OPA Review of NREL LA100: Summary

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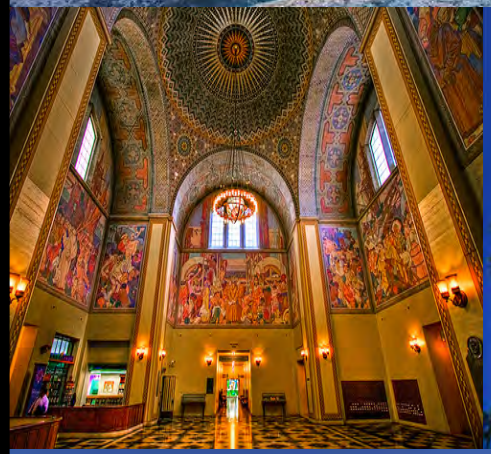



OPA/RPA Review of NREL's LA100 Study

- The OPA commissioned the Brattle Group to assist in monitoring and developing a review of the NREL LA100 study.
  - This presentation summarizes the discussion draft of this review.
  - The final version of this review will be presented to the DWP Board.
- 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.
- 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

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PRESENTED TO

City of Los Angeles

Office of Public Accountability / Ratepayer Advocate

AUGUST 19, 2021

LA100

The Los Angeles 100% Renewable Energy Study

Brattle

Disclaimer

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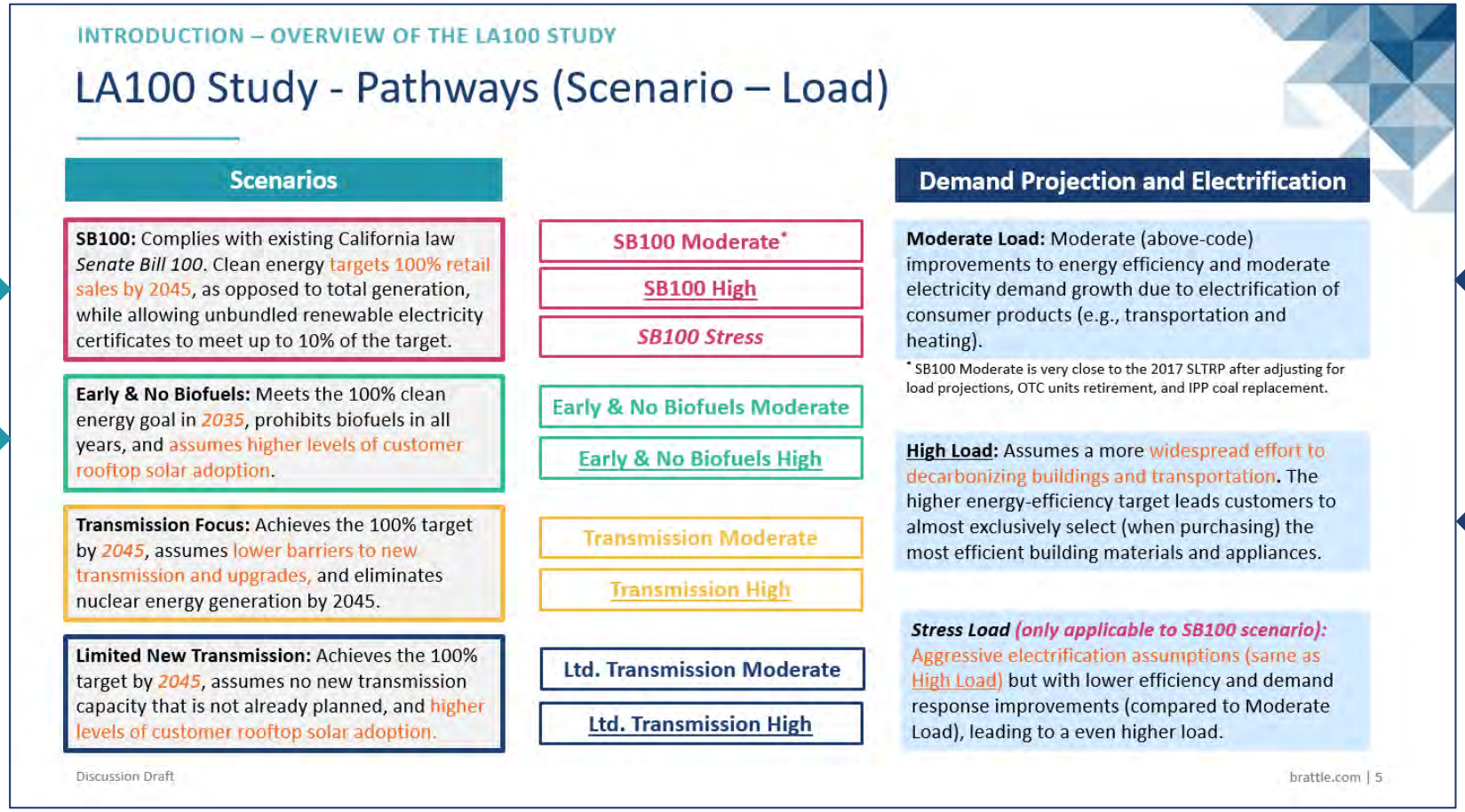
- The analyses that we provide here are necessarily based on assumptions with respect to conditions that may exist or events that may occur in the future. Most of these assumptions are based on publicly-available data, including the LA100 Study, study data, and report developed by the National Renewable 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.

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.

Modest scenario

Aggressive scenario



INTRODUCTION – OVERVIEW OF THE LA100 STUDY

LA100 Study - Pathways (Scenario – Load)

Scenarios		Demand Projection and Electrification
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*	**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).
	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	* SB100 Moderate is very close to the 2017 SLTRP after adjusting for load projections, OTC units retirement, and IPP coal replacement.
	Early & No Biofuels High	**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.
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	***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.
	Ltd. Transmission High	

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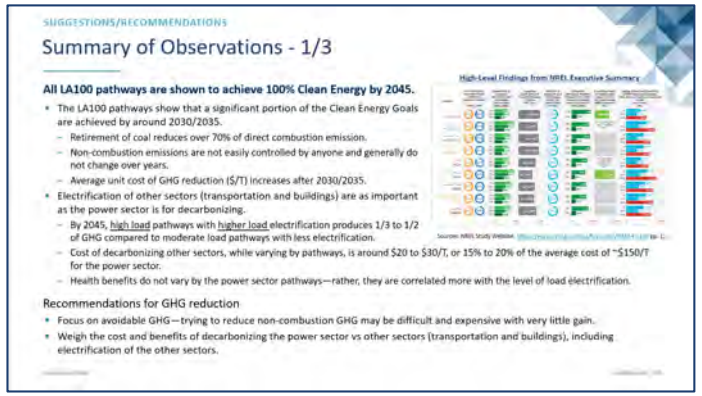
Modest electrification

Higher electrification

See slide 5 of full presentation.

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.


SUGGESTIONS/RECOMMENDATIONS

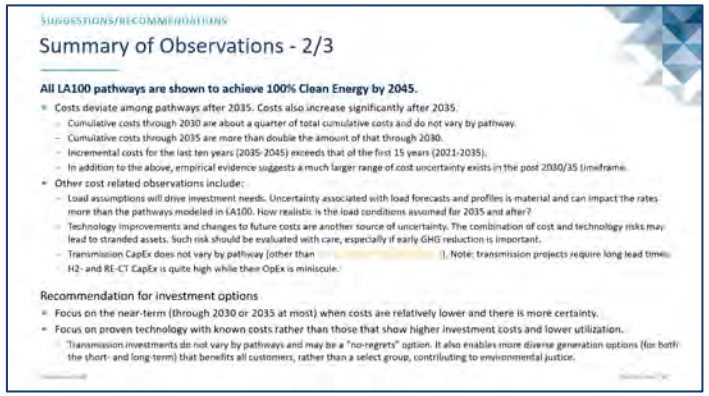
Summary of Observations - 1/3

All LA100 pathways are shown to achieve 100% Clean Energy by 2045.

