

Review of the LA100 Study

PRELIMINARY DRAFT – FOR DISCUSSION PURPOSES

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PRESENTED TO

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Office of Public Accountability /
Ratepayer Advocate

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The Los Angeles 100% Renewable Energy Study



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Overview of the LA100 Study

Study Purpose

- NREL, with the LADWP team and Advisory Group, performed The Los Angeles 100% Renewable Energy Study (**LA100 Study**) that evaluates multiple *pathways* for Los Angeles to achieve a clean energy future—with the goal of achieving 100% by 2045.
 - Pathways are combinations of 4 scenarios and 3 load projections (see next slide).
 - The pathways (or scenarios) do not provide a forecast or recommendation for future action, rather they represent a range of possibilities that can result from different decisions and investment choices.



Comparison to Modified Strategic Long-Term Resource Plan (SLTRP) 2017

- SLTRP 2017 is the latest IRP developed by LADWP.
- LA100 pathways are compared against a modified version of the SLTRP 2017.
 - Total clean energy (renewables, hydro, and nuclear) penetration achieved in the adjusted SLTRP 2017 (SLTRP 2017 Modified) is 77% in 2035, compared to 65% from the original SLTRP 2017.
 - Electric Vehicles (EV) adoption in the LA100 pathways moderate load projection is based on the “high case” EV adoption from the SLTRP 2017.
 - High electrification projection in the LA100 pathways follows the SLTRP 2017 “high case” until 2025, and then assumes more aggressive adoption from 2026 onward based on the NREL’s Electrification Futures Study.
 - The LA100 pathways with moderate load all show increases in costs relative to the 2017 SLTRP Recommended Case, driven by 1) higher renewable/clean energy penetration achieved by 2035, and 2) need to substitute the retired Once-Through-Cooling (OTC) capacity with alternative renewable resources.

LA100 Study - Pathways (Scenario – Load)

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.

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**.

Transmission Focus: Achieves the 100% target by **2045**, assumes **lower barriers to new transmission and upgrades**, and eliminates nuclear energy generation by 2045.

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**.

SB100 Moderate*

SB100 High

SB100 Stress

Early & No Biofuels Moderate

Early & No Biofuels High

Transmission Moderate

Transmission High

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).

* 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.

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.

LA100 Study - Greenhouse Gas Emission

Various Measures of Greenhouse Gas (GHG) Reduction

- **Power Sector vs Other Sectors**
 - The LA100 Study focuses on the power sector, in particular, emission from generation resources.
 - Other sectors expand to the transportation and building (commercial and residential) sectors, where GHG emission reduction is achieved through electrification of load (e.g., EVs, heating etc.), which is served by the Power Sector.
- **Combustion vs Non-Combustion (Power Sector)**
 - Within the power sector, GHG emission is categorized into two groups—those associated with direct combustion (e.g., through burning fossil fuel) and others (non-combustion).
 - Non-combustion emissions are those attributable to the power sector and include emission from the process of manufacturing of power sector equipment, construction and decommissioning of generation assets, extraction, processing, and transport of fuel used for power generation, etc. Estimates are based on literature review. LADWP has very little control over this.
 - Non-combustion GHG emissions include CO₂, methane, nitrous oxide, and sulfur hexafluoride (SF₆). Quantities are reported in Carbon Dioxide Equivalents (CO₂e).
- **GHG Emission Measurements**
 - GHG emission (unit is in million metric tons, or MMT) can be measured for snapshots (e.g., as for calendar year 2030) or added up for all years (e.g., from 2021 through 2030).



LA100 Study - Results and Observations

LA100 Study Results and Observations

- All pathways are confirmed to achieve 100% clean energy by 2045 while maintaining reliability.
 - All pathways include significant deployment of renewable and zero-carbon energy by 2035 (accounting for 84%–100% of energy), leading to annual GHG emission reduction levels of 76%–100% for the power sector (compared to 2020).
 - Costs grow exponentially after 2030/2035 while further GHG reduction from the power sector is limited.
- Electrification of other sectors (transportation and buildings) are as important as the power sector is for decarbonizing.
 - Electricity demand (both annual consumption and peak demand) is likely to continue its growth—electrification of the transportation sector propels overall growth while high levels of energy efficiency can offset growth for other power usage.
 - Electrification of vehicles and buildings leads to the largest improvements in air quality and associated benefits to health. These benefits are widespread across all communities (see slide 10).
 - Costs of electrification are not assessed as part of the LA100 Study (cost of serving the electrified load is included).
- Other observations include:
 - Customer installed rooftop solar, including up to a third existing single-family homes, is estimated to add up to 3 to 4 gigawatts (GW) by 2045. LADWP might also deploy up to an additional GW of non-rooftop, in-basin solar.
 - Distribution network upgrade is needed but costs are very small (~1% range of overall investment needs).
 - Clean energy investments alone may not notably impact LA's economy overall.



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=dhrs_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.

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

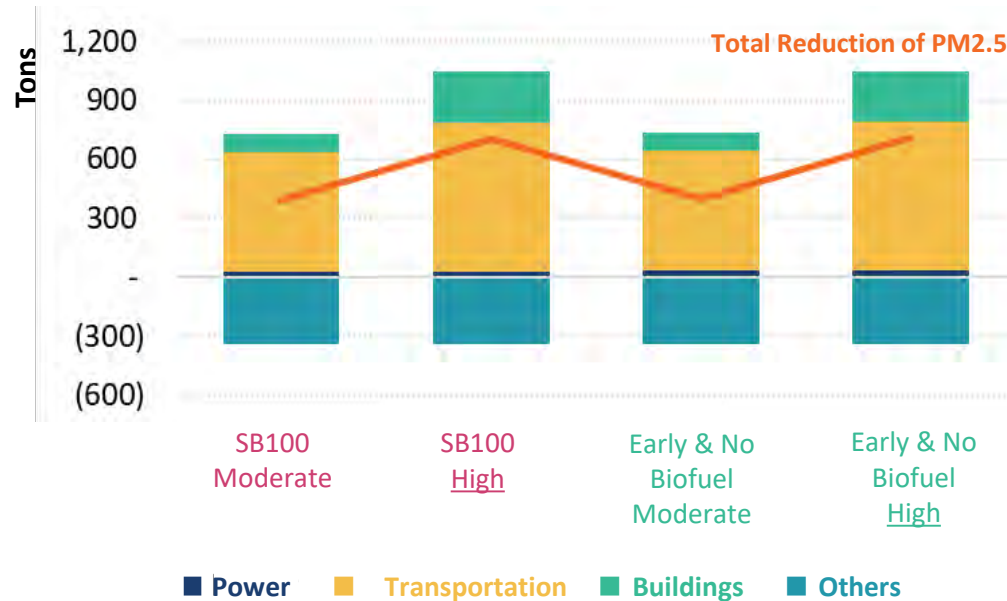
*2020 GHG emission for the power sector is estimated to be 12.8 MMT

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.

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 PM_{2.5} 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 (O₃) and PM_{2.5} in the atmosphere.
- O₃ 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 O₃ also decreases (and the LA100 Study shows O₃ 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 PM_{2.5} 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=agq&Resolution=dst&LoadScenario=moderate&RpmScenario=sb100&LayerId=agq.health-monetization&Variable=mean> and NREL report Chapter 9, <https://www.nrel.gov/docs/fy21osti/79444-9.pdf>, p.p 60.

Discussion Draft

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Convention and Calculation Example - 1/2

- Annual vs Cumulative

- Carbon emission can be measured for snapshots (e.g., as for calendar year 2030) or added up for all years (e.g., from 2021 through 2030).

Sample Data Illustration for GHG Emission (All Sectors)

Year	GHG Emission (MMT)		GHG Emission Reduction (MMT)	
	Annual	Cumulative	Annual (Baseline = 2020)	Cumulative (Baseline = 2020)
2020	35.5	35.5	NA	NA
2021	33.8	69.3	1.7	1.7
2022	32.2	101.5	3.3	5.0
2023	30.7	132.2	4.8	9.8
2024	29.3	161.5	6.2	16.0
2025	26.7	188.2	8.8	24.8
2026	25.3	213.5	10.2	35.0
2027	24.1	237.6	11.4	46.4
2028	23.1	260.7	12.4	58.8
2029	22.2	282.9	13.3	72.1
2030	20.9	303.8	14.6	86.7

Annual Snapshot:
For calendar year 2030,
the projected GHG
emission is 20.9 MMT.

Annual Snapshot of Emission Reduction from 2020

$$= \text{GHG Reduction}_{2023} = \text{GHG}_{2020} - \text{GHG}_{2023}$$

$$= 35.5 - 30.7 = 4.8 \text{ MMT}$$

For calendar year 2023, the projected GHG emission reduction compared to 2020 is 4.8 MMT.

Cumulative Reduction as of 2023

$$= \text{GHG Reduction}_{2021} + \text{GHG Reduction}_{2022} + \text{GHG Reduction}_{2023}$$

$$= 1.7 + 3.3 + 4.8 = 9.8 \text{ MMT}$$

Compared to 2020, the projected total GHG emission reduction in 2023 is 9.8 MMT.

$$\text{Cumulative} = \text{GHG}_{2020} + \text{GHG}_{2021} + \dots + \text{GHG}_{2030}$$

From year 2020 to 2030, the projected total GHG emission is 303.8 MMT.

Convention and Calculation Example - 2/2

- Throughout this presentation, we discuss cumulative GHG emission (and reduction), annual (or five year incremental) GHG emission (and reduction) and cumulative costs. Hereafter, cost of GHG emission (or reduction) assumes the average cost, derived from cumulative cost. See examples below.

Sample Data Illustration for GHG Emission and Cost

Year	GHG Emission (MMT)		GHG Emission Reduction (MMT)		Five year Cost (\$ millions 2019 \$)	
	Annual	Cumulative	Annual (Baseline = 2020)	Cumulative (Baseline = 2020)	Annual	Cumulative
2020	35.5	35.5	NA	NA	\$0	\$0
2021	33.8	69.3	1.7	1.7	-	-
2022	32.2	101.5	3.3	5.0	-	-
2023	30.7	132.2	4.8	9.8	-	-
2024	29.3	161.5	6.2	16.0	-	-
2025	26.7	188.2	8.8	24.8	\$6,809	\$6,809
2026	25.3	213.5	10.2	35.0	-	-
2027	24.1	237.6	11.4	46.4	-	-
2028	23.1	260.7	12.4	58.8	-	-
2029	22.2	282.9	13.3	72.1	-	-
2030	20.9	303.8	14.6	86.7	\$9,328	\$16,137

Examples

- Over the entire period (2020 through 2030), how much did it cost to reduce 1 unit (metric ton, tonne, or T) of GHG emissions?

- Cumulative unit cost of GHG Emission Reduction through 2030 is calculated as: Cumulative Cost / Cumulative GHG Emission Reduction

– $\$16,137 \text{ millions} \div 86.7 \text{ MMT} = \$186 / \text{T}$

- Hereafter, average unit cost calculated in this method will be referred to as **cumulative unit cost** (see slides 32, 33, 34, 40)

- Between 2026 and 2030 (last five years), how much did it cost to reduce 1 unit (T) of GHG emissions?

- Incremental unit cost (on a five year basis) of GHG Emission Reduction of 2030 is calculated as: Five year cost / Five year reduction

– $\$9,328 \text{ millions} \div (86.7 \text{ MMT} - 24.8 \text{ MMT}) = \$151 / \text{T}$

- Hereafter, average unit cost calculated in this method will be referred to as **incremental unit cost** (see slides 35, 36, 38, 39)

- On 2030 (relative to 2020), how much did it cost to reduce 1 unit (T) of GHG emissions

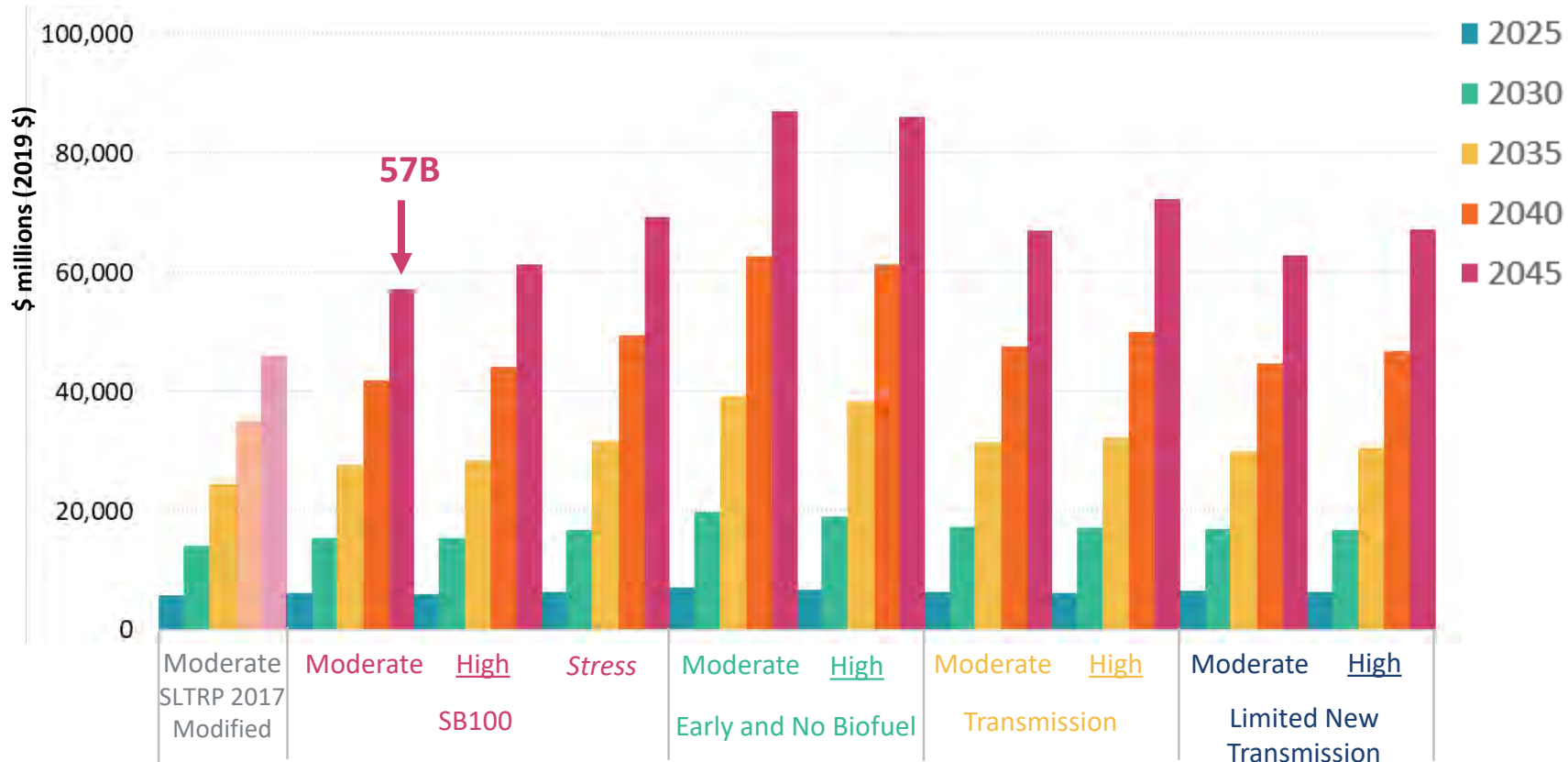
- Annual unit cost of GHG Emission Reduction on 2030 is calculated as: Cumulative Cost / Annual GHG Emission Reduction

– $\$16,137 \text{ millions} \div 14.6 \text{ MMT} = \$1,105 / \text{T}$

- Hereafter, average unit cost calculated in this method will be referred to as **annual unit cost** (see slide 30,37)

Estimated Total Costs by Pathway - 1/4

Cumulative Total Expenditure from 2021-2045 by Scenario



Cost Breakdown

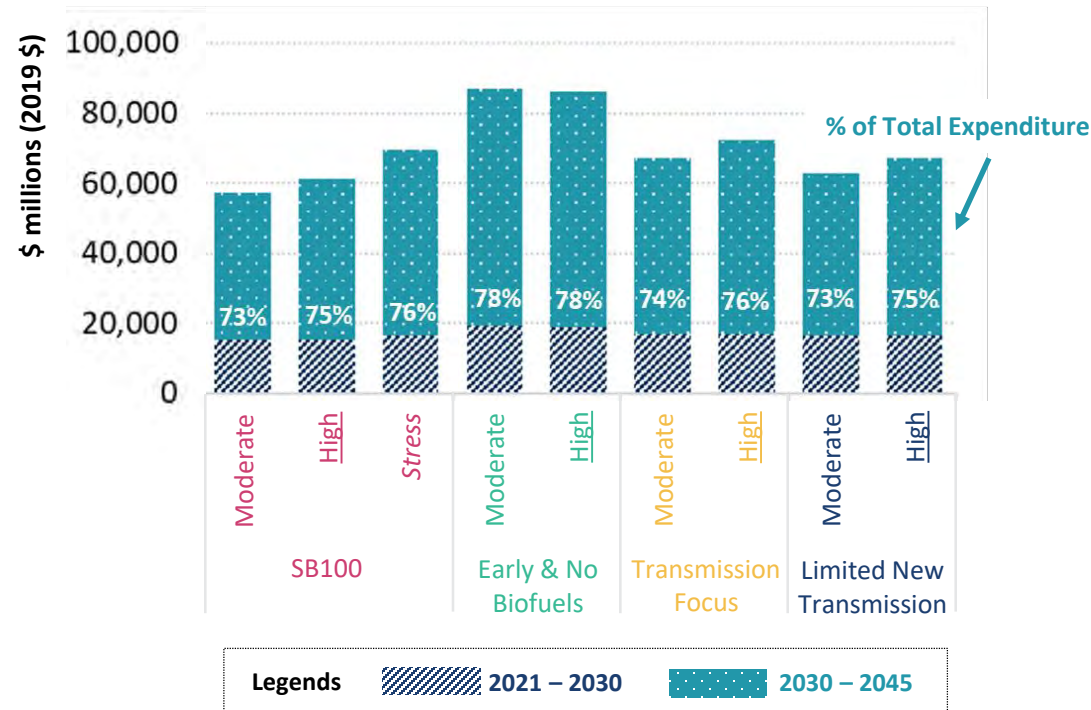
- Cost grows mildly exponentially. Common observation among all pathways include:
 - Cumulative costs through 2030 (green) do not vary much by pathway and are similar to those assessed in the SLTRP 2017.
 - Cumulative costs through 2035 (yellow) are more than twice the amount of that through 2030 (green).
 - Incremental costs for the last ten years (2035-2045) exceeds that of the first 15 years (2021-2035) (yellow).

Sources and notes: SLTPR 2017 Modified extends only through 2036. Cost and Load 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 and 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.

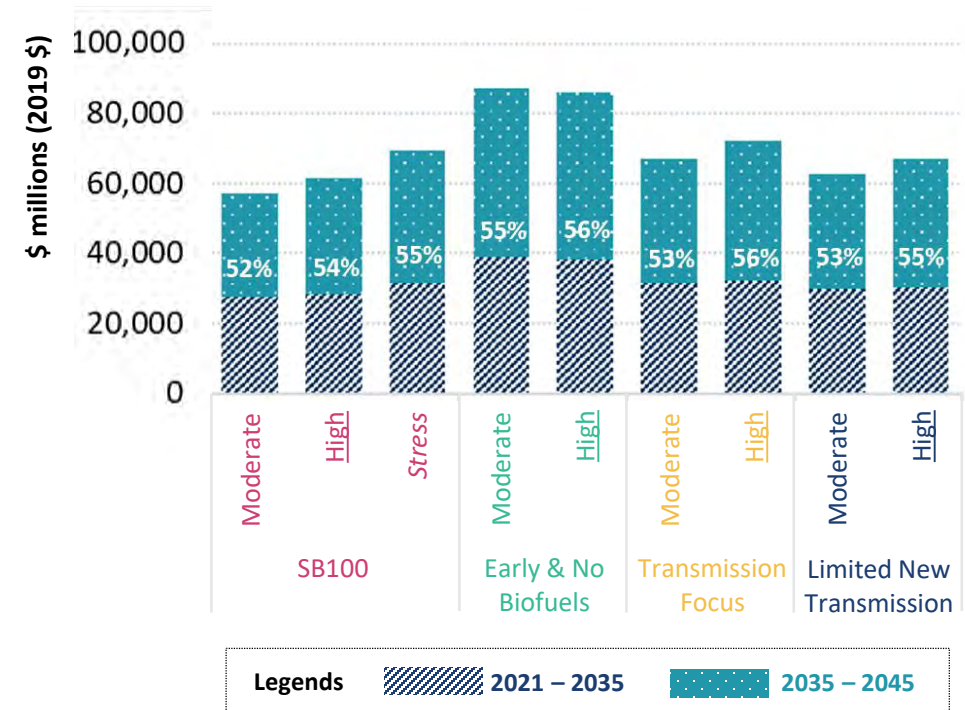
Estimated Total Costs by Pathway - 2/4

- Total cumulative costs through 2030 do not vary much by pathway and are about a quarter of total cumulative costs.
- Total cumulative costs through 2035 are more than twice the amount of that through 2030 and slightly more than half of the total cumulative costs through 2045.

Cumulative Total Expenditure Split - 2030 through 2045



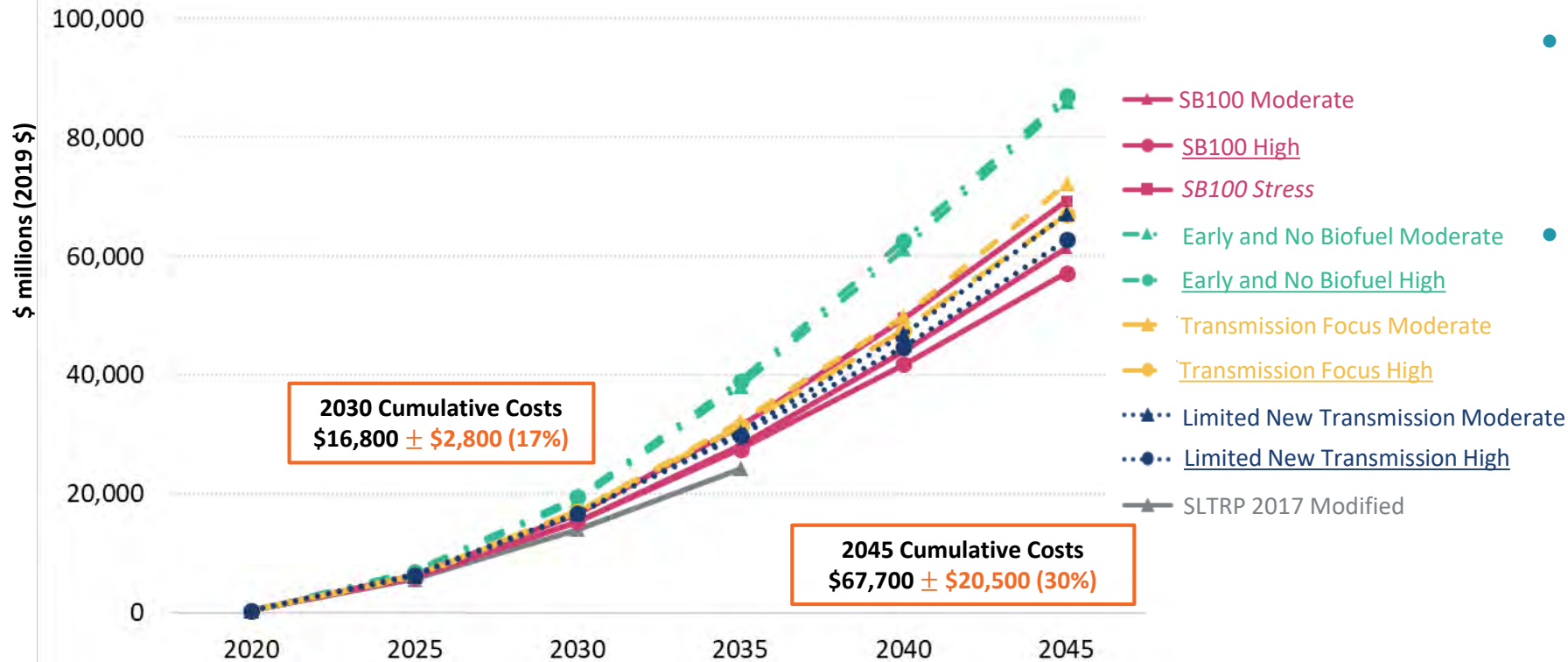
Cumulative Total Expenditure Split - 2035 through 2045



Sources and notes: SLTPR 2017 Modified extends only through 2036. 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=dllr_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.

Estimated Total Costs by Pathway - 3/4

Cumulative Total Expenditure by Scenario by Year



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%)

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=dhrs_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.

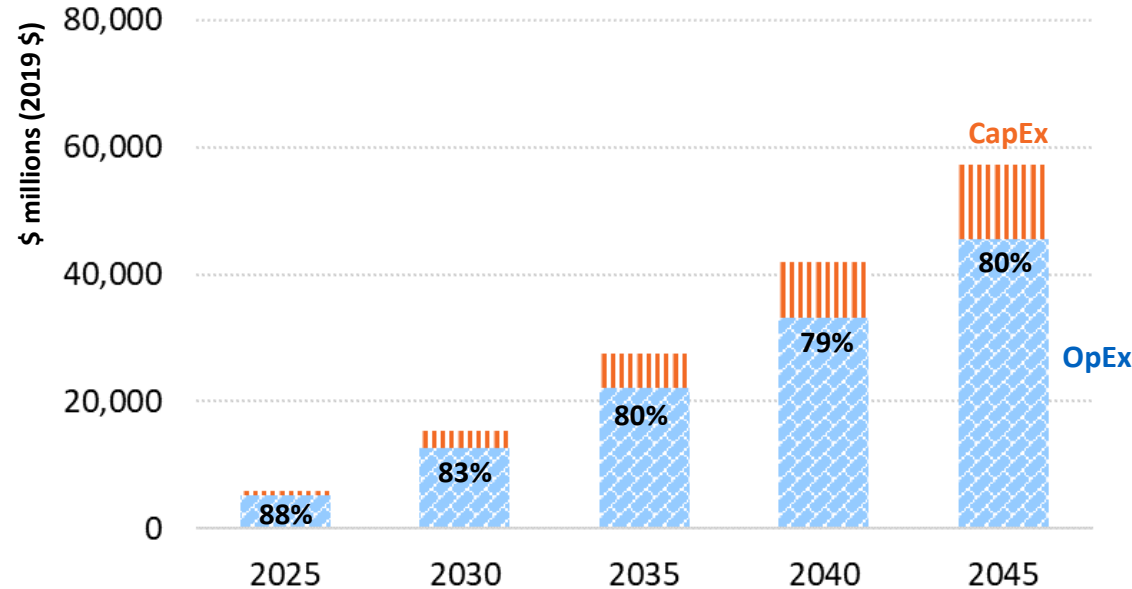
Cost Breakdown

- 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.

Estimated Total Costs by Pathway - 4/4

- Total costs are roughly 20% CapEx and 80% OpEx.
 - This observation does not vary much by pathways (OpEx is within 73% - 92% of total costs) with the OpEx share showing a slightly decreasing trend over the years.

SB100 Moderate Cumulative Total Expenditure Split (OpEx vs CapEx)



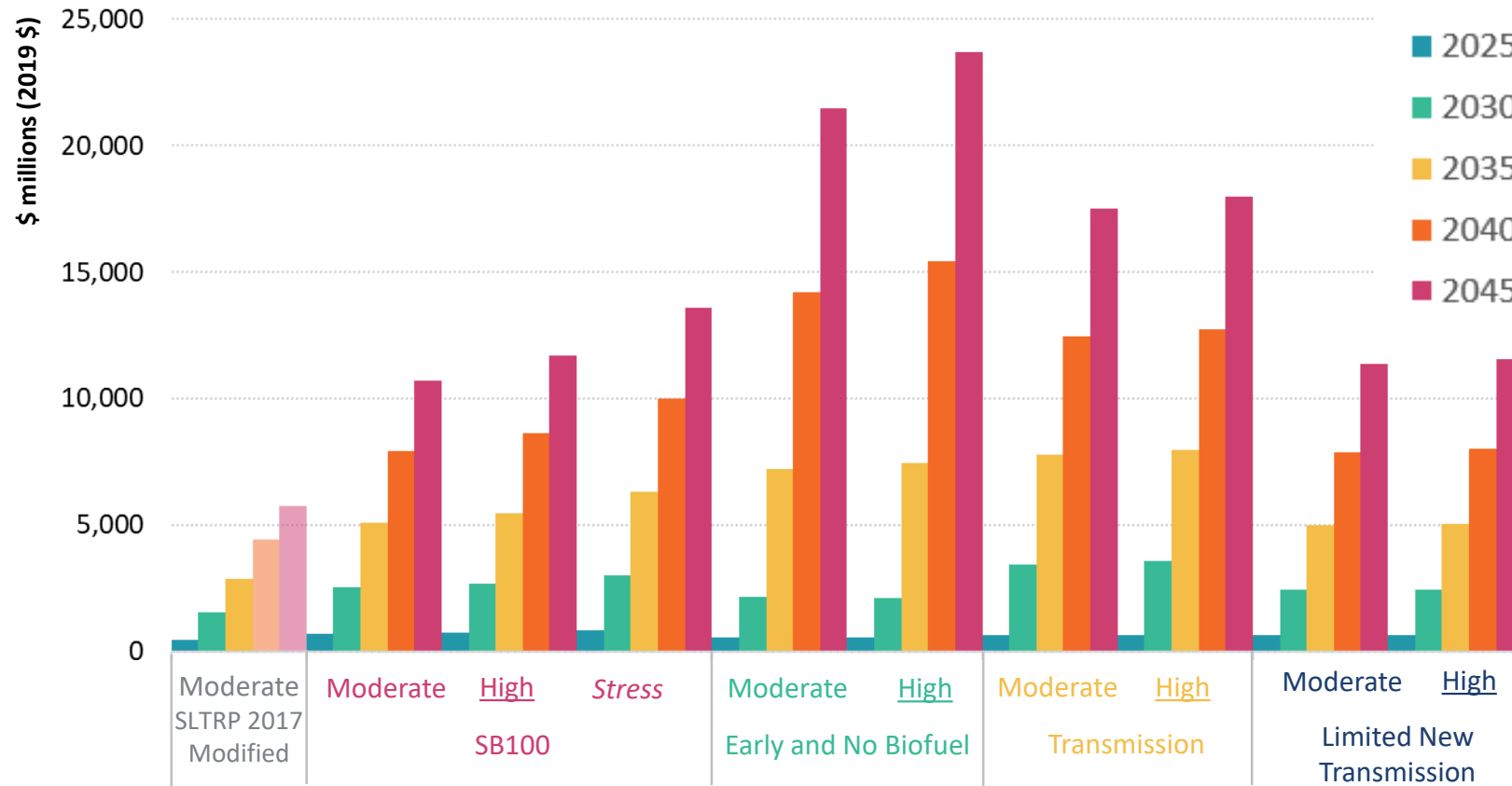
OpEx Share of Cumulative Total Expenditure by Pathways (%)

Pathways	2025	2030	2035	2040	2045
SLTRP 2017 Modified	92%	89%	88%		
SB100 Moderate	88%	83%	80%	79%	80%
SB100 High	88%	83%	82%	82%	83%
SB100 Stress	87%	82%	80%	80%	80%
Early & No Biofuels Moderate	92%	89%	81%	75%	73%
Early & No Biofuels High	92%	89%	81%	77%	75%
Transmission Focus Moderate	89%	79%	75%	73%	73%
Transmission Focus High	89%	80%	76%	75%	76%
Limited New Transmission Moderate	90%	85%	83%	82%	82%
Limited New Transmission High	89%	85%	84%	83%	83%

Sources and notes: 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=dhrs_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.

