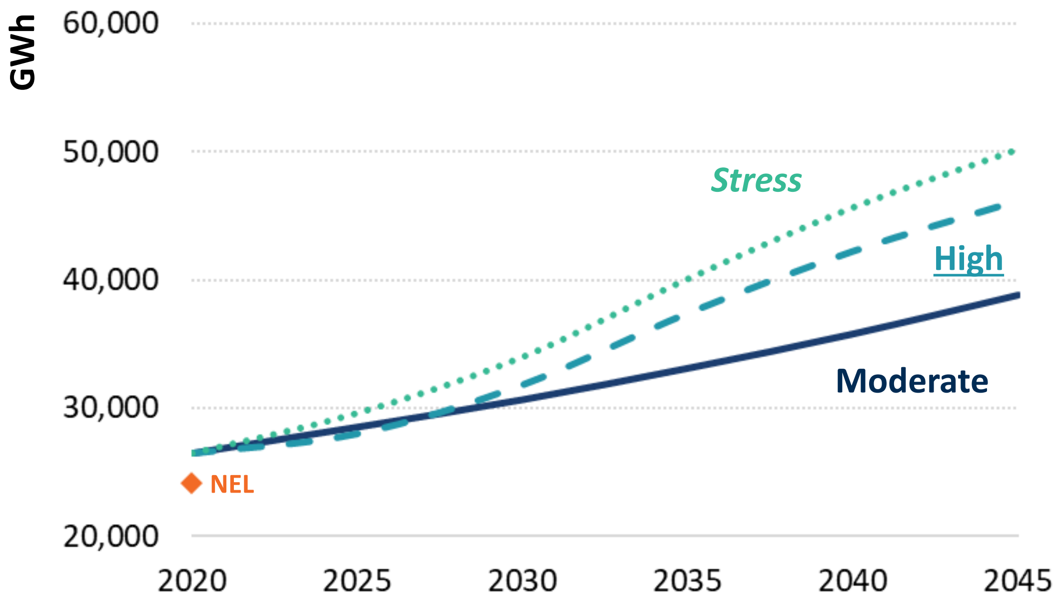


from DWP FSO April 1, 2021 presentation on LA100 rate impacts

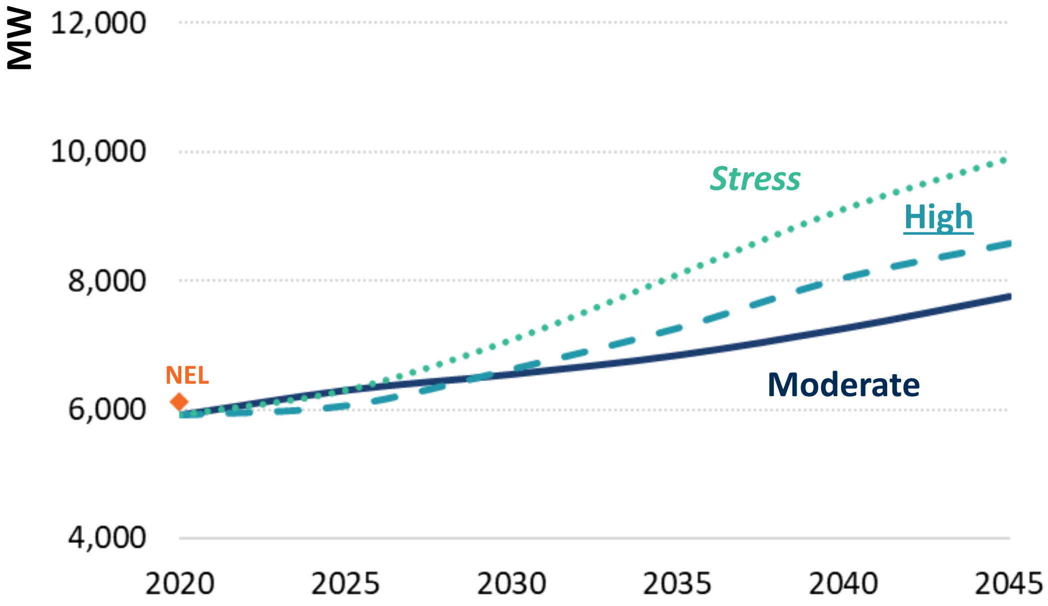
Load Projection - Within the LA100 Study

- Load projections by themselves are a source of uncertainty.
  - Variation of both types grows largely after 2030.
  - Energy consumption and peak load projections both vary by 25% (over 10,000 GWh/2,000 MW by 2045).
  - Demand response through 2030 grows by nearly 5x in all pathways.

Annual Energy Consumption Projections (SB100 Scenario)



Annual Peak Load Projections (SB100 Scenario)