- The LA100 pathways show that a significant portion of the Clean Energy Goals are achieved by around 2030/2035.
  - Retirement of coal reduces over 70% of direct combustion emission.
  - Non-combustion emissions are not easily controlled by anyone and generally do not change over years.
  - Average unit cost of GHG reduction ($/T) increases after 2030/2035.
- Electrification of other sectors (transportation and buildings) are as important as the power sector is for decarbonizing.
  - By 2045, high load pathways with higher load electrification produces 1/3 to 1/2 of GHG compared to moderate load pathways with less electrification.
  - Cost of decarbonizing other sectors, while varying by pathways, is around $20 to $30/T, or 15% to 20% of the average cost of ~$150/T for the power sector.
  - Health benefits do not vary by the power sector pathways—rather, they are correlated more with the level of load electrification.

Recommendations for GHG reduction

- Focus on avoidable GHG—trying to reduce non-combustion GHG may be difficult and expensive with very little gain.
- Weigh the cost and benefits of decarbonizing the power sector vs other sectors (transportation and buildings), including electrification of the other sectors.


SUGGESTIONS/RECOMMENDATIONS

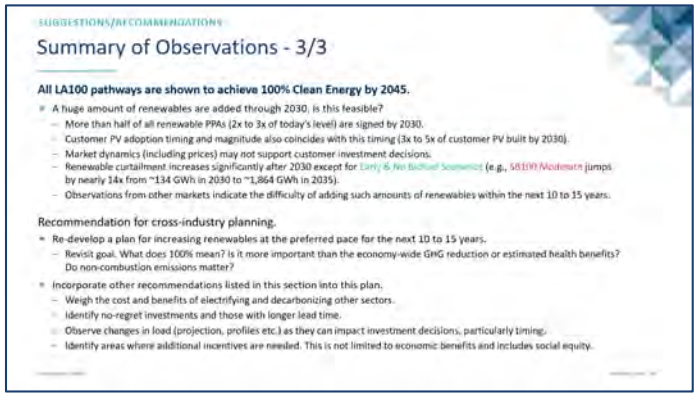
Summary of Observations - 2/3

All LA100 pathways are shown to achieve 100% Clean Energy by 2045.

- Costs deviate among pathways after 2035. Costs also increase significantly after 2035.
  - Cumulative costs through 2030 are about a quarter of total cumulative costs and do not vary by pathway.
  - Cumulative costs through 2035 are more than double the amount of that through 2030.
  - Incremental costs for the last ten years (2035-2045) exceeds that of the first 15 years (2021-2035).
  - In addition to the above, empirical evidence suggests a much larger range of cost uncertainty exists in the post 2030/35 timeframe.
- Other cost related observations include:
  - Load assumptions will drive investment needs. Uncertainty associated with load forecasts and profiles is material and can impact the rates more than the pathways modeled in LA100. How realistic is the load conditions assumed for 2035 and after?
  - Technology improvements and changes to future costs are another source of uncertainty. The combination of cost and technology risks may lead to stranded assets. Such risk should be evaluated with care, especially if early GHG reduction is important.
  - Transmission CapEx does not vary by pathway (other than). Note: transmission projects require long lead times.
  - H2- and RE-CT CapEx is quite high while their OpEx is miniscule.

Recommendation for investment options

- Focus on the near-term (through 2030 or 2035 at most) when costs are relatively lower and there is more certainty.
- Focus on proven technology with known costs rather than those that show higher investment costs and lower utilization.
  - Transmission investments do not vary by pathways and may be a "no-regrets" option. It also enables more diverse generation options (for both the short- and long-term) that benefits all customers, rather than a select group, contributing to environmental justice.


SUGGESTIONS/RECOMMENDATIONS

Summary of Observations - 3/3

All LA100 pathways are shown to achieve 100% Clean Energy by 2045.

- A huge amount of renewables are added through 2030. Is this feasible?
  - More than half of all renewable PPAs (2x to 3x of today's level) are signed by 2030.
  - Customer PV adoption timing and magnitude also coincides with this timing (3x to 5x of customer PV built by 2030).
  - Market dynamics (including prices) may not support customer investment decisions.
  - Renewable curtailment increases significantly after 2030 except for Early & No Biofuel Scenarios (e.g., SB100 Moderate) jumps by nearly 14x from ~134 GWh in 2030 to ~1,864 GWh in 2035).
  - Observations from other markets indicate the difficulty of adding such amounts of renewables within the next 10 to 15 years.

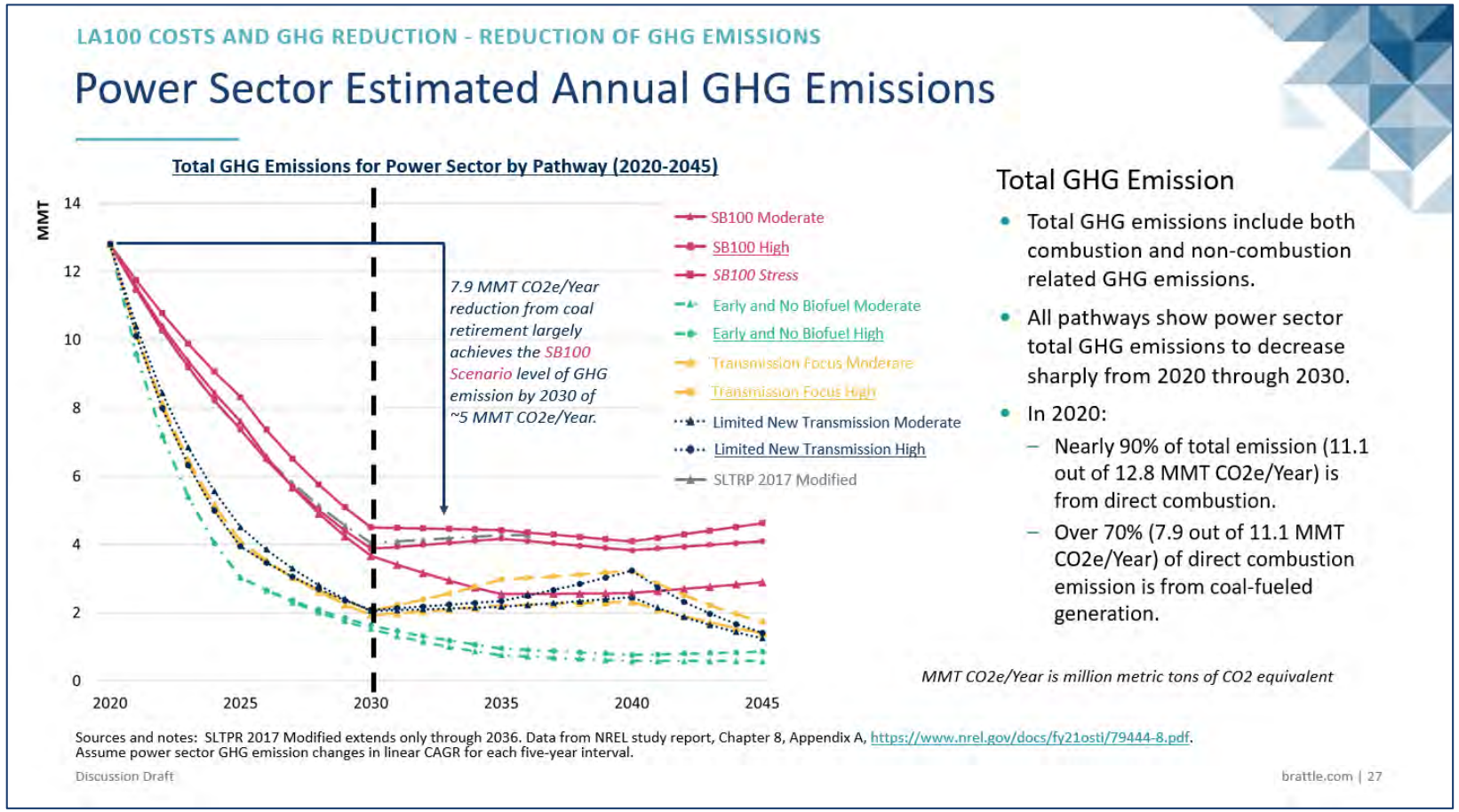
Recommendation for cross-industry planning.

