LA100

The Los Angeles 100% Renewable Energy Study

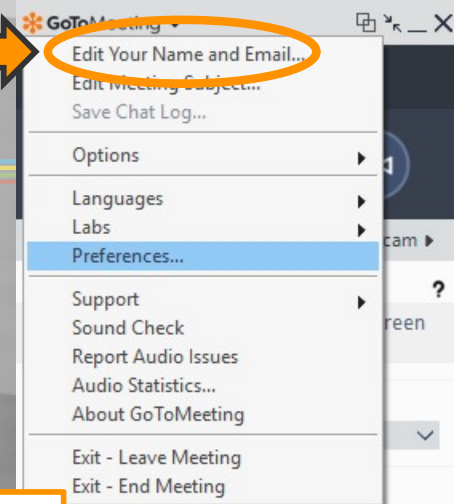
Advisory Group Meeting #13

Virtual Meeting #3

LA DWP Los Angeles Department of Water & Power | NREL Transforming ENERGY

The Los Angeles 100% Renewable Energy Study

Welcome to the LA100 Advisory Group meeting!
Please consider adding your affiliation to your name identification.



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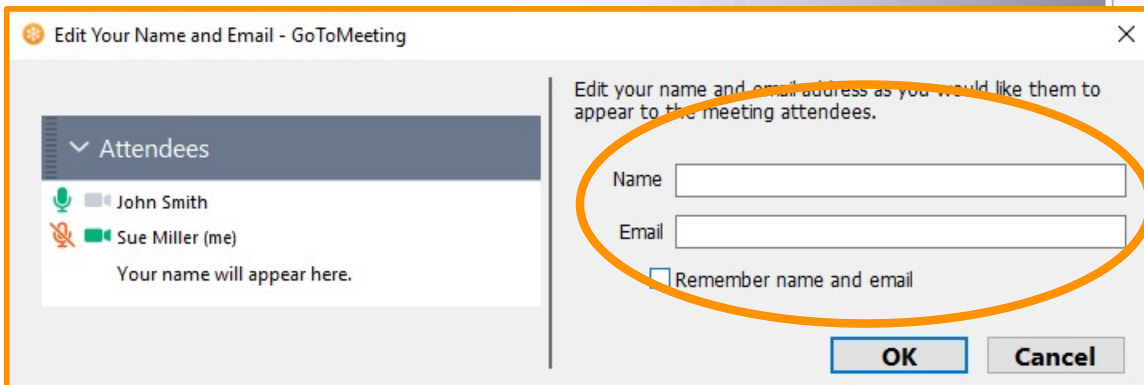

Los Angeles Department of Water & Power

NREL Transforming ENERGY

Advisory Group #13 Agenda

October 1
- Community outreach and engagement – LA100 and more broadly (LADWP, NREL)
- Demonstration of Interactive Website (NREL)
- Discussion/Q&A

October 8
- 100% RE Investment Pathways, Part 1: Technology and Cost Sensitivity Analysis
- Discussion/Q&A

Today (October 22)
- Welcome
- Greenhouse Gas Emissions, Power & Non-Power Sectors
- Update to Air Quality Modeling Methods
- Discussion/Q&A

October 29
- 100% RE Investment Pathways, Part 2: Reliability
- Discussion/Q&A

Tips for Productive Discussions

Let one person speak at a time

Keep phone/computer on mute until ready to speak

Help ensure everyone gets equal time to give input

Type “Hand” in Chat Function to raise hand

Keep input concise so others have time to participate

Also make use of Chat function

Actively listen to others, seek to understand perspectives

Offer ideas to address questions and concerns raised by others

Hold questions until after presentations

LA100

The Los Angeles 100% Renewable Energy Study

Greenhouse Gas Emissions Impacts

Power, Buildings, and Transportation Sectors

Advisory Group Meeting #13, Virtual Meeting #3

Garvin Heath

National Renewable Energy Laboratory

October 22, 2020

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Methods for Greenhouse Gas (GHG) Analysis – Recap and Update

Scope of GHG Analysis

- NREL's bulk power model directly estimates CO_2 emissions from combustion
- The study could simply use this and finish there
  - This is perhaps where most analysts would stop