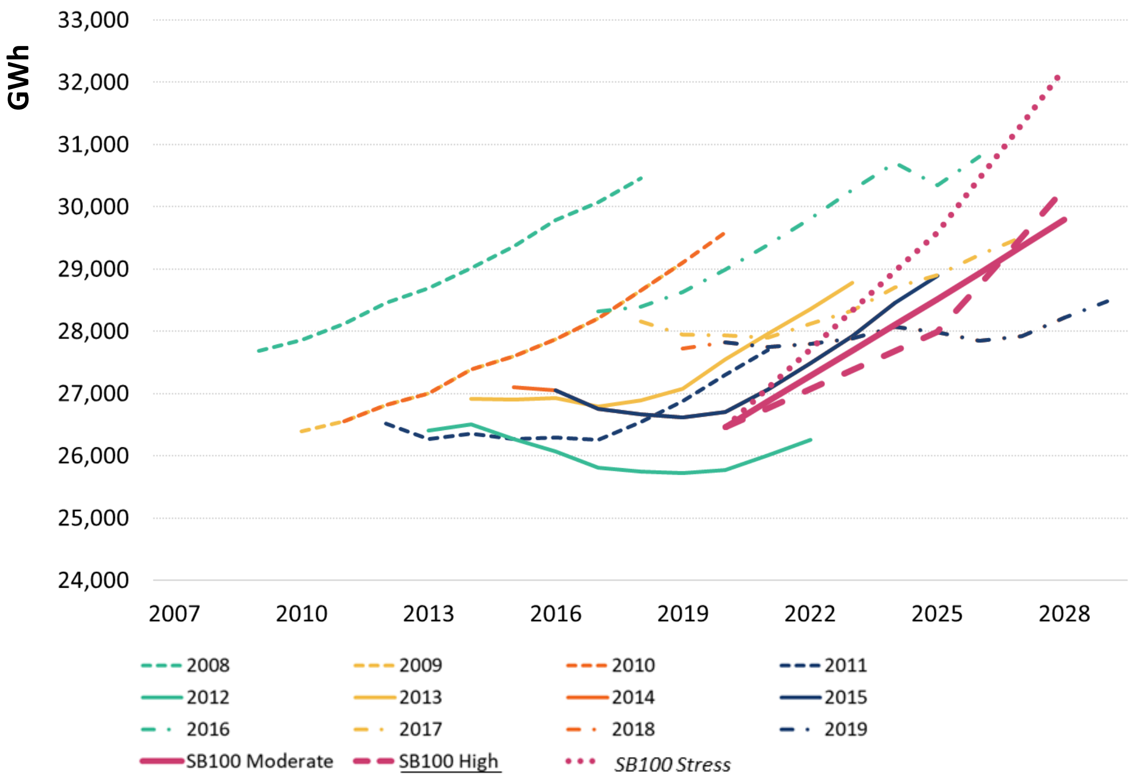


Sources and notes: Data from NREL Study website, https://maps.nrel.gov/la100/data-viewer?Theme=electricity-demand&SubTheme=electricity-consumption&Resolution=lc&LoadScenario=moderate&LayerId=electricity-demand.peak-demand&Year=2045&Variable=kwh&TemporalResolution=annual&TimePeriod=peak. NEL reported an annual consumption of 24,095 GWh (9% lower than NREL projection of 26,457 GWh) and annual peak load of 6,110 MW (3.5% higher than NREL forecast of 5,909 MW). While underestimate the peak load and overestimate of the annual consumption will both lead to increase in average rates (~14%).

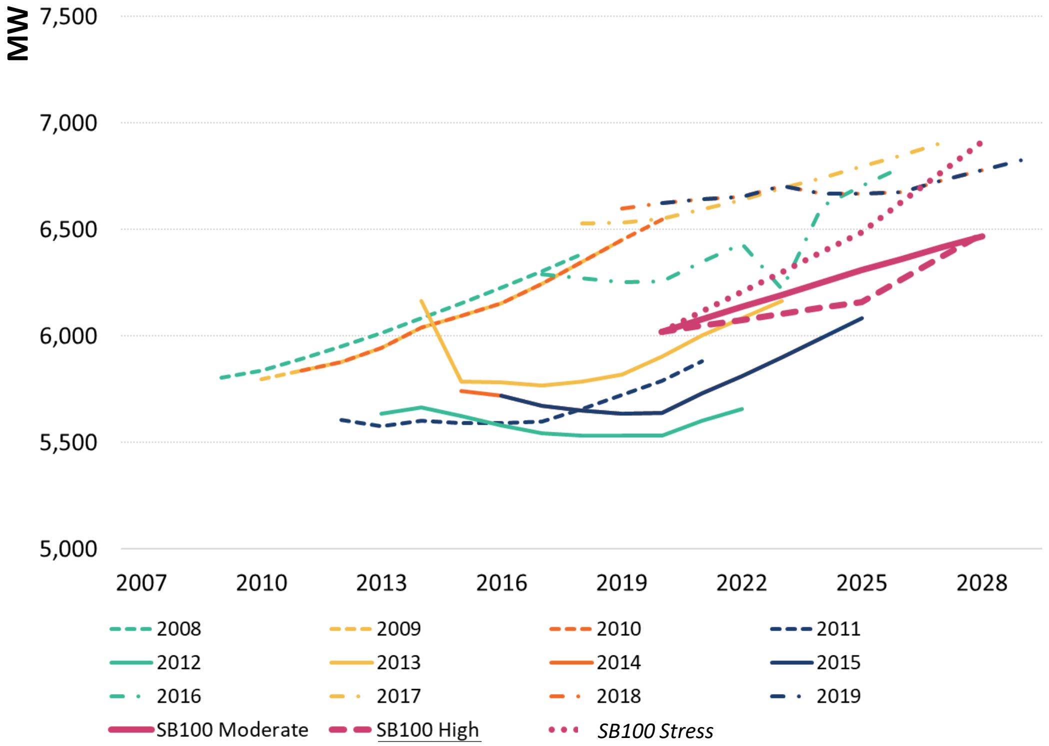
Load Projection - Variance Over Time

- Load projections by themselves are a source of uncertainty.
  - Variation of projections (both energy and peak load) changes over time.
  - Variation assumed in LA100 Study pales compared to historical observations.

Annual Energy Consumption Projections (SB100 Scenario)