- 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? Do non-combustion emissions matter?
- Incorporate other recommendations listed in this section into this plan.
  - Weigh the cost and benefits of electrifying and decarbonizing other sectors.
  - Identify no-regret investments and those with longer lead time.
  - 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.

GHG Emissions by Pathways

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



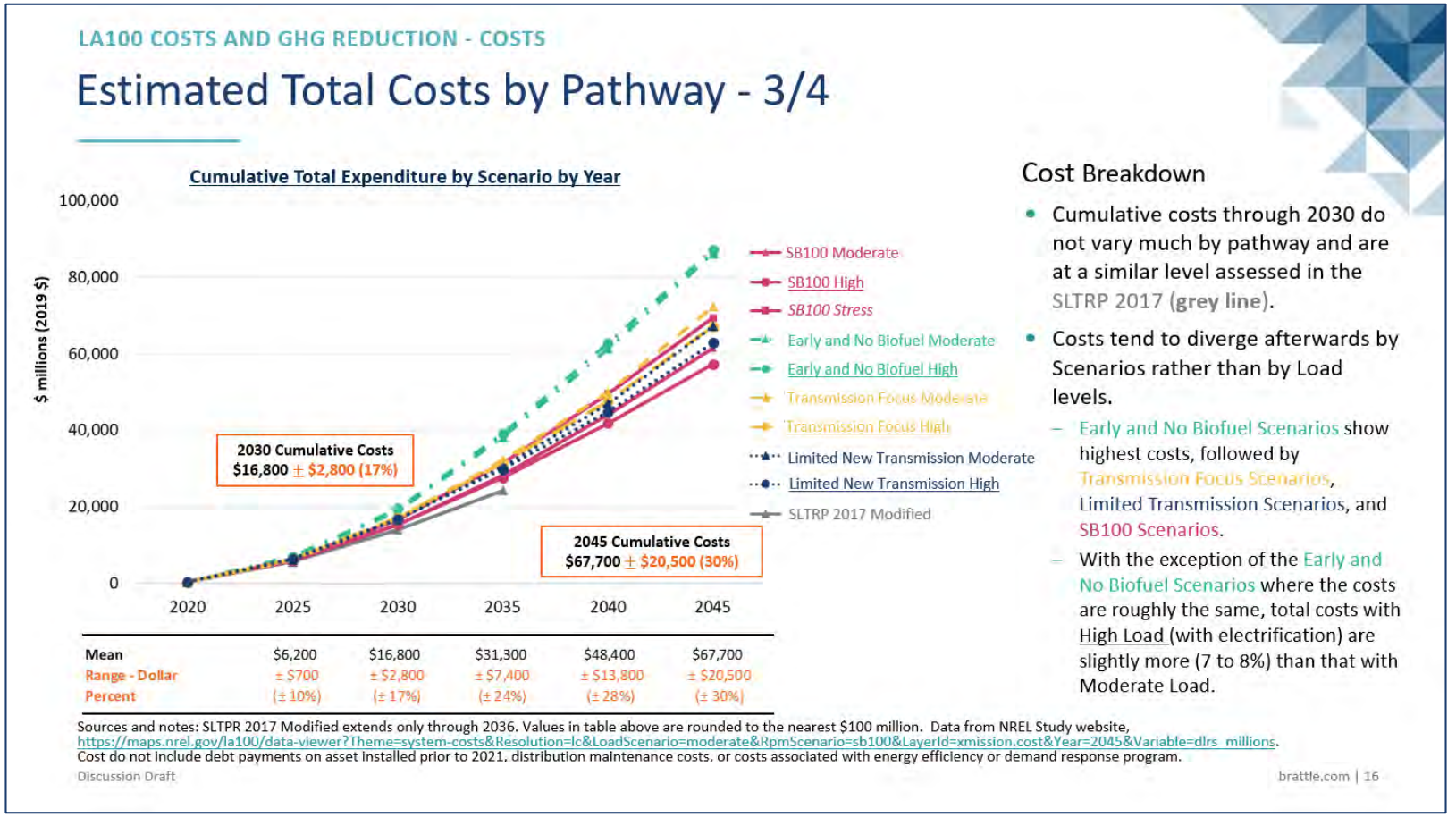
LA 100 Study looks at:

- 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.

Costs by Pathways - 1/2

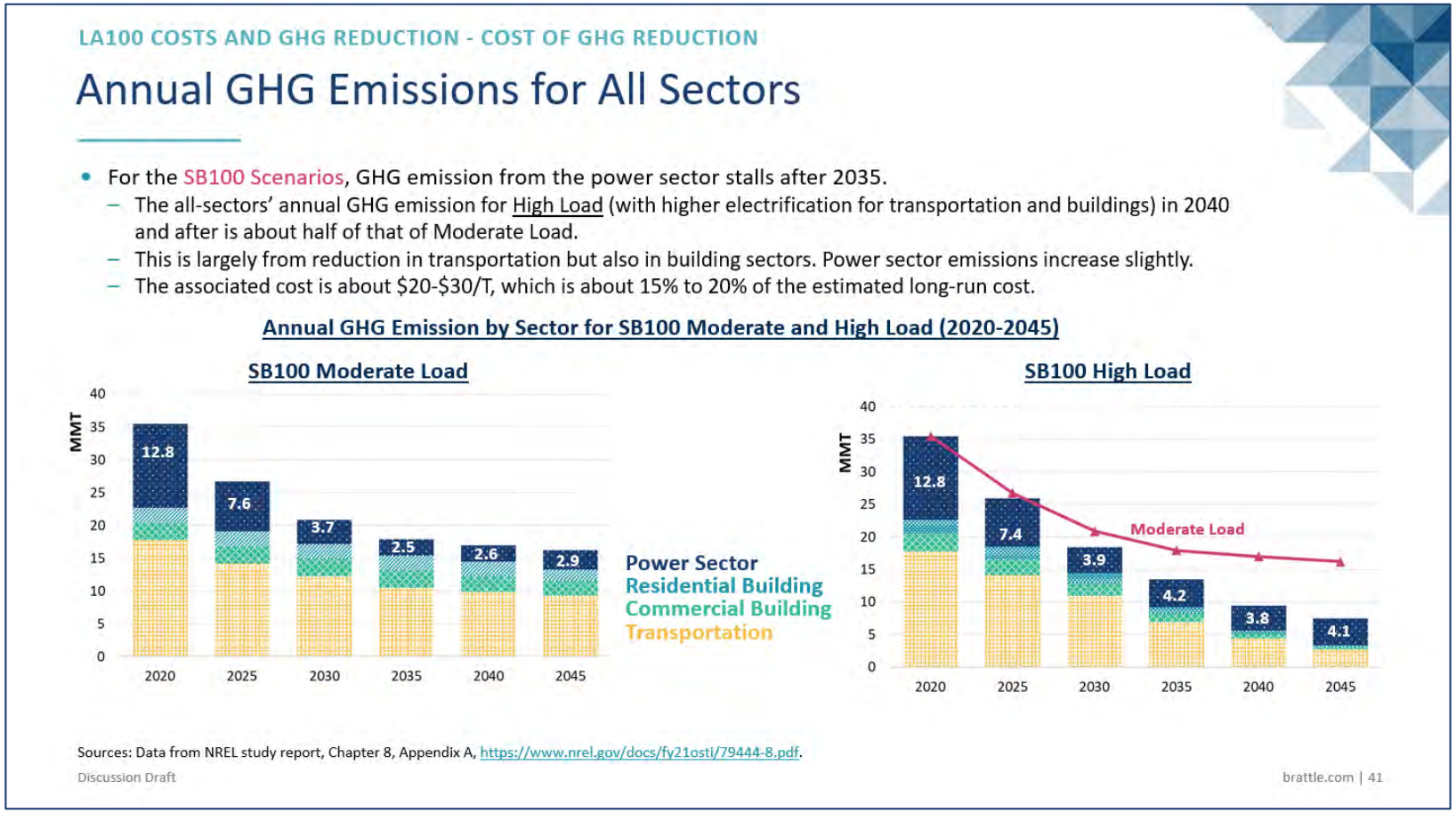
- **Costs grow exponentially in future years (after 2030).**
  - <25% through 2030, <50% (2x of costs through 2030) through 2035. More than half of all costs in the last ten years (2035-2045).