Estimated CapEx by Pathway - 1/2

Cumulative Capital Expenditure from 2021-2045 by Scenario



CapEx Breakdown of pathways

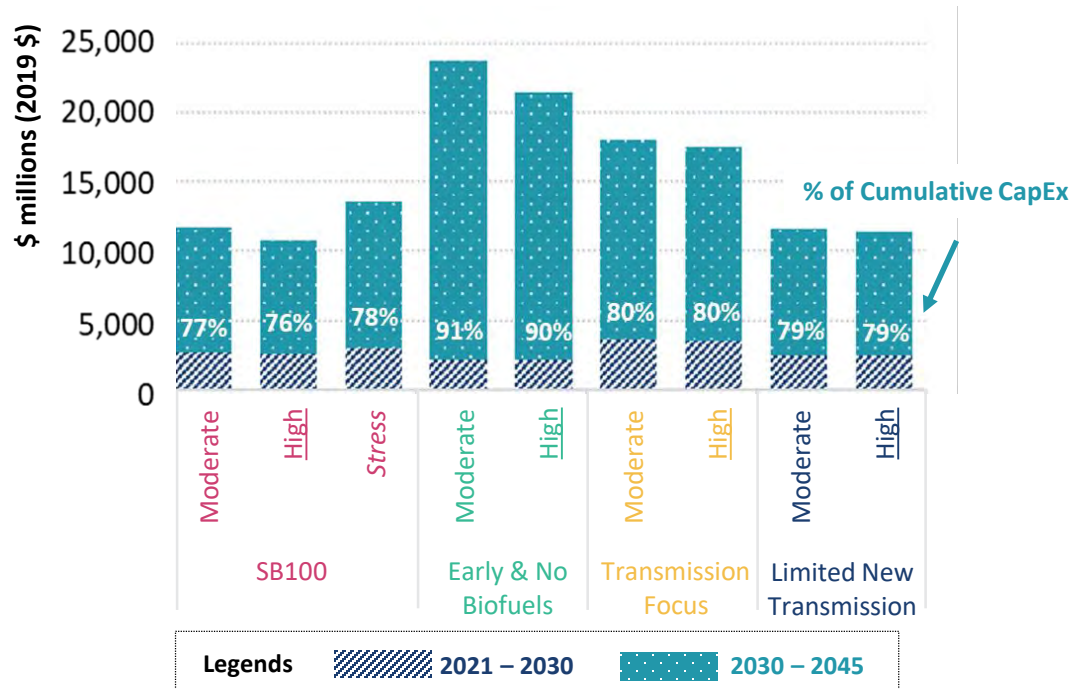
- CapEx growth is mildly exponential.
 - Cumulative costs through 2030 (**green**) do not vary much by pathway.
 - Cumulative costs through 2035 (**yellow**) are more than twice the amount of that through 2030 (**green**).
 - Incremental costs for the last ten years (2035-2045) exceeds that of the first 15 years (2021-2035) (**yellow**).

Sources and notes: SLTRP 2017 Modified extends only through 2036. 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=dhrs_millions.

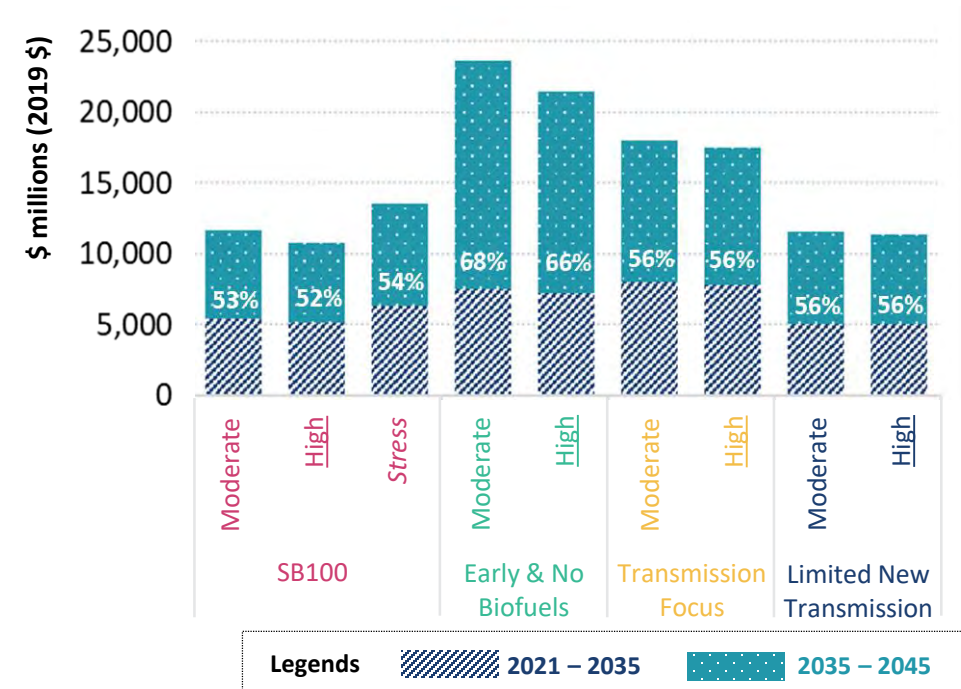
Estimated CapEx by Pathway - 2/2

- Cumulative CapEx through 2030 do not vary much by pathway and are about 20% of cumulative total CapEx (slightly lower ratio than total costs).
- Cumulative CapEx through 2035 are more than twice the amount of that through 2030 and between half to two-thirds of the cumulative total CapEx through 2045 (higher ratio than total costs).

Cumulative CapEx Share - 2030 through 2045



Cumulative CapEx Share - 2035 through 2045

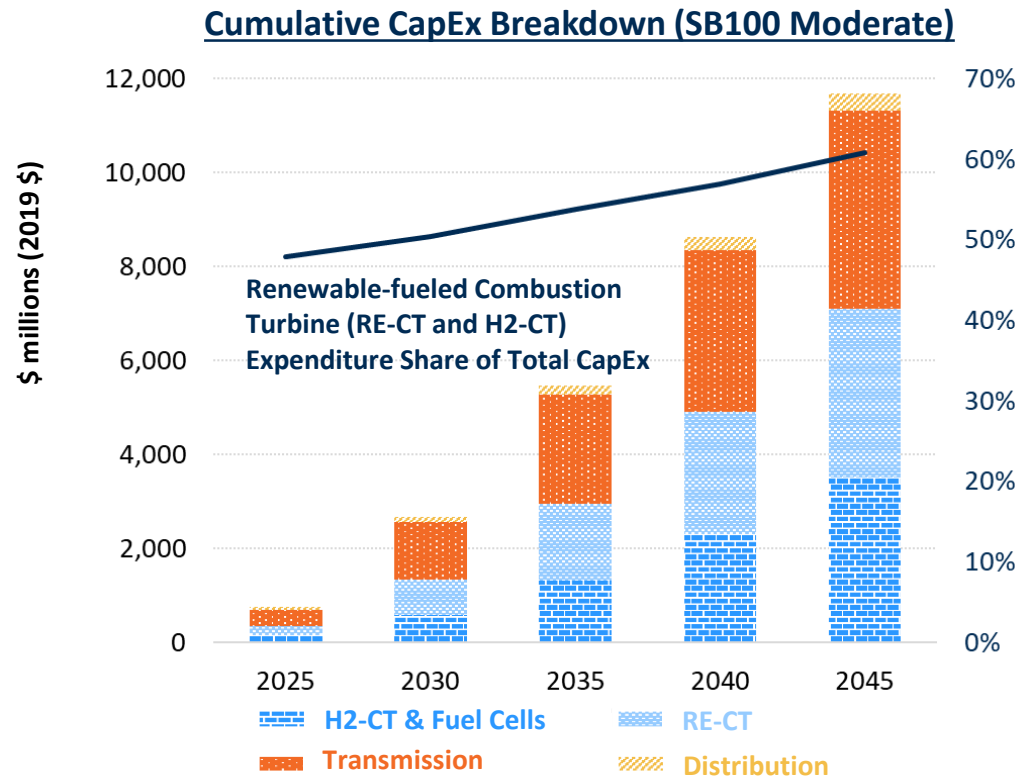


Sources: Data from NREL Study website,
https://maps.nrel.gov/la100/data-viewer?Theme=system-costs&Resolution=lc&LoadScenario=moderate&RpmScenario=sb100&LayerId=xmission.cost&Year=2045&Variable=dhrs_millions.

Discussion Draft

Renewable-Fueled Combustion Turbine Investments - 1/2

- CapEx breakdown will vary by pathway and year.
 - A large portion of the balance is Renewable-fueled CTs (H2-and RE-CTs).
 - Renewable-fueled CT Capacity adds up to 3 GW to 5 GW by 2045.



H2- and RE-CT Combined Capacity for Moderate Load (MW)

Moderate Load Pathways	2025	2030	2035	2040	2045
SB100	899	1,883	2,747	2,871	2,994
Early and No Biofuels	57	304	2,649	3,066	3,917
Transmission Focus	617	1,593	2,216	2,339	5,105
Limited New Transmission	513	1,516	2,086	2,346	4,841

H2- and RE-CT Combined Capacity for High Load (MW)

High Load Pathways	2025	2030	2035	2040	2045
SB100	716	1,583	1,722	1,987	2,243
Early and No Biofuels	57	304	2,825	2,825	3,050
Transmission Focus	505	1,268	1,852	1,986	4,399
Limited New Transmission	468	1,464	1,818	2,167	4,353

Sources and notes: SLTPR 2017 Modified extends only through 2036. Other renewables (including wind, solar and geothermal) are assumed to be PPAs. 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.

Renewable-Fueled Combustion Turbine Investments - 2/2

- CapEx breakdown will vary by pathway and year.
 - The 3 GW to 5 GW of renewable-fueled CTs share about 60% (on average) of total CapEx.
 - Transmission Focus** pathways are about 40%.
 - Early and No Biofuel** pathways are about 80%. In absolute values, this is about 2.5x of other pathways. This is driven by the high-cost of H2-CTs (roughly 3x of RE-CT in 2045, 4.5x of RE-CT in 2030).

Renewable-fueled CT CapEx by Pathways (\$ millions in 2019\$)

Pathways	2025	2030	2035	2040	2045
SLTRP 2017 Modified	\$ 118	\$ 316	\$ 549		
SB100 Moderate	\$ 358	\$ 1,348	\$ 2,943	\$ 4,911	\$ 7,111
SB100 High	\$ 312	\$ 1,198	\$ 2,502	\$ 4,100	\$ 5,980
SB100 Stress	\$ 420	\$ 1,672	\$ 3,679	\$ 6,087	\$ 8,742
Early & No Biofuels Moderate	\$ 150	\$ 779	\$ 4,867	\$ 11,588	\$ 18,835
Early & No Biofuels High	\$ 150	\$ 779	\$ 4,561	\$ 10,276	\$ 16,588
Transmission Focus Moderate	\$ 288	\$ 1,160	\$ 2,580	\$ 4,338	\$ 6,931
Transmission Focus High	\$ 260	\$ 1,034	\$ 2,314	\$ 3,927	\$ 6,290
Limited New Transmission Moderate	\$ 261	\$ 1,094	\$ 2,468	\$ 4,204	\$ 6,851
Limited New Transmission High	\$ 252	\$ 1,067	\$ 2,370	\$ 4,021	\$ 6,591

Renewable-fueled CT CapEx by Pathways (% of Total CapEx)

Pathways	2025	2030	2035	2040	2045
SLTRP 2017 Modified	26%	21%	19%		
SB100 Moderate	48%	50%	54%	57%	61%
SB100 High	44%	47%	49%	52%	56%
SB100 Stress	51%	55%	58%	61%	64%
Early & No Biofuels Moderate	27%	36%	65%	75%	80%
Early & No Biofuels High	27%	36%	63%	72%	77%
Transmission Focus Moderate	43%	32%	32%	34%	39%
Transmission Focus High	39%	30%	30%	32%	36%
Limited New Transmission Moderate	40%	45%	49%	52%	59%
Limited New Transmission High	38%	44%	47%	51%	58%

Sources and notes: SLTPR 2017 Modified extends only through 2036. Other renewables (including wind, solar and geothermal) are assumed to be PPAs. 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.

Transmission Investments - 1/2

- CapEx breakdown will vary by pathway and year. However, capital expenditure for transmission appears to be uniform (in \$ amounts) across most pathways, with the exception of the **Transmission Focus** pathways.
 - The amount also aligns with the SLTRP 2017 estimates.
 - The buildouts do differ by pathway (see next slide).
- Transmission enables more diverse generation options (both short-term for energy imports and long-term for resource planning), and benefits all customers, rather than a select group (e.g., rooftop PV holders), contributing to environmental justice.
 - Co-developing transmission with other utilities may hedge the risk of no or negative load growth while maintaining optionality.

Transmission Expenditures by Pathways (\$ millions in 2019\$)

Pathways	2025	2030	2035	2040	2045
SLTRP 2017 Modified	\$334	\$1,220	\$2,330		
SB100 Moderate	\$334	\$1,220	\$2,330	\$3,440	\$4,214
SB100 High	\$334	\$1,220	\$2,330	\$3,440	\$4,214
SB100 Stress	\$334	\$1,221	\$2,331	\$3,441	\$4,221
Early & No Biofuels Moderate	\$334	\$1,227	\$2,348	\$3,497	\$4,354
Early & No Biofuels High	\$334	\$1,228	\$2,351	\$3,480	\$4,310
Transmission Focus Moderate	\$334	\$2,303	\$5,213	\$8,123	\$10,700
Transmission Focus High	\$334	\$2,303	\$5,213	\$8,123	\$10,700
Limited New Transmission Moderate	\$334	\$1,220	\$2,330	\$3,440	\$4,213
Limited New Transmission High	\$334	\$1,220	\$2,330	\$3,440	\$4,213

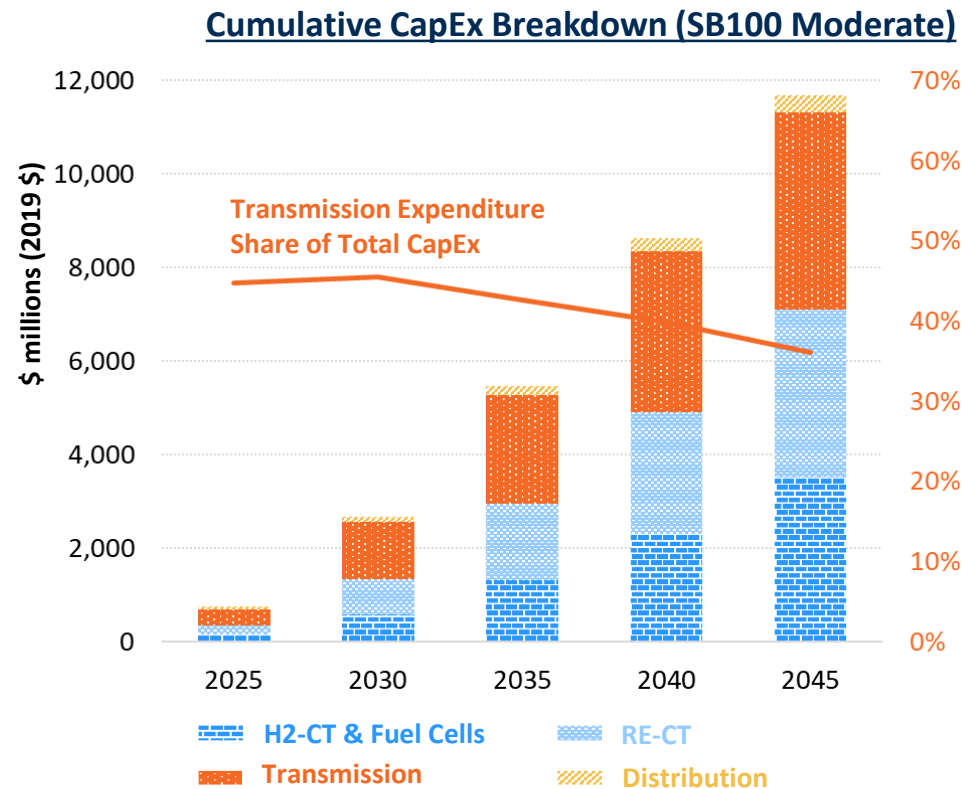
Transmission Expenditures by Pathways (% of CapEx)

Pathways	2025	2030	2035	2040	2045
SLTRP 2017 Modified	74%	79%	81%		
SB100 Moderate	45%	46%	43%	40%	36%
SB100 High	47%	48%	46%	43%	39%
SB100 Stress	40%	40%	37%	34%	31%
Early & No Biofuels Moderate	61%	57%	31%	23%	18%
Early & No Biofuels High	60%	57%	33%	25%	20%
Transmission Focus Moderate	49%	64%	65%	64%	59%
Transmission Focus High	51%	66%	67%	65%	61%
Limited New Transmission Moderate	51%	50%	46%	43%	36%
Limited New Transmission High	51%	50%	47%	44%	37%

Sources and notes: SLTPR 2017 Modified extends only through 2036. Other renewables (including wind, solar and geothermal) are assumed to be PPAs. 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.

Transmission Investments - 2/2

- CapEx breakdown will vary by pathway and year. However, capital expenditure for transmission appears to be uniform (in \$ amounts) across most pathways, with the exception of the **Transmission Focus** pathways.
 - The 50+ MW of in-basin AC appears to be a no-regret option.



New* Transmission Builds for Moderate Load Pathways

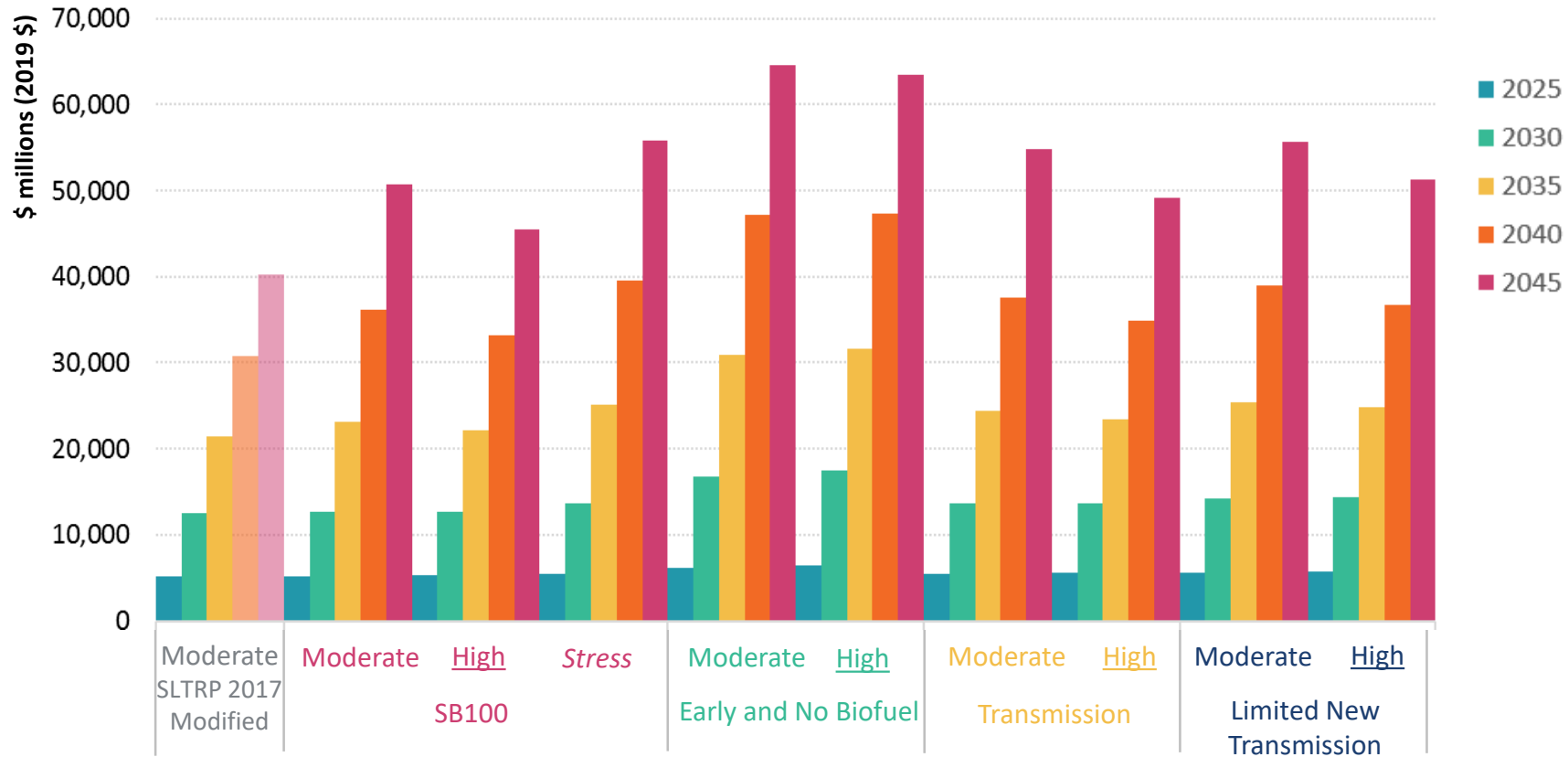
Moderate Load Pathways	In-Basin		Out-of-Basin	
	AC	DC	AC	DC
SB100	54 MW 1 Line ~3 km	0	0	0
Early and No Biofuels	231 MW 3 Lines ~30 km	0	2455 MW 3 Lines 379 km	0
Transmission Focus	57 MW 1 Line 3 km	7500 MW 3 Lines 60 km	0	1700 MW 1 Line 110 km
Limited New Transmission*	0	0	0	0

*Limited New Transmission pathways only build transmission projects that are already approved, and nothing new beyond that.

Sources: 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=dllr_millions.

Estimated OpEx by Pathway - 1/3

Cumulative Operational Expenditure from 2021-2045 by Scenario



OpEx by Scenario

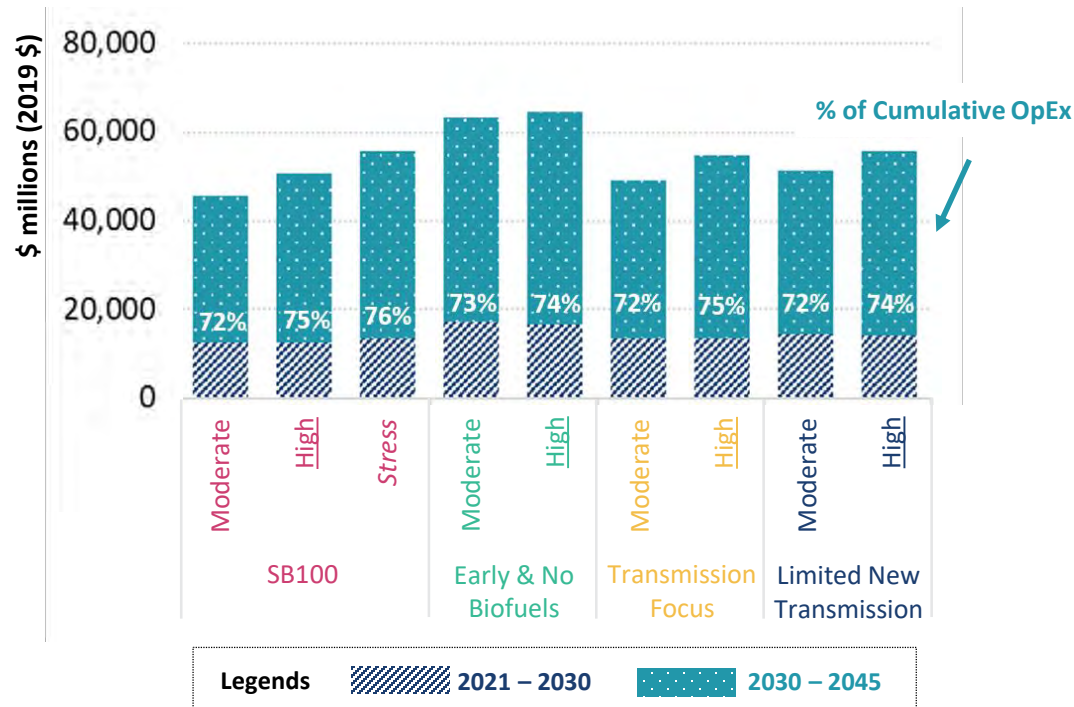
- OpEx observations follow that of total costs and CapEx.
 - Cumulative costs through 2030 (**green**) do not vary much by pathway.
 - Cumulative costs through 2035 (**yellow**) are roughly double the amount of that through 2030 (**green**).
 - Incremental costs for the last ten years (2035-2045) exceeds that of the first 15 years (2021-2035) (**yellow**).

Sources and notes: SLTPR 2017 Modified extends only through 2036. 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=dhrs_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.

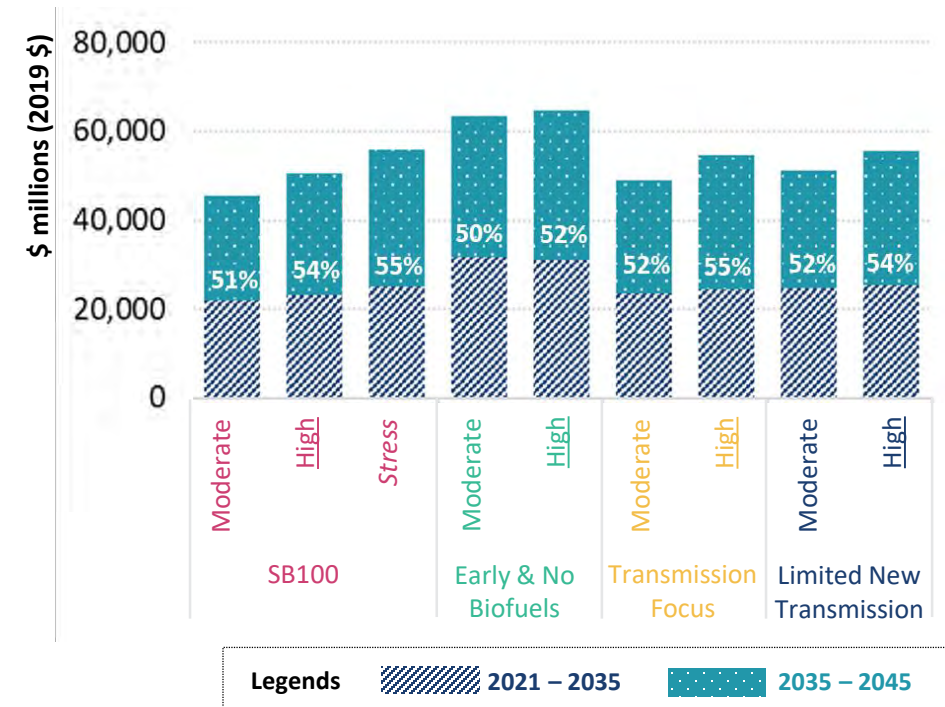
Estimated OpEx by Pathway - 2/3

- Cumulative OpEx through 2030 do not vary much by pathway and are about a quarter of the cumulative total OpEx (similar to the ratio of total costs).
- Cumulative OpEx through 2035 are more than twice the amount of that through 2030 and between half to two-thirds of the cumulative CapEx through 2045 (higher ratio than total costs).

Cumulative OpEx Split - 2030 through 2045



Cumulative OpEx Split - 2035 through 2045

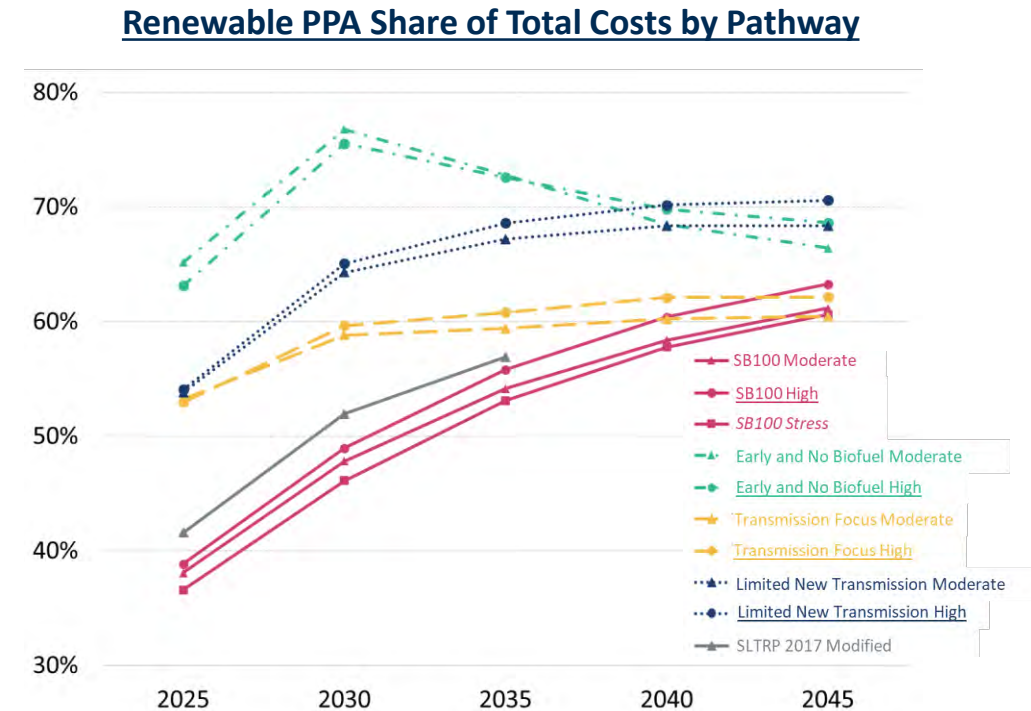
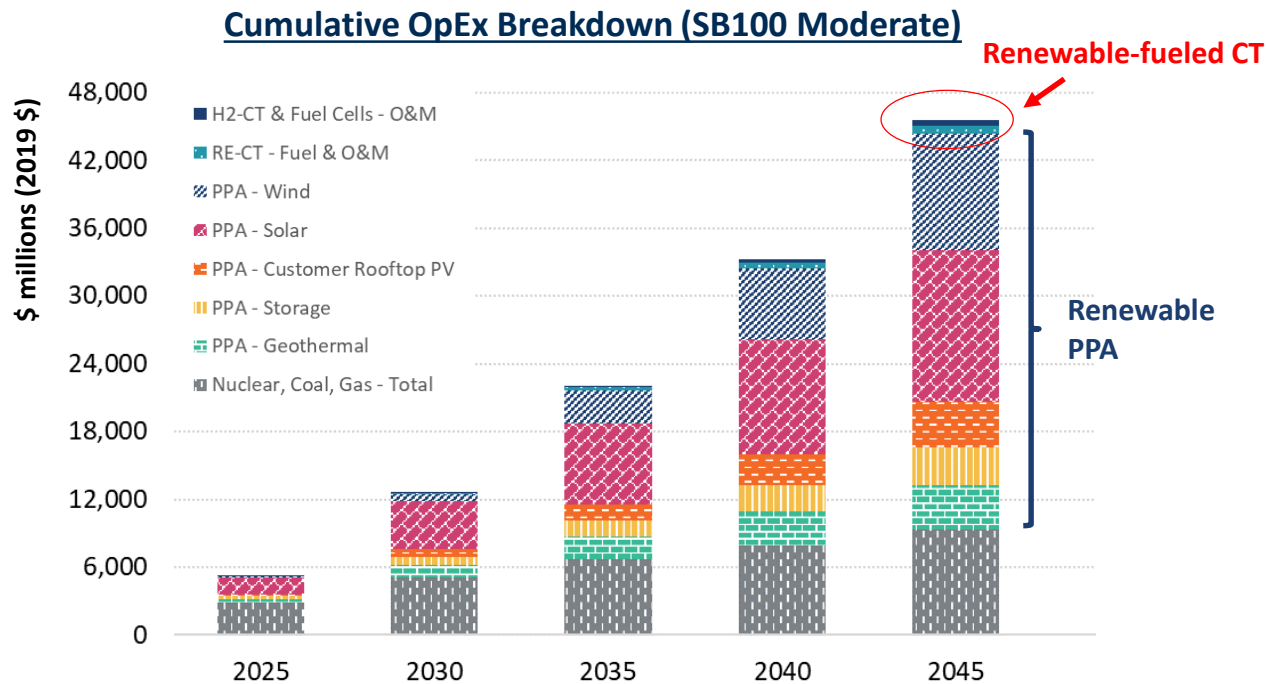


Sources: Data from NREL Study website,
https://maps.nrel.gov/la100/data-viewer?Theme=system-costs&Resolution=lc&LoadScenario=moderate&RpmScenario=sb100&LayerId=xmission.cost&Year=2045&Variable=dhrs_millions.