Goal of GHG Analysis: Include All *Attributable* GHG Emissions from Each Scenario

Besides power-sector combustion, other GHG emissions are attributable to LA100 scenarios:

1. **Every electric generation technology, even renewable, must be built, operated, and decommissioned—and those activities have GHG emissions**
   - Life-cycle assessment (LCA) is a well-recognized method to quantify emissions

2. **Other GHGs besides CO_2—methane, nitrous oxide—are important for certain generation technologies, including renewable ones**
   - Examples include biogas sources (landfill gas, wastewater treatment plants, etc.)
     - Note that biomass CO_2 emissions are considered balanced by the prior plant uptake of CO_2 and thus is net zero, as per EPA guidance
   - SF_6 has not been a gas of focus for most prior studies because of its small contribution to total GHG emissions (CO_2e), but it is included here based on our method

3. **In addition to the electric sector, buildings and transportation are also affected by LA100 scenarios in ways that reduce their GHG emissions**

Life-Cycle Assessment (LCA): Quantifying Attributable Impacts (e.g., Energy Choices)

LCA quantifies resource consumption, energy use, and emissions, from cradle to grave

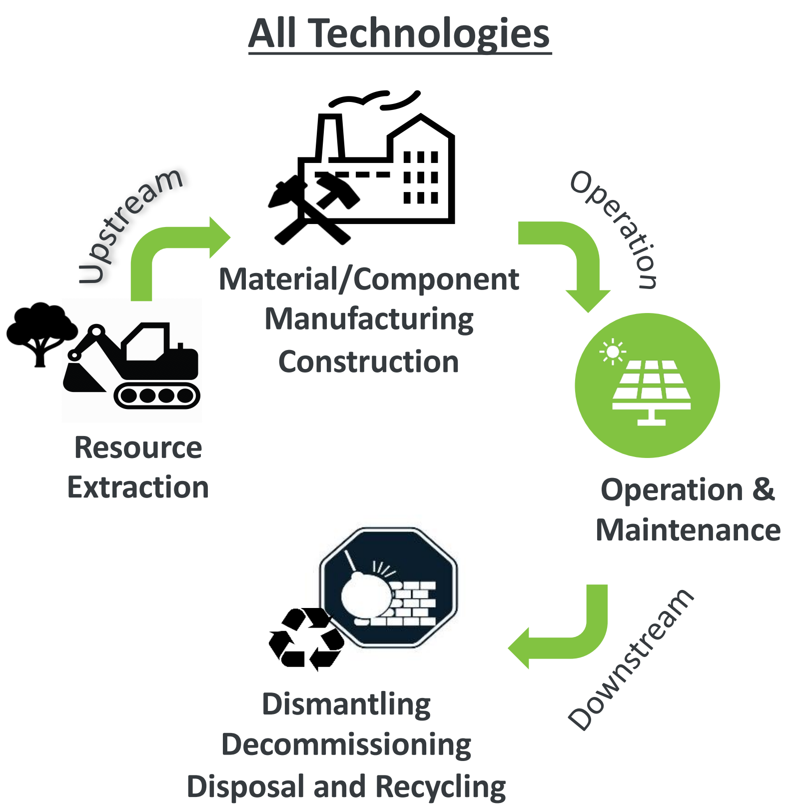
- Practiced for 40 years
- Methods codified in standards and guidelines