See slide 16 of full presentation.

Benefits of Electrification - 1/2

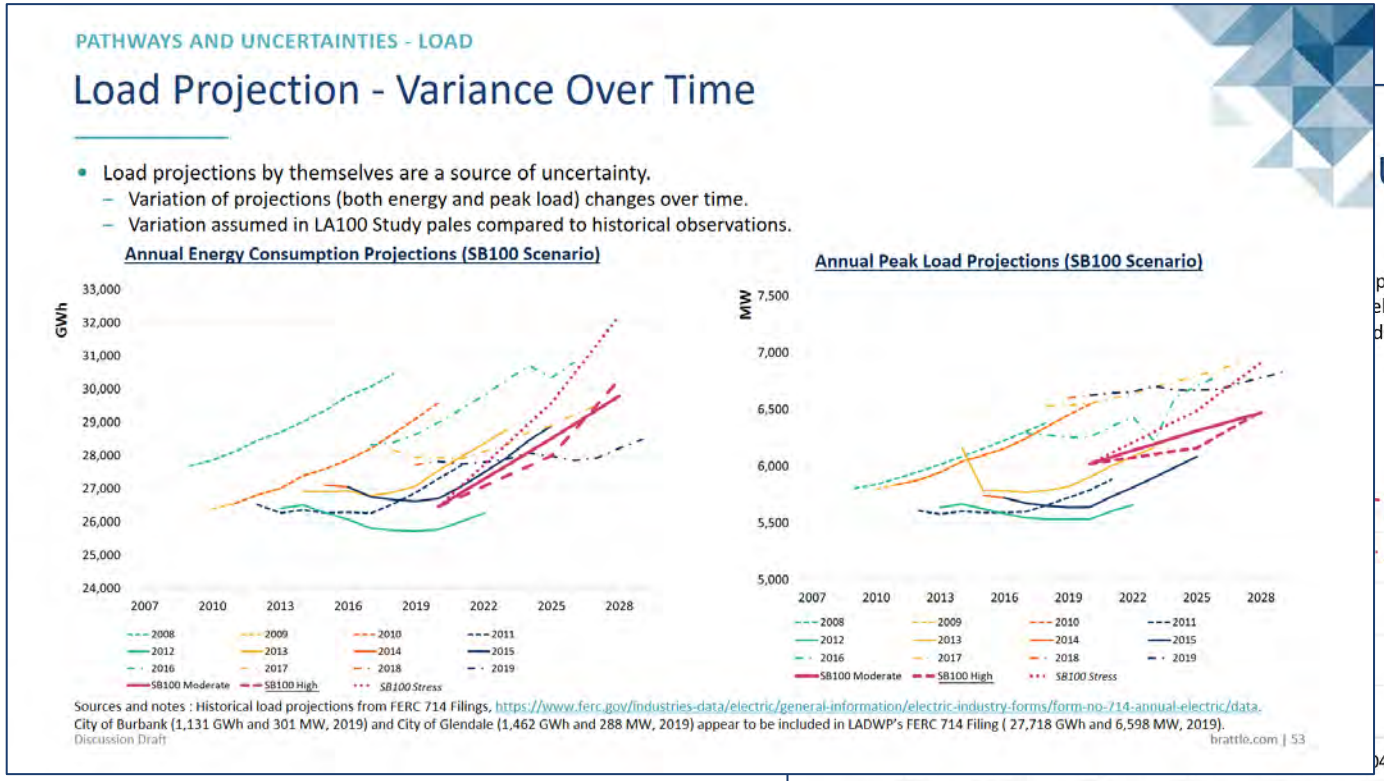
- **Electrification of other sectors reduce more GHG for lower incremental costs.**
  - Study does not account for the cost of electrification but includes the cost of serving the newly electrified load.

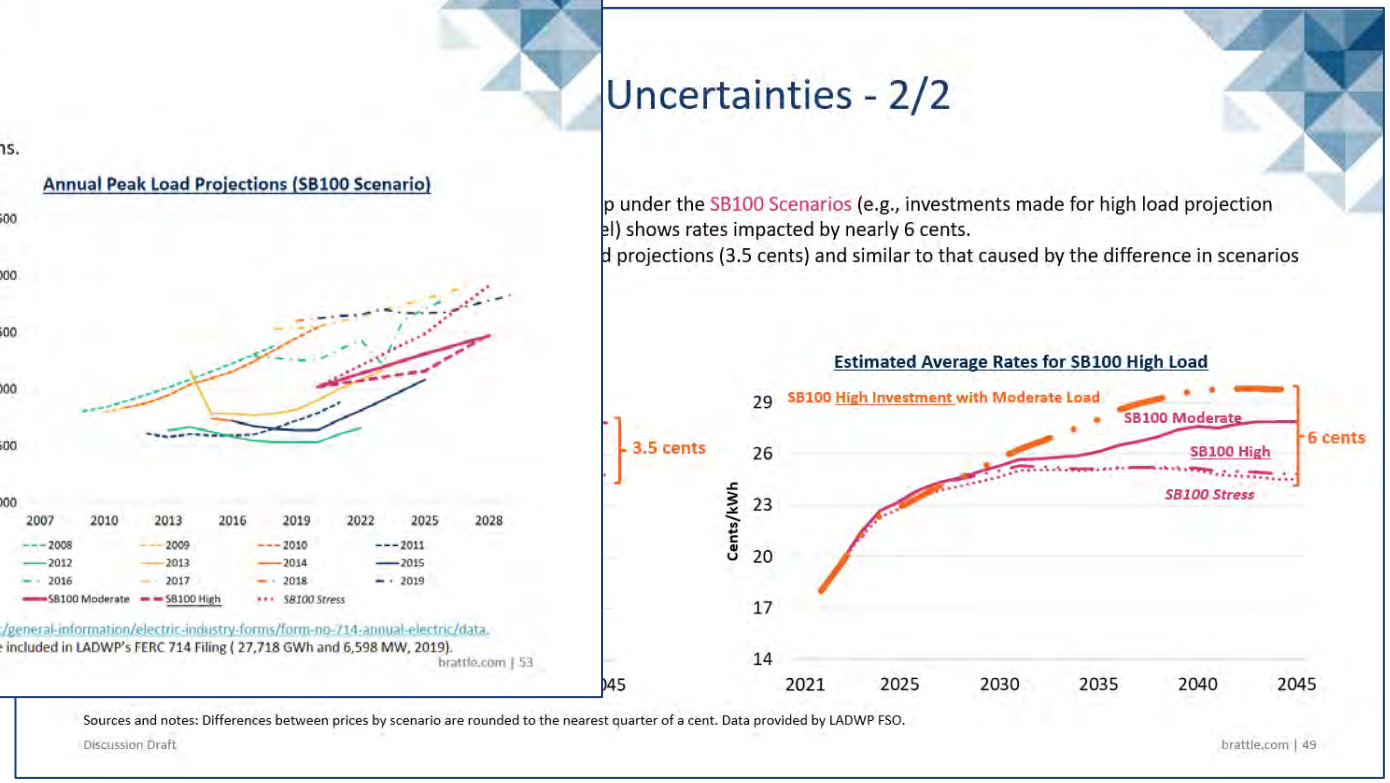


See slides 41 through 44 of full presentation. Slide 41 is shown above.