Discussion Draft

Estimated OpEx by Pathway - 3/3

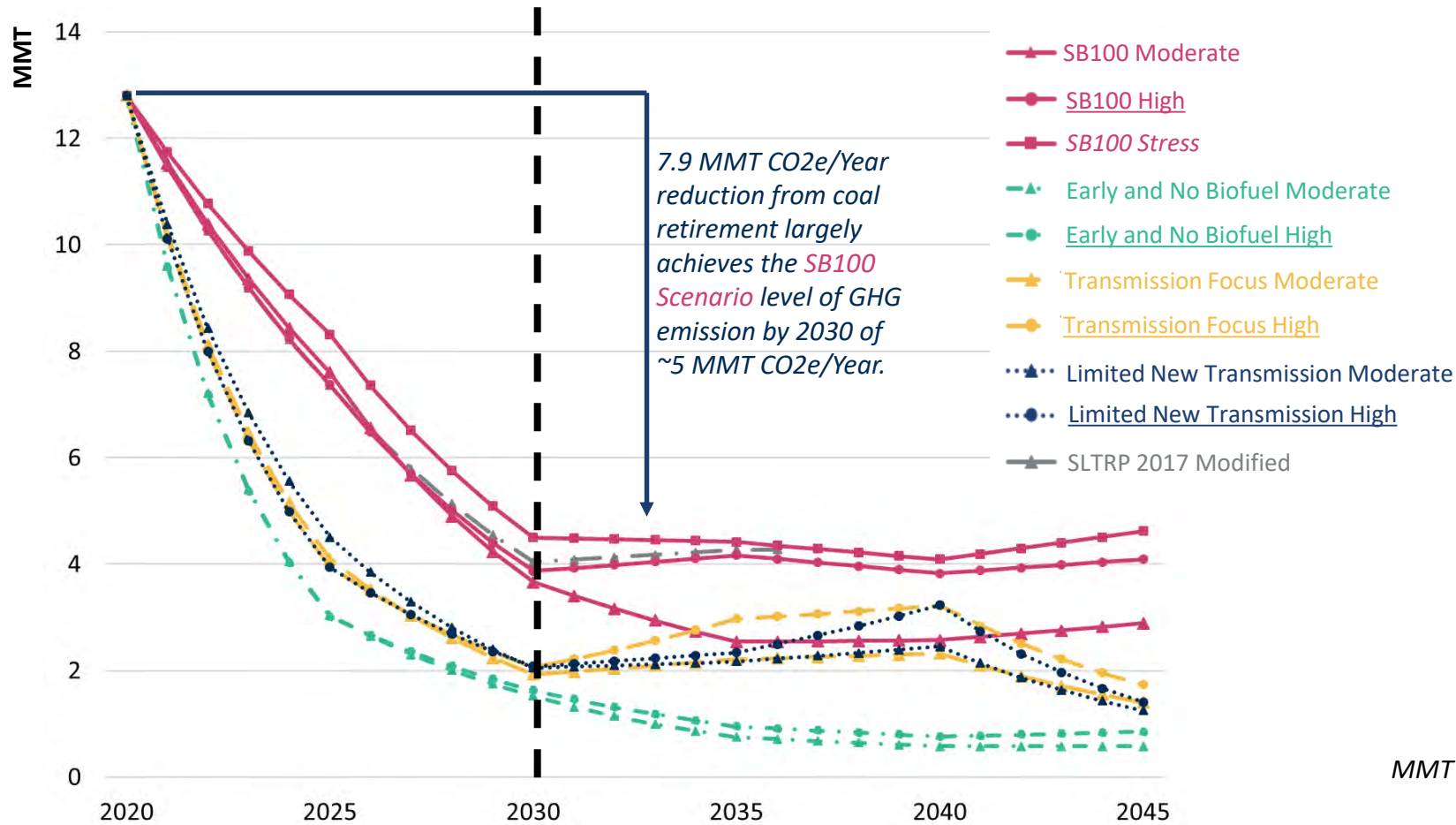
- Renewable PPAs share the bulk of the OpEx and generally increase over the years.
 - The exception is the **Early and No Biofuel Scenarios**, which show much higher costs (total, CapEx, and OpEx) over other pathways.
 - While the H2-CT and RE-CT shares of the CapEx (3 to 5 GW of capacity by 2045) is significant (see slides 20 and 21), their share of OpEx is minuscule.



Sources and notes: SLTRP 2017 Modified extends only through 2036. 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=dhrs_millions.

Power Sector Estimated Annual GHG Emissions

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



Total GHG Emission

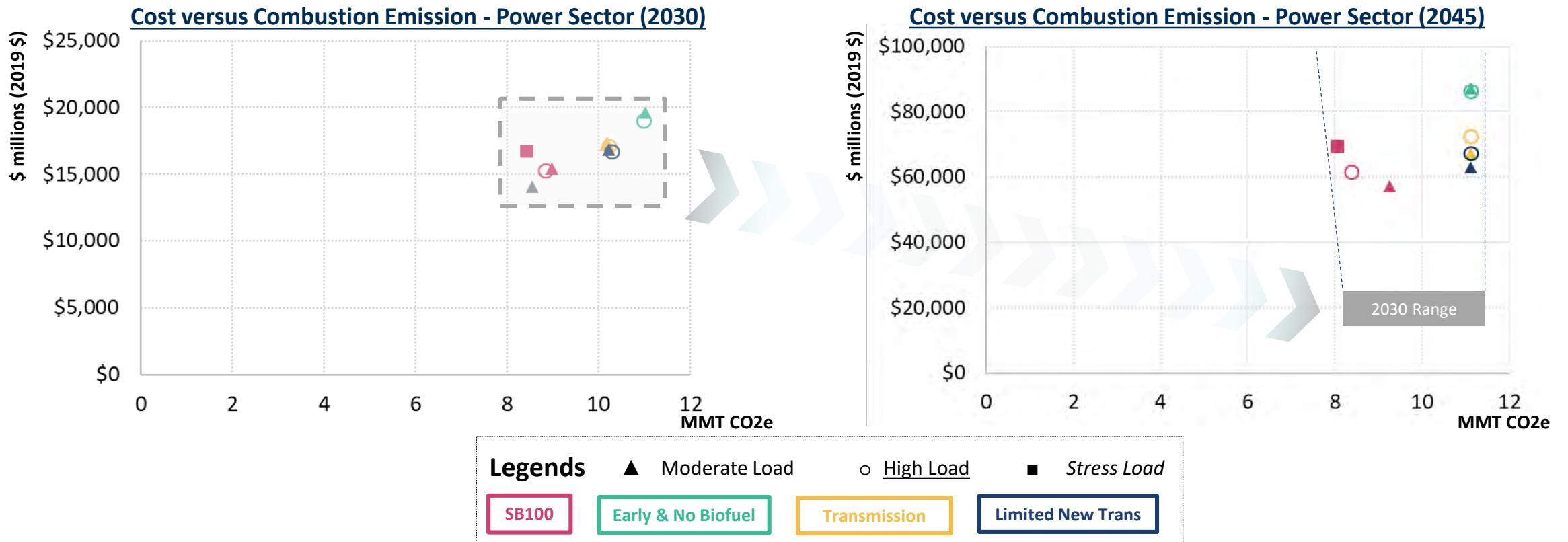
- Total GHG emissions include both combustion and non-combustion related GHG emissions.
- All pathways show power sector total GHG emissions to decrease sharply from 2020 through 2030.
- In 2020:
 - Nearly 90% of total emission (11.1 out of 12.8 MMT CO₂e/Year) is from direct combustion.
 - Over 70% (7.9 out of 11.1 MMT CO₂e/Year) of direct combustion emission is from coal-fueled generation.

MMT CO₂e/Year is million metric tons of CO₂ equivalent

Sources and notes: SLTRP 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.

Estimated Annual Costs of GHG Reduction - 1/2

- Comparing 2045 to 2030, annual unit costs quadruple while annual GHG emission from combustion stay roughly the same.

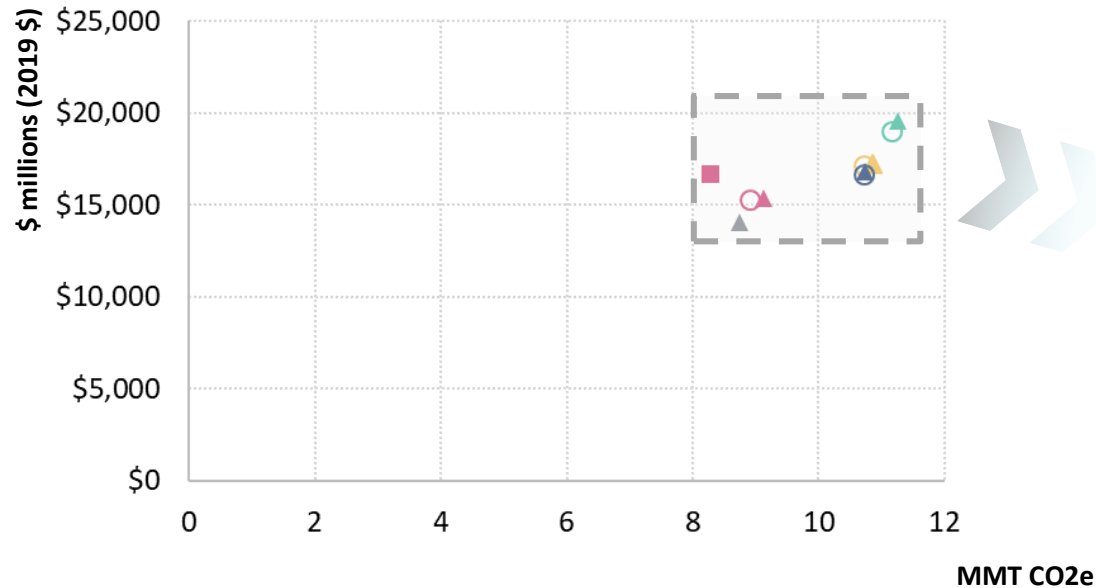


Sources and notes: SLTPR 2017 Modified extends only through 2036. Data from NREL study website, https://maps.nrel.gov/la100/data-viewer?Theme=ghg&Resolution=rs&LoadScenario=moderate&RpmScenario=sb100&LayerId=ghg.power_and_nonpower&Variable=ann_ghg_mmt. Assume combustion GHG emission changes in linear CAGR for each five-year interval.

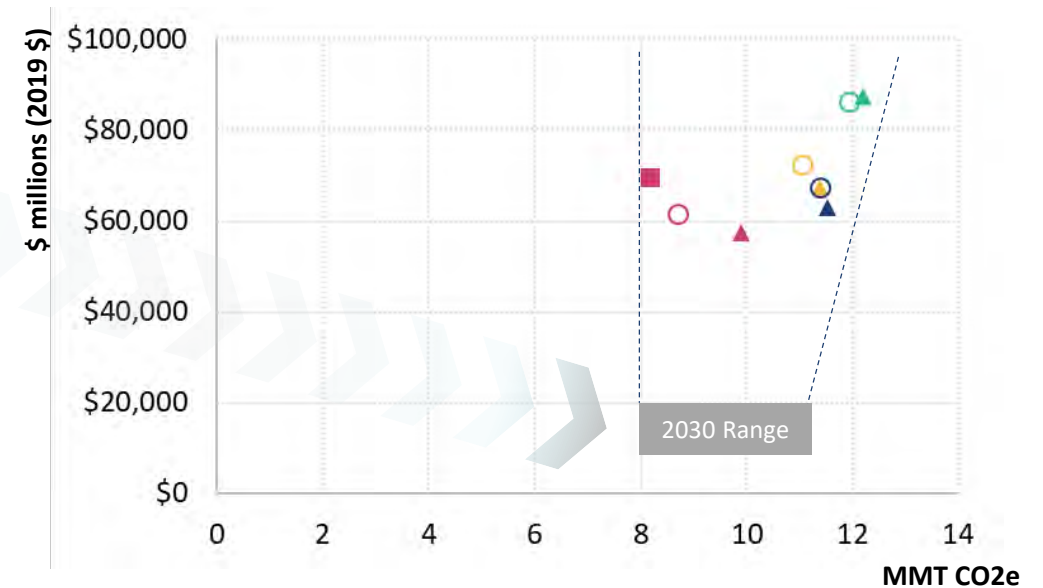
Estimated Annual Costs of GHG Reduction - 2/2

- Comparing 2045 to 2030, annual unit costs quadruple while annual GHG emission from the power sector (combustion and non-combustion combined) stay roughly the same.

Cost versus Total Emission - Power Sector (2030)



Cost versus Total Emission - Power Sector (2045)



Legends

▲ Moderate Load

○ High Load

■ Stress Load

SB100

Early & No Biofuel

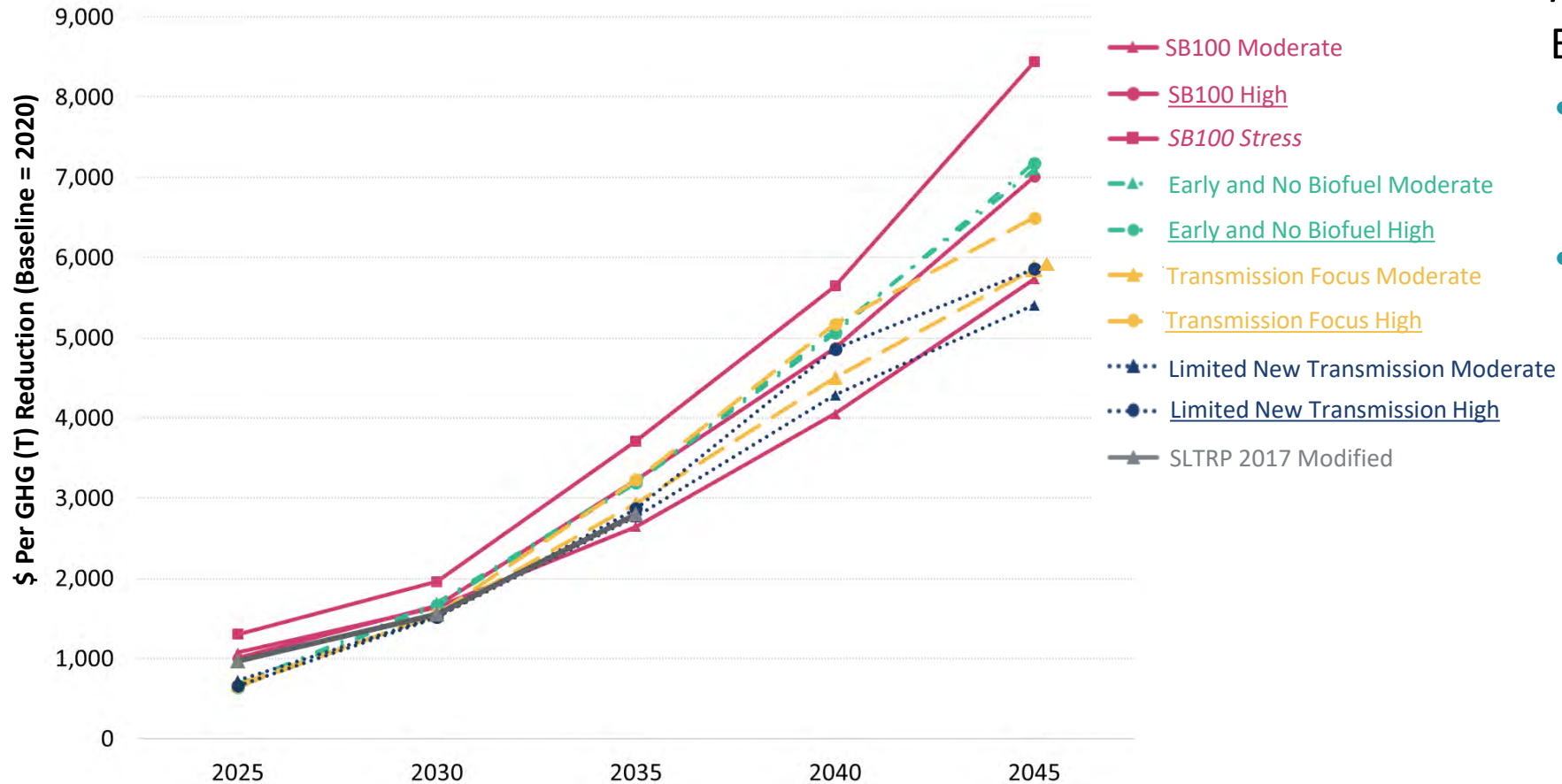
Transmission

Limited New Trans

Sources and notes: SLTPR 2017 Modified extends only through 2036. 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.

Estimated Annual Costs per Tonne of GHG Reduction

Annual Unit Cost of GHG Reduction by Scenario - Power Sector



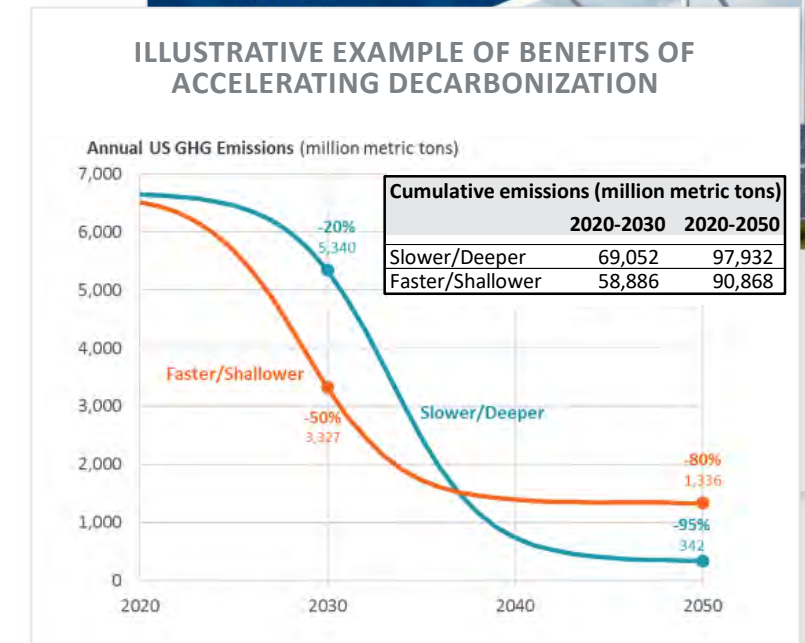
Annual Unit Cost of GHG Emission Reduction

- Total GHG emissions include both combustion and non-combustion related GHG emissions.
- All pathways show power sector total GHG emissions to increasing exponentially. Average value of all pathways show:
 - ~\$1,000/T (metric ton) in 2025
 - ~\$1,500/T in 2030
 - ~\$3,000/T in 2035
 - ~\$5,000/T in 2040
 - ~\$7,000/T in 2045

Sources and notes: SLTRP 2017 Modified extends only through 2036. The unit price here is calculated by cost increase from 2020 (approximately \$400 million) being divided by GHG reduction achieved for each year. 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.

Annual and Cumulative GHG Emission

- Annual vs Cumulative GHG emissions
 - GHG emission can be measured for snapshots (e.g., annual emissions as of 2030) or added up for all years (e.g., from 2021 through 2030).
 - Once emitted, GHG will persist in the atmosphere for decades or longer.
 - Cumulative GHG emission (i.e., the amount of greenhouse gas in the atmosphere) is what causes warming, not the rate at which they are emitted in any given year.
 - Therefore, early reductions in GHG emissions can be thought of in many ways more important than eventual depth of reductions, because of the cumulative and persistent nature of it in the atmosphere.
 - A recent whitepaper published by Brattle* illustrates how earlier adoption can lead to lower cumulative GHG emission. In this example, the faster/shallower decarbonization will reduce ~7,000 MMT more than the slower/deeper decarbonization cumulative emissions(through 2050).
- The LA100 Study looks at both annual and cumulative GHG emissions
 - Discussion so far has been focused on annual GHG emissions.

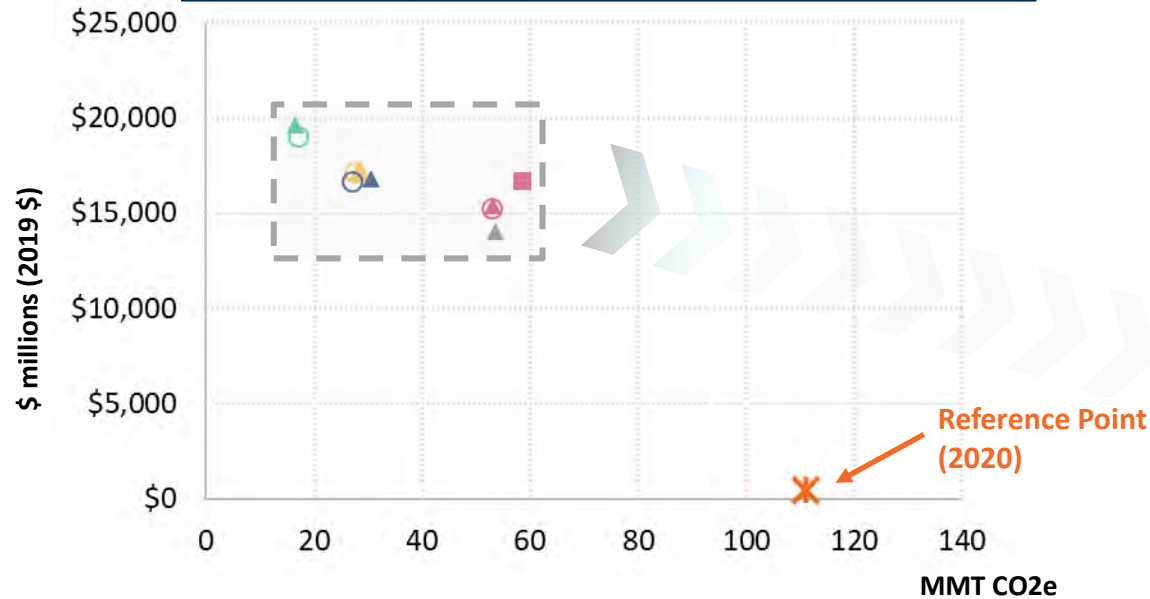


* Clean Energy and Sustainability Accelerator, available at: https://brattlefiles.blob.core.windows.net/files/20809_clean_energy_and_sustainability_accelerator.pdf

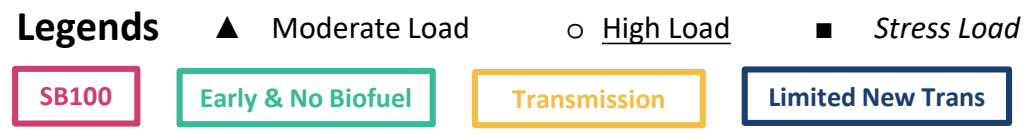
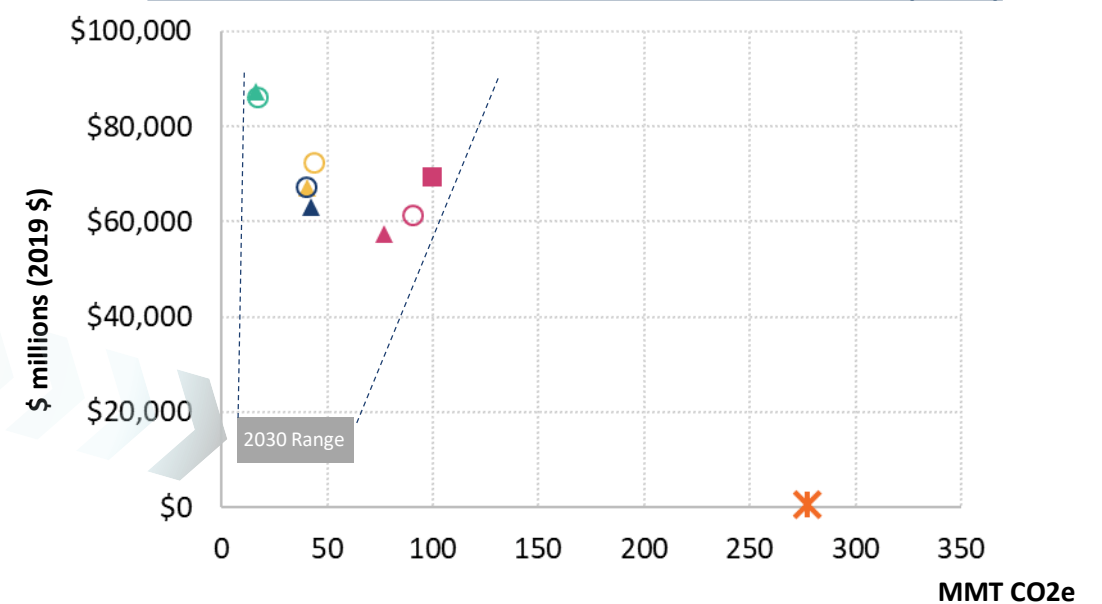
Estimated Cumulative GHG Emission and Costs - 1/3

- Comparing 2045 to 2030, cumulative costs quadruple while cumulative emissions from combustion stay roughly the same.
 - SB100 Scenarios' combustion emissions increase because the policy targeting 100% retail sales allows for combustion and load does grow.

Cost versus Combustion Emission - Power Sector (2030)



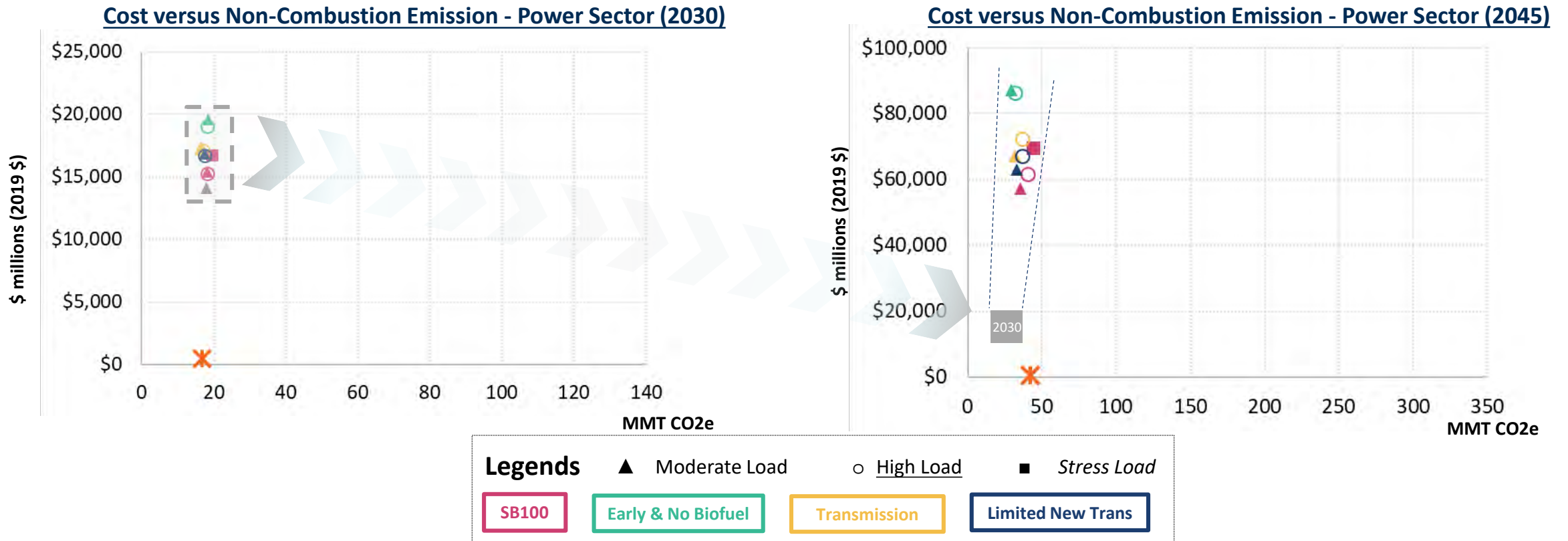
Cost versus Combustion Emission - Power Sector (2045)



Sources and notes: SLTPR 2017 Modified extends only through 2036. Data from NREL study report, 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.

Estimated Cumulative GHG Emission and Costs - 2/3

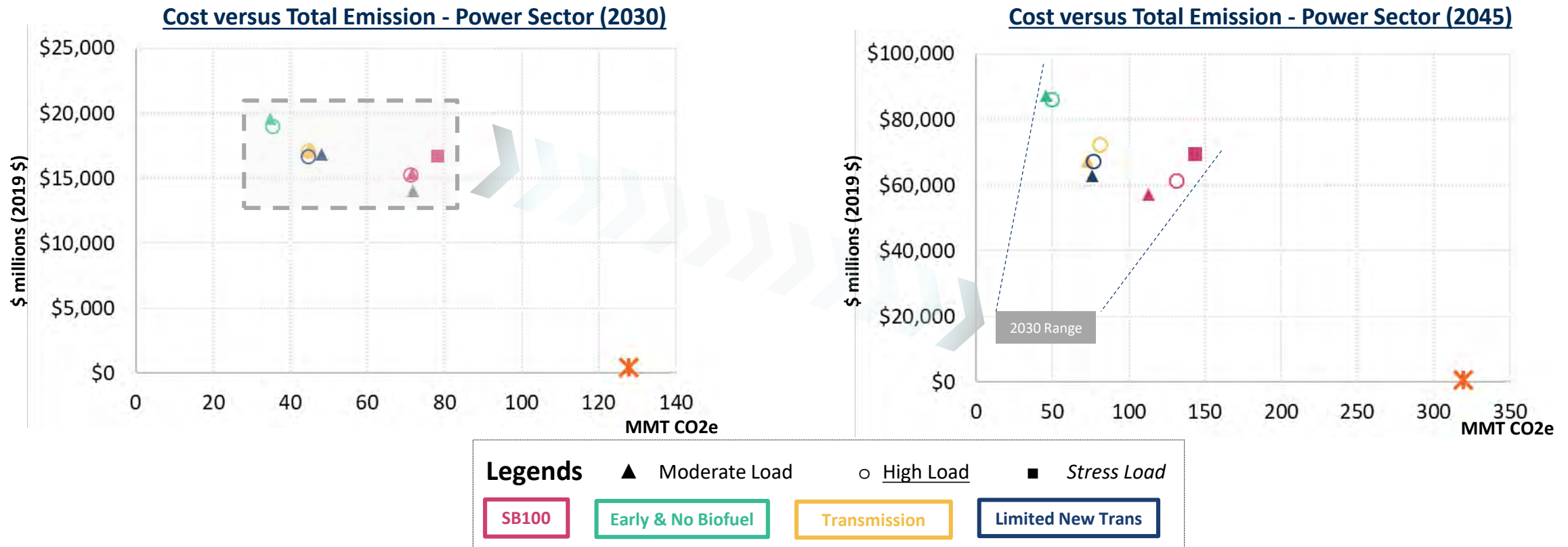
- Comparing 2045 to 2030, cumulative costs quadruple while cumulative non-combustion emissions double.
 - Emissions from non-combustion sources are much smaller and further do not vary by pathway.



Sources and notes: SLTPR 2017 Modified extends only through 2036. Data from NREL study report, 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.

Estimated Cumulative GHG Emission and Costs - 3/3

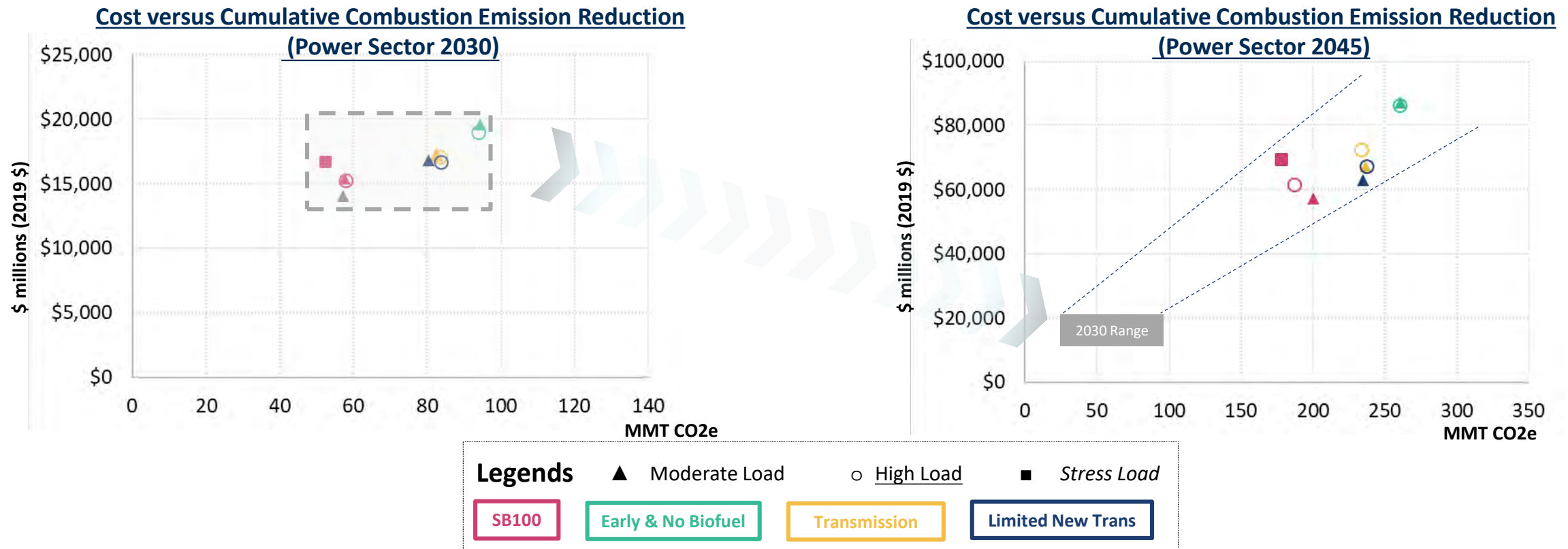
- Comparing 2045 to 2030, cumulative costs quadruple while total cumulative emissions slightly increase.
 - Increase is largely from non-combustion emissions (these do not vary by pathway and not directly controllable by LADWP).