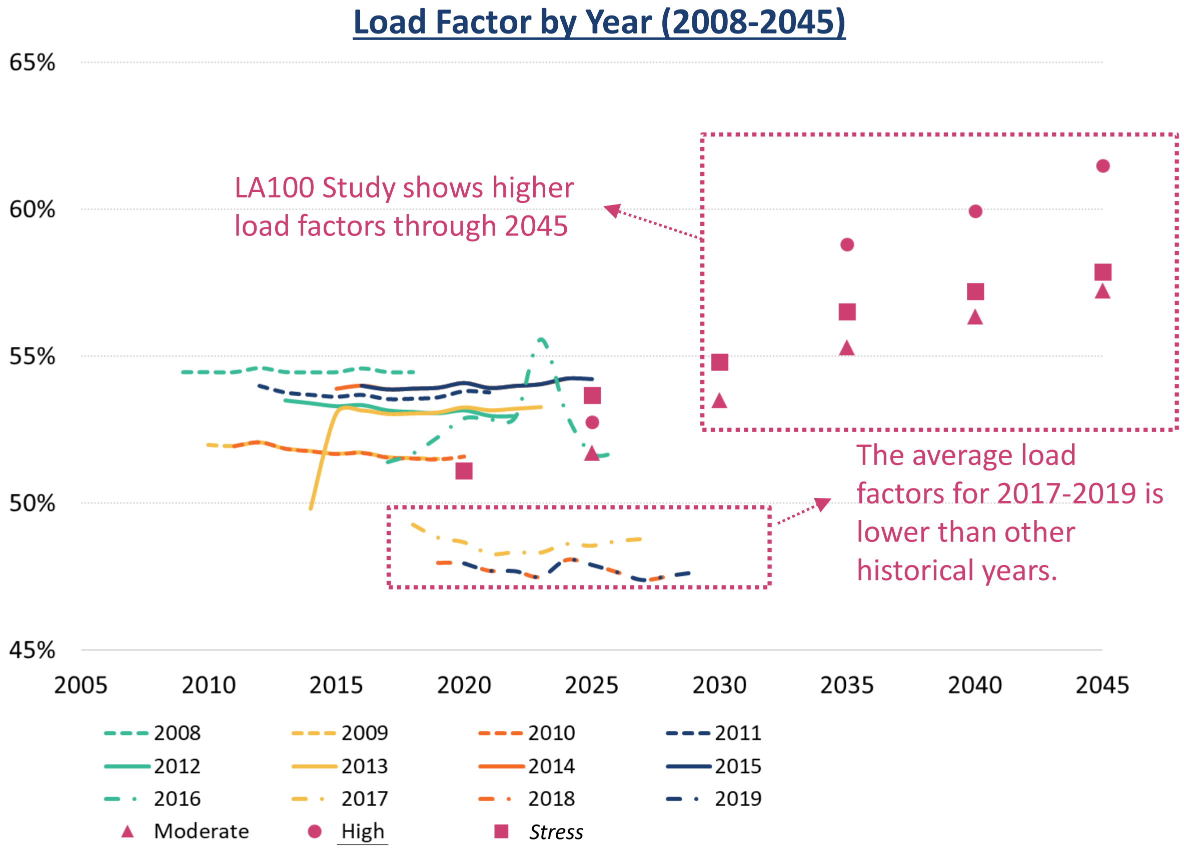
Annual Peak Load Projections (SB100 Scenario)

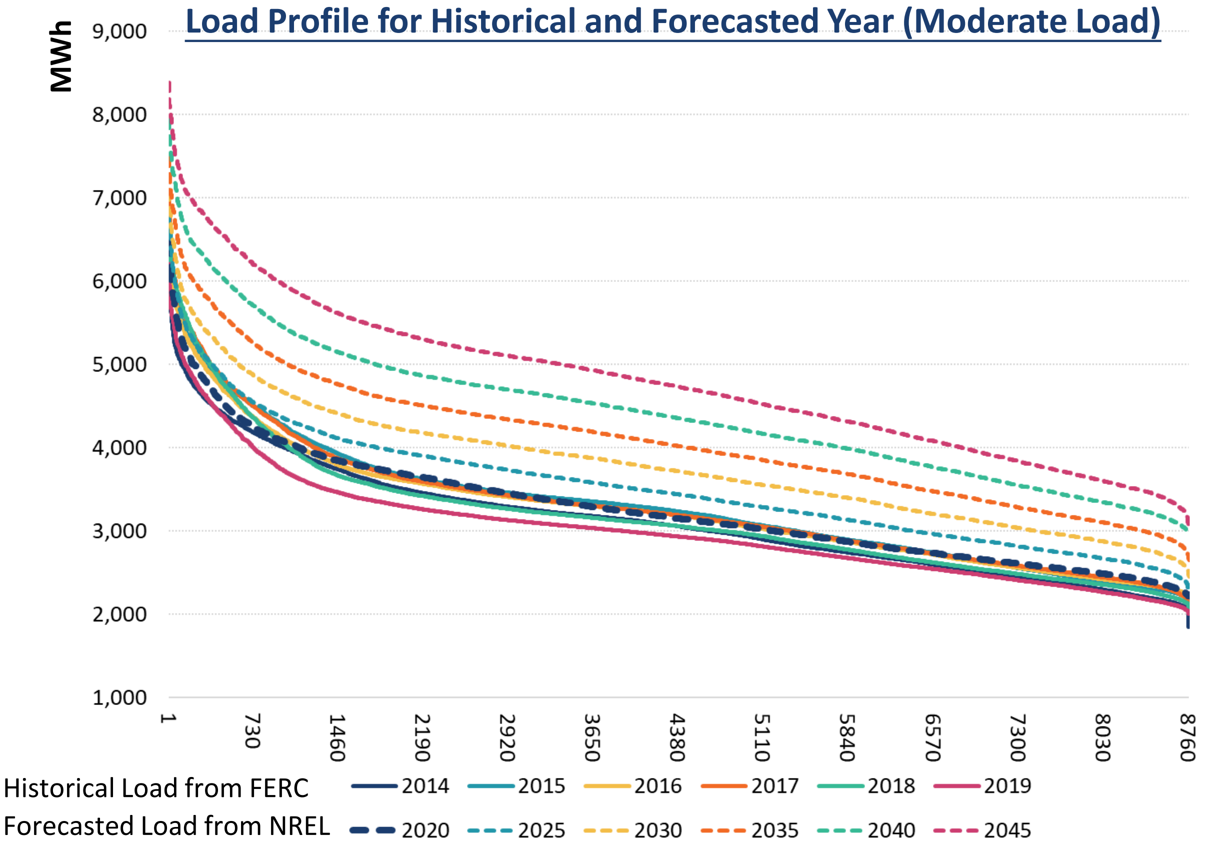


Sources and notes : Historical load projections from FERC 714 Filings, https://www.ferc.gov/industries-data/electric/general-information/electric-industry-forms/form-no-714-annual-electric/data.
City of Burbank (1,131 GWh and 301 MW, 2019) and City of Glendale (1,462 GWh and 288 MW, 2019) appear to be included in LADWP's FERC 714 Filing (27,718 GWh and 6,598 MW, 2019).

Load Profiles

- LA100 Study assumes an optimistic prediction of a growing load factor, in contrast to the historical trend.
  - Less peaky (i.e. flat) load estimated for future years.
  - Flatter load will require less flexibility and may underestimate renewable curtailments (both will underestimate costs).