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.

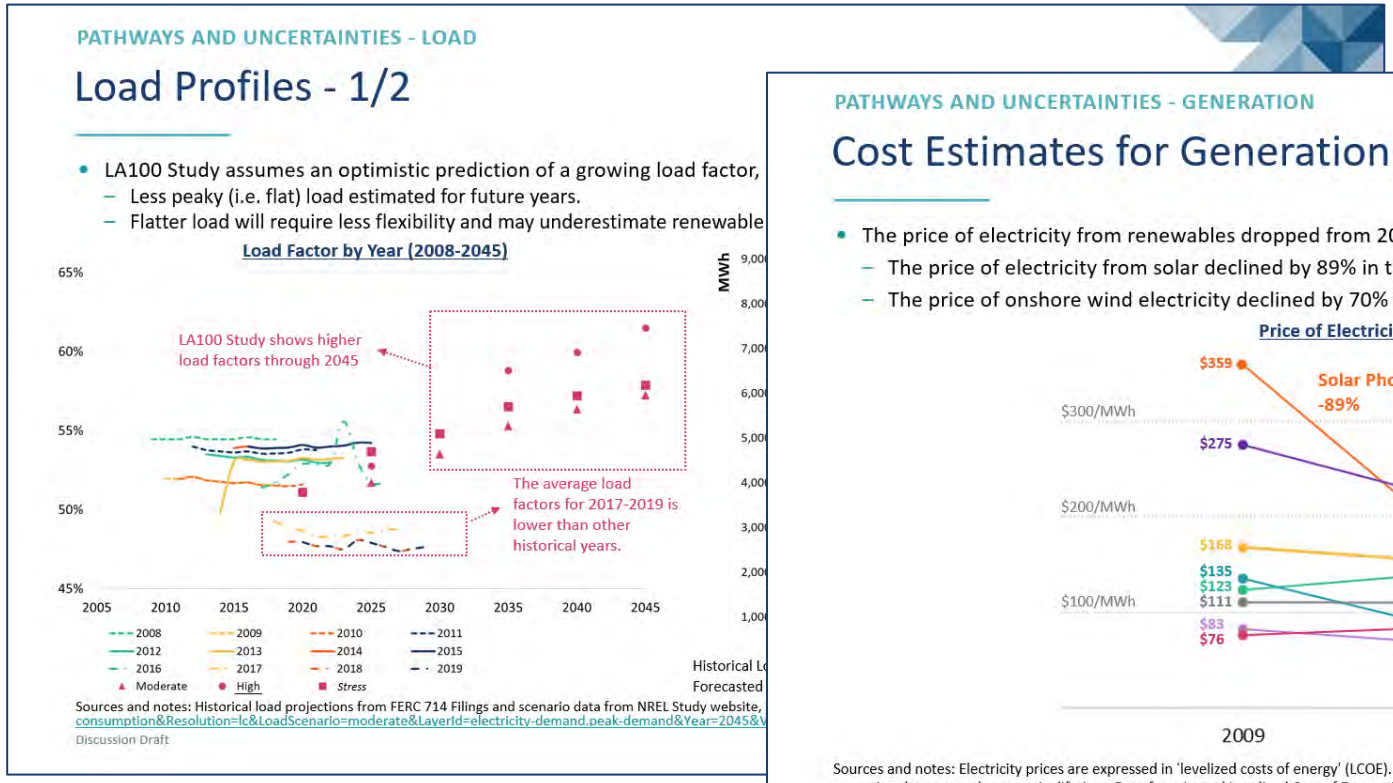


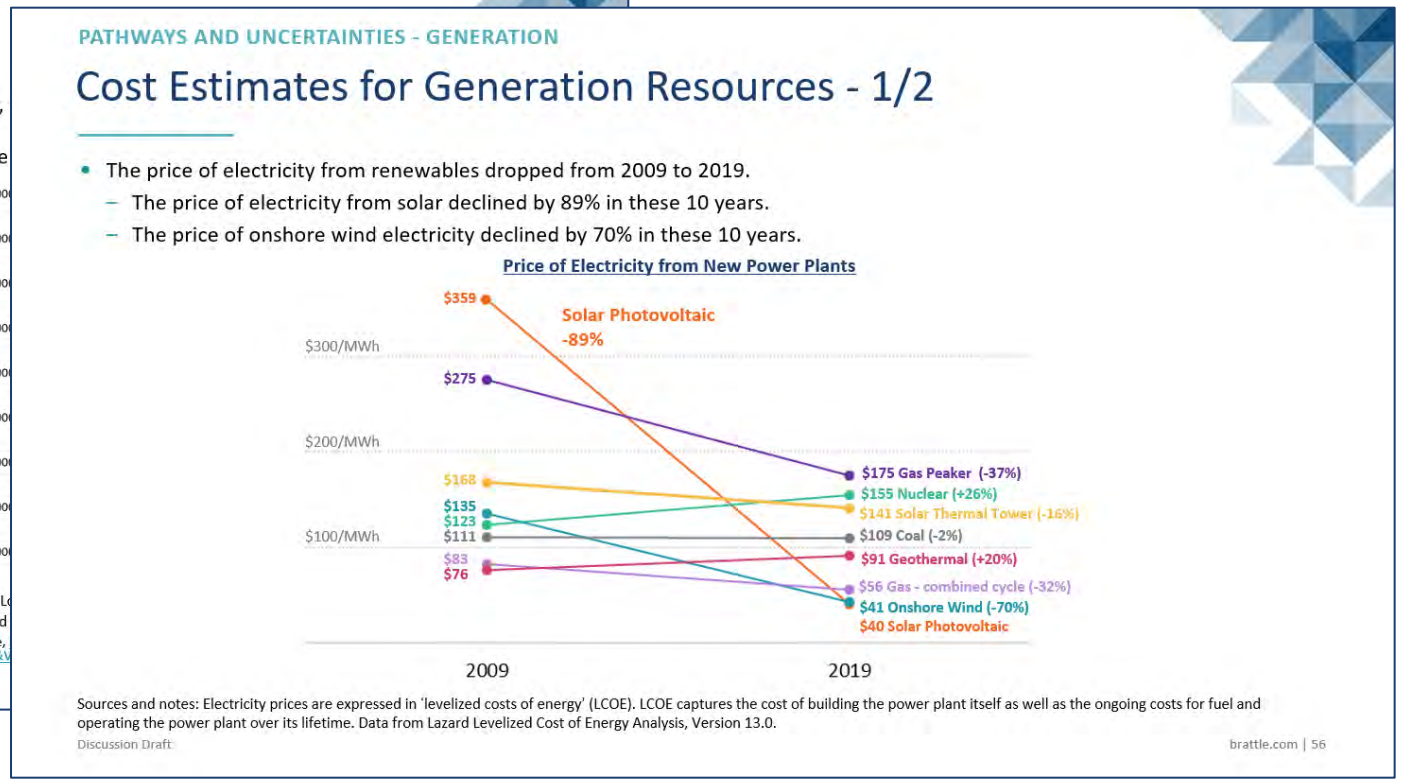


See slide 46 through 55 of full presentation. Slides 49 and 53 are shown above.

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.