Sources and notes: SLTPR 2017 Modified extends only through 2036. Data from NREL study report, 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.

Estimated Incremental Costs of GHG Reduction - 1/2

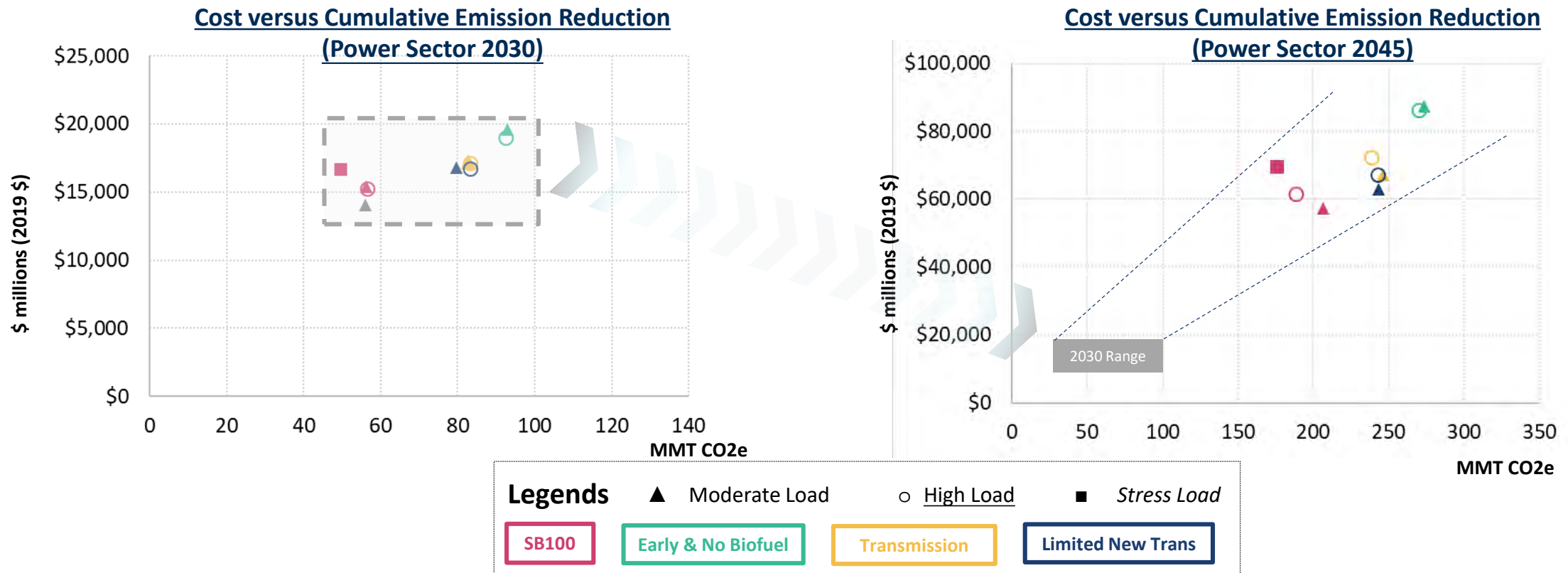
- Comparing 2045 to 2030, incremental costs quadruple while cumulative emissions from combustion triples.



Sources and notes: SLTPR 2017 Modified extends only through 2036. GHG reduction is calculated using 2020 as baseline. 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.

Estimated Incremental Costs of GHG Reduction - 2/2

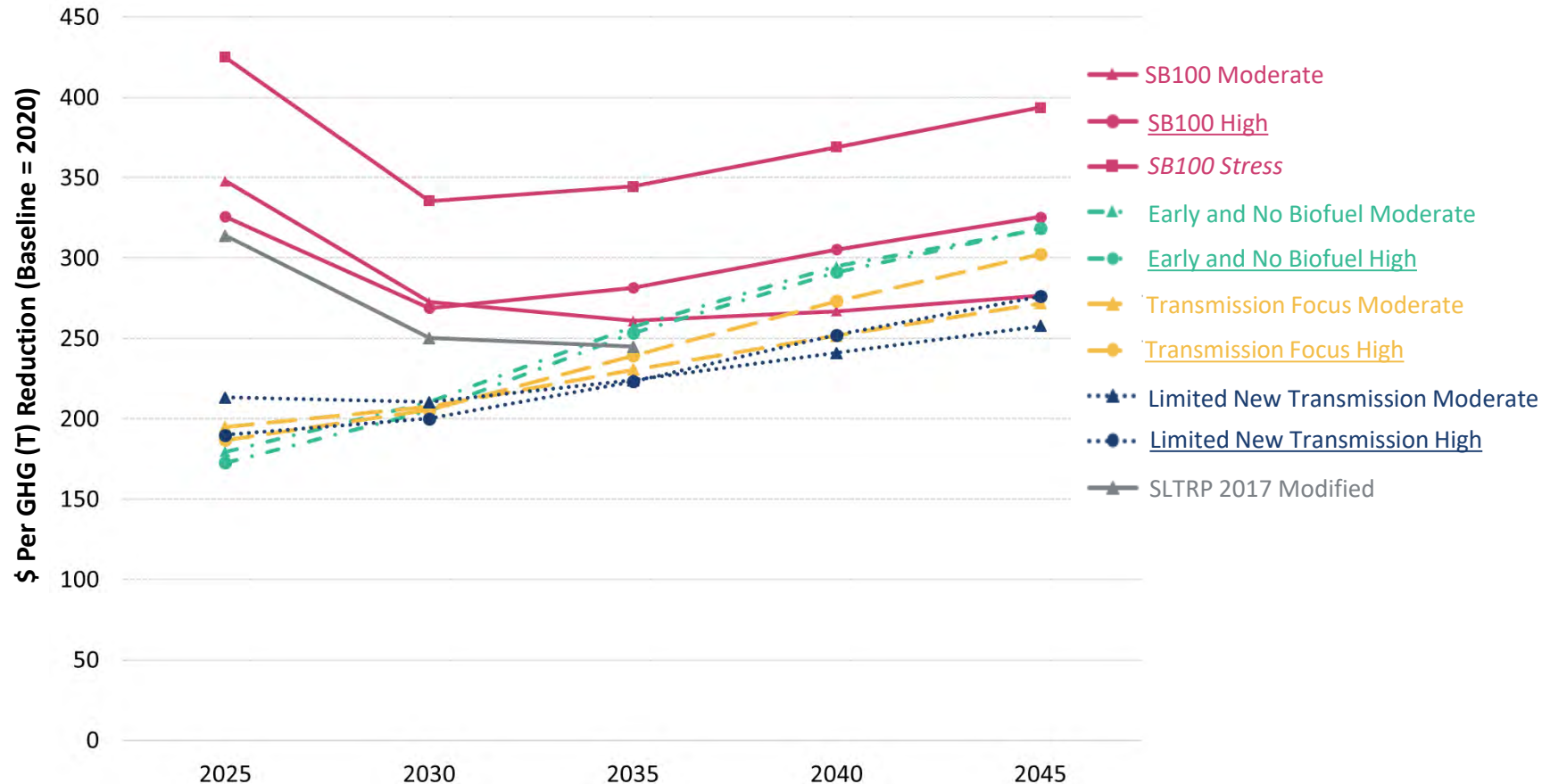
- Comparing 2045 to 2030, incremental costs quadruple while cumulative emissions from the power sector triples.
 - If a linear correlation exists, cumulative emissions would be in the 2.5x range (10 years through 2030 vs 25 years through 2045).



Sources and notes: SLTPR 2017 Modified extends only through 2036. GHG reduction is calculated using 2020 as baseline. 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.

Average Unit Cost of Cumulative GHG Reduction - Power Sector

Average Unit Cost of Cumulative GHG Reduction by Scenario (Power Sector)



Sources and notes: SLTRP 2017 Modified extends only through 2036. 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.

Discussion Draft

GHG Emission

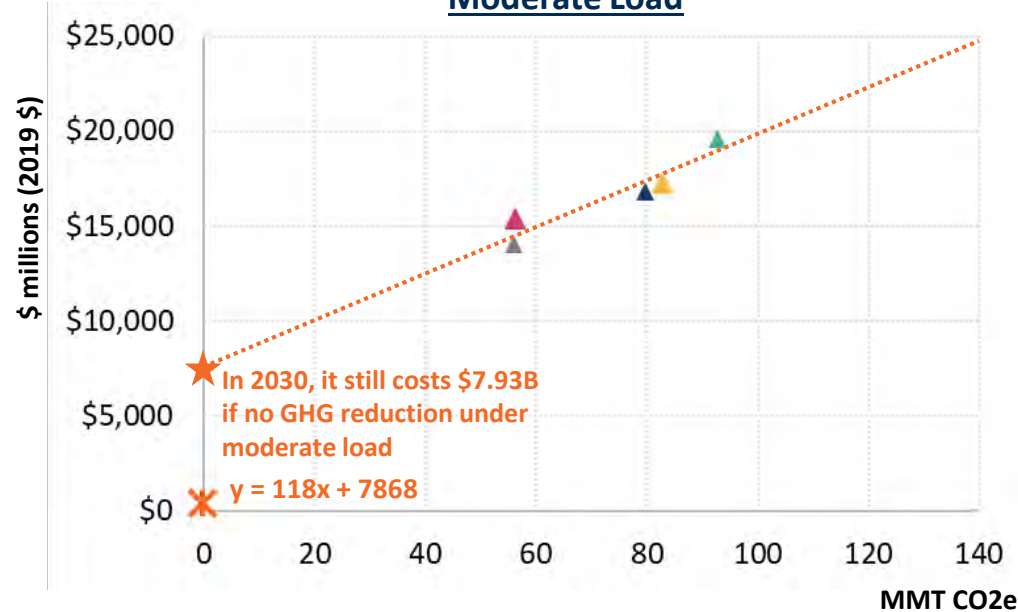
- All pathways show average unit cost of GHG reduction increasing over time.
 - With the exception of the **SB100 Stress** pathway, the cost per tonne of GHG reduction is roughly in the \$200 to \$300 range.
- **SB100 Scenarios** show higher costs in earlier years because less aggressive reductions in those years.
 - **Early and No Biofuel** and **Limited New Transmission Scenarios** assume much more customer PVs in the earlier years.
 - NREL does not assume any costs for customer PVs, unless LADWP signs PPAs with them.

Incremental Costs of Cumulative GHG Reduction - Power Sector

- There appears to be linear correlation among the scenarios in both 2030 and 2045.
 - Each scenario's relative position do not vary between the years (the differences among the scenarios are very small).

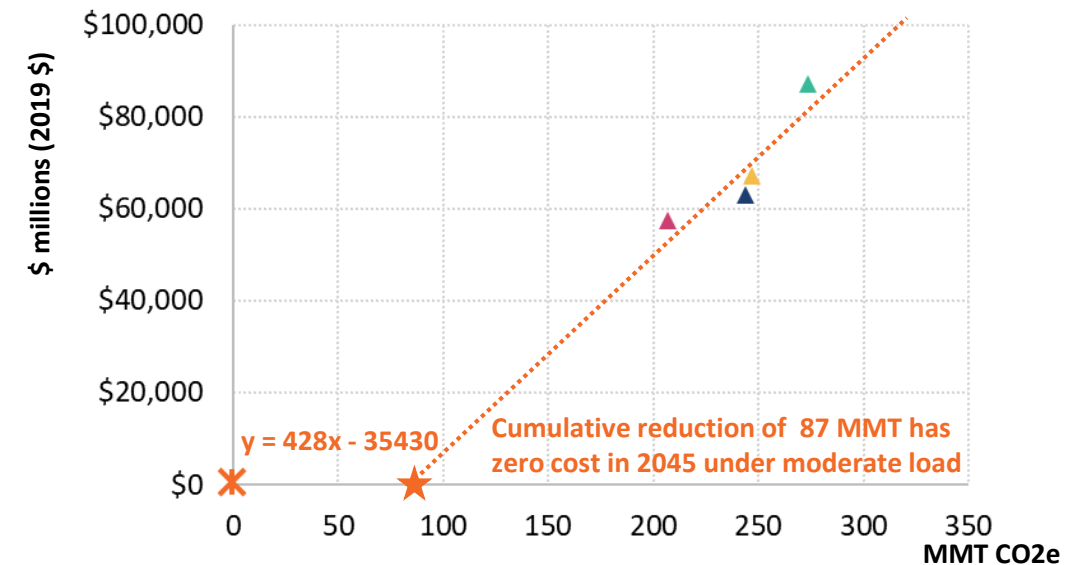
Cost versus Cumulative Emission Reduction - Power Sector (2030)

Moderate Load



Cost versus Cumulative Emission Reduction - Power Sector (2045)

Moderate Load



Legends

▲ Moderate Load ○ High Load ■ Stress Load

SB100

Early & No Biofuel

Transmission

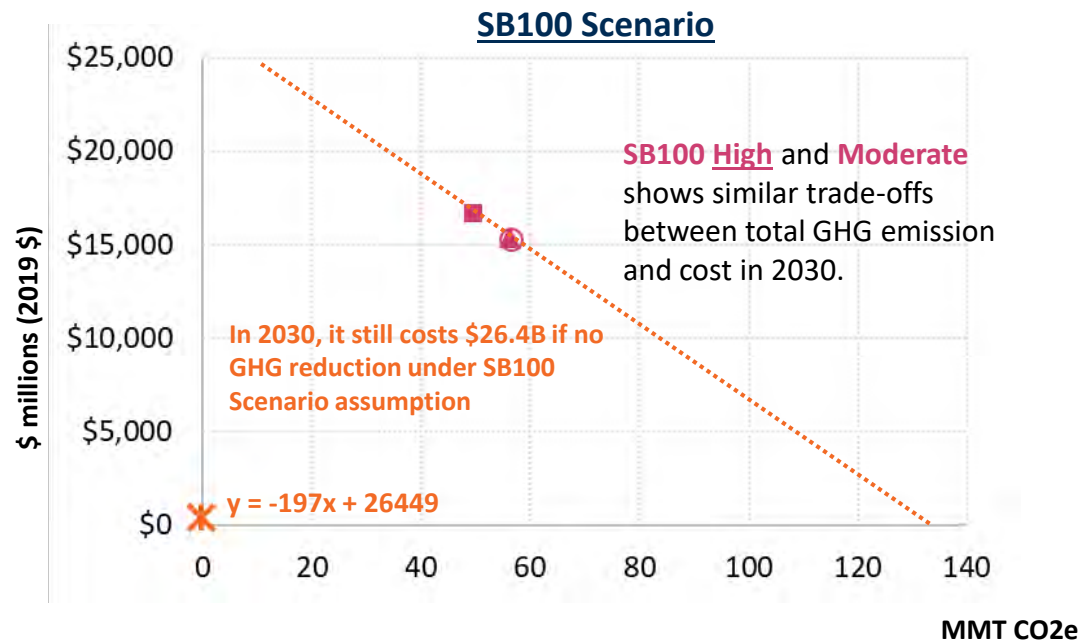
Limited New Trans

Sources and notes: The absolute value of the slope of the model represents the incremental cost in \$/T. SLTPR 2017 Modified extends only through 2036. 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.

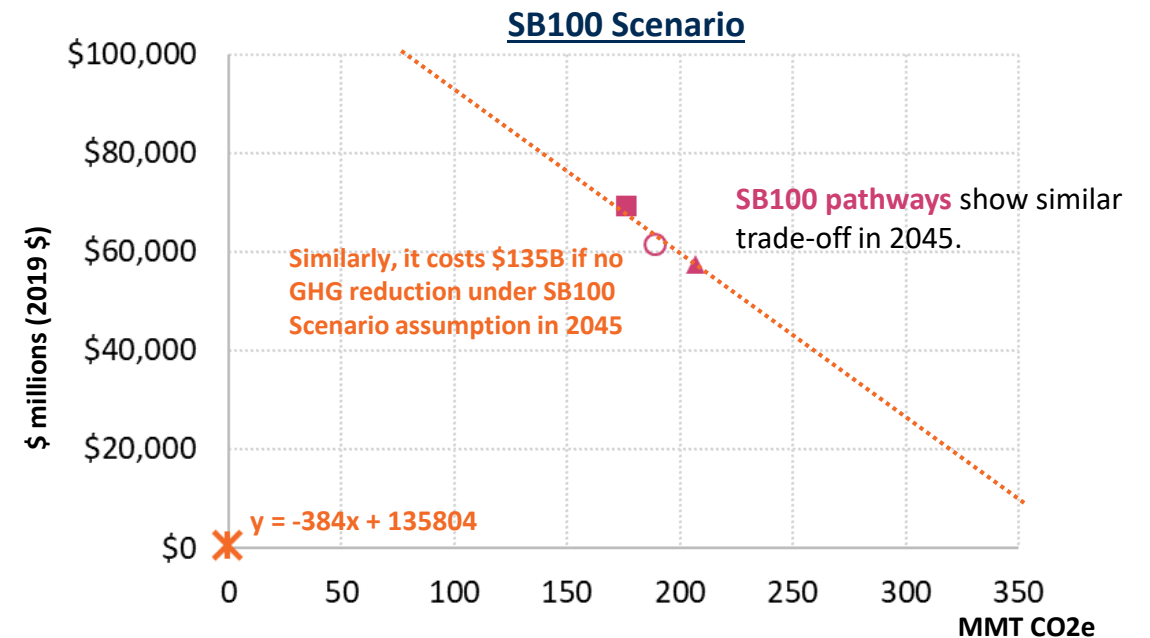
Incremental Costs of Cumulative GHG Reduction - Power Sector

- Comparing 2045 to 2030, incremental cost for the same scenario by different load presents more variabilities and starts to diverge.

Cost versus Cumulative Emission Reduction - Power Sector (2030)



Cost versus Cumulative Emission Reduction - Power Sector (2045)



Legends

▲ Moderate Load ○ High Load ■ Stress Load

SB100

Early & No Biofuel

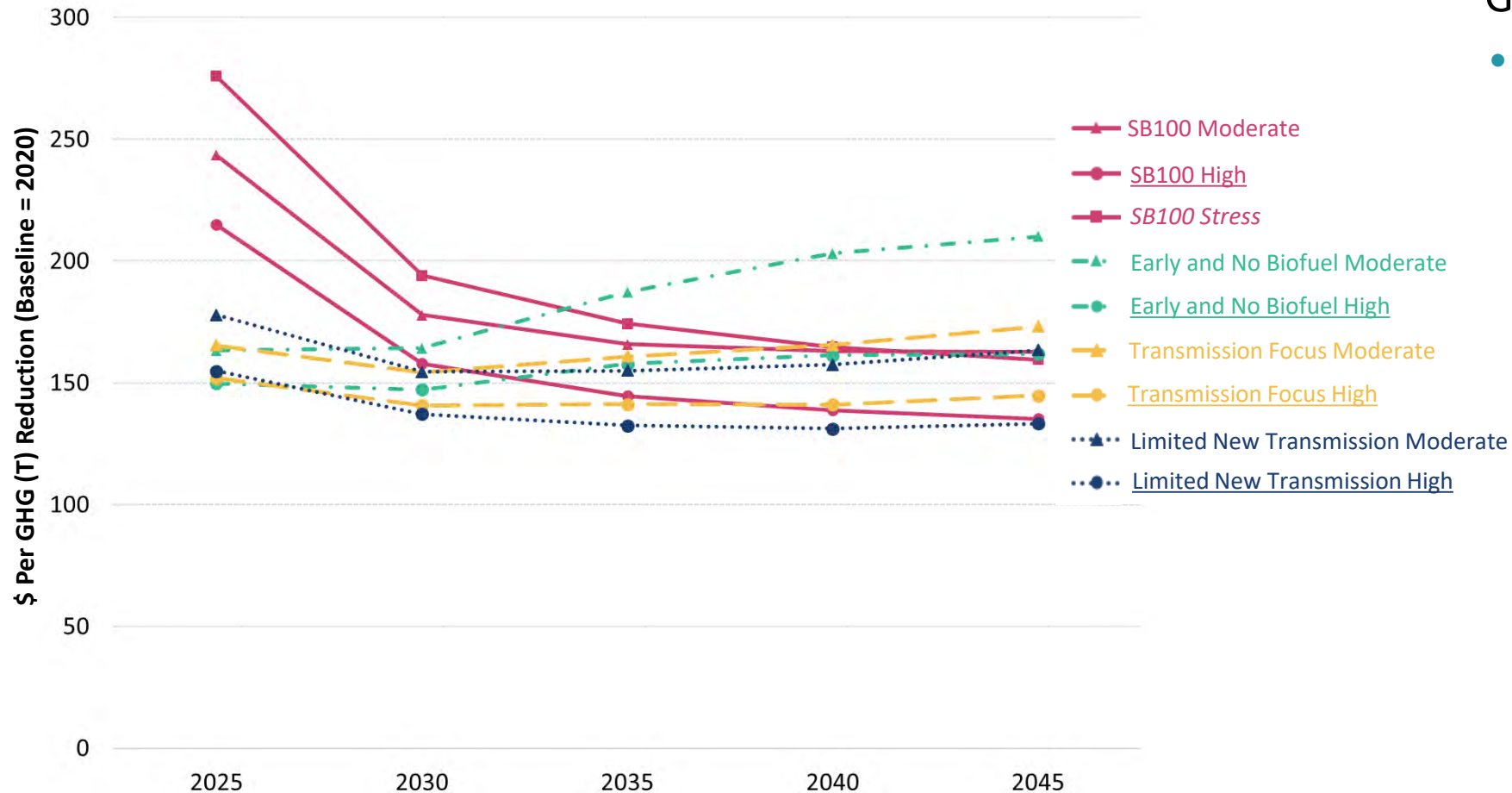
Transmission

Limited New Trans

Sources and notes: The absolute value of the slope of the model represents the incremental cost in \$/T. SLTPR 2017 Modified extends only through 2036. 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.

Cumulative Unit Cost of Total GHG Reduction - All Sectors

Cumulative Unit Cost of Total GHG Reduction by Scenario (All Sectors)



GHG Emission

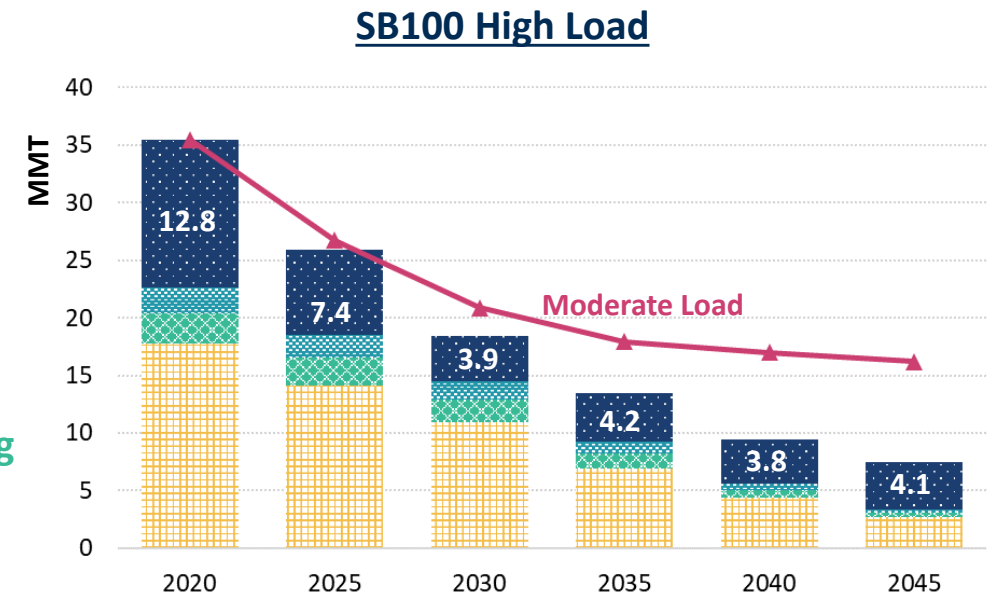
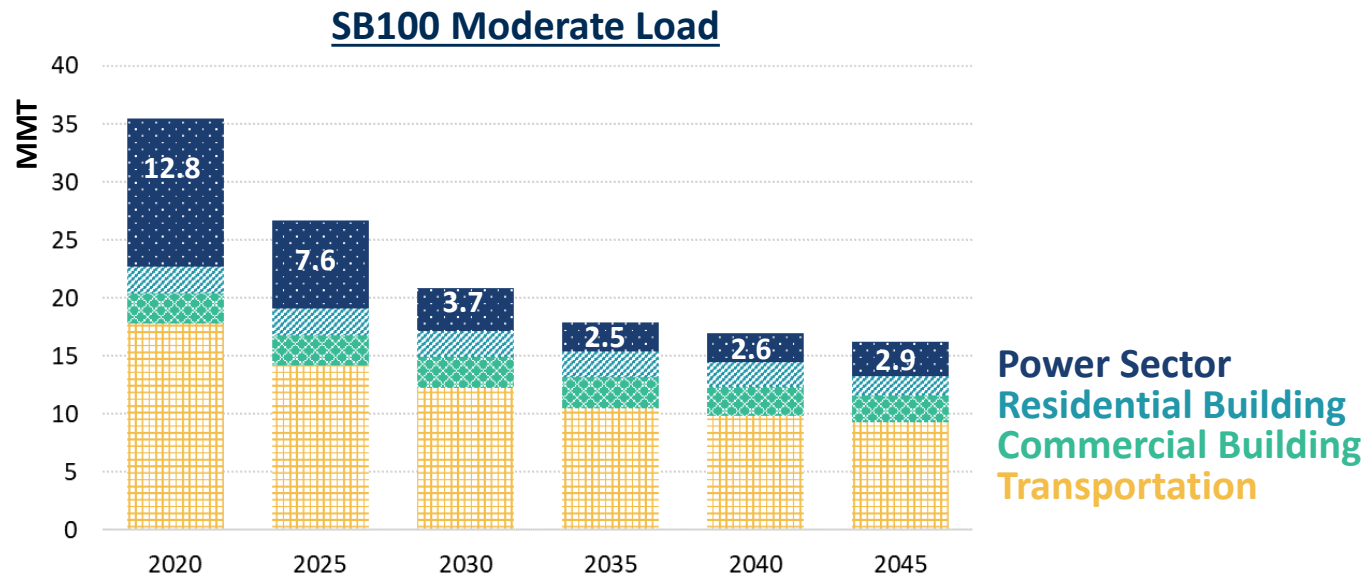
- In all scenarios, High Load shows lower cost per tonne of GHG reduction than Moderate Load.
- High Load assumes higher load electrification, suggesting it is a better way for reducing GHG.
- Delta is \$20 to \$30/T, or 15% to 20% of the average cost of ~\$150/T.
- This delta is smaller than the growth 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.

Annual GHG Emissions for All Sectors

- For the **SB100 Scenarios**, GHG emission from the power sector stalls after 2035.
 - The all-sectors' annual GHG emission for High Load (with higher electrification for transportation and buildings) in 2040 and after is about half of that of Moderate Load.
 - This is largely from reduction in transportation but also in building sectors. Power sector emissions increase slightly.
 - The associated cost is about \$20-\$30/T, which is about 15% to 20% of the estimated long-run cost.

Annual GHG Emission by Sector for SB100 Moderate and High Load (2020-2045)

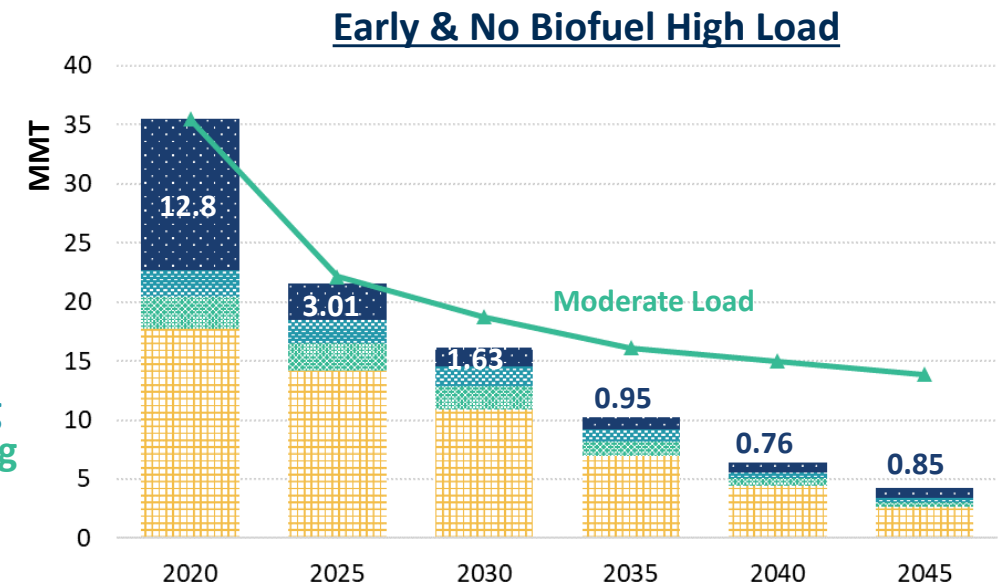
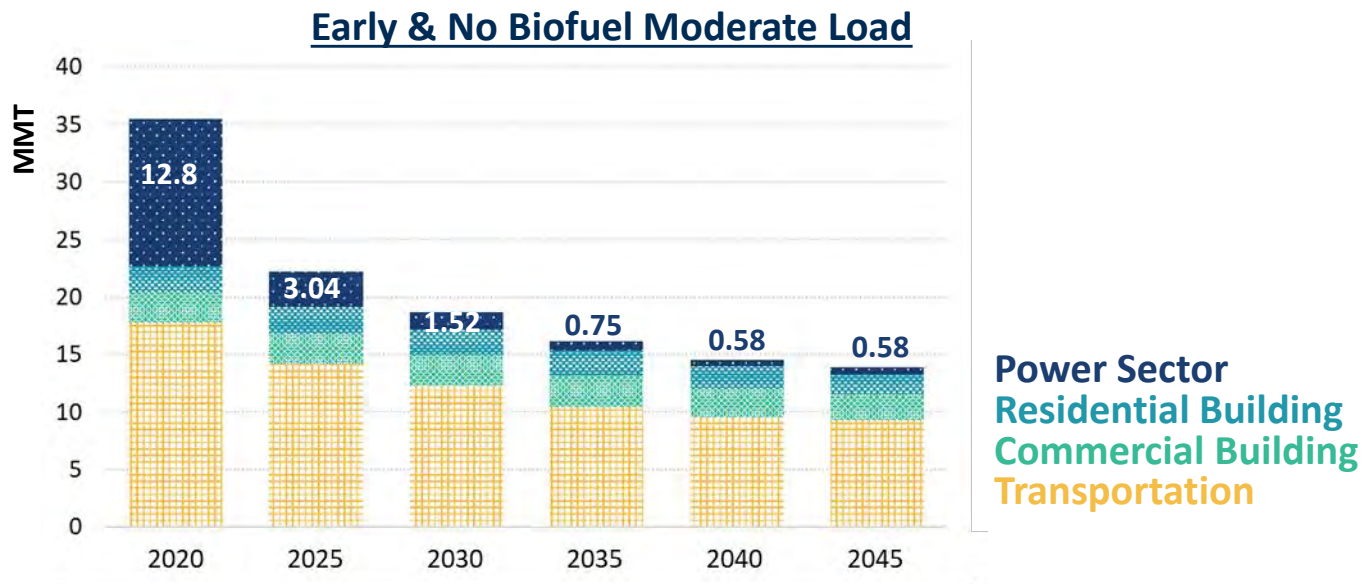


Sources: Data from NREL study report, Chapter 8, Appendix A, <https://www.nrel.gov/docs/fy21osti/79444-8.pdf>.

Annual GHG Emissions for All Sectors

- Similarly, for the **Early & No Biofuel Scenarios**, GHG emission from the power sector stalls after 2035.
 - The all-sectors' annual GHG emission for **High Load** (with higher electrification for transportation and buildings) in 2040 and after is about a third of that of Moderate Load.
 - This is largely from reduction in transportation but also in building sectors. Power sector emissions increase slightly.