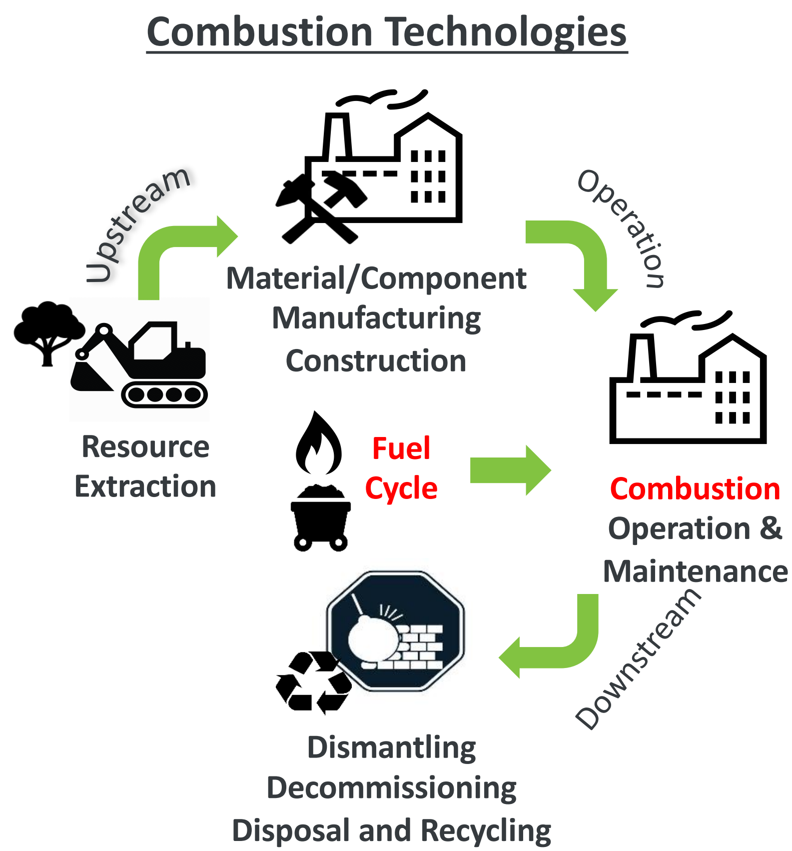
Forms a basis for consistent comparison of renewable and conventional energy technologies; internationally recognized and used in, e.g., Intergovernmental Panel on Climate Change (IPCC) reports

Typical metrics:

- GHG emissions
- Water consumption and discharges
- Energy use
- Raw material consumption
- Air pollutant emissions

Life-Cycle Assessment (LCA): Quantifying Attributable Impacts (e.g., Energy Choices)





Assumptions and Caveats

- **Power sector**:
  - Includes the **full life cycle of emissions** associated with electricity generation technologies (including construction, operation, and decommissioning) as well as emissions associated with fuels (combustion and the fuel cycle)
  - We do not consider GHG emissions from **other electric infrastructure** (e.g., transmission lines, distribution lines, substations)
- **Buildings** (residential and commercial) and **Transportation** (light-duty vehicles and buses) sources
  - Only emissions associated with **fuel combustion and the fuel cycle** (fuel extraction, processing and transport) are considered
  - We do not account for life-cycle GHG emissions associated with **changes to infrastructure outside the power sector** (e.g., equipment to electrify buildings or vehicles, charging stations)
- Loads assumptions have been presented in prior Advisory Group (AG) meetings and are on the LA100 website

General Approach to Estimating Life-Cycle GHG Emissions
Step 1: **Power sector combustion**

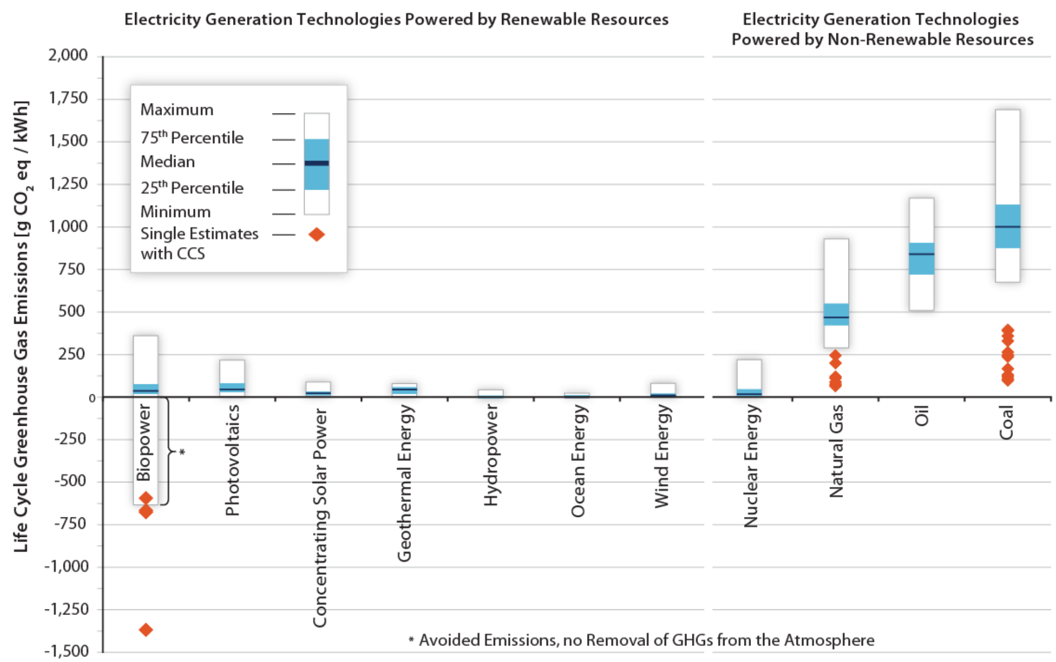
Production cost model used in LA100 directly estimates combustion CO_2 emissions based on fuel burn and fuel carbon content