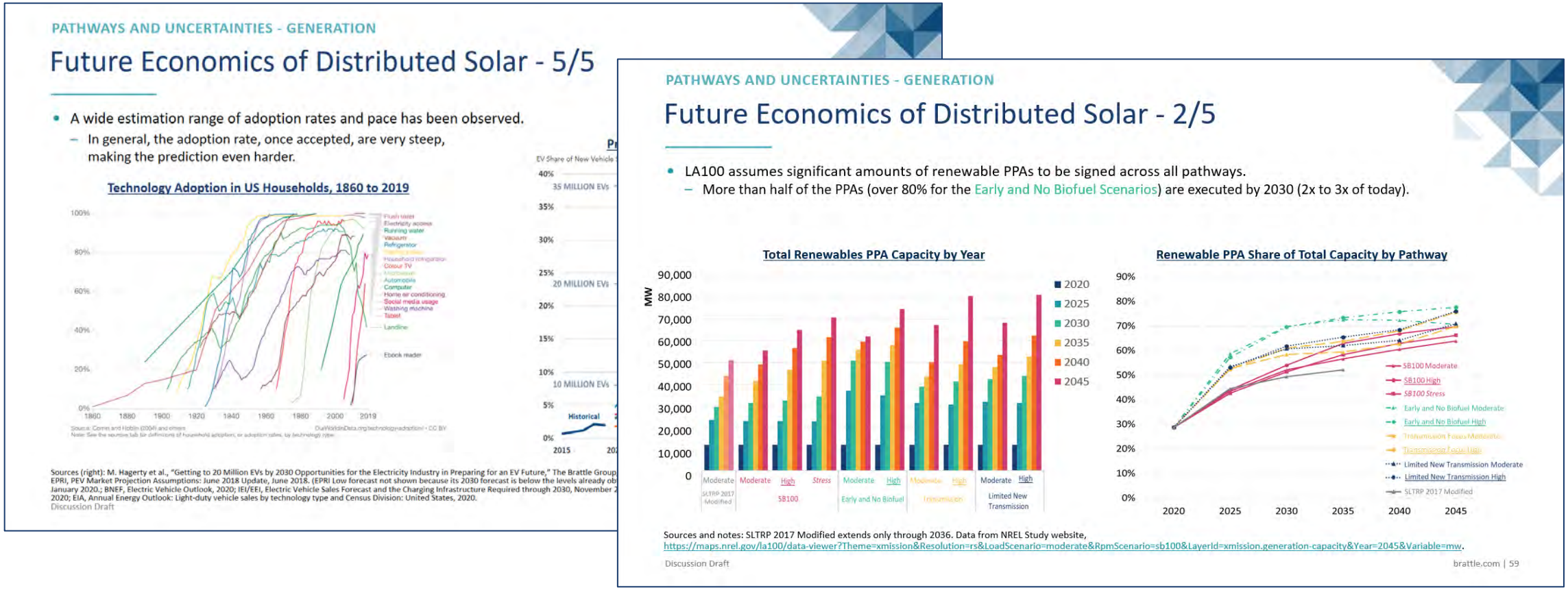




See slides 54 through 57 of full presentation. Slides 54 and 56 are shown above.

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.



PATHWAYS AND UNCERTAINTIES - GENERATION

Future Economics of Distributed Solar - 5/5

- 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

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; EPRI, PEV Market Projection Assumptions: June 2018 Update, June 2018. (EPRI Low forecast not shown because its 2030 forecast is below the levels already ob... January 2020.; BNEF, Electric Vehicle Outlook, 2020; IEI/EEI, Electric Vehicle Sales Forecast and the Charging Infrastructure Required through 2030, November 2... 2020; EIA, Annual Energy Outlook: Light-duty vehicle sales by technology type and Census Division: United States, 2020.

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PATHWAYS AND UNCERTAINTIES - GENERATION

Future Economics of Distributed Solar - 2/5

- LA100 assumes significant amounts of renewable PPAs to be signed across all pathways.
  - More than half of the PPAs (over 80% for the Early and No Biofuel Scenarios) are executed by 2030 (2x to 3x of today).

Total Renewables PPA Capacity by Year

Renewable PPA Share of Total Capacity by Pathway

Sources and notes: SLTRP 2017 Modified extends only through 2036. Data from NREL Study website, https://maps.nrel.gov/la100/data-viewer?Theme=xmission&Resolution=rs&LoadScenario=moderate&RpmScenario=sb100&LayerId=xmission.generation-capacity&Year=2045&Variable=mw.

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

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

Full Report

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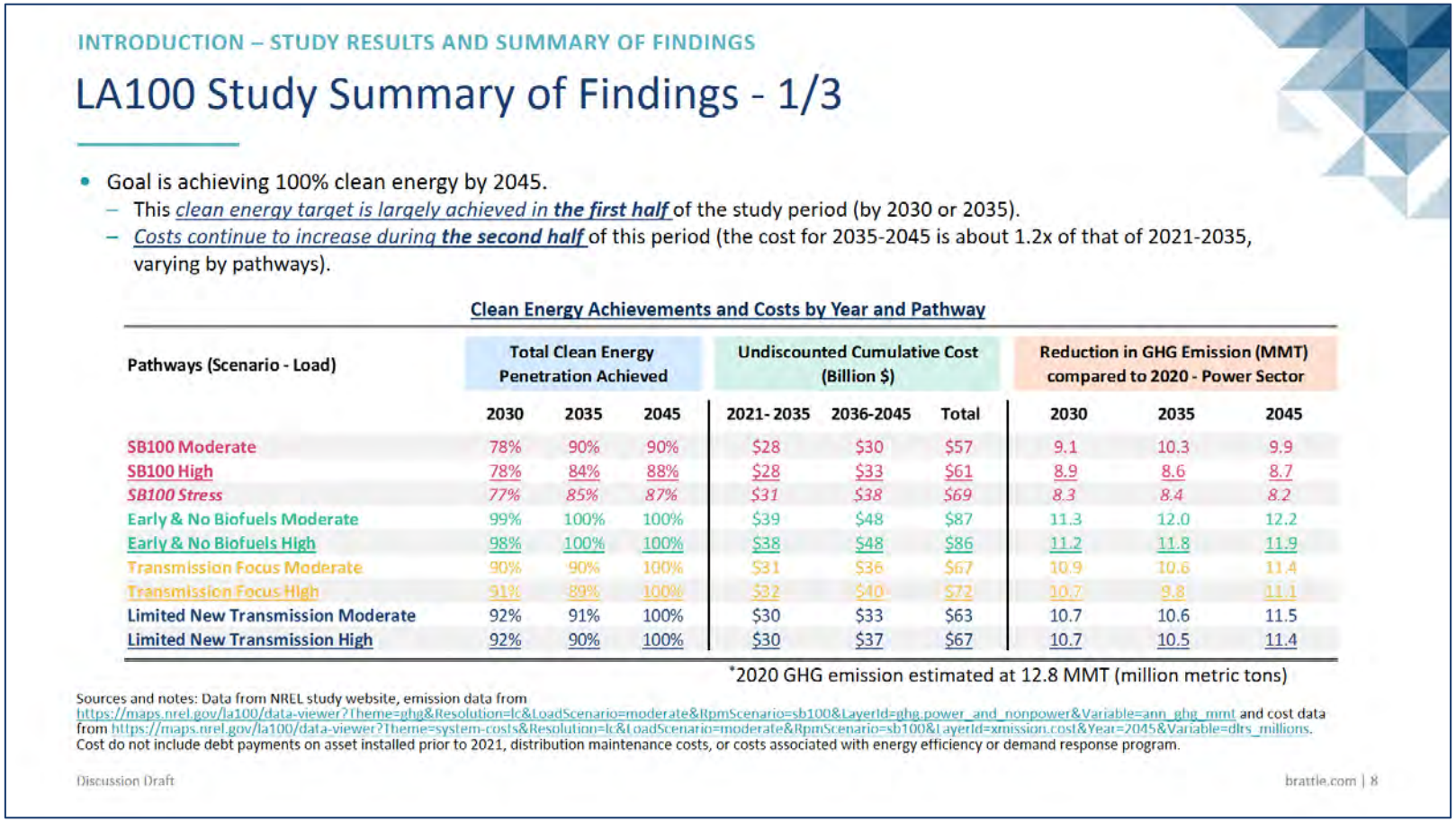
Summary of LA 100 Results - 1/2

- **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).