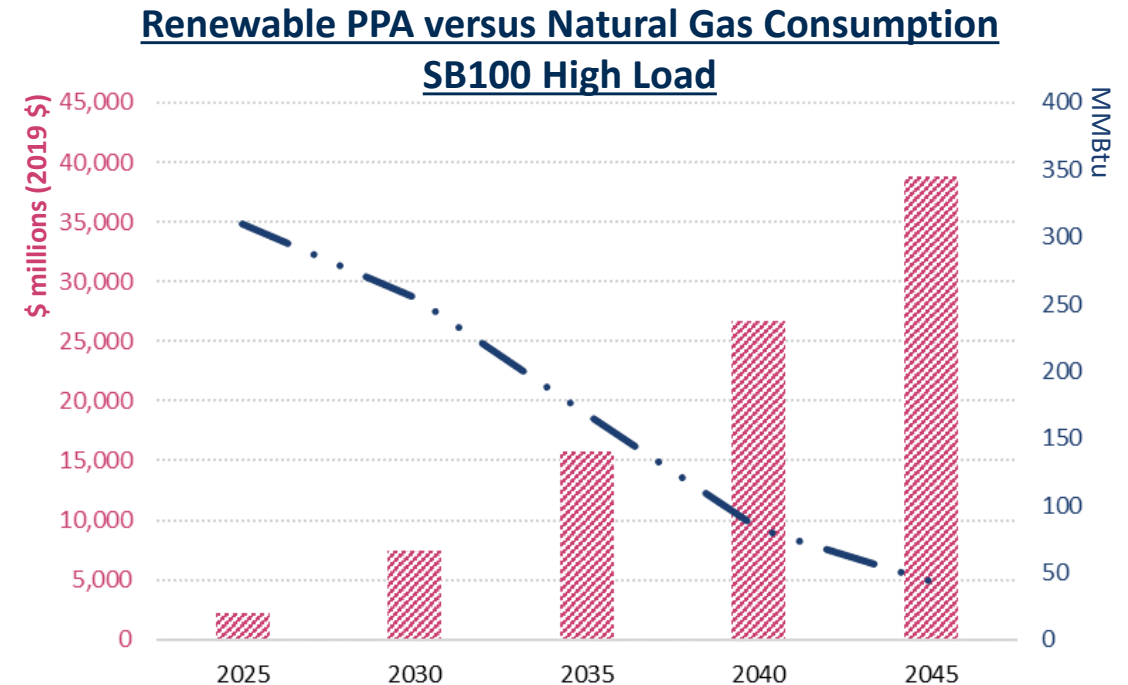
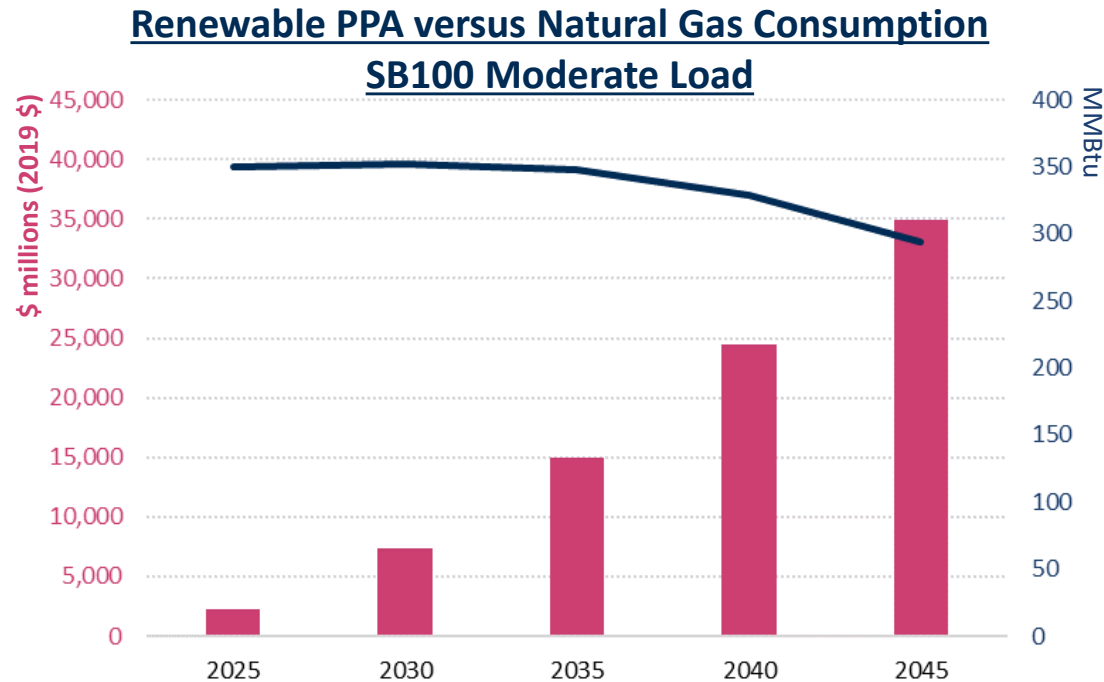
Annual GHG Emission by Sector for Early & No Biofuel Moderate and High Load (2020-2045)



Sources: Data from NREL study report, Chapter 8, Appendix A, <https://www.nrel.gov/docs/fy21osti/79444-8.pdf>.

Annual GHG Emissions for All Sectors

- There are low cost GHG reduction options in the non-power sectors.
 - GHG emission from the power sector stalls after 2030/2035.
 - The charts below compares the renewable PPA costs (roughly representing the total load including electrified load) and natural gas consumptions for buildings (residential and commercial).



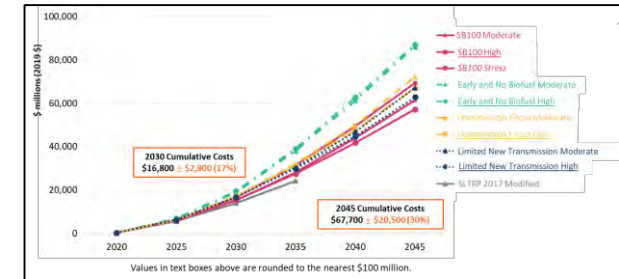
Sources: Data from NREL study website, <https://maps.nrel.gov/la100/data-viewer?Theme=electricity-demand&SubTheme=annual-gas-demand&Resolution=lc&LoadScenario=moderate&LayerId=electricity-demand.annual-gas-demand&Year=2045&Variable=btu>

Summary of Observations from Cost Estimates

Common observations across all pathways include:

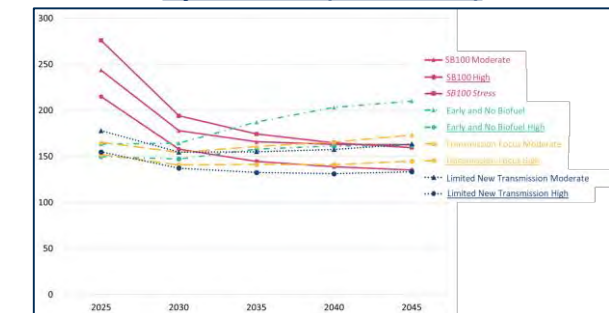
- Costs grow exponentially in the second half of the study period.
 - Costs through 2030 do not vary much by pathways and are about a quarter of total cumulative costs.
 - Costs double between 2030 and 2035, then grow exponentially thereafter.
 - Costs growth after 2035 is more than half of total cumulative cost.
- Other cost related observations include:
 - Transmission CapEx do not vary by pathway (other than **Transmission Focus Scenarios**).
 - Transmission enables more diverse generation options (both short- and long-term) that benefits all customers, rather than a select group, contributing to environmental justice.
 - H2- and RE-CT CapEx are quite high while their OpEx is miniscule.
- Significant benefits of GHG reduction is achieved through the first half of the study period (through 2030/2035) at much lower costs.
 - Incremental cost per reduction in GHG becomes much higher (more than doubles) after 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 these 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 are correlated to load electrification, rather than any specific pathway.

Cumulative Total Expenditure by Scenario by Year



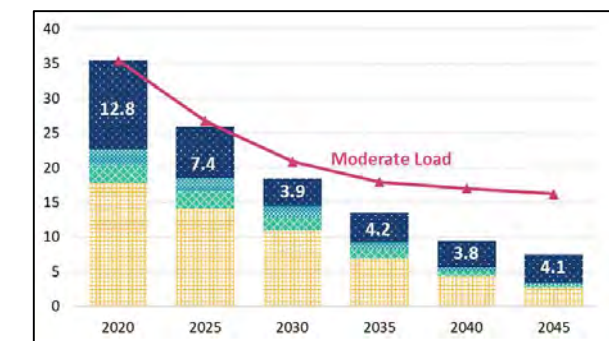
See slide 16

Cumulative Unit Cost of Total GHG Reduction by Scenario (All Sectors)



See slide 40

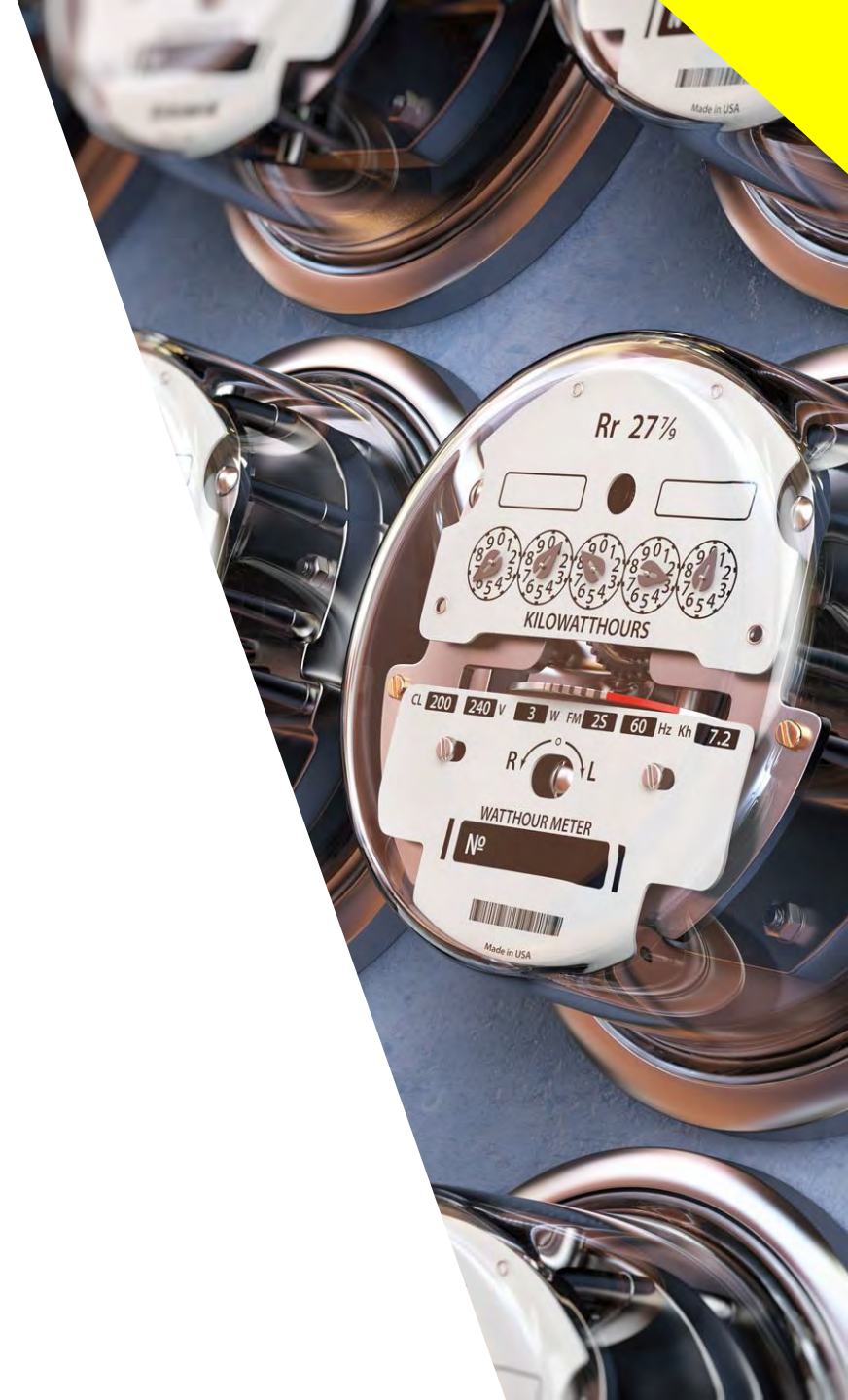
SB100 High Load GHG Emission by Sector



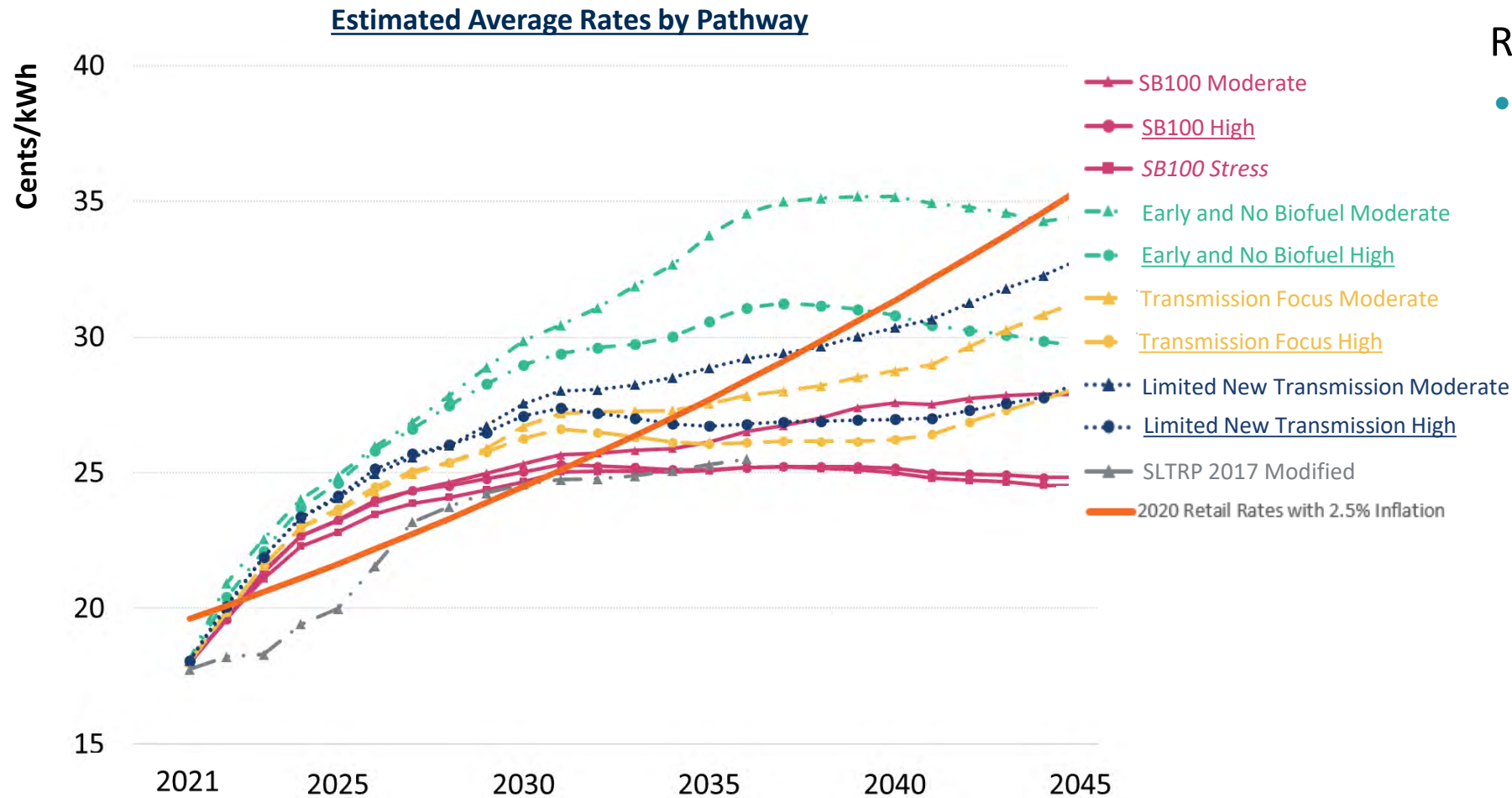
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Estimated Power Prices by Pathway - 1/2



Rate Estimates

- All pathways show modest increase in estimated rates.
 - Similar to costs, rates do not vary much through 2030.
 - Unlike costs, rate grows in early years (through 2030), then generally becomes flatter after 2030.
 - Estimated rates growth through 2045 are below that of inflation (2.5%).
 - Within a scenario, high load pathways result in lower rates (by 10% to 15%) compared to moderate load pathways.

Sources and notes: SLTRP 2017 Modified extends only through 2036. The average 2020 rate is 19.1 cents/kWh (baseline year). Data provided by LADWP FSO.

Estimated Power Prices by Pathway - 2/2

- All pathways show modest increase in estimated rates.
 - Unlike costs, rate grows in early years (through 2030), then generally becomes flatter after 2030.
 - Within a scenario, high load pathways typically result in lower rate increase (by ~0.5% per year) compared to moderate load pathways.

Compound Annual Growth Rate (CAGR) by Pathways*¹

Pathways	5 Year CAGR					10 Year CAGR				Average CAGR 2020 - 2045
	2025	2030	2035	2040	2045	2020 - 2030	2025 - 2035	2030 - 2040	2035 - 2045	
SLTRP 2017 Modified	0.9%	4.2%	0.6%			2.5%	2.4%			1.8% ^{*2}
SB100 Moderate	4.0%	1.7%	0.6%	1.1%	0.2%	2.8%	1.2%	0.9%	0.7%	1.5%
Early & No Biofuels Moderate	5.4%	3.7%	2.5%	0.8%	-0.4%	4.6%	3.1%	1.7%	0.2%	2.4%
Transmission Focus Moderate	4.3%	2.5%	0.6%	0.9%	1.7%	3.4%	1.6%	0.7%	1.3%	2.0%
Limited New Transmission Moderat	4.7%	2.7%	0.9%	1.0%	1.6%	3.7%	1.8%	1.0%	1.3%	2.2%
SB100 High	4.0%	1.5%	0.1%	0.0%	-0.3%	2.7%	0.8%	0.1%	-0.1%	1.0%
Early & No Biofuels High	5.2%	3.3%	1.1%	0.1%	-0.7%	4.2%	2.2%	0.6%	-0.3%	1.8%
Transmission Focus High	4.4%	2.1%	-0.2%	0.1%	1.4%	3.2%	1.0%	0.0%	0.8%	1.6%
Limited New Transmission High	4.8%	2.3%	-0.3%	0.2%	1.0%	3.5%	1.0%	0.0%	0.6%	1.6%
SB100 Stress	3.6%	1.6%	0.3%	-0.1%	-0.4%	2.6%	1.0%	0.1%	-0.2%	1.0%

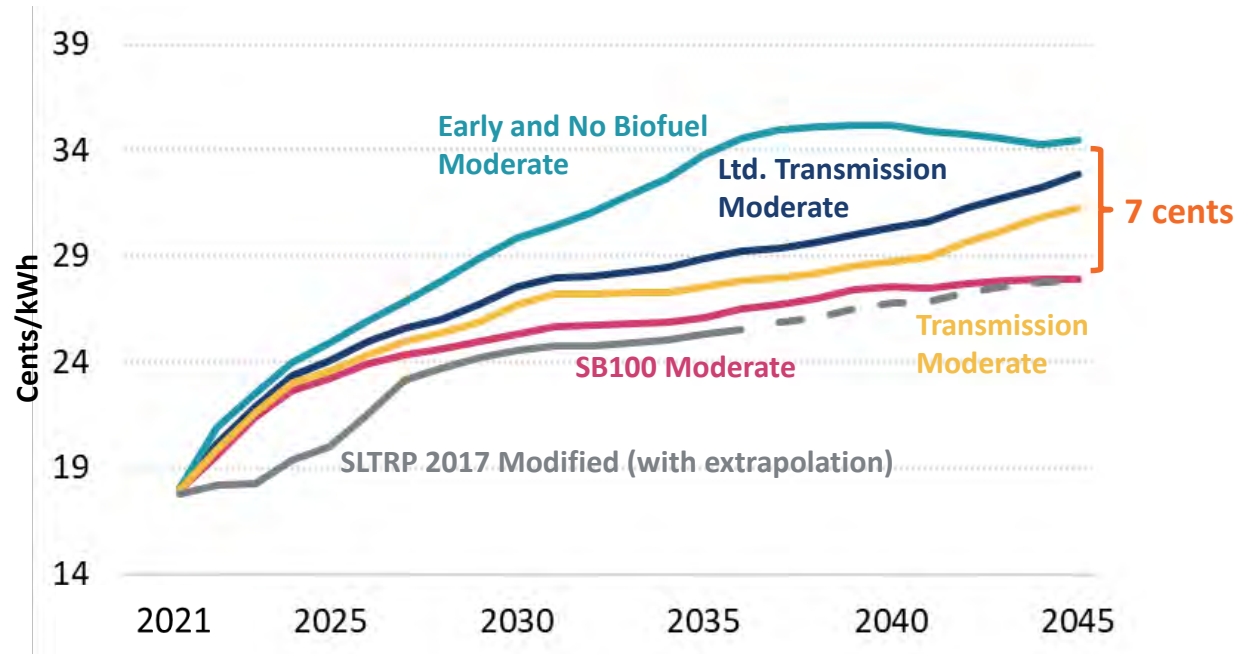
Sources and notes: *1 The average 2020 rate is 19.1 cents/kWh (baseline year). Data provided by LADWP FSO.

*2 CAGR for SLTPR 2017 Modified extends only through 2036.

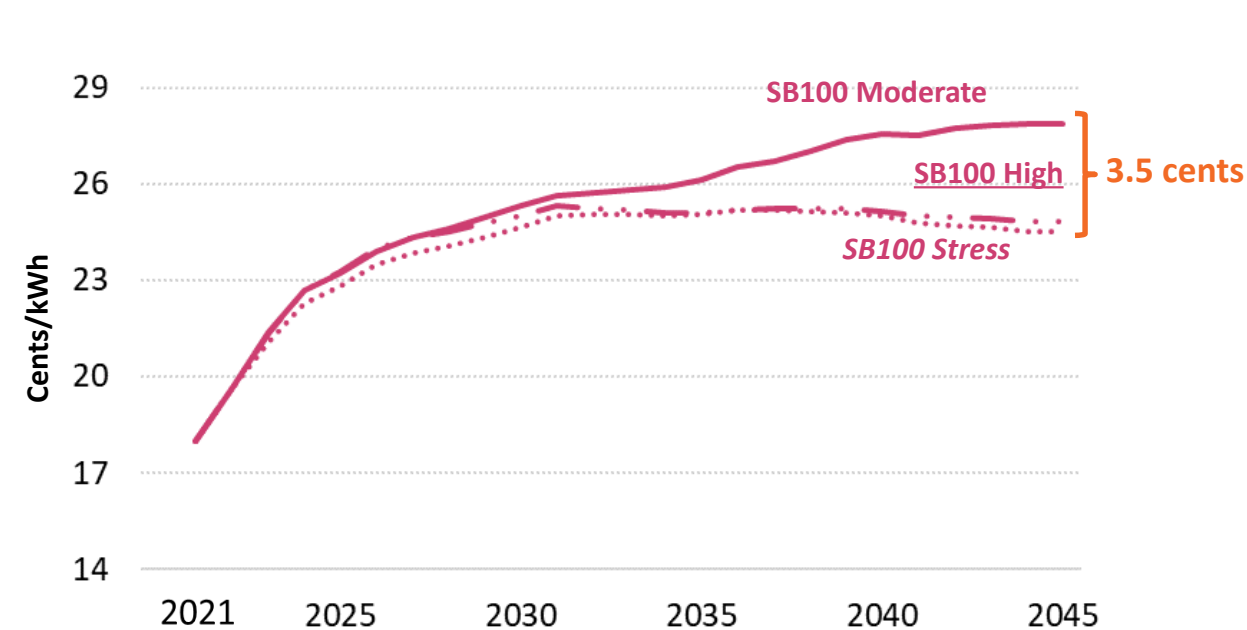
Estimated Power Prices and Uncertainties - 1/2

- Load projections by themselves are a source of uncertainty.
 - Rate variation caused by load projection by 2045 (3.5 cents) is about half of that caused by Scenario (7 cents).
 - Variation of both types grows largely after 2030.

Estimated Average Rates for Moderate Load Pathways



Estimated Average Rates for SB100 Pathways by Load Level

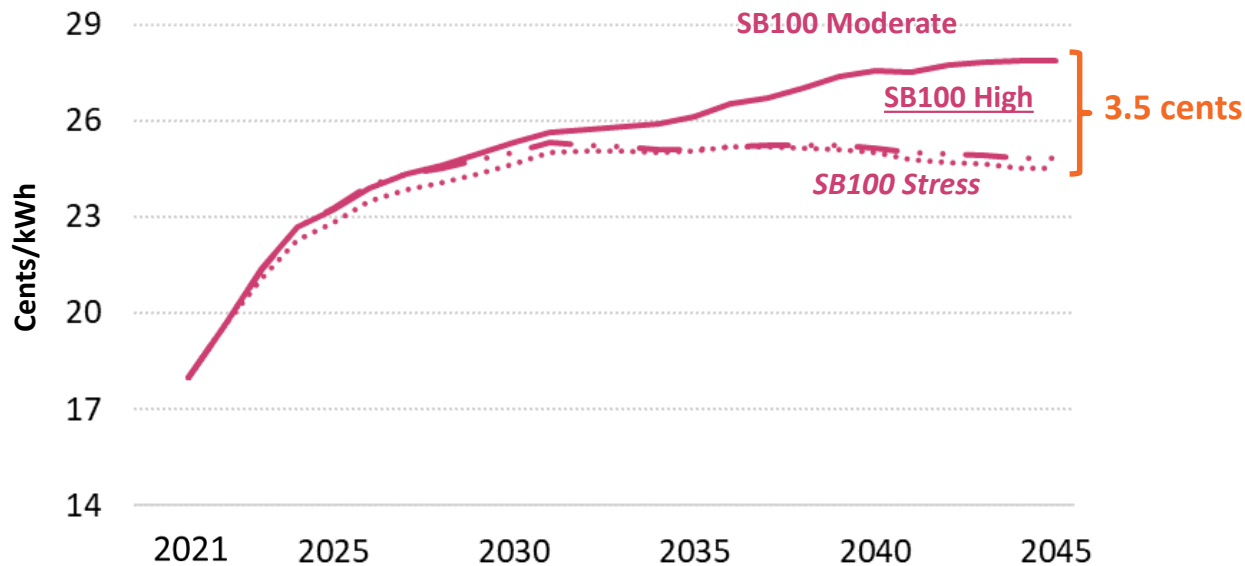


Sources and notes: Differences between prices by scenario are rounded to the nearest quarter of a cent. Data provided by LADWP FSO.

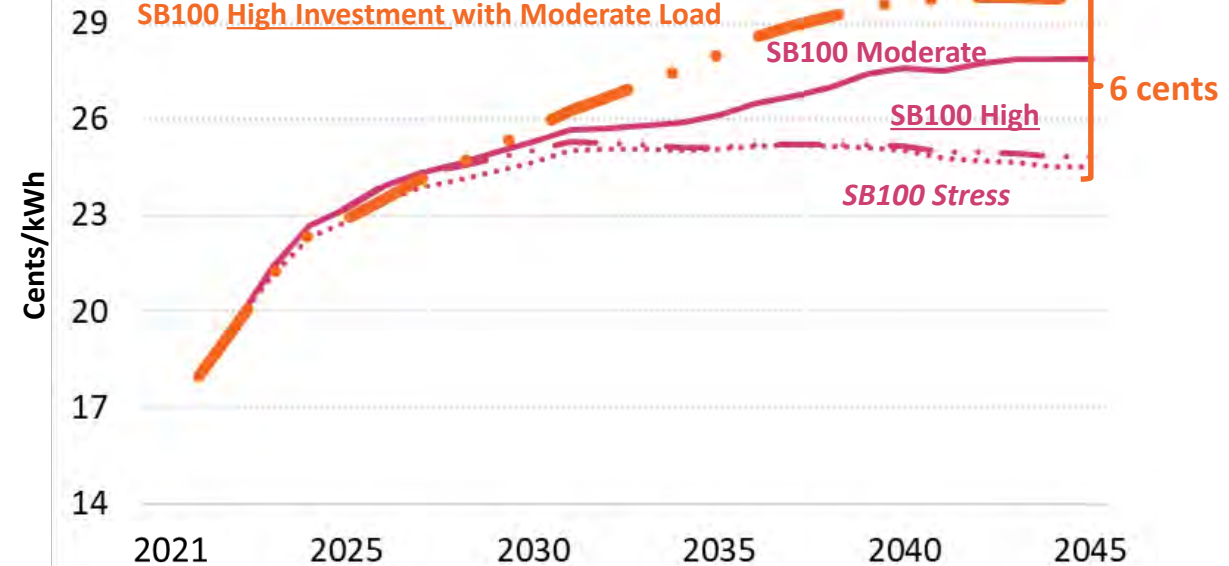
Estimated Power Prices and Uncertainties - 2/2

- Load realization is another source of uncertainty.
 - Rate variation caused by expected load not showing up under the **SB100 Scenarios** (e.g., investments made for high load projection but actual load turned out to be at moderate load level) shows rates impacted by nearly 6 cents.
 - This is nearly double the rate variations caused by load projections (3.5 cents) and similar to that caused by the difference in scenarios (7 cents).
 - Variation grows after 2030.

Estimated Average Rates of SB100 Pathways



Estimated Average Rates for SB100 High Load



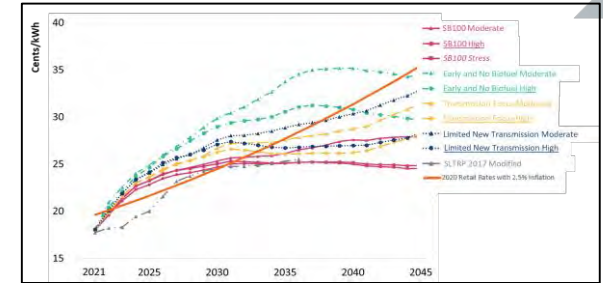
Sources and notes: Differences between prices by scenario are rounded to the nearest quarter of a cent. Data provided by LADWP FSO.

Summary of Observations from Rate Estimates

Common observations across all pathways include:

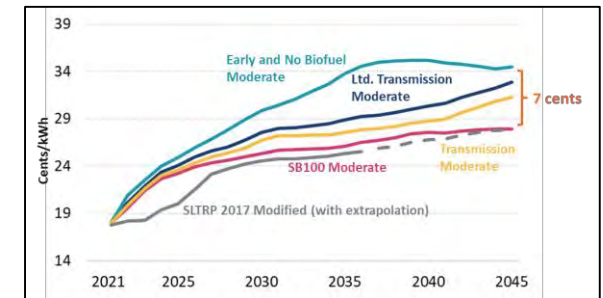
- Average rates will grow at a rate that is less than 2.5% of assumed future inflation.
 - Similar to costs, average rates through 2030 do not vary much by pathways.
 - Unlike costs, rate growth is much steeper in the earlier years (in the 25 cents to 30 cents range by 2030), and tend to flatten out in the later years (in the 25 cents to 35 cents range by 2045).
 - This difference is likely caused by existing debt.
 - Within a given scenario, high load pathways typically result in lower rates (by 10% to 15%) compared to moderate load pathways.
- Difference in scenarios and uncertainty in load drive rates. Assuming the different pathways estimates:
 - Difference in scenarios for the same load can lead to a 7 cents difference (nearly 40% of today's average rate).
 - Difference in load projection for the same scenario can lead to a 3.5 cents difference (~20% of today's average rate).
 - Difference in realized load (e.g., only moderate level of load showing up after investing under high load projection) can lead to a 6 cents difference.