General Approach to Estimating Life-Cycle GHG Emissions Step 2: **Power Sector Non-Combustion Life Cycle**

NREL's prior systematic review of LCAs provides estimates for non-combustion GHG emissions, including non-CO_2 emissions:

- Three additional life-cycle phases:
  1. **Upstream** materials manufacturing and plant construction (per unit capacity)
  2. **Downstream** plant decommissioning (per unit capacity)
  3. **Ongoing operations and maintenance**, as well as fuel cycle emissions that are modulated by generation (per unit generation)
- Two technologies not previously evaluated: **battery storage** and **fuel cells**
  - Followed the same systematic literature review approach as for all prior evaluations

Systematic Review of ALL Published LCAs: IPCC Special Report on Renewables (2012)



	Biopower	Photovoltaics	Concentrating Solar Power	Geothermal Energy	Hydropower	Ocean Energy	Wind Energy	Nuclear Energy	Natural Gas	Oil	Coal
Count of Estimates	222(+4)	124	42	8	28	10	126	125	83(+7)	24	169(+12)
Count of References	52(+0)	26	13	6	11	5	49	32	36(+4)	10	50(+10)

NREL NATIONAL RENEWABLE ENERGY LABORATORY

ipcc INTERGOVERNMENTAL PANEL ON climate change

IPCC SRREN, Summary for Policy Makers, Fig. 8

CCS = carbon capture and sequestration

Includes the data used in LA100, plus about 500 more studies subsequently reviewed (total close to 3,000, with consistent results to these)

General Approach to Estimating Life-Cycle GHG Emissions Step 3: **Buildings and Transportation Combustion**

Fuels evaluated

- Buildings (residential and commercial):
  - Space and water heating and cooking: natural gas
    - No blending of renewable natural gas is considered as there is no mandate nor reporting to CARB of its historic use
  - All other fuels have negligible use in LA
    - For instance, the 2^{nd} most used fuel, propane, is used by only 0.3% of residential buildings and no commercial ones
- Transportation
  - Light-duty vehicles: gasoline (with 2% ethanol blended)
  - Buses (school and transit):
    - Gasoline,
    - Diesel (with some renewable diesel blending),
    - Natural gas (CNG; with some renewable natural gas blending as reported to CARB)

General Approach to Estimating Life-Cycle GHG Emissions
Step 3: **Buildings and Transportation Combustion**