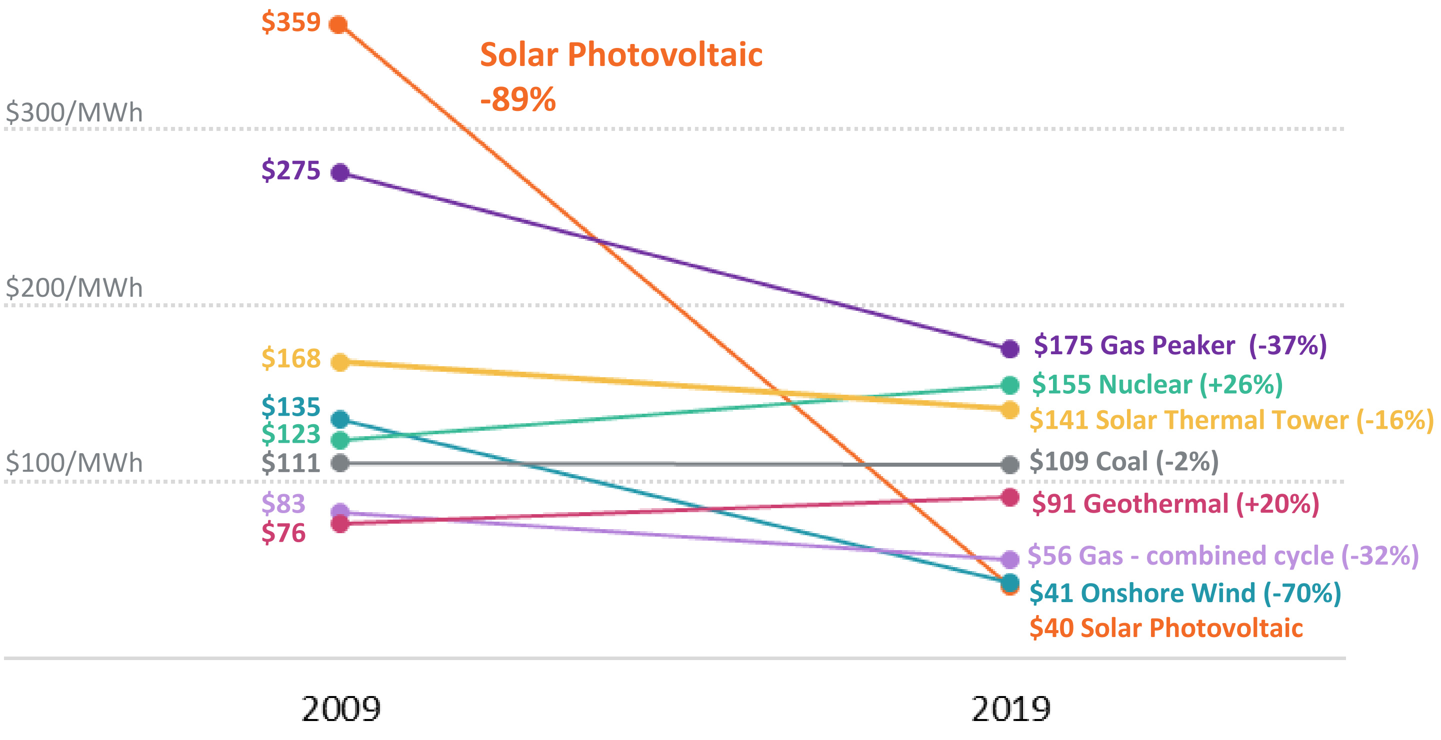
Sources and notes: Historical load projections from FERC 714 Filings and scenario data from NREL Study website, https://maps.nrel.gov/la100/data-viewer?Theme=electricity-demand&SubTheme=electricity-consumption&Resolution=lc&LoadScenario=moderate&LayerId=electricity-demand.peak-demand&Year=2045&Variable=kwh&TemporalResolution=annual&TimePeriod=peak.

SLTRP-15

Cost Estimates for Generation Resources

- The price of electricity from renewables dropped from 2009 to 2019.
  - The price of electricity from solar declined by 89% in these 10 years.
  - The price of onshore wind electricity declined by 70% in these 10 years.

Price of Electricity from New Power Plants

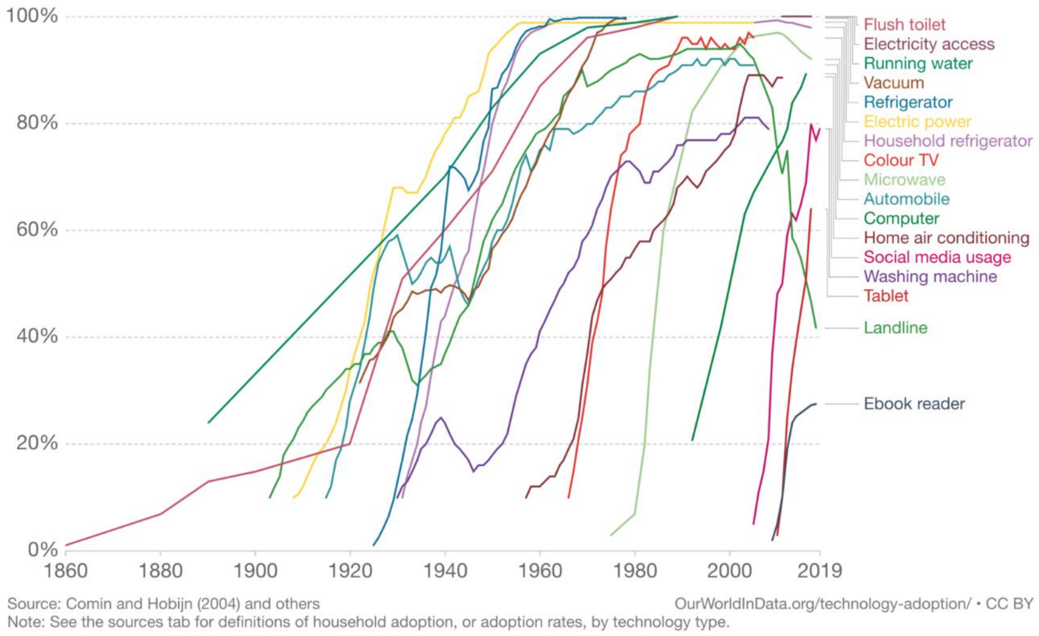


Sources and notes: Electricity prices are expressed in 'levelized costs of energy' (LCOE). LCOE captures the cost of building the power plant itself as well as the ongoing costs for fuel and operating the power plant over its lifetime. Data from Lazard Levelized Cost of Energy Analysis, Version 13.0.