Estimated Rates by Pathway



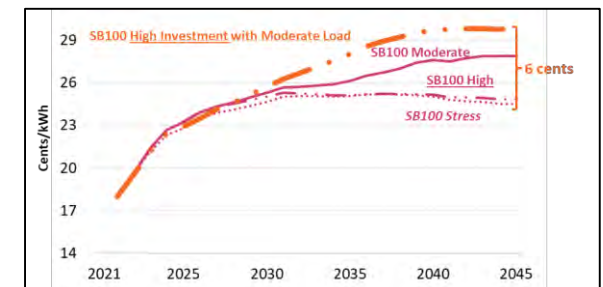
See slide 46

Estimated Average Rates for Moderate Load Pathways



See slide 48

SB100 High Load GHG Emission by Sector



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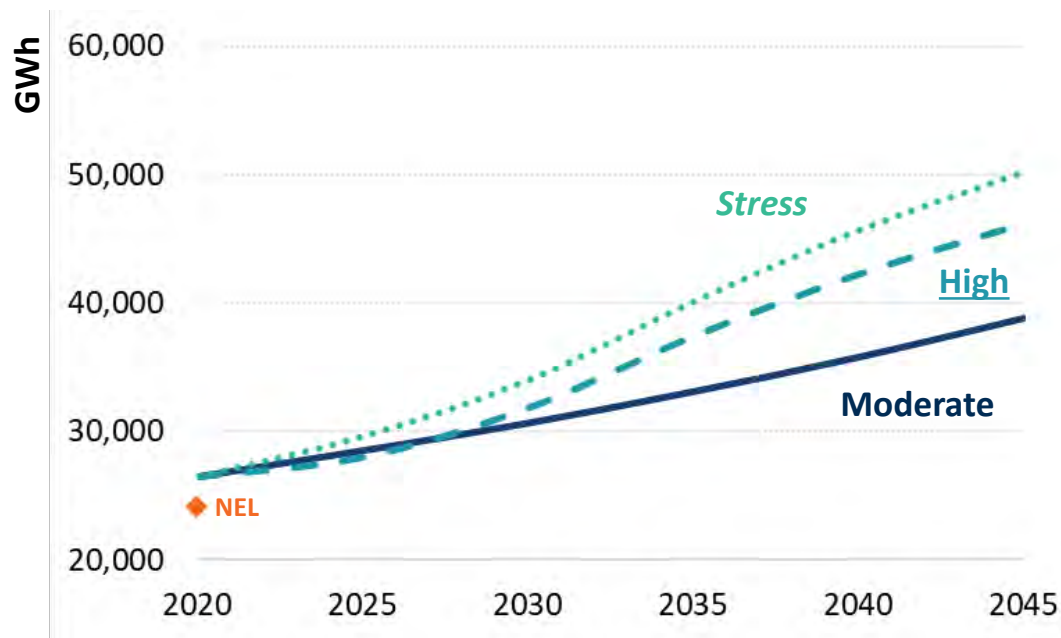
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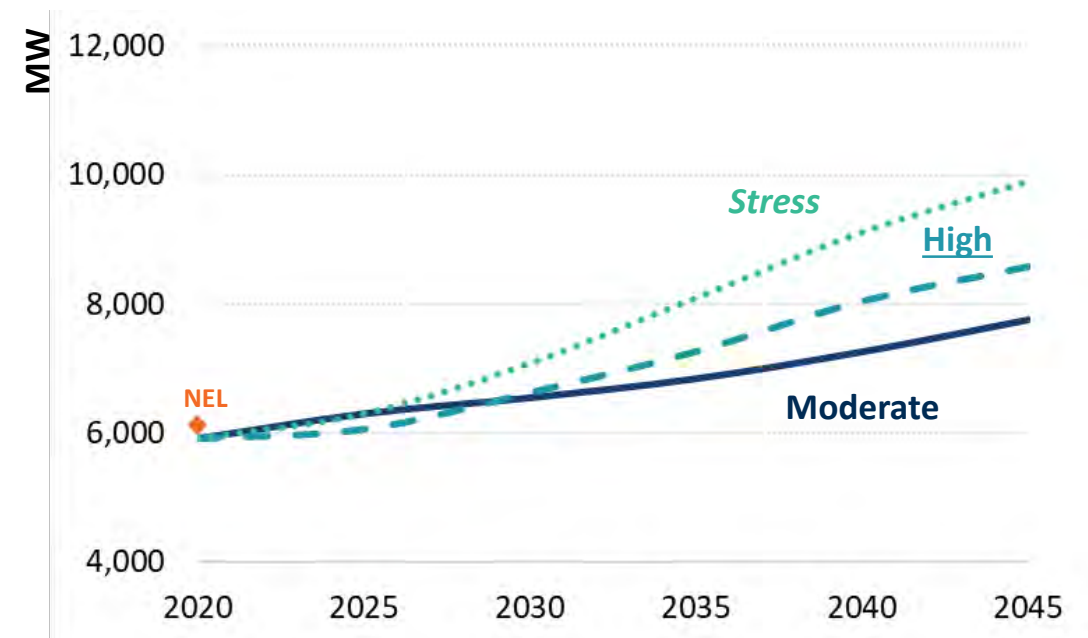
Load Projection - Within the LA100 Study

- 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)

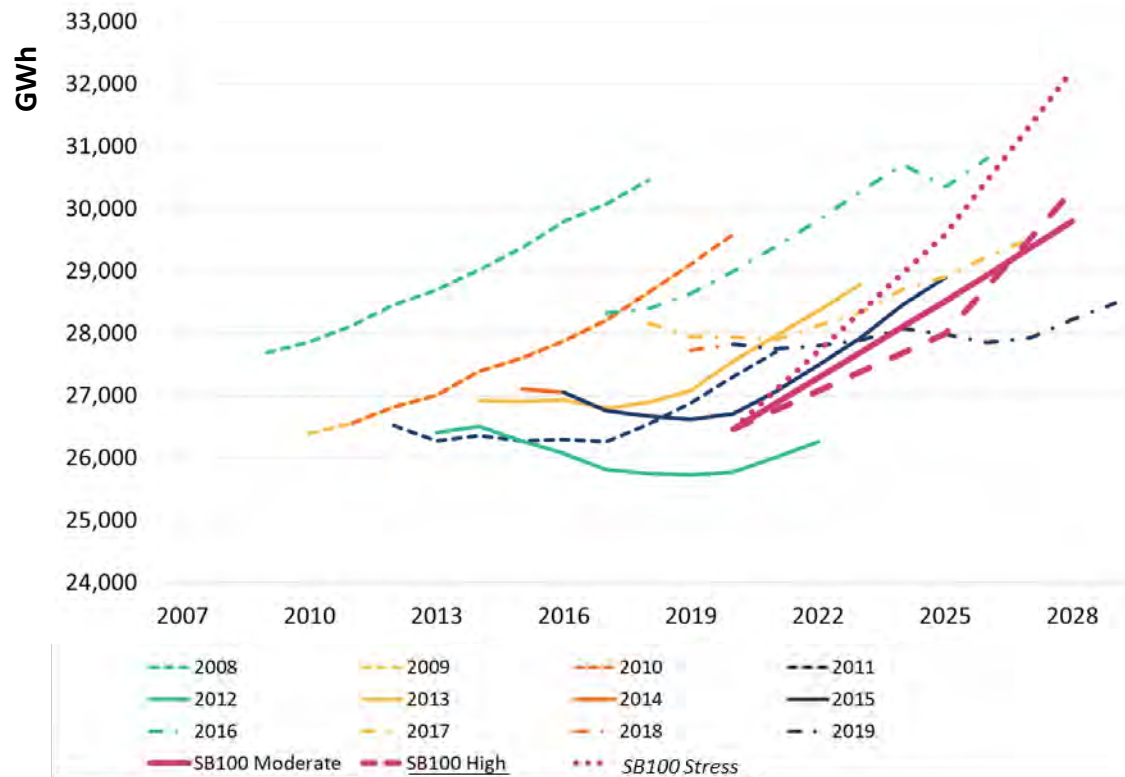


Sources and notes: Data from NREL Study website, <https://maps.nrel.gov/la100/data-viewer?Theme=electricity-demand&SubTheme=electricity-consumption&Resolution=lc&LoadScenario=moderate&LayerId=electricity-demand.peak-demand&Year=2045&Variable=kwh&TemporalResolution=annual&TimePeriod=peak>. NEL reported 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%).

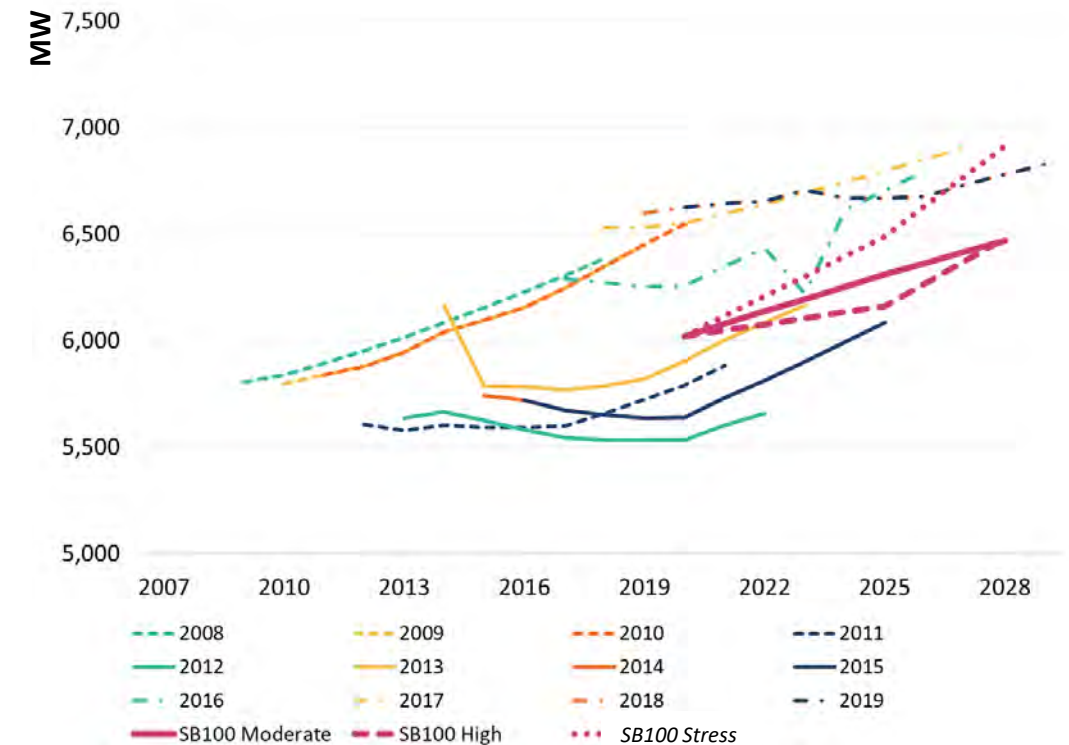
Load Projection - Variance Over Time

- 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)



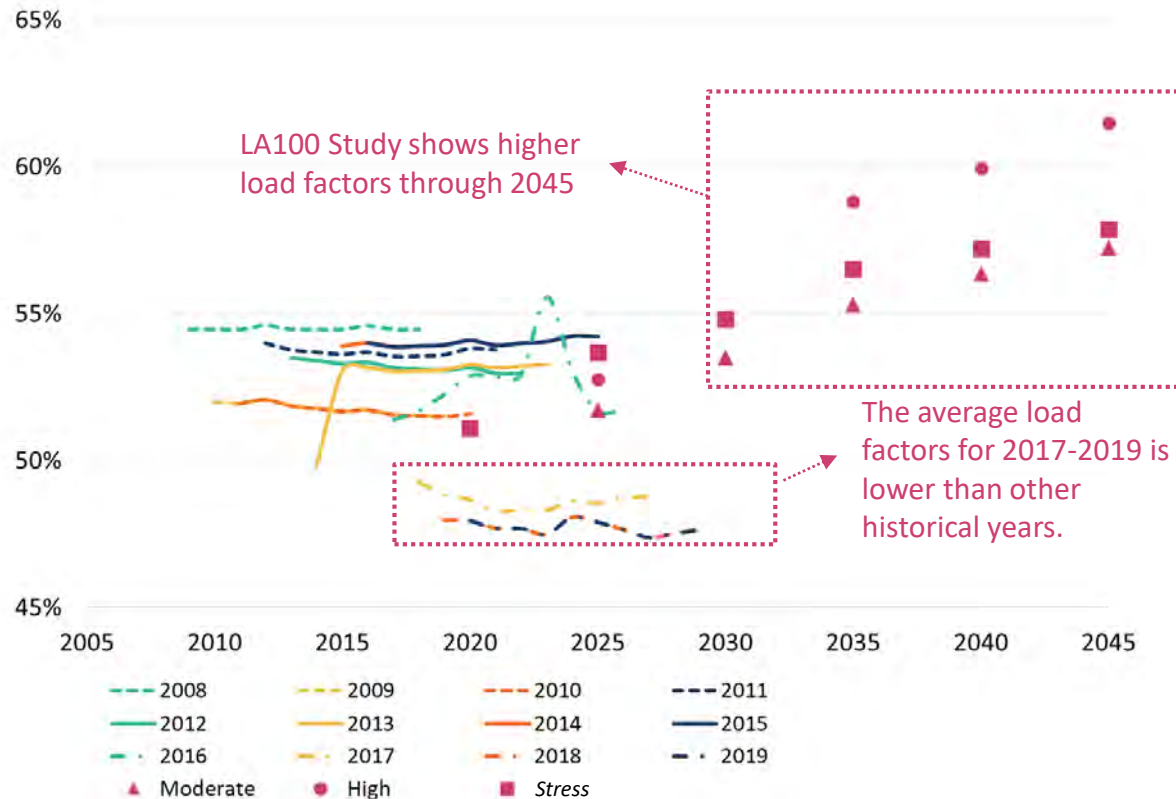
Sources and notes : Historical load projections from FERC 714 Filings, <https://www.ferc.gov/industries-data/electric/general-information/electric-industry-forms/form-no-714-annual-electric/data>.

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).

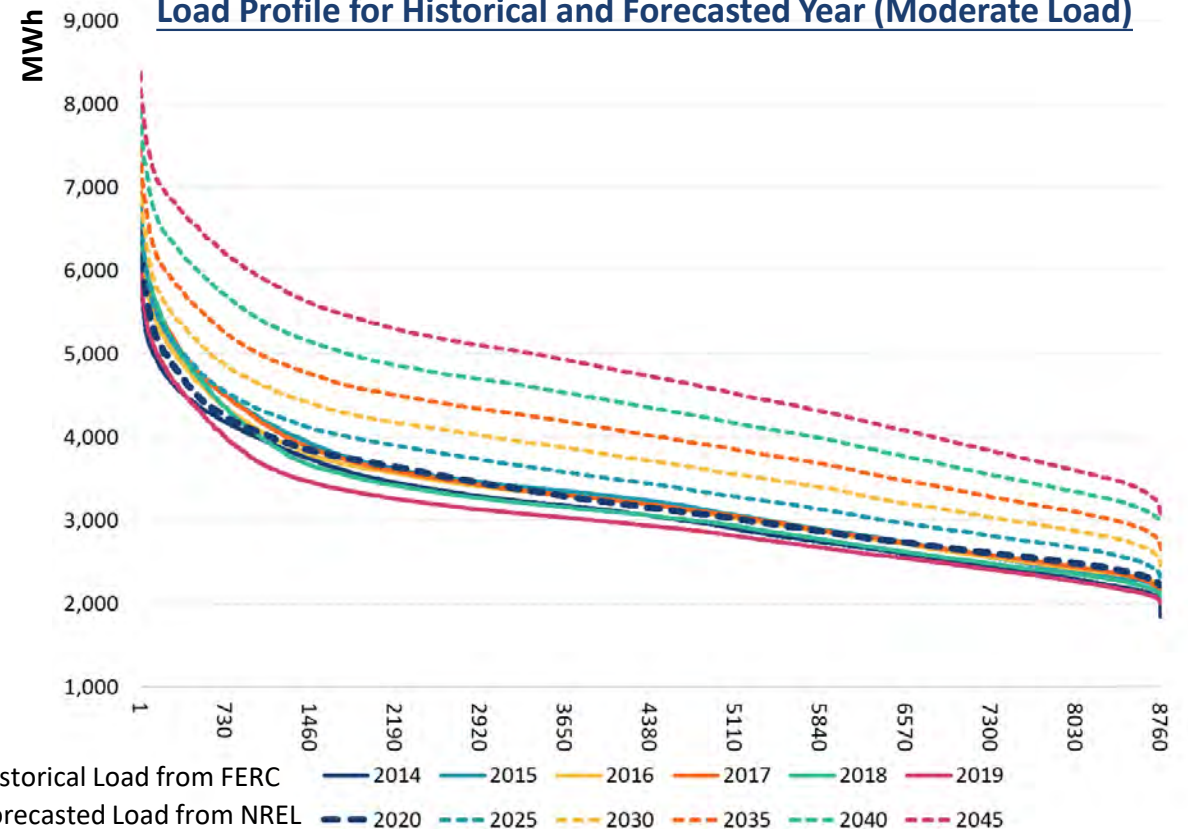
Load Profiles - 1/2

- 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).

Load Factor by Year (2008-2045)



Load Profile for Historical and Forecasted Year (Moderate Load)



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>.

Load Profiles - 2/2

Marginal Benefit (%) of Load Reduction for SB100 Moderate

	2020	2025	2030	2035	2040	2045	Mean
First 20 hours	5%	5%	5%	5%	5%	5%	5%
21- 40 hours	5%	4%	3%	3%	3%	3%	3%
41 - 60 hours	3%	3%	3%	3%	2%	3%	3%
61 - 80 hours	3%	2%	3%	2%	2%	1%	2%
81 - 100 hours	2%	3%	2%	2%	2%	1%	2%

Summary of Calendar Time of Top 100 hours of Moderate Scenario

2020		2025		2030		2035		2040		2045	
8/10	10AM - 4PM	8/7	10AM - 5PM	8/7	10AM - 7PM	8/7	10AM - 7PM	8/10	10AM - 7PM	8/7	10AM - 7PM
8/11	9AM - 4PM	8/8	10AM - 5PM	8/8	10AM - 5PM	8/8	10AM - 5PM	8/11	10AM - 5PM	8/8	10AM - 5PM
8/12	9AM - 4PM	8/9	9AM - 5PM	8/9	9AM - 5PM	8/9	9AM - 5PM	8/12	9AM - 5PM	8/9	10AM - 6PM
8/13	9AM - 5PM	8/10	9AM - 5PM	8/10	9AM - 5PM	8/10	9AM - 6PM	8/13	9AM - 7PM	8/10	9AM - 7PM
8/14	10AM - 5PM	8/11	9AM - 5PM	8/11	9AM - 5PM	8/11	9AM - 5PM	8/14	9AM - 7PM	8/11	9AM - 7PM
8/15	11AM - 4PM	8/12	11AM - 4PM	8/12	11AM - 4PM	8/12	11AM - 4PM	8/15	11AM - 4PM	8/12	11AM - 4PM
8/17	10AM - 3PM	8/14	10AM - 3PM	8/14	10AM - 4PM	8/14	10AM - 4PM	8/17	10AM - 4PM	8/14	10AM - 4PM
8/18	1PM - 2PM	8/17	12PM - 3PM	8/17	1PM - 3PM	8/17	1PM - 2PM	8/20	2PM	8/18	12PM - 3PM
8/20	1PM - 2PM	8/18	12PM - 3PM	8/18	12PM - 3PM	8/18	1PM - 3PM	8/21	12PM - 3PM	8/28	3PM
8/21	12PM - 3PM	8/28	12PM - 3PM	8/28	2PM	8/29	11AM - 3PM	9/1	11AM - 4PM	8/29	11AM - 3PM
8/31	1PM - 3PM	8/29	11AM - 3PM	8/29	11AM - 3PM	8/30	12PM - 2PM	9/17	12PM - 3PM	9/14	11AM - 6PM
9/1	11AM - 3PM	8/30	12PM - 2PM	8/30	12PM - 2PM	9/14	12PM - 3PM	9/18	10AM - 6PM	9/15	10AM - 6PM
9/2	11AM - 3PM	9/14	12PM - 3PM	9/14	12PM - 3PM	9/15	10AM - 6PM	10/5	11AM - 5PM	10/2	11AM - 5PM
9/17	12PM - 3PM	9/15	10AM - 5PM	9/15	10AM - 5PM	10/2	11AM - 4PM	10/6	12PM - 1PM	10/27	11AM - 2PM
9/18	10AM - 5PM	10/2	11AM - 4PM	10/2	11AM - 4PM	10/3	12PM - 2PM	10/30	11AM - 3PM		
10/5	11AM - 3PM	10/3	12PM - 3PM	10/3	12PM - 2PM	10/27	11AM - 3PM				
10/6	12PM - 2PM	10/27	11AM - 3PM	10/27	11AM - 3PM						
10/21	2PM										
10/30	11AM - 3PM										

Sources: Hourly load data provided by NREL.

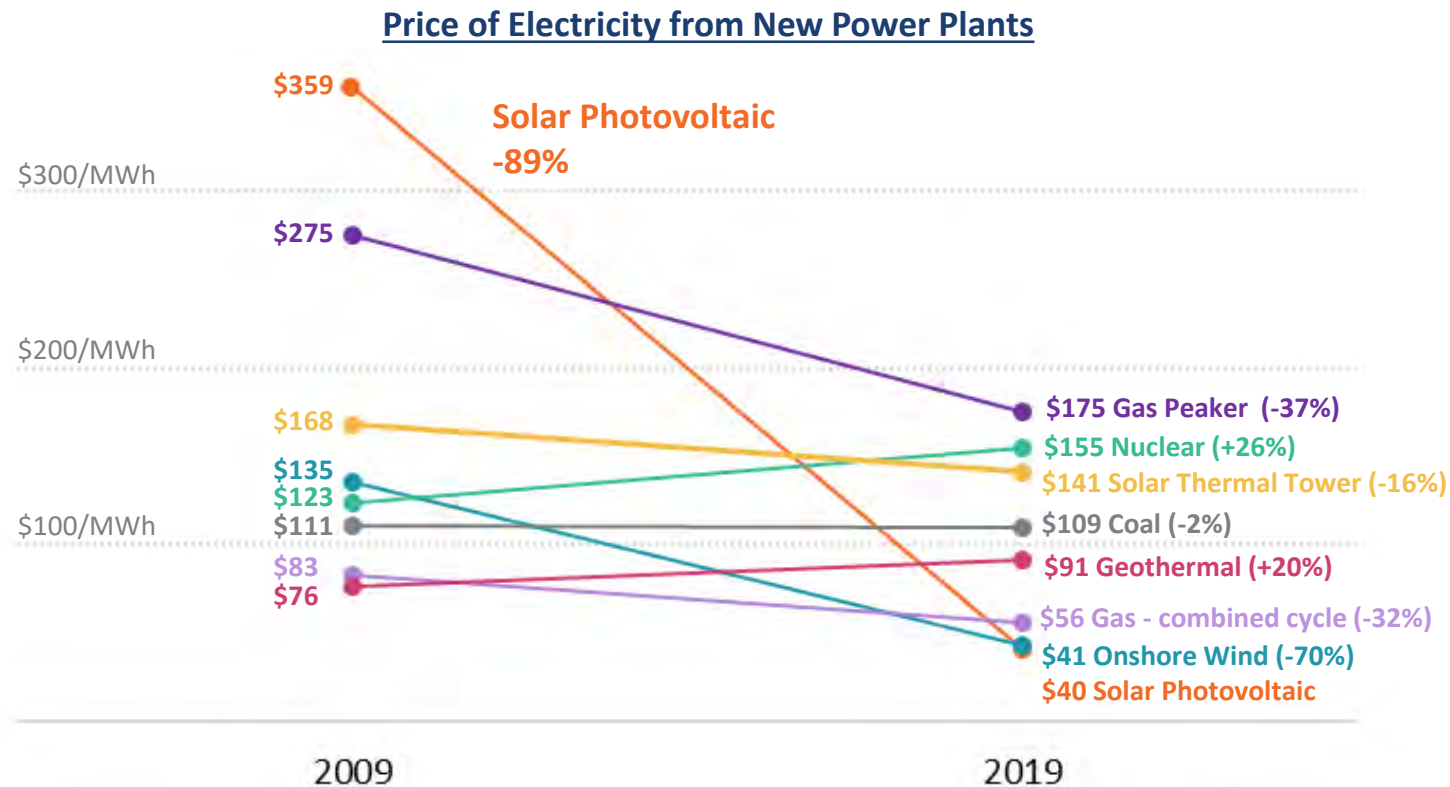
Discussion Draft

Future Load Profiles

- The LA100 Study load profile suggests opportunities for demand side resources.
 - Top 20 hours reduce peak load by 5% and top 100 hours reduce peak load by 15%.
 - Top 100 hours are concentrated in early August, suggesting a targeted demand side resource program may be worth evaluating.
- Future load profile (and growth) will vary by rate and pace of electrification—a large source of uncertainty.
 - LA100 Study shows shift in daily peak hours depending on pathways.

Cost Estimates for Generation Resources - 1/2

- 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.

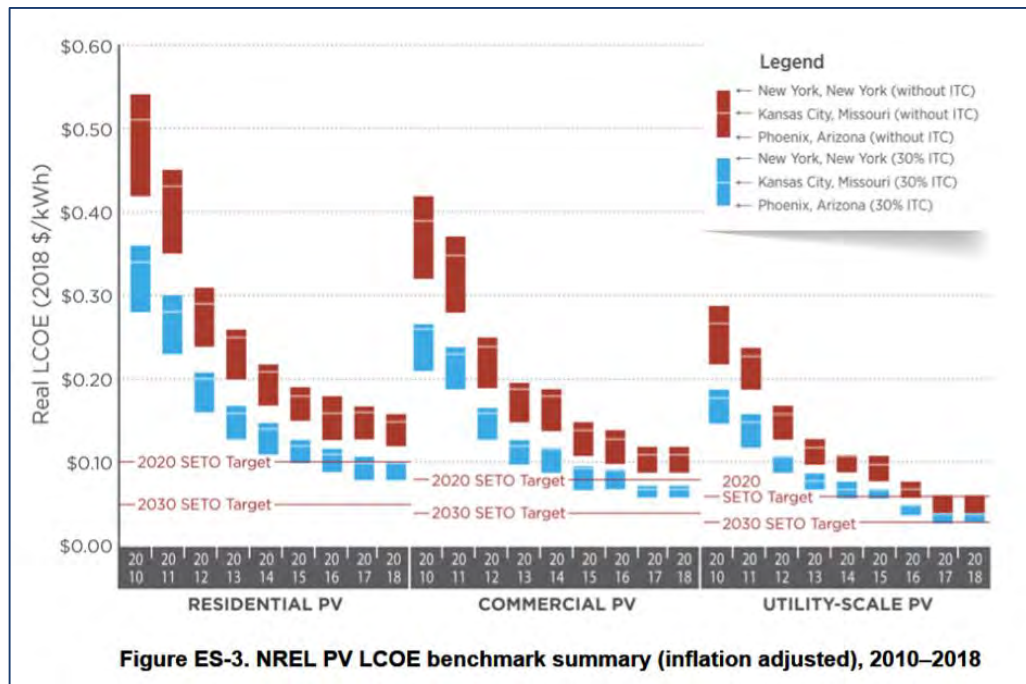


Sources and notes: Electricity prices are expressed in 'levelized costs of energy' (LCOE). LCOE captures the cost of building the power plant itself as well as the ongoing costs for fuel and operating the power plant over its lifetime. Data from Lazard Levelized Cost of Energy Analysis, Version 13.0.

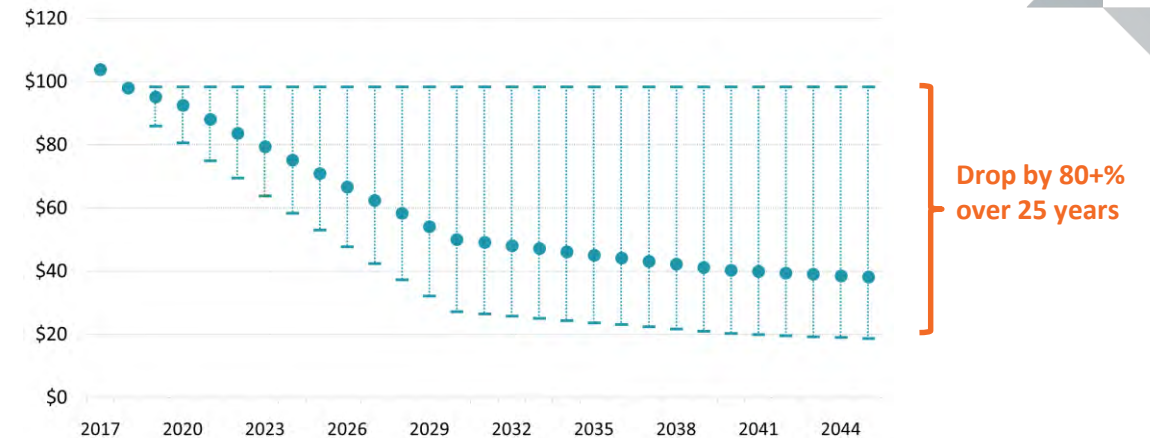
Cost Estimates for Generation Resources - 2/2

- NREL's Annual Technology Baseline (ATB)*¹ shows modest future cost reduction for solar.
 - NREL's historical analysis*² shows a significantly higher drop in renewable costs (~ 80% for solar PV installations, and ~40% for onshore wind over the past five years).

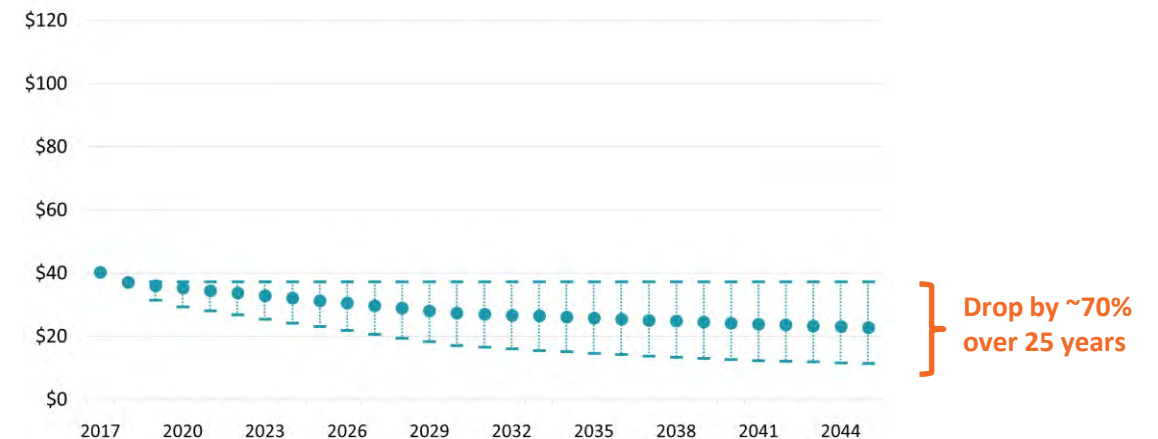
Drop in PV LCOE (Historical)



LCOE for Residential PV in Los Angeles by Year



LCOE for Utility PV in Los Angeles by Year



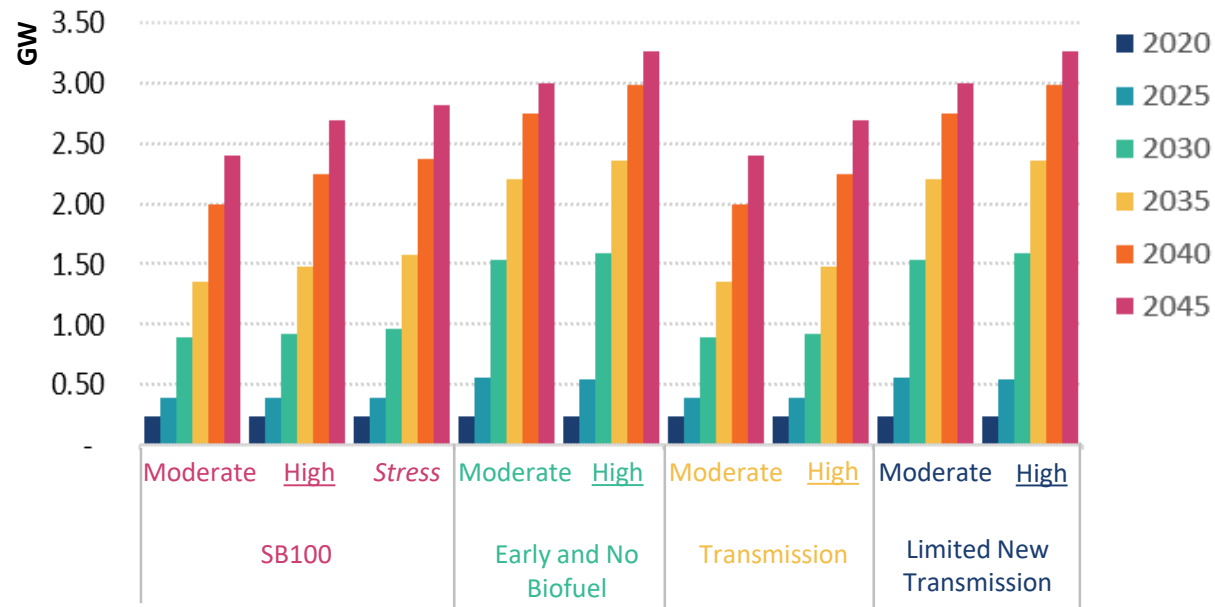
Sources: *1: <https://www.nrel.gov/news/program/2020/2020-annual-technology-baseline-electricity-data-now-available.html>

*2: U.S. Solar Photovoltaic System Cost Benchmark: Q1 2018, National Renewable Energy Laboratory

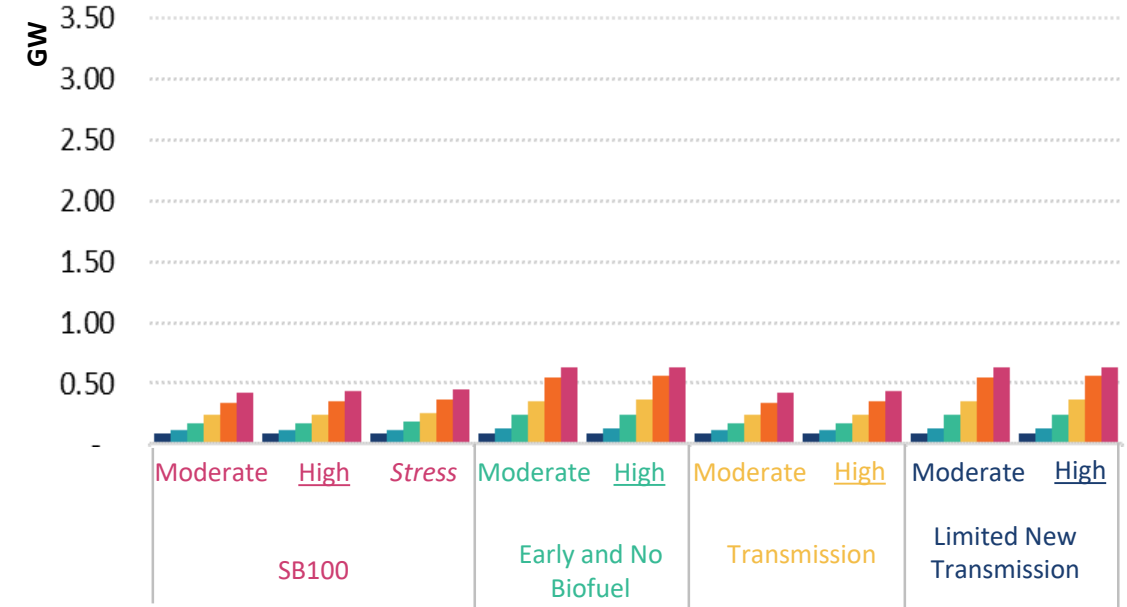
Future Economics of Distributed Solar - 1/5

- LA100 assumes significant amounts of customer PV installations across all pathways.
 - In all pathways, they add up to around 3 to 4 GW by 2045 with about half of that installed in the last ten years (2036-2045).
 - PV capacity expands by 8x to 10x through 2045. 3x to 5x of this growth is within the next ten years (through 2030).