INTRODUCTION – STUDY RESULTS AND SUMMARY OF FINDINGS

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.

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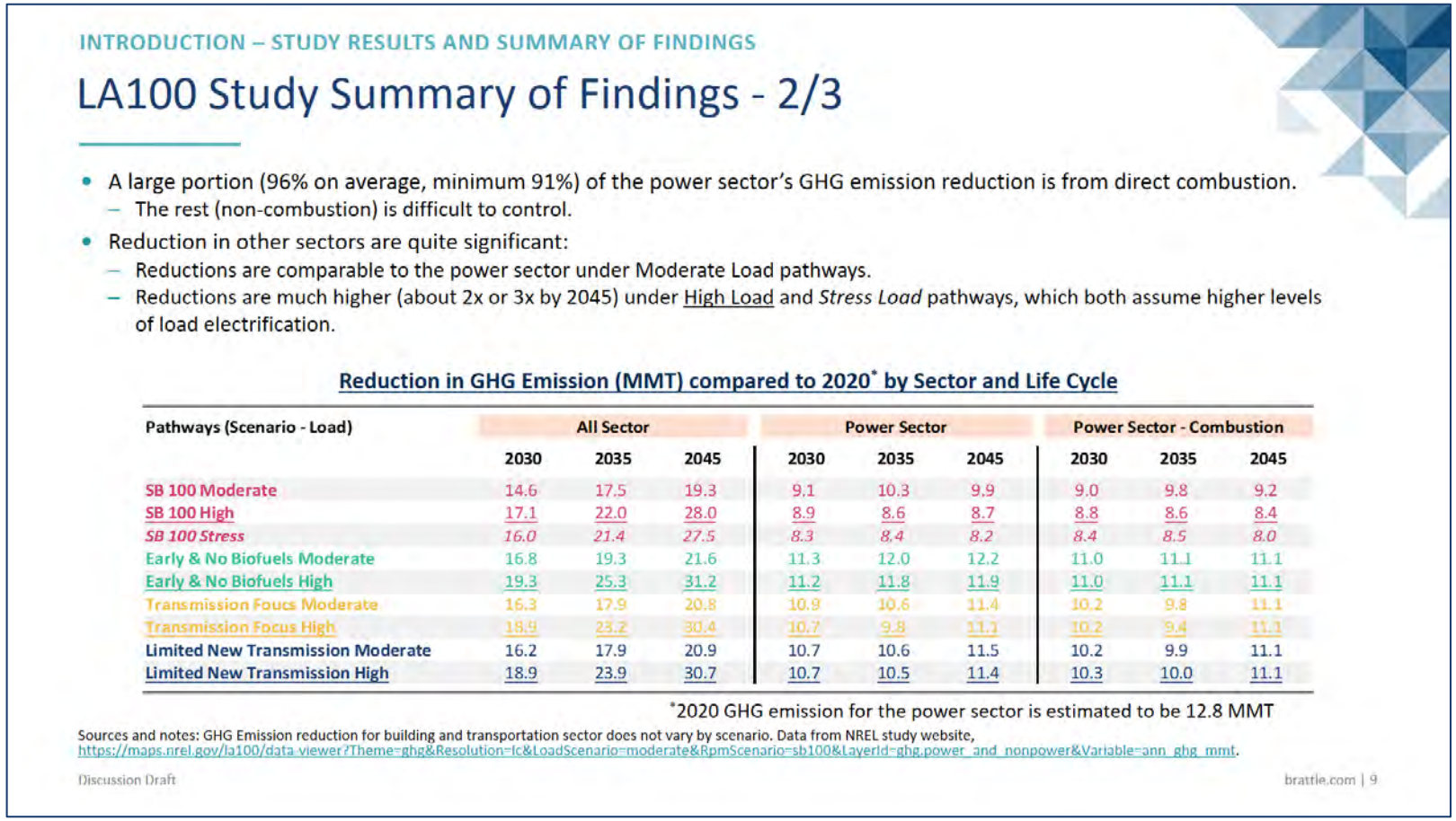
Summary of LA 100 Results - 2/2

- **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.



INTRODUCTION – STUDY RESULTS AND SUMMARY OF FINDINGS

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 Focus 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.

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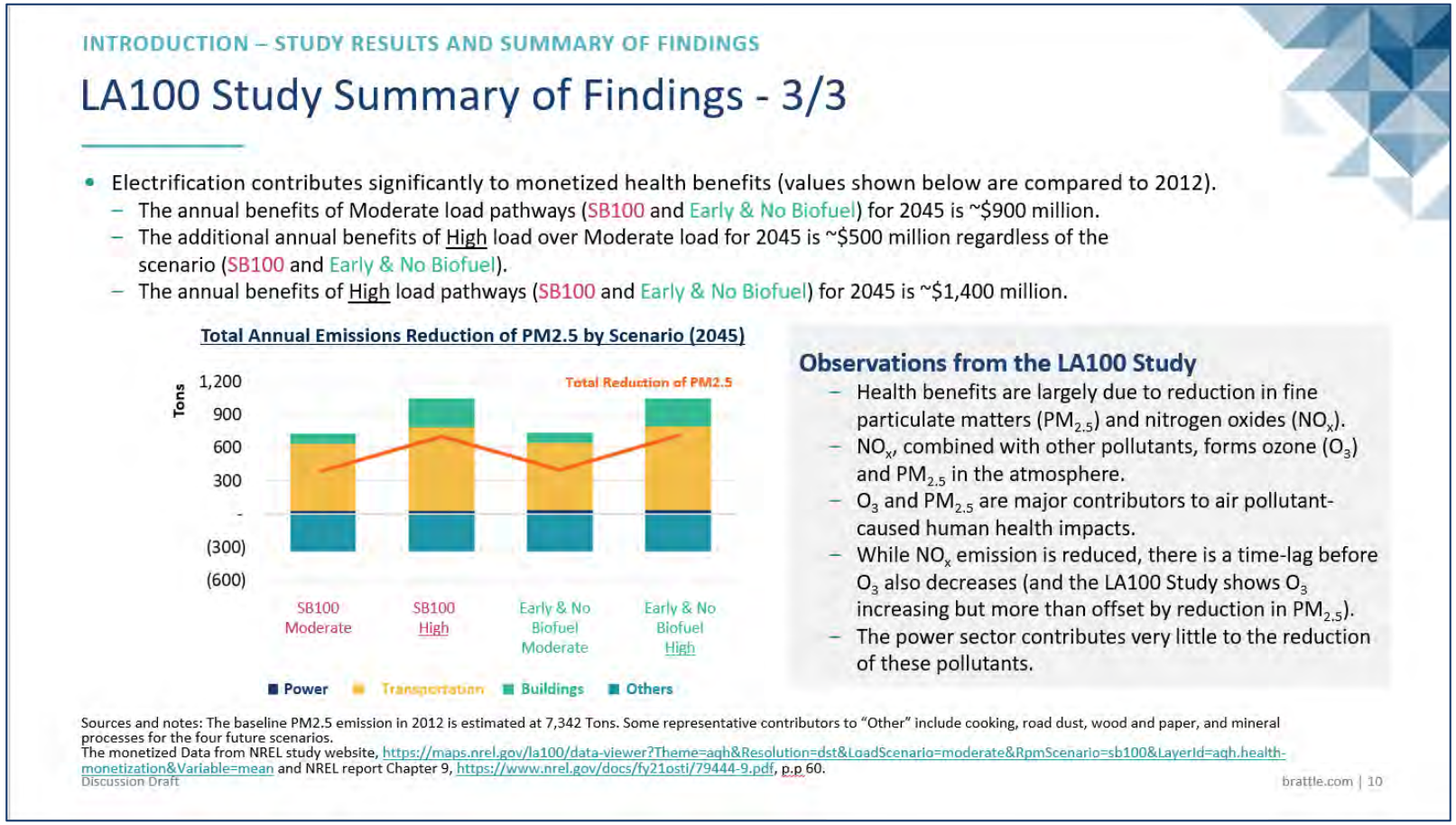
See slide 9 of full presentation.