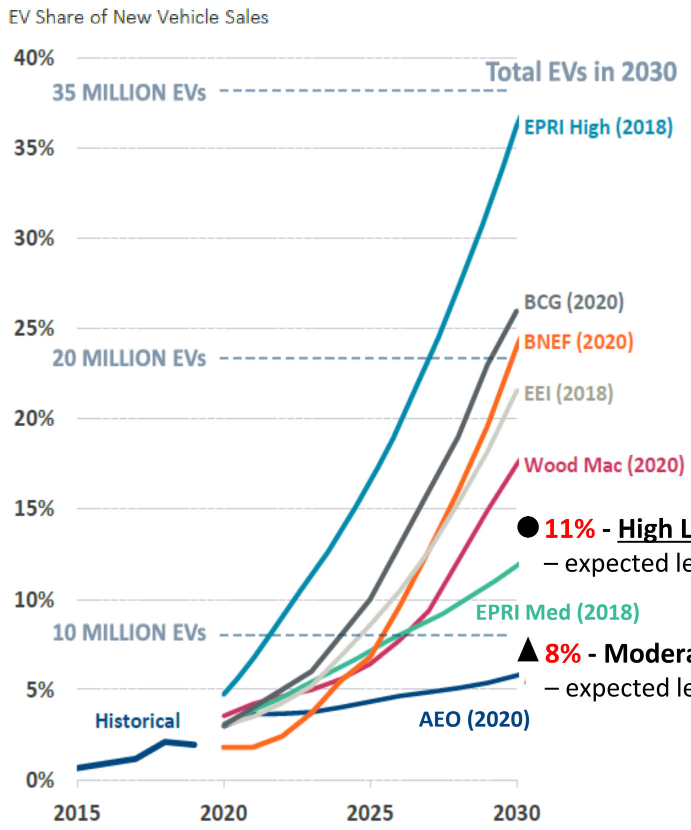
Future Economics

- A wide estimation range of adoption rates and pace has been observed.
  - In general, the adoption rate, once accepted, are very steep, making the prediction even harder.

Technology Adoption in US Households, 1860 to 2019



Projected U.S EV Sales



● 11% - High Load (2030)
– expected level to achieve 80% by 2045

▲ 8% - Moderate Load (2030)
– expected level to achieve 30% by 2045

Sources (right): M. Hagerty et al., “Getting to 20 Million EVs by 2030 Opportunities for the Electricity Industry in Preparing for an EV Future,” The Brattle Group, June 2020.
EPRI, PEV Market Projection Assumptions: June 2018 Update, June 2018. (EPRI Low forecast not shown because its 2030 forecast is below the levels already obtained.); BCG, Who Will Drive Electric Cars to the Tipping Point?, January 2020.; BNEF, Electric Vehicle Outlook, 2020; IEI/EEI, Electric Vehicle Sales Forecast and the Charging Infrastructure Required through 2030, November 2018; Wood Mackenzie, Electric car forecast to 2040, accessed May 2020; EIA, Annual Energy Outlook: Light-duty vehicle sales by technology type and Census Division: United States, 2020.

Recommendations

- **Focus on avoidable GHG reduction, including weighing the costs and benefits of decarbonizing the power vs other sectors.**
  - Higher electrification shows larger benefits but cost (and pace) of electrification is an uncertainty.
- **Focus on the near-term (through 2030 or 2035) with less uncertainty in pathways and costs.**
  - Focus on proven technology with well understood costs while keeping options open.
  - Identify no-regret investments and those with longer lead time.
  - Transmission provides optionality in both the short- and long-term while contributing to environmental justice (utility-scale renewables enabled by transmission typically costs less (on a $/MWh basis) while providing benefits to ALL customers.
- **Re-develop a plan for increasing renewables at the preferred pace for the next 10 to 15 years.**
  - Revisit goal.
    - What does 100% mean?
    - Is it more important than the economy-wide GHG reduction or estimated health benefits?
    - Observe changes in load (projection, profiles etc.) as they can impact investment decisions, particularly timing.
  - Identify areas where additional incentives are needed.
  - This is not limited to economic benefits, and includes social equity.

See slides 66 through 68 of full presentation.

Disclaimer

- This presentation was prepared for the City of Los Angeles (LA), Office of Public Accountability/Ratepayer Advocate (OPA/RPA) for discussion purposes. All results and any errors are the responsibility of the authors and do not represent the opinion of The Brattle Group (Brattle) or its clients.
- The analyses that we provide here are necessarily based on assumptions with respect to conditions that may exist or events that may occur in the future. Most of these assumptions are based on publicly-available data, including the LA100 Study, study data, and report developed by the National Renewable Energy Laboratory (NREL) for the Los Angeles Department of Water and Power (LADWP). Brattle and OPA/RPA are aware that there is no guarantee that the assumptions and methodologies used will prove to be correct or that the forecasts will match actual results of operations. Our analysis, and the assumptions used, are also dependent upon future events that are not within our control or the control of any other person, and do not account for certain regulatory uncertainties. Actual future results may differ, perhaps materially, from those indicated. Brattle does not make, nor intends to make, nor should anyone infer, any representation with respect to the likelihood of any future outcome, can not, and does not, accept liability for losses suffered, whether direct or consequential, arising out of any reliance on our analysis. While the analysis that Brattle is providing may assist OPA/RPA and others in rendering informed views of how LA can advance towards a 100% clean energy system, it is not meant to be a substitute for the exercise of their own business judgments.

OPA Conclusions

- LADWP is committed and working hard to eliminate its last coal generation by 2025.
- The most important keys to success are outside LADWP, in transportation and building electrification.
- LADWP's system needs to be strengthened and stay flexible to manage:
  - ever higher levels of clean resources and
  - serve evolving, uncertain levels of electricity use,
  - while avoiding early over-commitment to technologies whose cost and performance changes may be extremely large.