Cumulative Capacity of Rooftop Solar by Scenario
Residential



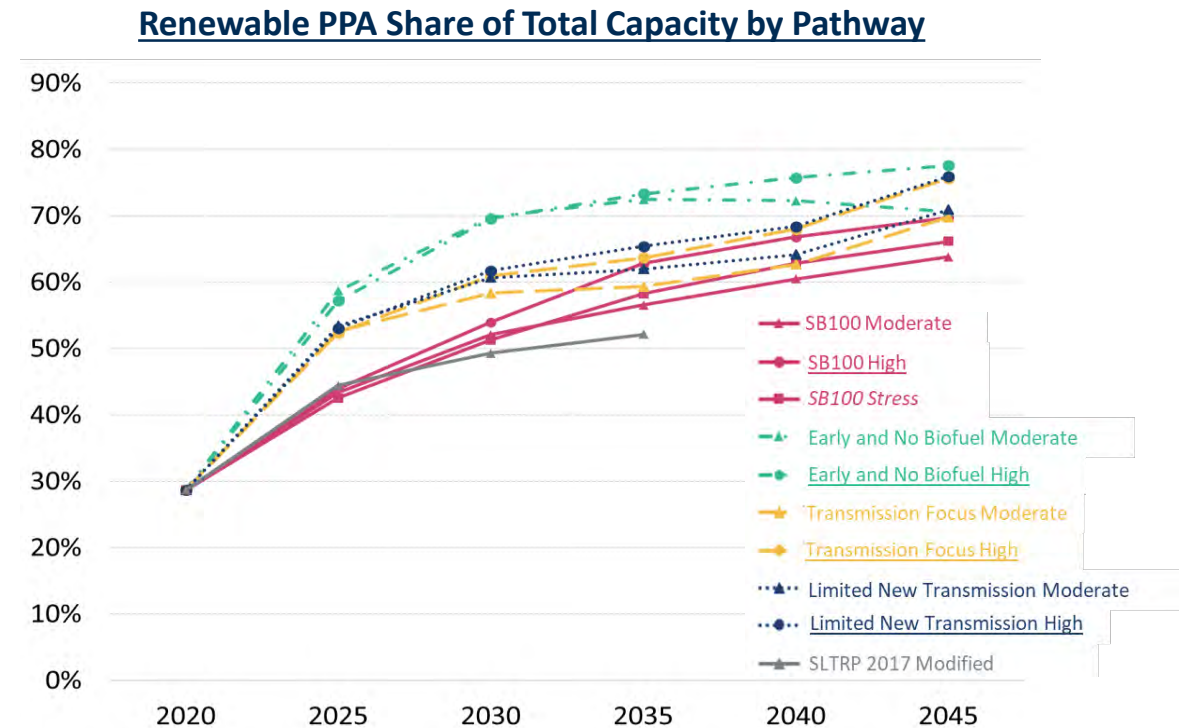
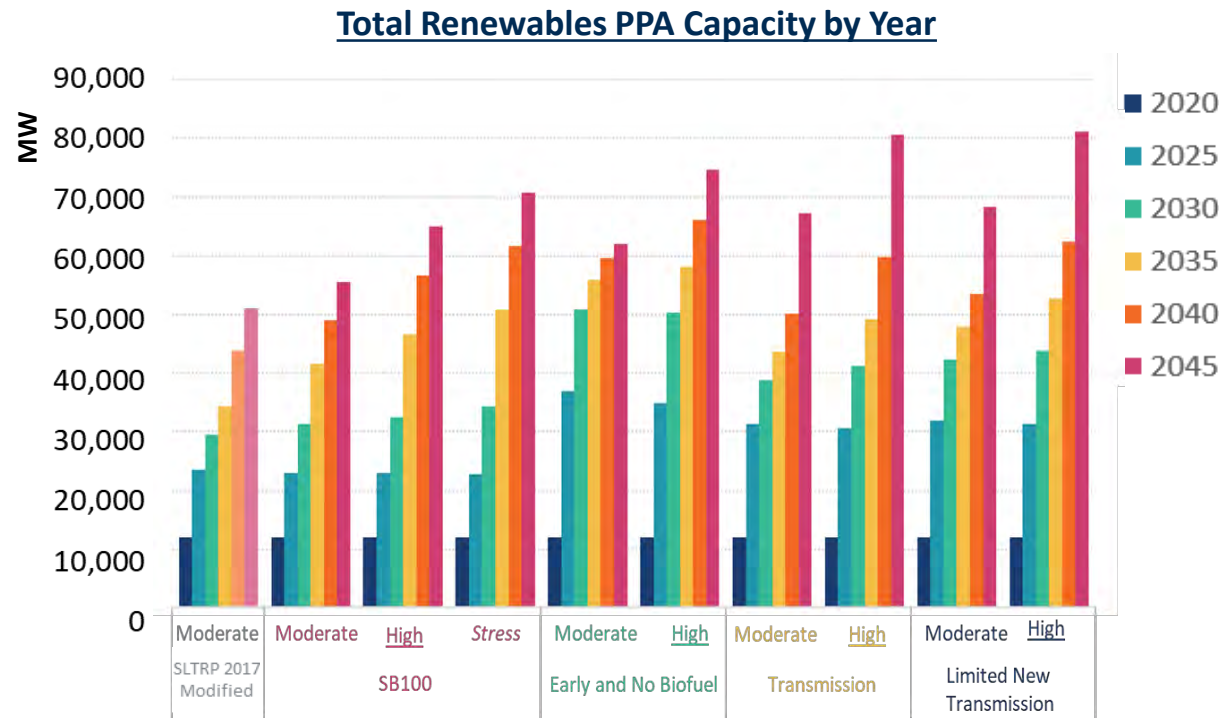
Cumulative Capacity of Rooftop Solar by Scenario
Commercial & Industrial



Sources: Data from NREL Study website, https://maps.nrel.gov/la100/data-viewer?Theme=distribution-grid&SubTheme=rooftop&Resolution=rs_dist&LoadScenario=moderate&RpmScenario=sb100&LayerId=distribution.local-solar-rooftop-deployment-potential&Year=2045&Variable=pv_kw

Future Economics of Distributed Solar - 2/5

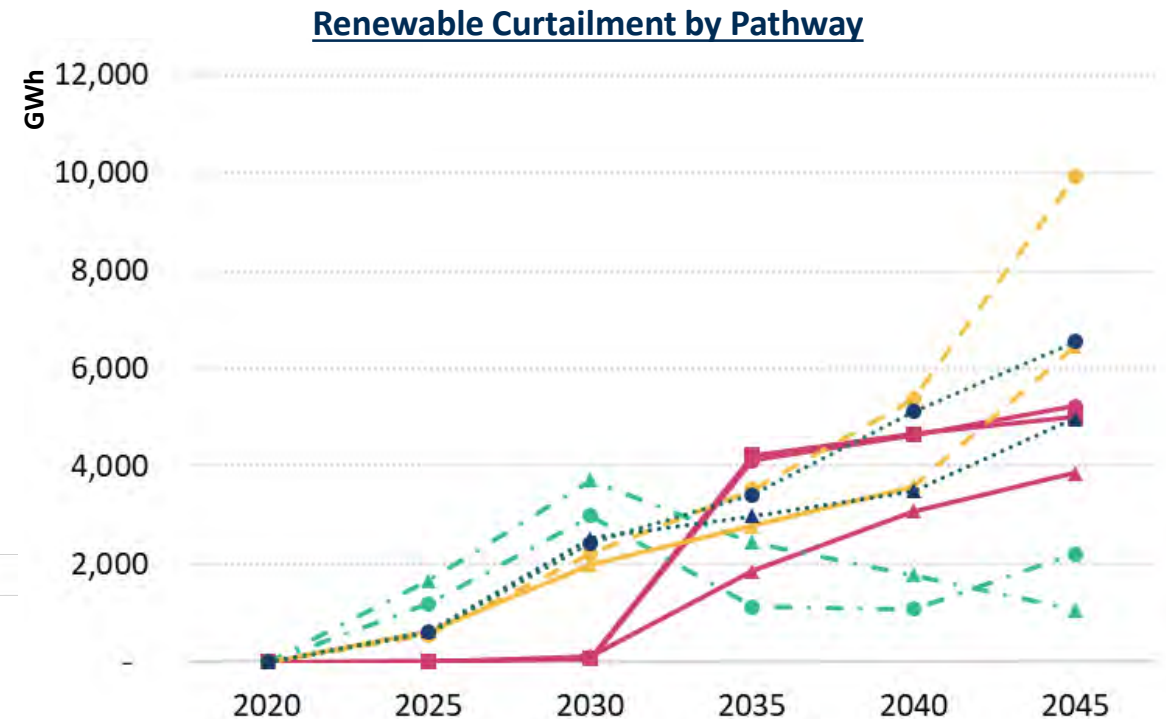
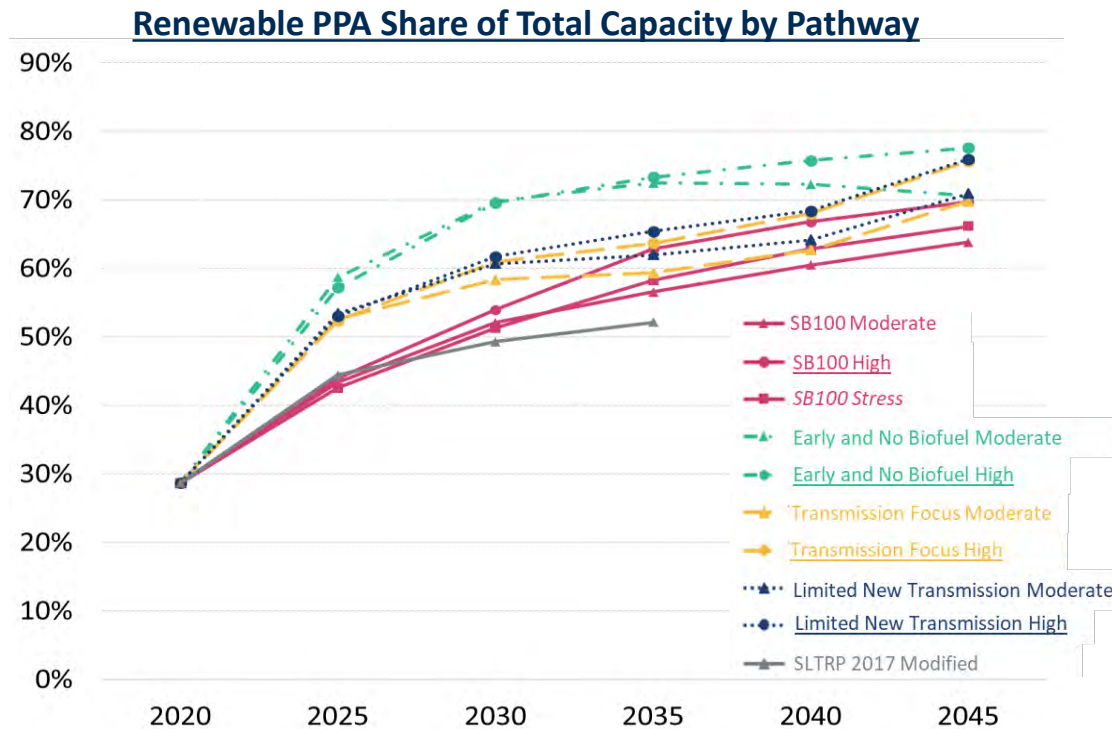
- LA100 assumes significant amounts of renewable PPAs to be signed across all pathways.
 - More than half of the PPAs (over 80% for the **Early and No Biofuel Scenarios**) are executed by 2030 (2x to 3x of today).



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>.

Future Economics of Distributed Solar - 3/5

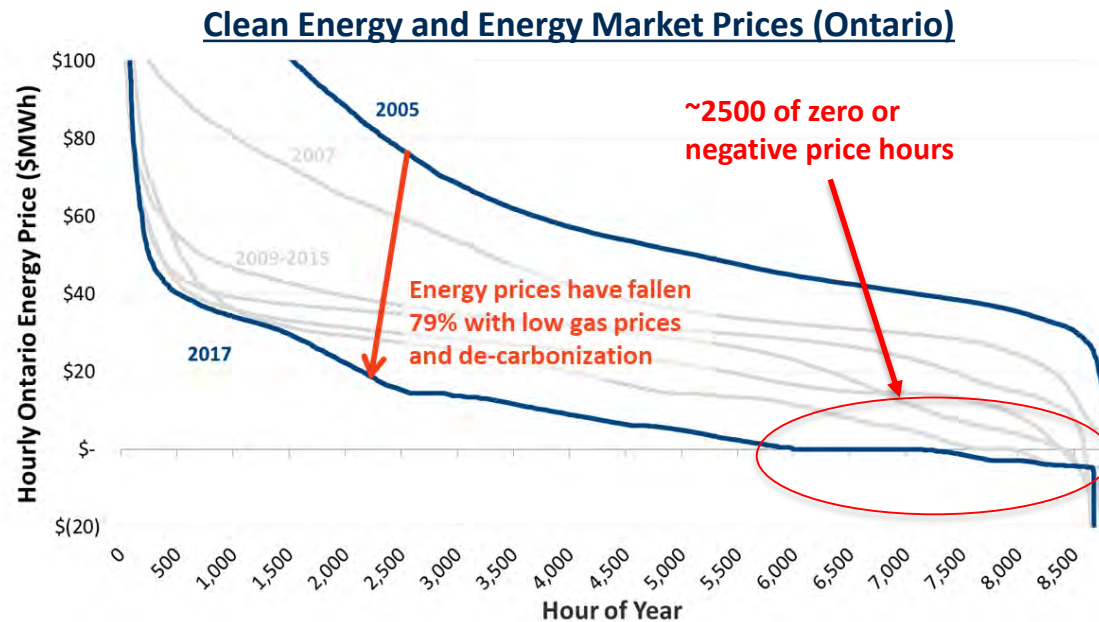
- LA100 assumes significant amounts of renewable PPAs to be signed across all pathways.
 - Renewable curtailment increases significantly after 2030 except for **Early & No Biofuel Scenarios** (e.g., **SB100 Moderate** jumps by nearly 14x from ~134 GWh in 2030 to ~1,864 GWh in 2035).



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>.

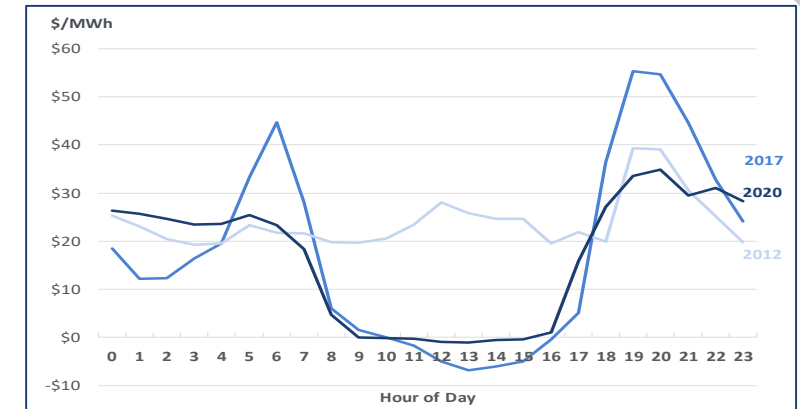
Future Economics of Distributed Solar - 4/5

- Higher renewables will likely have dramatic consequences for power market prices.
 - Ontario, with 90% clean energy fleet, shows ~2,500 hours of zero or negative priced hours.
 - California duck also shows negative prices in mid-day.
 - Will LA follow a similar track where renewables crowd out each other, and if so, will there be incentives for customers to install their own PVs?

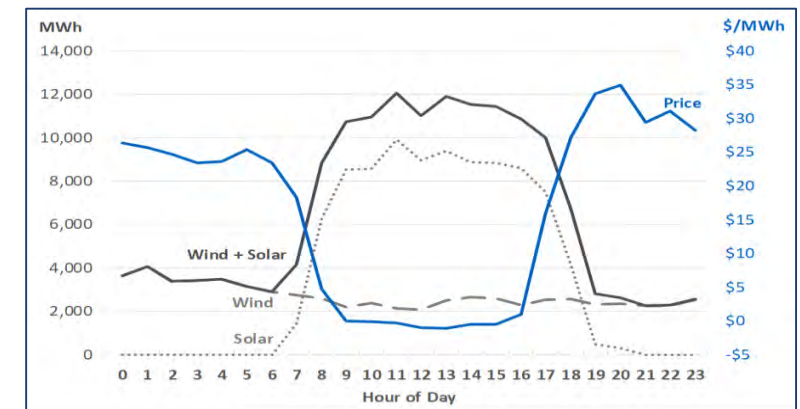


Sources: <http://www.ieso.ca/en/Corporate-IESO/Media/Year-End-Data>

SP15 Day-Ahead Market Prices for the Second Sunday in April



SP15 Day-Ahead Market Prices and Wind and Solar Generation for the Second Sunday in April 2020

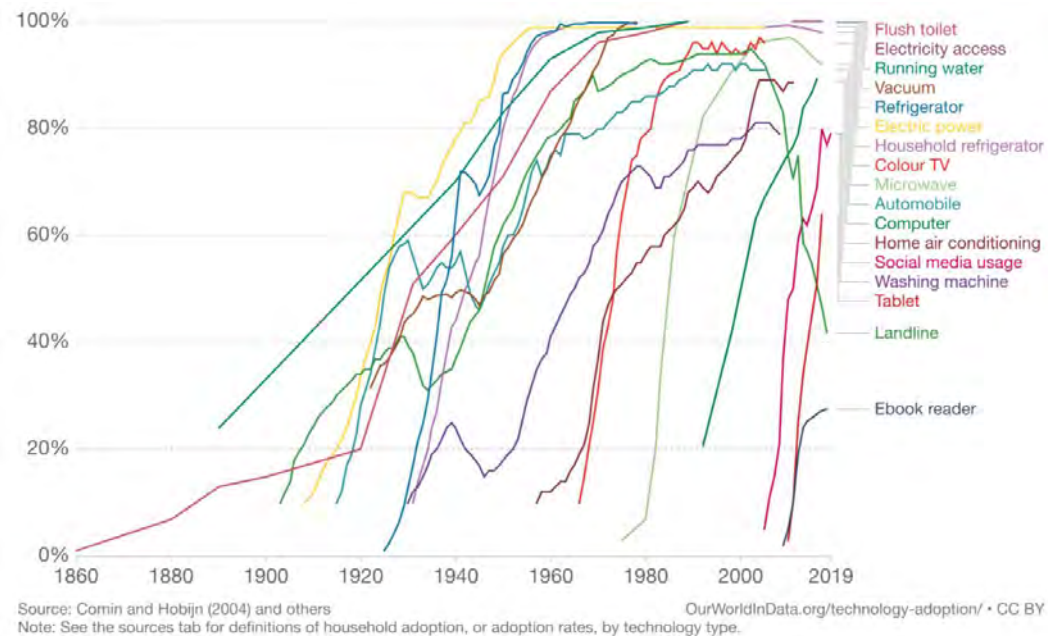


Sources: S&P Market Intelligence and EIA, data as of 1/11/2021

Future Economics of Distributed Solar - 5/5

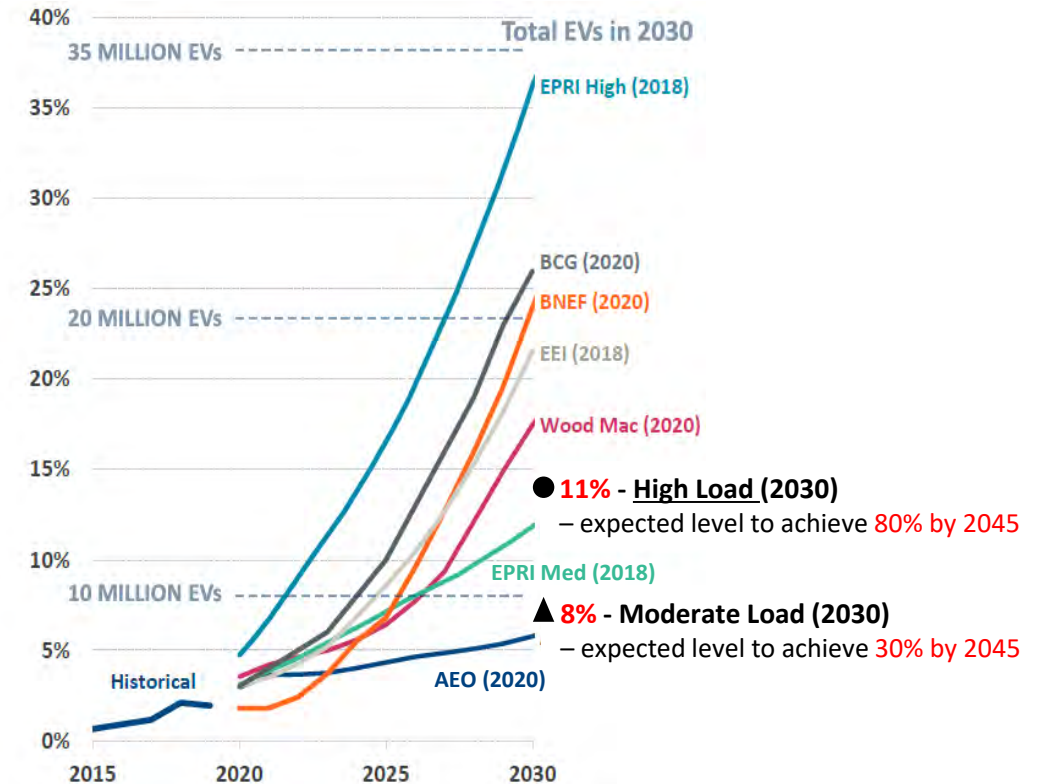
- A wide estimation range of adoption rates and pace has been observed.
 - In general, the adoption rate, once accepted, are very steep, making the prediction even harder.

Technology Adoption in US Households, 1860 to 2019



Projected U.S EV Sales

EV Share of New Vehicle Sales



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.

Market Dynamics and Temporal Responses

+ : reinforcement effects

(e.g., higher fuel prices lead to higher electrification)

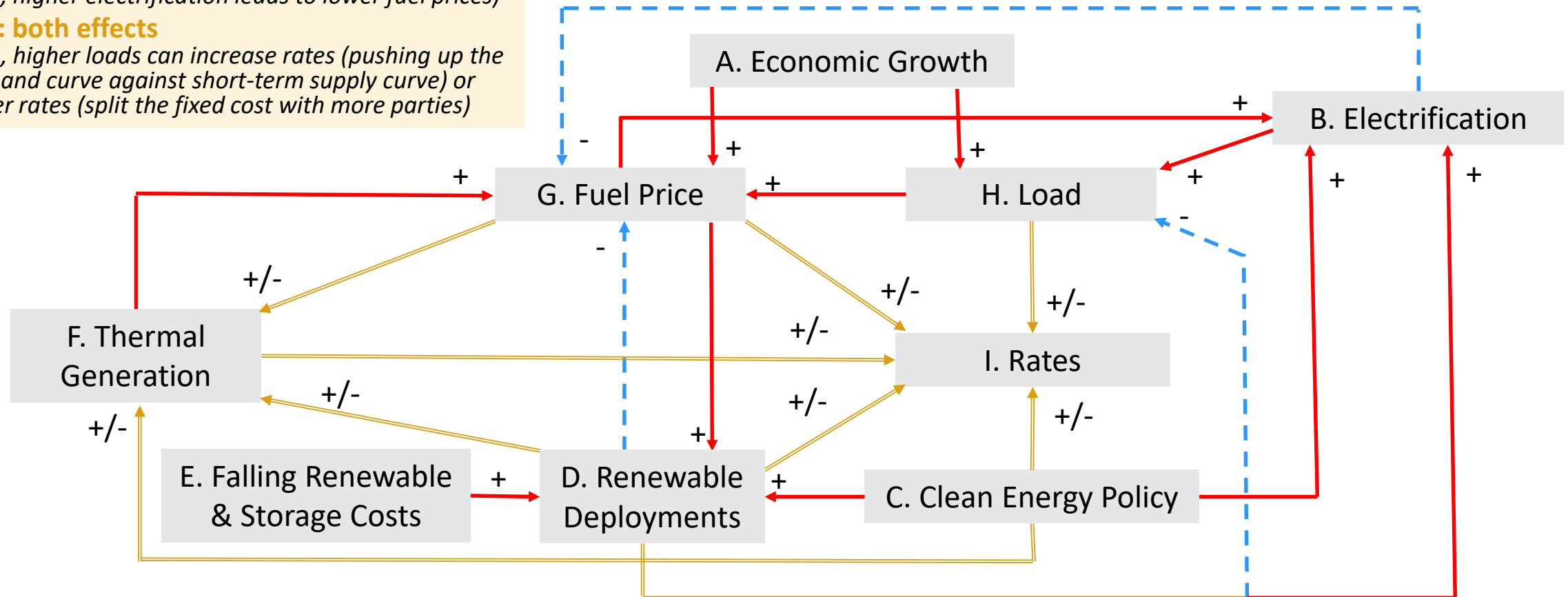
- : balancing effects

(e.g., higher electrification leads to lower fuel prices)

+/- : both effects

(e.g., higher loads can increase rates (pushing up the demand curve against short-term supply curve) or lower rates (split the fixed cost with more parties))

- While the end-point is defined, the timing and pace of change is uncertain.
 - Market dynamics and responses vary and evolve over by time.
 - Impact to rates will depend largely on the timing.

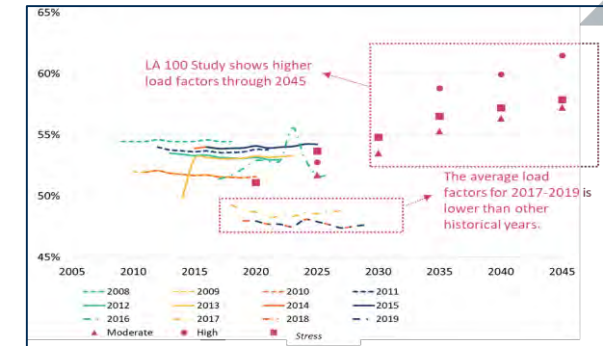


Summary of Observations on Uncertainties

Common observations across all pathways include:

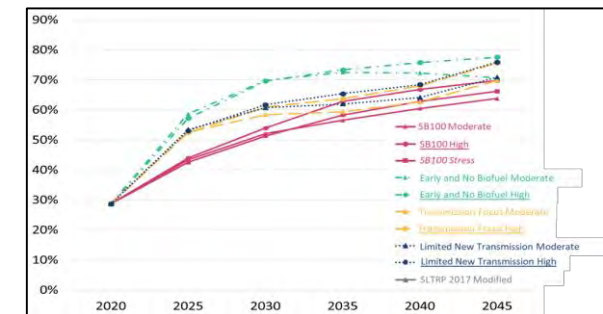
- **Load Uncertainties**
 - Load projections define development needs. While LA100 models different load levels, the historical variation appears much larger, and also change over time.
 - Realized loads are a risk in themselves. The mismatch between load projections that drives investments and actually realized load can swing the rates significantly.
 - Future load factors assumed in LA100 may be optimistic, and potentially leading to lower flexibility needs and lower renewable curtailments—both which would underestimate investment costs.
- **Cost Uncertainties**
 - Generation costs have changed much more than what LA100 assumes. This variable is in addition to the cost variation estimated to occur after 2030.
- **Market Dynamics and Response Timing Uncertainties**
 - More than half of all renewable PPAs (2x to 3x of today's level) 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.
 - Various projections and historical observations suggests a steep adoption rate after a technology is widely accepted—that timing and pace is very difficult to estimate.

Load Factors



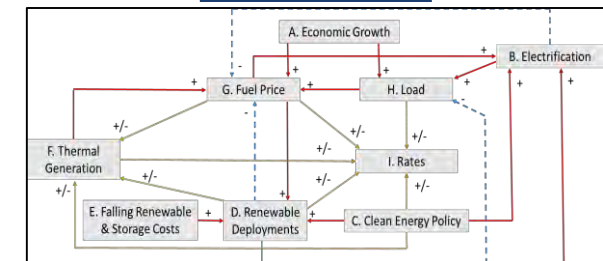
See slide 54

Renewable PPAs



See slide 59

Market Dynamics



See slide 63

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- **Suggestions/Recommendation**
- Appendices



Summary of Observations - 1/3

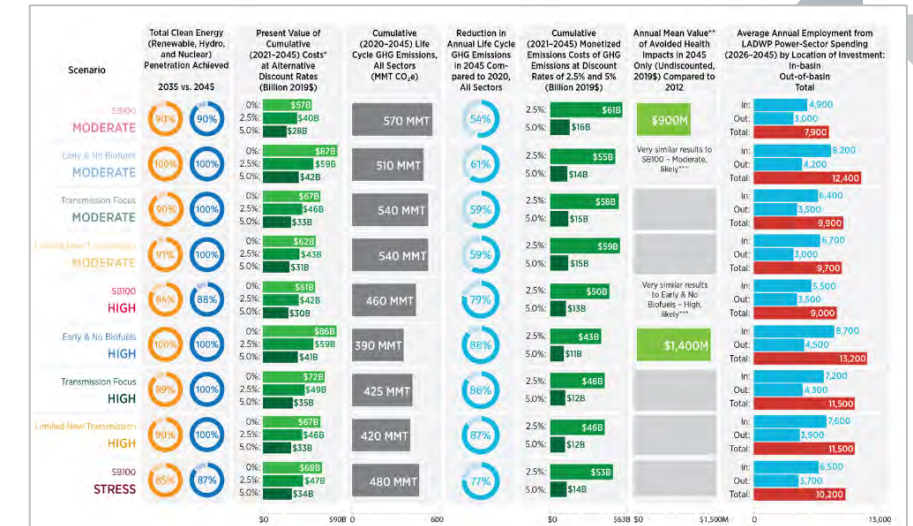
All LA100 pathways are shown to achieve 100% Clean Energy by 2045.