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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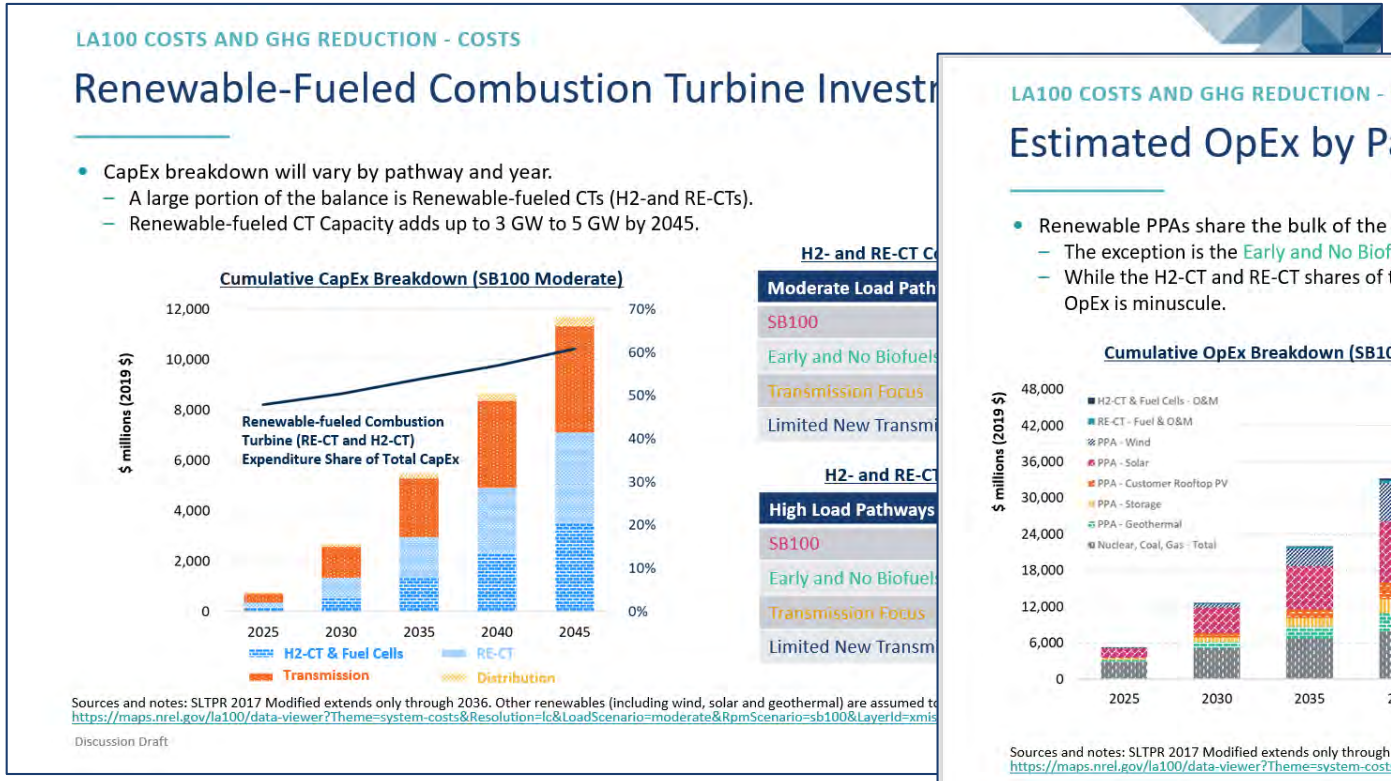
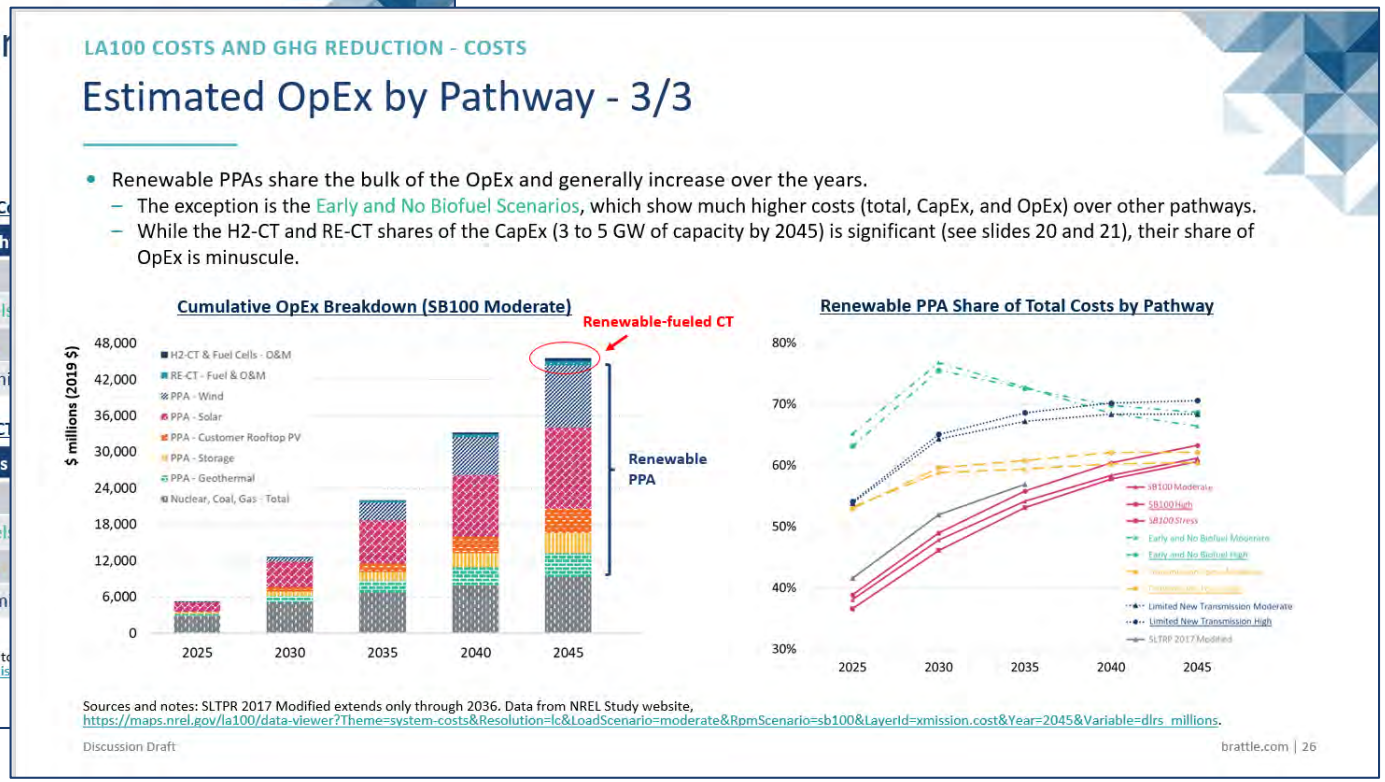
Costs by Pathways - 2/2

- **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.