SUPPLEMENTAL SLIDES

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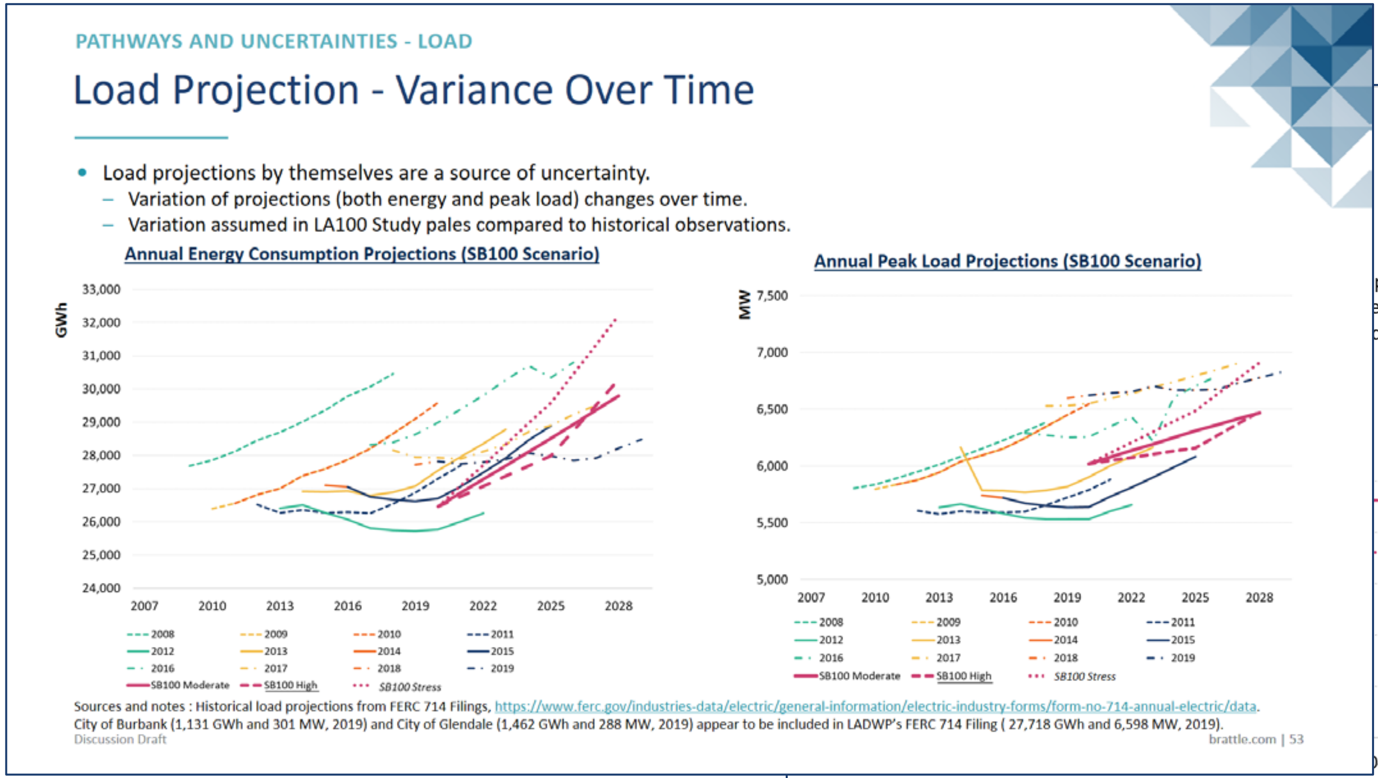
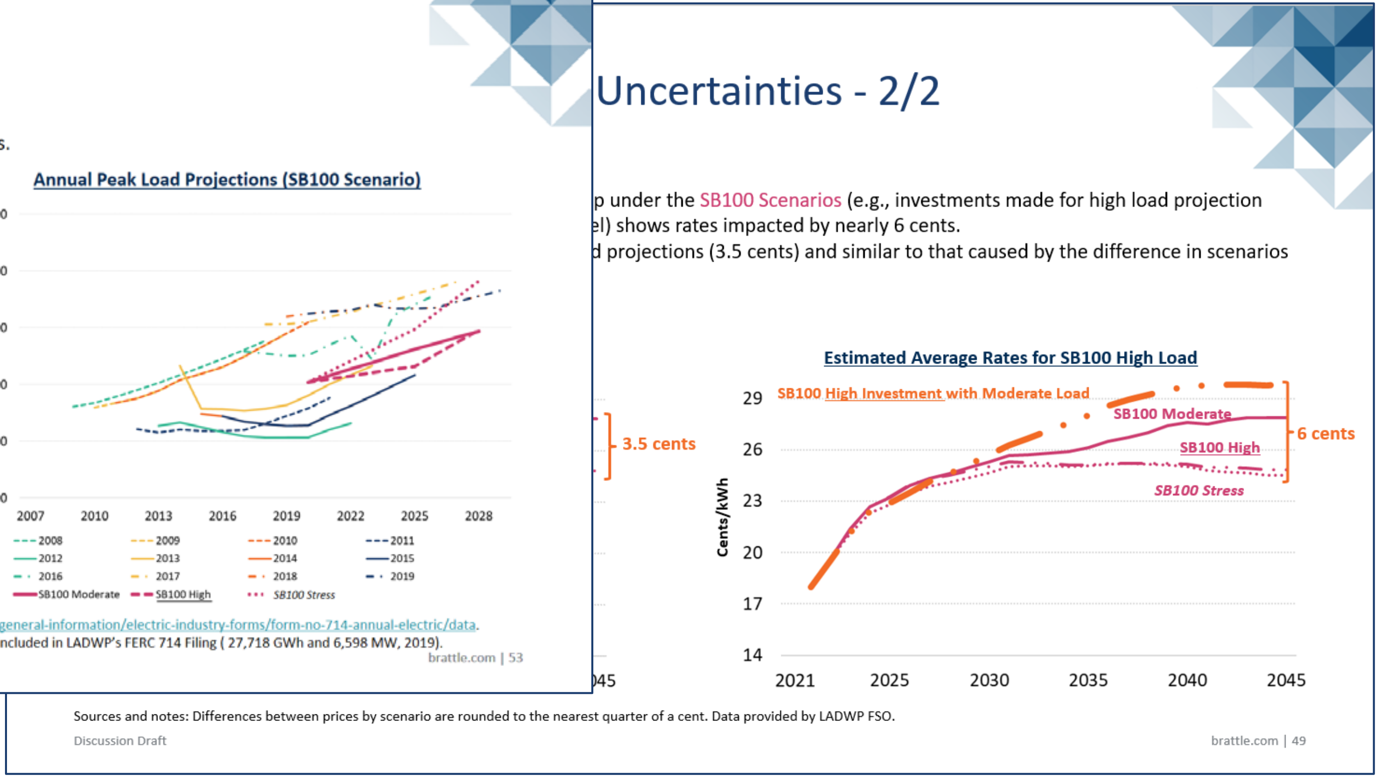
Uncertainties - 1/3

- **Load projection has varied year to year, and their accuracy is not guaranteed.**
  - Rate uncertainty associated with scenarios and realized loads are of similar levels of magnitude.