- 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.

High-Level Findings from NREL Executive Summary



Sources: NREL Study Website. <https://www.nrel.gov/docs/fy21osti/79444-ES.pdf> pp. 11.

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 **Transmission Focus Scenarios**). 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.

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.

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- **Appendices**



LA100 Study Financial Assumptions

LA100 Study relies on 2019 ATB Assumptions:

Financial Data Used in Resource Planning Model (RPM)

Name	Value	Information	Source
Inflation Rate	2.50%		ATB2019
Capital Recovery Period	30 years		ATB2019
Interest Rate (real)	1.2% - 3.5%	Varies by technology	ATB2019
Interest During Construction [nominal]	3.9% - 8%	Varies by technology	ATB2019
Rate of Return on Equity (real)	2.45% - 12.45%	Varies by technology	ATB2019
Debt Fraction (real)	40% - 100%	Varies by technology	ATB2019
Tax Rate	25%	Includes federal and states.	ATB2019
Present Value of Depreciation	0.5 - 0.8	Varies by technology	ATB2019
WACC (real)	Calculated using other assumptions		ATB2019

- Key data points include:
 - Cost of debt during the construction and operation of the asset (the cost of equity during construction is NOT included).
 - Amount of debt provided during construction.
 - Required debt service coverage ratio (DSCR) debt providers used to determine the amount of debt (i.e., leverage) they would provide to a project during the operation of the asset.

Sources and notes: ATB assumptions from <https://atb.nrel.gov/electricity/2020/finance-impact.php>; Financial Data table from <https://www.nrel.gov/docs/fy21osti/79444-6.pdf>, Table 32.

Market Dynamics Diagram Narrative - 1/3

A. Economic Growth -> G. Fuel Prices

- + Increase in economic growth leading to higher fuel consumption.

A. Economic Growth -> H. Load

- + Increase in economic growth leading to higher consumption and load growth.

B. Electrification -> G. Fuel Price

- - Higher electrification leading to lower fuel consumption.

B. Electrification -> H. Load

- + Higher electrification leading to higher load.

C. Clean Energy Policy -> B. Electrification

- + Stronger clean energy policies leading to increased electrification (either directly or indirectly).

C. Clean Energy Policy -> D. Renewables Deployment

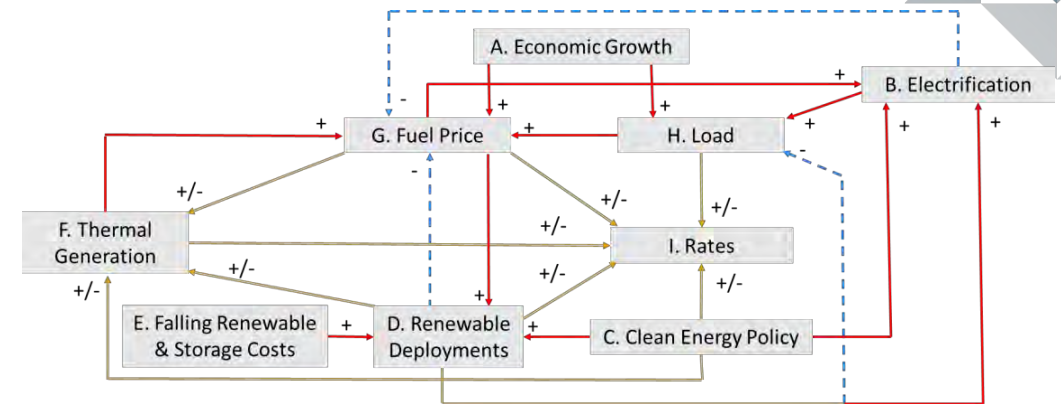
- + Stronger clean energy policies leading to increased renewables (either directly or indirectly).

C. Clean Energy Policy -> F. Thermal Generation

- - Stronger clean energy policies leading to increased retirements of thermal generation.
- + Clean energy policies favoring nuclear (and providing subsidies), or favoring gas over coal.

C. Clean Energy Policy -> I. Rates

- + Clean energy policies reducing energy prices in the short-run.
- - Clean energy policies requiring additional investments, leading to higher fixed costs.



Market Dynamics Diagram Narrative - 2/3

D. Renewable Deployments -> B. Electrification

- + Increased renewables deployment lowering energy prices and increasing electrification.

D. Renewable Deployments -> F. Thermal Generation

- + Increased renewables deployment requiring more ramping capabilities and leading to higher capacity prices.
- - Increased renewables reducing generation from thermal resources and further lowering energy prices, leading to earlier retirements.

D. Renewable Deployments -> G. Fuel Price

- - Increased renewables deployment reducing fuel demand for power generation.

D. Renewable Deployments -> H. Load

- - Increased distributed renewables reducing net load.

D. Renewable Deployments -> I. Rates

- + Renewables deployment requiring more investments.
- - Increased renewables deployment lowering energy prices.

E. Falling Renewable & Storage Costs -> D. Renewable Deployments

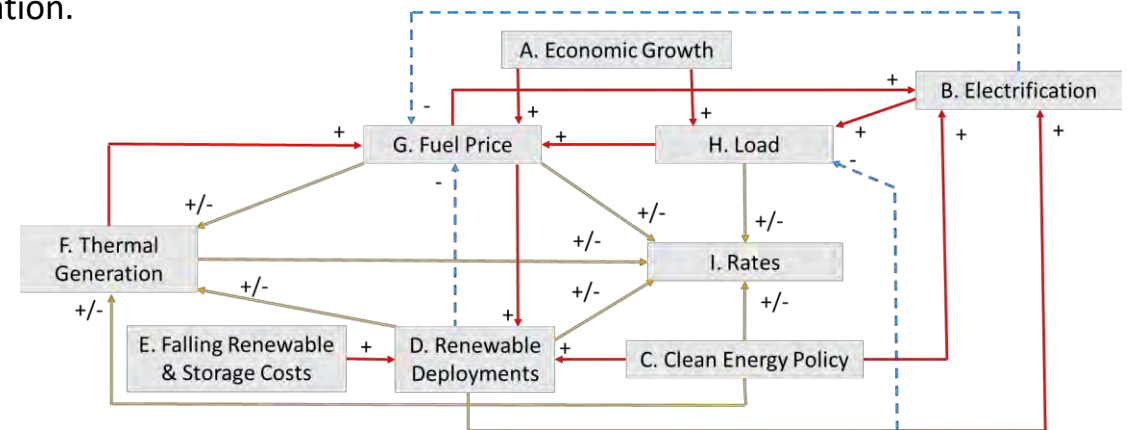
- + Lower prices will increase renewables deployments.

F. Thermal Generation -> G. Fuel Price

- + More thermal generation needs putting upward pressure on fuel prices.

F. Thermal Generation -> I. Rates

- + More thermal generation increasing short-run energy costs.
- - More generation from depreciated thermal assets lowering fixed costs.



Market Dynamics Diagram Narrative - 3/3

G. Fuel Price -> B. Electrification

- + Higher fuel prices encouraging electrification.

G. Fuel Price -> D. Renewable Deployments

- + Higher fuel prices increasing thermal generation cost and encouraging renewable deployment.

G. Fuel Price -> F. Thermal Generation

- + Higher fuel prices increasing energy prices and net revenues for thermal generation.
- - Higher fuel prices decreasing generation from thermal generation and net revenue.

G. Fuel Price -> I. Rates

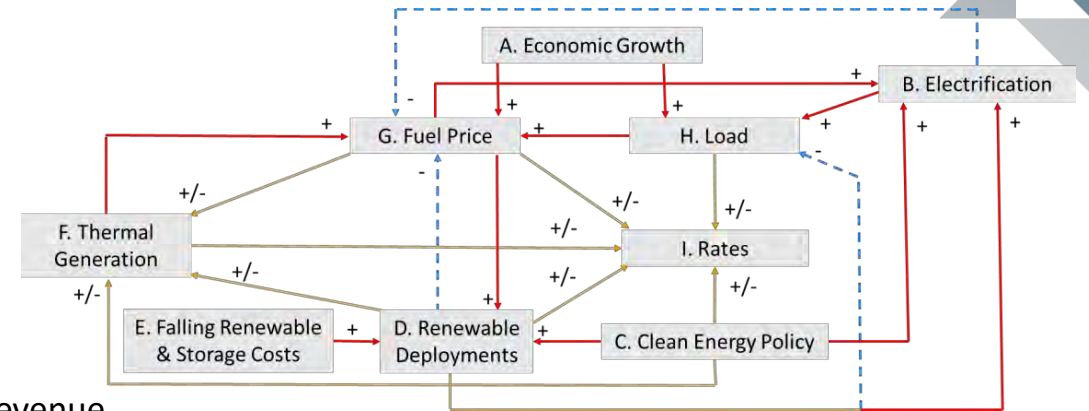
- + Higher fuel prices increasing short-run energy costs.
- - Higher fuel price reducing generation from thermal resources, leading to lower rates.

H. Load -> G. Fuel Price

- + Higher load increasing fuel needs for generation, putting upward pressure on prices.

H. Load -> I. Rates

- + Higher load will increase needs for generation, pushing the demand curve up the supply curve.
- - Higher load may result in lower share of fixed costs.



Glossary

ATB: Annual Technology Baseline

CapEx: Capital Expenses

CO2e: Carbon Dioxide Equivalents

CT: Combustion Turbine

DSCR: Debt Service Coverage Ratio

DR: Demand Response

EE: Energy Efficiency

EV: Electric Vehicles

FERC: Federal Energy Regulatory Commission

FSO: Financial Services Office

GHG: Greenhouse Gas

GW: Gigawatt

GWh: Gigawatt hour

H2: Hydrogen

IRP: Integrated Resource Plan

LA: Los Angeles

LADWP: Los Angeles Department of Water and Power

LCOE: Levelized Cost of Energy

MW: Megawatt

MWh: Megawatt hour

MMT: Millions Metric Ton

NEL: Net Energy for Load

NO_x: Nitrogen Oxides

NREL: National Renewable Energy Laboratory

O₃: Ozone

OPA/RPA: Office of Public Accountability/Ratepayer Advocate

OpEx: Operating Expenses

PM_{2.5}: Fine Particulate Matters

PPA: Power Purchase Agreement

PV: Photovoltaic

RE: Renewable

SB100: Senate Bill 100

SF6: Sulfur Hexafluoride

SLTRP: Strategic Long-Term Resource Plan

SP15: the South of Path 15 Zone of the California ISO Control Area

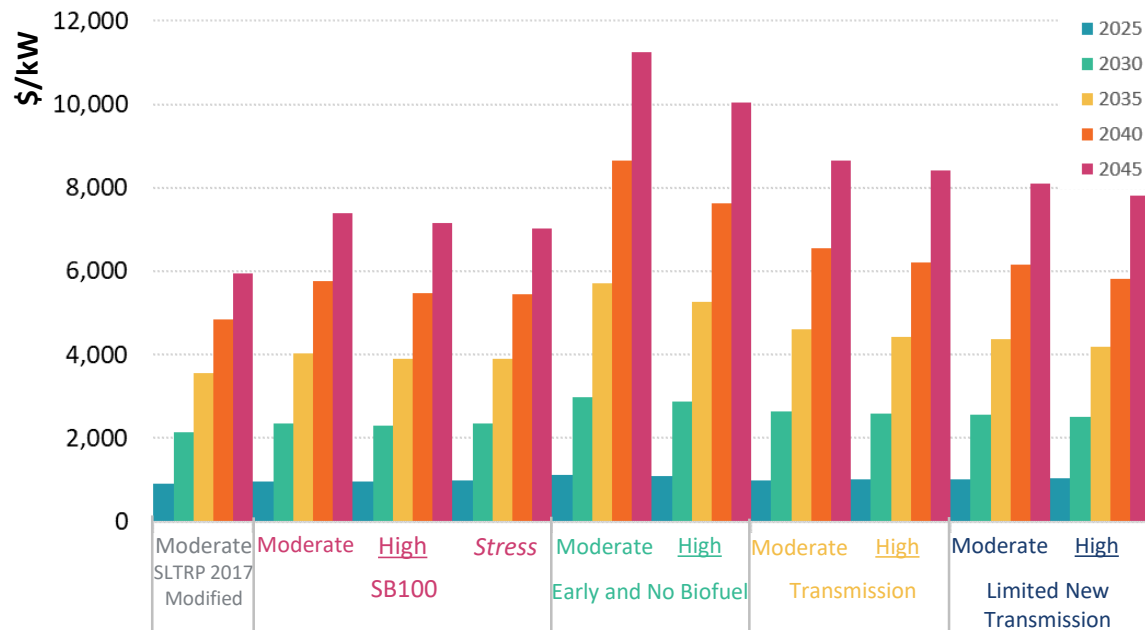
T: Tonne, metric ton

WACC: Weighted Average Cost of Capital

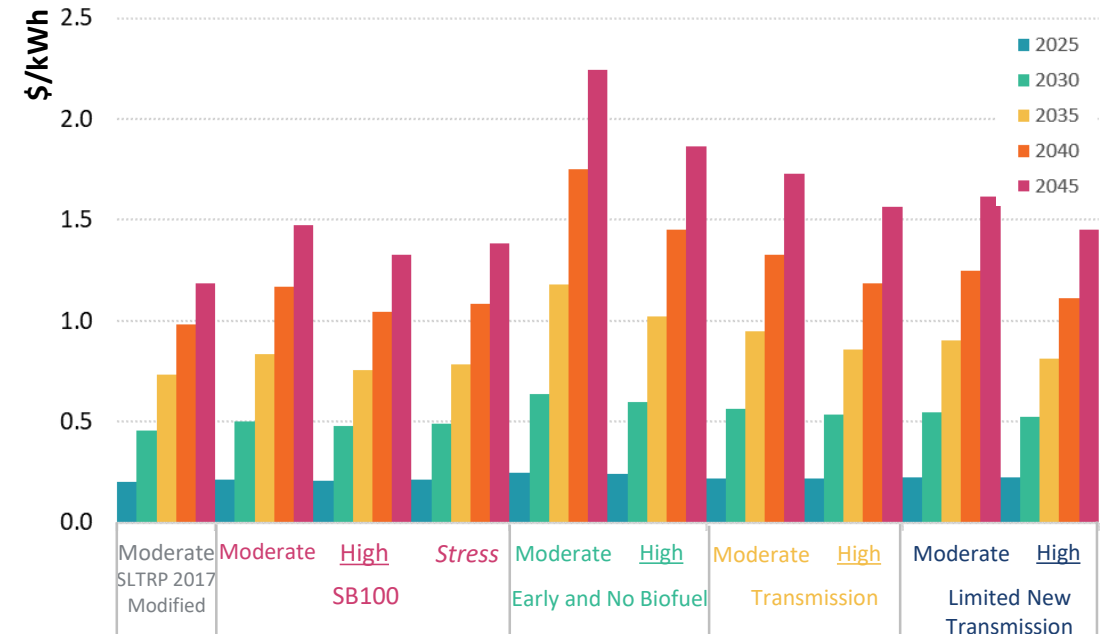
Estimated Unit Cost by Pathway - 1/3

- Unit price per peak load and unit price per energy consumption show a similar trend with the total expenditure (slide 14).

Unit Price per Peak Load by Scenario (Total Costs)



Unit Price per Energy Consumption by Scenario (Total Costs)



Sources and notes: SLTPR 2017 Modified extends only through 2036. Cost and Load data from NREL Study website,

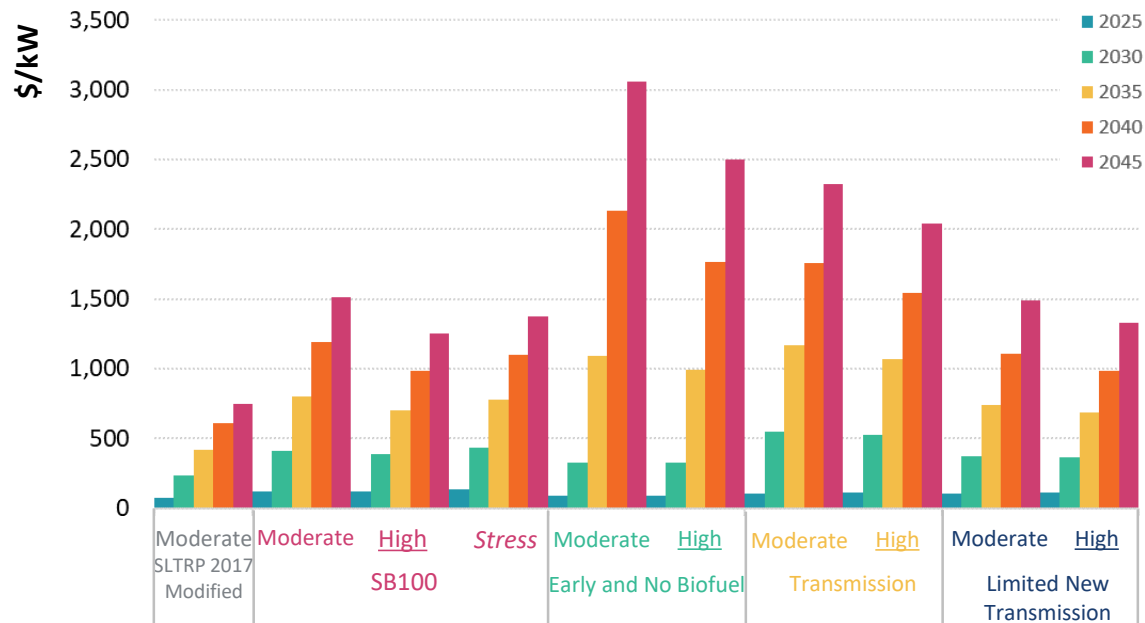
https://maps.nrel.gov/la100/data-viewer?Theme=system-costs&Resolution=lc&LoadScenario=moderate&RpmScenario=sb100&LayerId=xmission.cost&Year=2045&Variable=dllrs_millions and Data from NREL Study website, <https://maps.nrel.gov/la100/data-viewer?Theme=electricity-demand&SubTheme=electricity-consumption&Resolution=lc&LoadScenario=moderate&LayerId=electricity-demand.peak-demand&Year=2045&Variable=kwh&TemporalResolution=annual&TimePeriod=peak>.

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. Unit price per peak load is calculated as expenditure in million dollars on slide 14 divided by energy peak load of MW on slide 51. Unit price per energy consumption is calculated as expenditure in million dollars on slide 14 divided by energy consumption in GWh on slide 52.

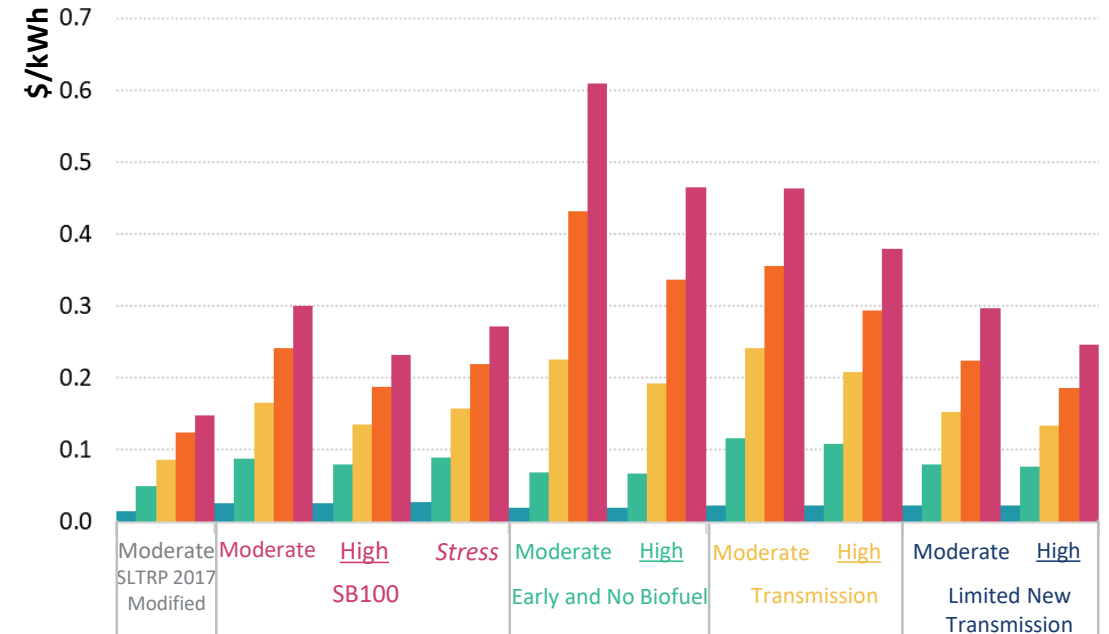
Estimated Unit Cost by Pathway - 2/3

- Unit price per peak load and unit price per energy consumption show a similar trend with the total CapEx (slide 18).

Unit Price per Peak Load by Scenario (CapEx)



Unit Price per Energy Consumption by Scenario (CapEx)



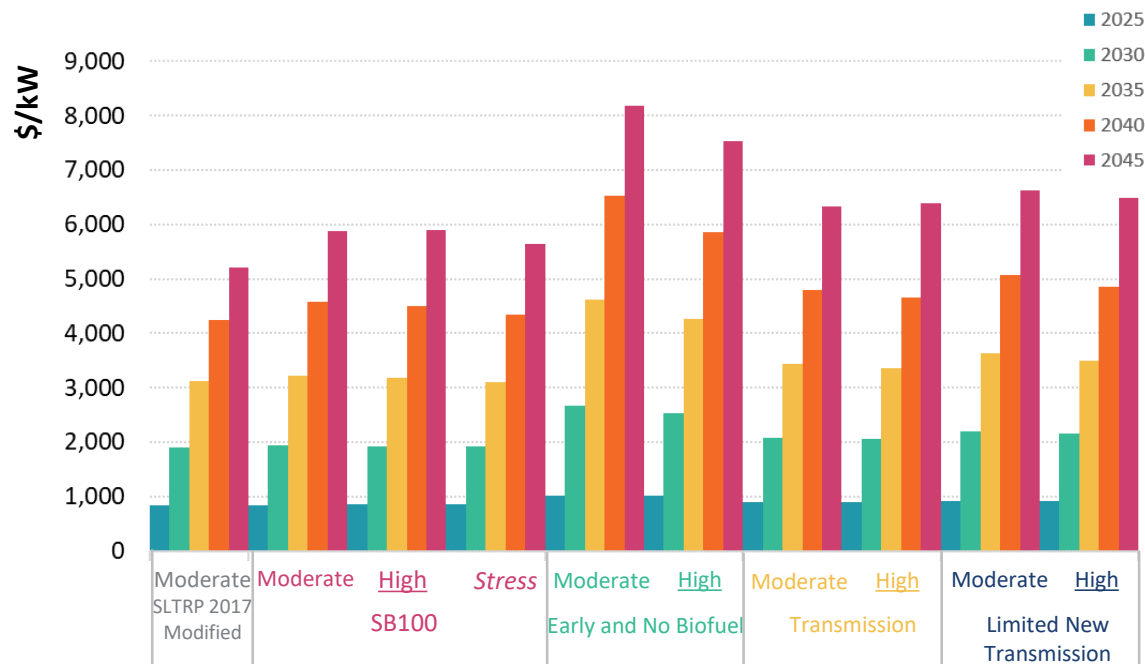
Sources and notes: SLTPR 2017 Modified extends only through 2036. Cost and Load data from NREL Study website, https://maps.nrel.gov/la100/data-viewer?Theme=system-costs&Resolution=lc&LoadScenario=moderate&RpmScenario=sb100&LayerId=xmission.cost&Year=2045&Variable=dllr_millions and Data from NREL Study 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>.

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. Unit price per peak load is calculated as expenditure in million dollars on slide 18 divided by energy peak load of MW on slide 51. Unit price per energy consumption is calculated as expenditure in million dollars on slide 18 divided by energy consumption in GWh on slide 52.

Estimated Unit Cost by Pathway - 3/3

- Unit price per peak load and unit price per energy consumption show a similar trend with total OpEx (slide 24).

Unit Price per Peak Load by Scenario (OpEx)



Unit Price per Energy Consumption by Scenario (OpEx)

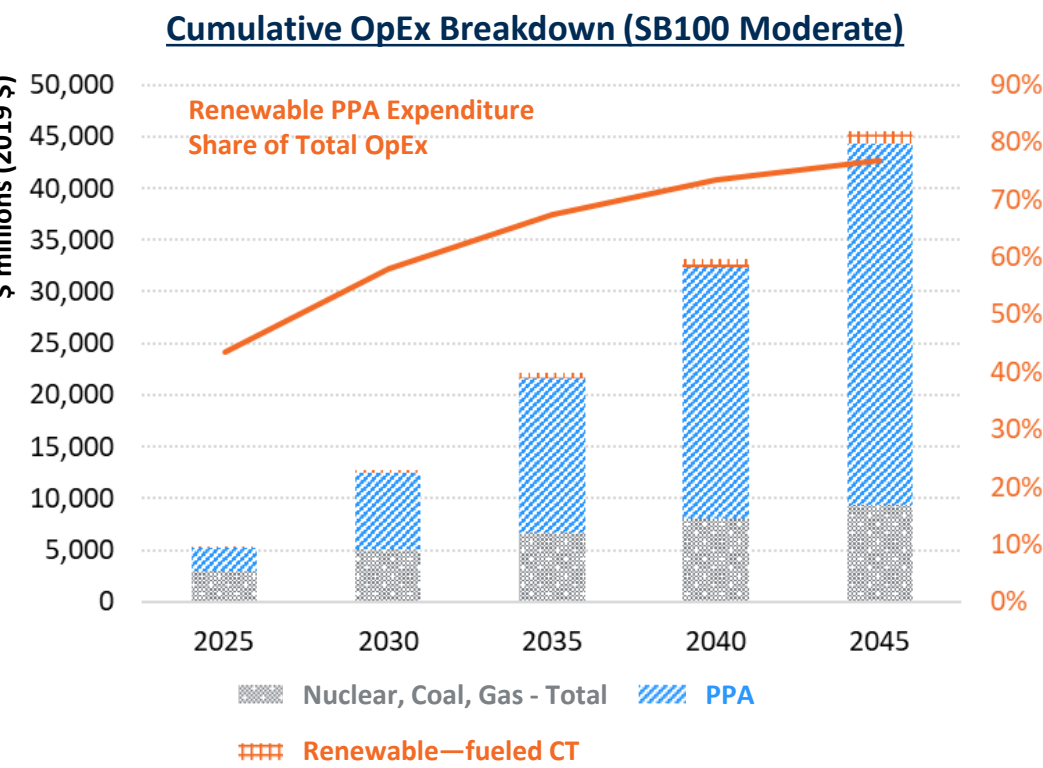


Sources and notes: SLTPR 2017 Modified extends only through 2036. Cost and Load data from NREL Study website, https://maps.nrel.gov/la100/data-viewer?Theme=system-costs&Resolution=lc&LoadScenario=moderate&RpmScenario=sb100&LayerId=xmission.cost&Year=2045&Variable=dlrs_millions and Data from NREL Study 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>.

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. Unit price per peak load is calculated as expenditure in million dollars on slide 24 divided by energy peak load of MW on slide 51. Unit price per energy consumption is calculated as expenditure in million dollars on slide 24 divided by energy consumption in GWh on slide 52.

Estimated OpEx by Pathway - 1/2

- Renewable PPAs share the bulk of the OpEx and generally increase over the years.
 - The exception is the **Early and No Biofuel Scenarios**, which show much higher costs (total, CapEx, and OpEx) over other pathways.



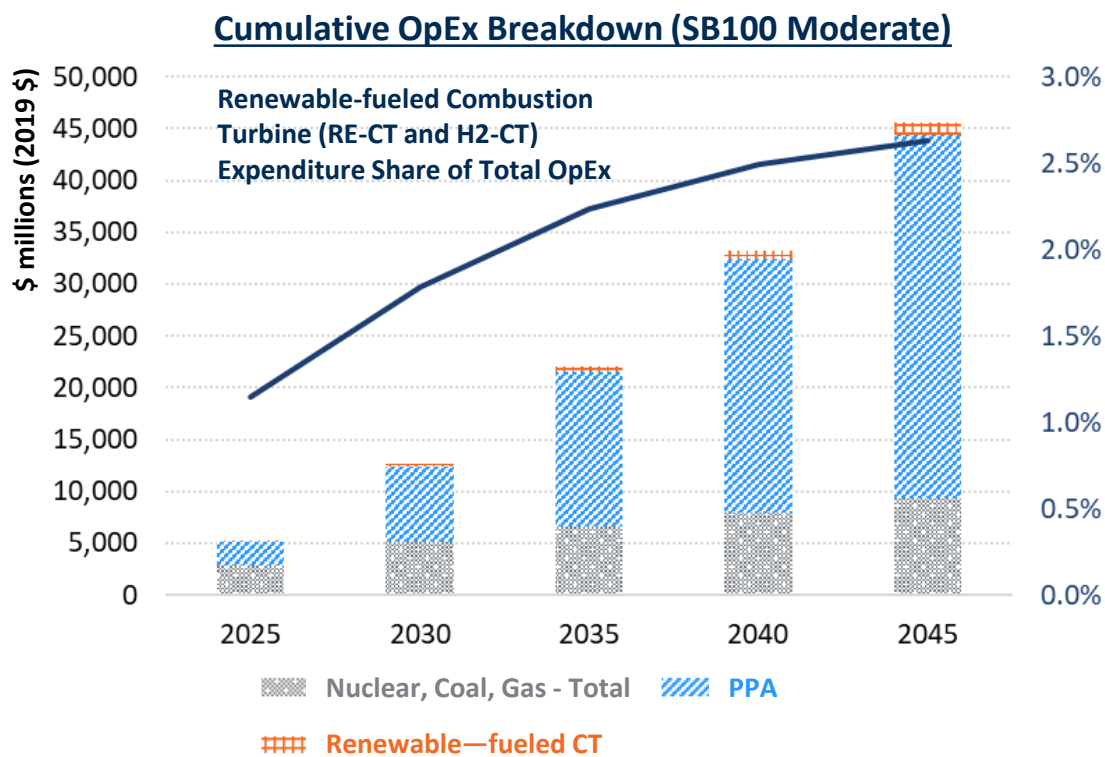
Renewable PPA Expenditures by Pathways (% of Total OpEx)

Pathways	2025	2030	2035	2040	2045
SLTRP 2017 Modified	45%	58%	65%		
SB100 Moderate	43%	58%	68%	74%	77%
SB100 High	44%	59%	68%	74%	77%
SB100 Stress	42%	56%	66%	72%	75%
Early & No Biofuels Moderate	71%	86%	90%	91%	91%
Early & No Biofuels High	69%	85%	89%	91%	91%
Transmission Focus Moderate	60%	74%	80%	82%	83%
Transmission Focus High	59%	75%	80%	83%	82%
Limited New Transmission Moderate	60%	75%	81%	83%	84%
Limited New Transmission High	60%	76%	82%	84%	85%

Sources and notes: SLTRP 2017 Modified extends only through 2036. Other renewables (including wind, solar and geothermal) are assumed to be PPAs. 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=dllrs_millions.

Estimated OpEx by Pathway - 2/2

- While the H2-CT and RE-CT shares of the CapEx (3 to 5 GW of capacity by 2045) is significant (see slides 20 and 21), their share of OpEx is minuscule.



Renewable-fueled CT OpEx by Pathways (% of Total OpEx)					
Pathways	2025	2030	2035	2040	2045
SLTRP 2017 Modified	0%	0%	0%	1%	1%
SB100 Moderate	1%	2%	2%	2%	3%
SB100 High	1%	2%	2%	2%	2%
SB100 Stress	1%	3%	3%	3%	3%
Early & No Biofuels Moderate	0%	1%	2%	4%	5%
Early & No Biofuels High	0%	1%	2%	3%	4%
Transmission Focus Moderate	1%	1%	2%	2%	5%
Transmission Focus High	1%	1%	2%	2%	6%
Limited New Transmission Moderate	1%	1%	2%	2%	5%
Limited New Transmission High	1%	1%	2%	2%	4%

Sources and notes: SLTRP 2017 Modified extends only through 2036. Other renewables (including wind, solar and geothermal) are assumed to be PPAs. 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.

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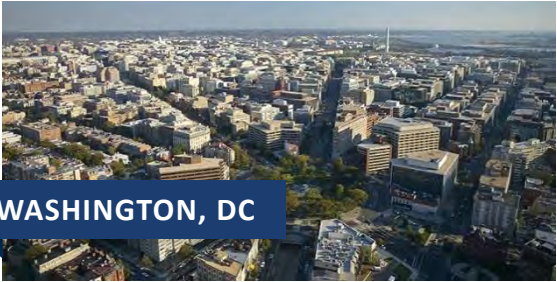
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