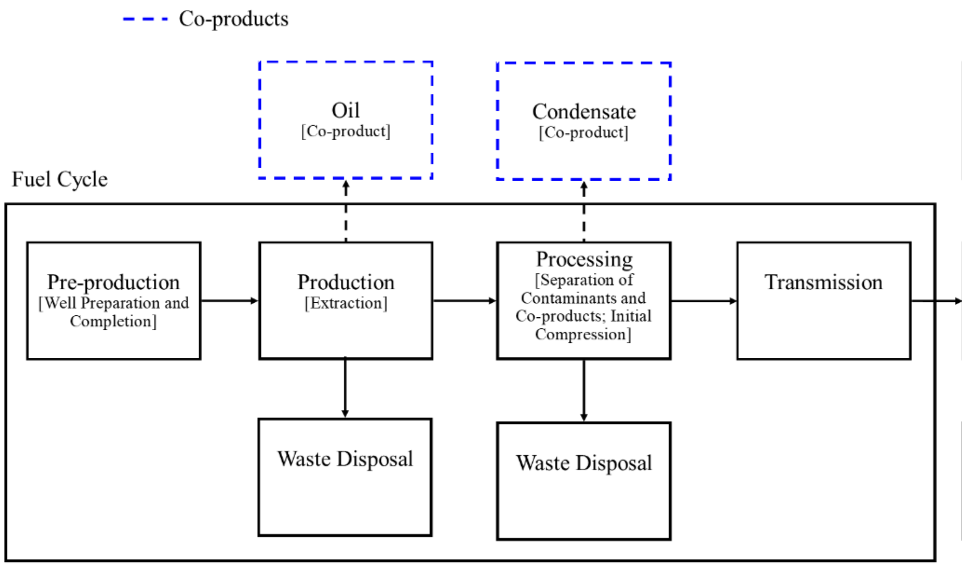
- Fuel use
  - **Residential and commercial building** fuel use based on NREL energy models as used in load modeling for LA100
    - Based on projections of population (stock), economic growth, adoption of more energy-efficient appliance (beyond code appliances) and management practices, and the rate of appliance electrification
  - **Light-duty vehicles:**
    - LA100 EV adoption projections yield fraction of gasoline-powered vehicles;
    - Vehicle Miles Travelled (VMT) from CARB's EMFAC model for each vehicle class;
    - Fuel economy from CARB's CA-GREET3.0
  - **Buses:** 100% electrified by 2030
    - Prior years fleet size from CARB's EMFAC;
    - VMT from FleetDNA
- GHG emission factors per fuel
  - GHG emission factors (mass emission per unit of fuel combusted) are from CARB's CA-GREET3.0 using default assumptions

General Approach to Estimating Life-Cycle GHG Emissions Step 4: **Buildings and transportation non-combustion fuel cycle**

Estimate **fuel cycle emissions** for fuel use in buildings and transportation sources:

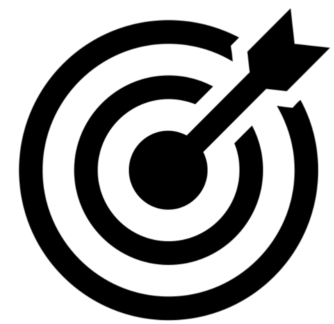
- Extraction, processing, and transportation of fuels to the site of use (combustion)
  - Includes estimates of fuel "leakage" (intentional and unintentional) in the supply chain
  - Does not include specific accidents or incidents, but does account for some probability of these kinds of events over long time periods
  - Not LA-specific infrastructure
- GHGs considered align with the CA Low Carbon Fuel Standard: CO_2, methane, nitrous oxide, volatile organic compounds, and carbon monoxide
- GHG emission factors (mass emission per unit of fuel combusted) are from CA-GREET3.0 using default assumptions from the model

Natural Gas Fuel Cycle



California Statewide GHG Emissions Targets

- In 2005, Executive Order S-3-05 set a target for statewide GHG emissions **80% below 1990 levels** by 2050
  - Approximately 350 Million Metric Tonnes (MMT) CO_2e/yr lower than the 1990 level
- AB 32 (2006) established a CA GHG reduction target of getting back to 1990 GHG emission levels by 2020, which was achieved in 2017
- Executive Order B-30-15 (2015) and SB 32 (2016) established another intermediate CA GHG reduction target of **40% below 1990 levels** by 2030
  - Approximately 172 MMTCO_2e/yr lower than 1990 level