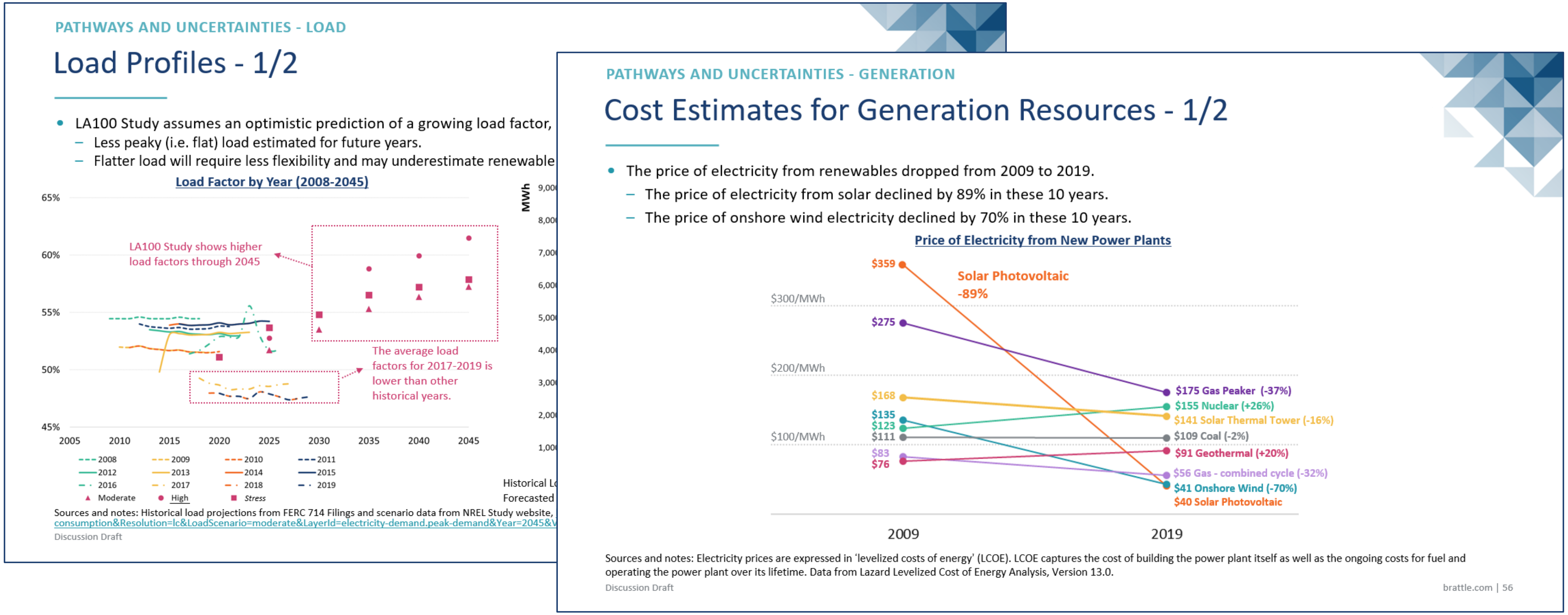




See slide 46 through 55 of full presentation. Slides 49 and 53 are shown above.

Uncertainties - 2/3

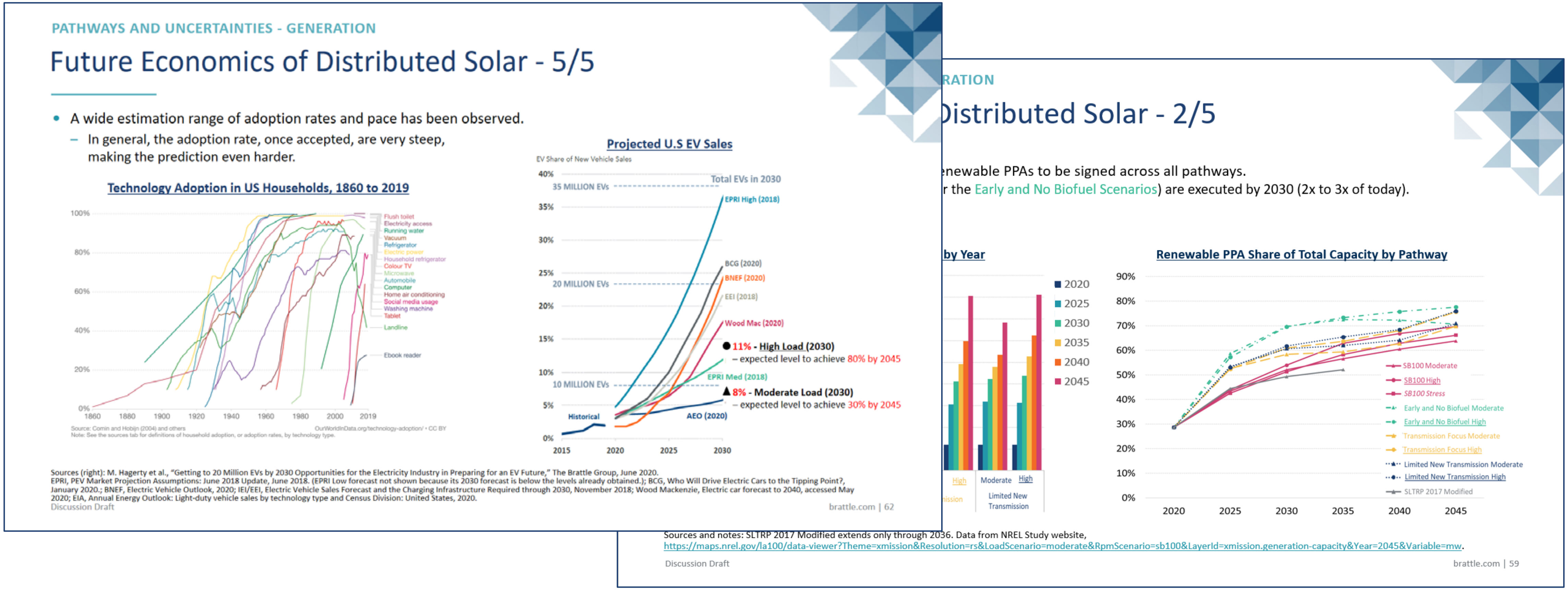
- **Assumptions for load and future generation costs are uncertainties.**
  - Load factor (average load / peak load) is higher than historical observations, potentially leading to lower flexibility needs, lower renewable curtailments, and lower cost estimates.



See slides 54 through 57 of full presentation. Slides 54 and 56 are shown above.

Uncertainties - 3/3

- **Uncertainties associated with timing of investments for future generation.**
  - Adoption rate and timing of new technologies, including electrification (of building and transportation sectors) and distributed energy resources by customers, will impact LADWP's planning.



See slides 58 through 62 of full presentation. Slides 59 and 62 are shown above.

Summary of LA 100 Results - 1/2

- **Clean energy target (GHG emission reduction) is mostly achieved in the first half (through 2030/2035)**
  - Cost estimates for the first 15 years (2021-2035) is less than the cost estimates for the last 10 years (2036-2045).

LA100 Study Summary of Findings - 1/3

- Goal is achieving 100% clean energy by 2045.
  - This *clean energy target is largely achieved in **the first half*** of the study period (by 2030 or 2035).
  - *Costs continue to increase during **the second half*** of this period (the cost for 2035-2045 is about 1.2x of that of 2021-2035, varying by pathways).

Clean Energy Achievements and Costs by Year and Pathway

Pathways (Scenario - Load)	Total Clean Energy Penetration Achieved			Undiscounted Cumulative Cost (Billion $)			Reduction in GHG Emission (MMT) compared to 2020 - Power Sector		
	2030	2035	2045	2021- 2035	2036-2045	Total	2030	2035	2045
SB100 Moderate	78%	90%	90%	$28	$30	$57	9.1	10.3	9.9
SB100 High	78%	84%	88%	$28	$33	$61	8.9	8.6	8.7
SB100 Stress	*77%*	*85%*	*87%*	*$31*	*$38*	*$69*	*8.3*	*8.4*	*8.2*
Early & No Biofuels Moderate	99%	100%	100%	$39	$48	$87	11.3	12.0	12.2
Early & No Biofuels High	98%	100%	100%	$38	$48	$86	11.2	11.8	11.9
Transmission Focus Moderate	90%	90%	100%	$31	$36	$67	10.9	10.6	11.4
Transmission Focus High	91%	89%	100%	$32	$40	$72	10.7	9.8	11.1
Limited New Transmission Moderate	92%	91%	100%	$30	$33	$63	10.7	10.6	11.5
Limited New Transmission High	92%	90%	100%	$30	$37	$67	10.7	10.5	11.4

*2020 GHG emission estimated at 12.8 MMT (million metric tons)

Sources and notes: Data from NREL study website, emission data from https://maps.nrel.gov/la100/data-viewer?Theme=ghg&Resolution=lc&LoadScenario=moderate&RpmScenario=sb100&LayerId=ghg.power_and_nonpower&Variable=ann_ghg_mmt and cost data from https://maps.nrel.gov/la100/data-viewer?Theme=system-costs&Resolution=lc&LoadScenario=moderate&RpmScenario=sb100&LayerId=xmission.cost&Year=2045&Variable=dlrs_millions.
Cost do not include debt payments on asset installed prior to 2021, distribution maintenance costs, or costs associated with energy efficiency or demand response program.

See slide 8 of full presentation.

Summary of LA 100 Results - 2/2

- **Electrification of other sectors (building and transportation) provides significantly higher GHG emission reduction.**
  - High Load pathways (higher electrification) provides 1.5x of GHG emission reduction compared to Moderate Load pathways.

LA100 Study Summary of Findings - 2/3

- A large portion (96% on average, minimum 91%) of the power sector's GHG emission reduction is from direct combustion.
  - The rest (non-combustion) is difficult to control.
- Reduction in other sectors are quite significant:
  - Reductions are comparable to the power sector under Moderate Load pathways.
  - Reductions are much higher (about 2x or 3x by 2045) under High Load and *Stress Load* pathways, which both assume higher levels of load electrification.

Reduction in GHG Emission (MMT) compared to 2020* by Sector and Life Cycle

Pathways (Scenario - Load)	All Sector			Power Sector			Power Sector - Combustion		
	2030	2035	2045	2030	2035	2045	2030	2035	2045
SB 100 Moderate	14.6	17.5	19.3	9.1	10.3	9.9	9.0	9.8	9.2
SB 100 High	17.1	22.0	28.0	8.9	8.6	8.7	8.8	8.6	8.4
SB 100 Stress	*16.0*	*21.4*	*27.5*	*8.3*	*8.4*	*8.2*	*8.4*	*8.5*	*8.0*
Early & No Biofuels Moderate	16.8	19.3	21.6	11.3	12.0	12.2	11.0	11.1	11.1
Early & No Biofuels High	19.3	25.3	31.2	11.2	11.8	11.9	11.0	11.1	11.1
Transmission Foucs Moderate	16.3	17.9	20.8	10.9	10.6	11.4	10.2	9.8	11.1
Transmission Focus High	18.9	23.2	30.4	10.7	9.8	11.1	10.2	9.4	11.1
Limited New Transmission Moderate	16.2	17.9	20.9	10.7	10.6	11.5	10.2	9.9	11.1
Limited New Transmission High	18.9	23.9	30.7	10.7	10.5	11.4	10.3	10.0	11.1

*2020 GHG emission for the power sector is estimated to be 12.8 MMT

Sources and notes: GHG Emission reduction for building and transportation sector does not vary by scenario. Data from NREL study website, https://maps.nrel.gov/la100/data-viewer?Theme=ghg&Resolution=lc&LoadScenario=moderate&RpmScenario=sb100&LayerId=ghg.power_and_nonpower&Variable=ann_ghg_mmt.

See slide 9 of full presentation.