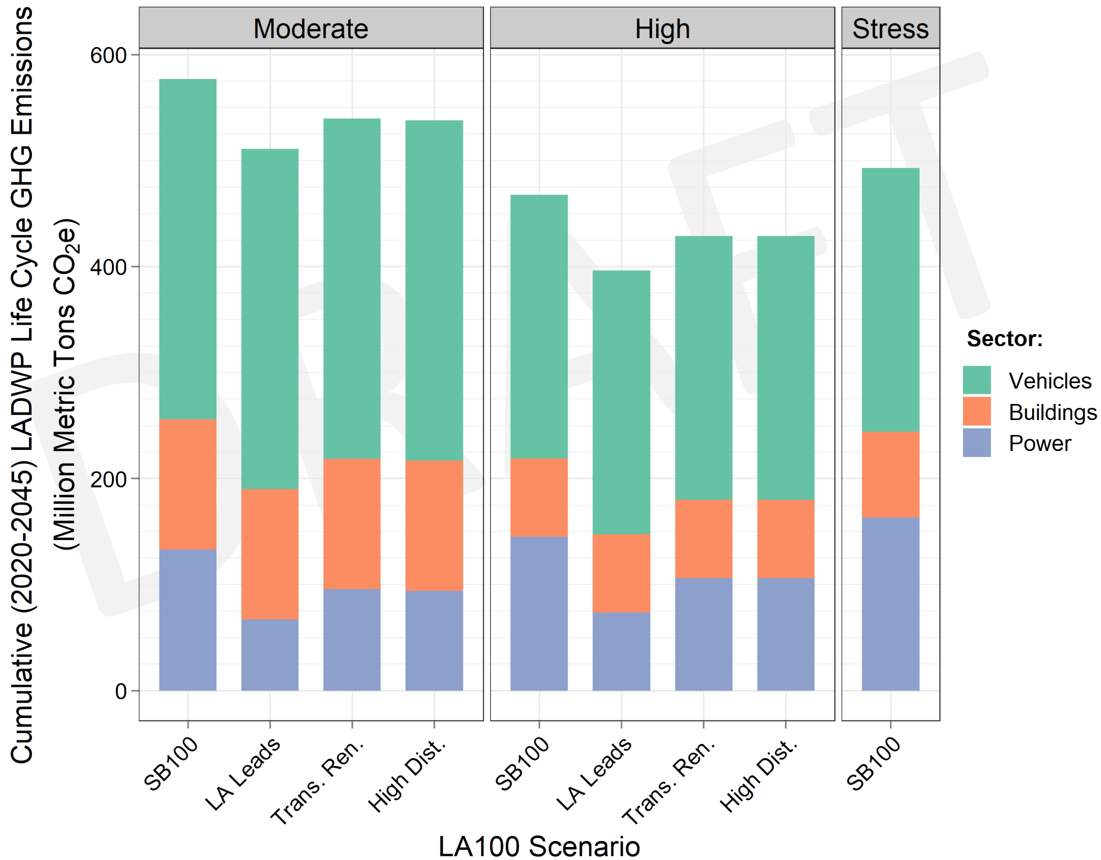
California Statewide GHG Emissions Targets – For Comparison to Combustion Emissions

- Can only compare combustion emissions to the CA targets
  - They are what is emitted within CA borders and within a given year (fuel cycle and life cycle emissions are sums of emissions across both space and time)
- When considering all sectors affected by LA100 (power + buildings + transportation), we report the percentage a given LA100 scenario would contribute to meeting CA statewide GHG targets by 2030 and 2045
- In the power-sector GHG results, we compare estimated annual combustion GHG emission levels in each LA100 scenario to those at which LADWP generation assets would need to operate to contribute commensurately to the specified targets

Combustion and Life-Cycle Greenhouse Gas Emissions, Power and Non-Power Sectors

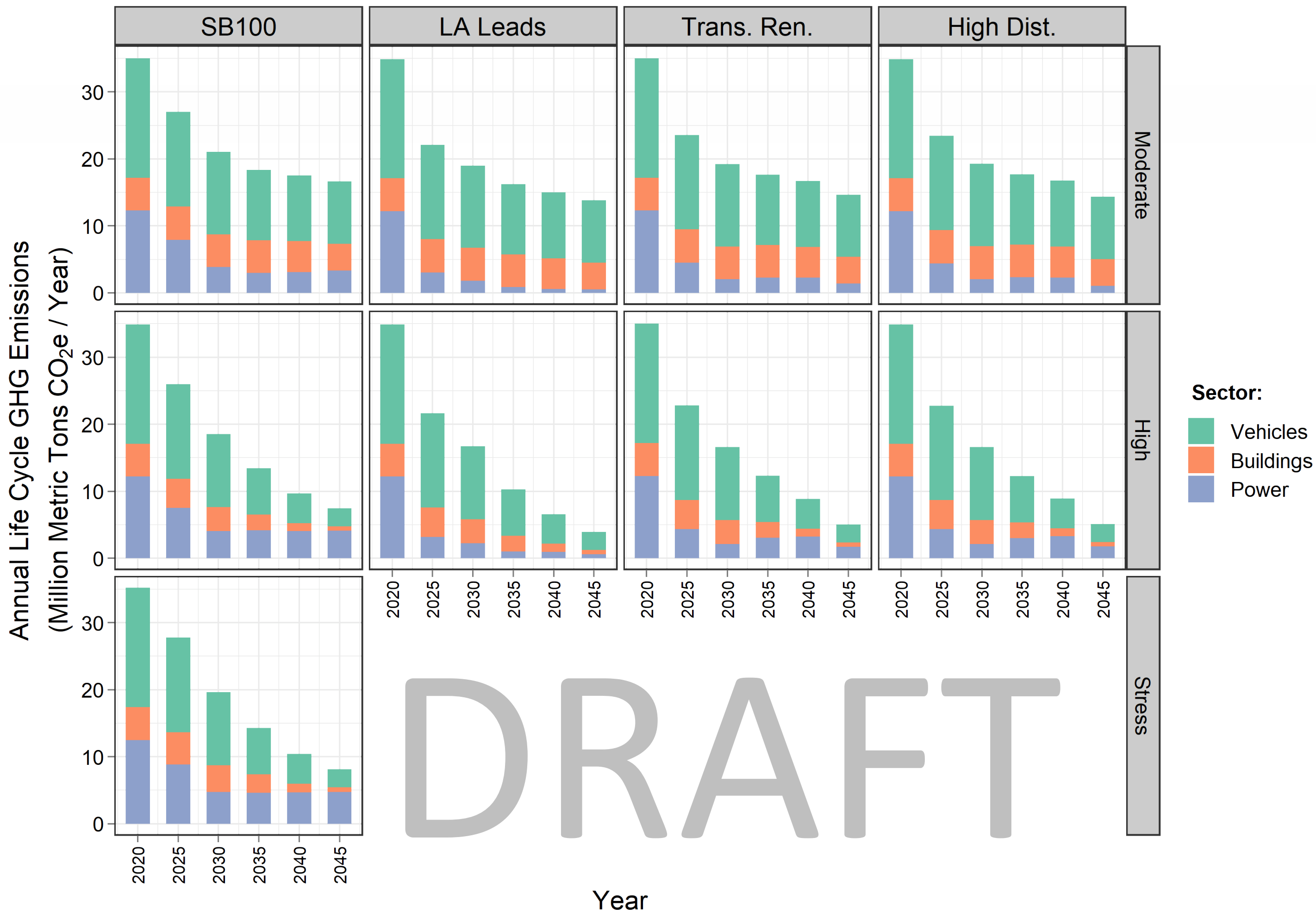
Cumulative Life-Cycle Greenhouse Gas Emissions, Power and Non-Power Sectors

- LA Leads – High scenario exhibits the **lowest** cumulative (2020-2045) life-cycle GHG emissions (~ 400 MMTCO_2e)
- The SB100 – Moderate scenario has the **highest** (~ 580 MMT CO_2e)
- Vehicle sector GHG emissions account for between 50% (SB100 – Stress) and 63% (LA Leads – High) of cumulative GHG emissions
  - Power sector between 13% (LA Leads – Moderate) and 33% (SB100 – Stress)
  - Buildings sector between 16% (SB100 – High) and 24% (LA Leads – Moderate)



Life-Cycle Greenhouse Gas Emissions, Power and Non-Power Sectors

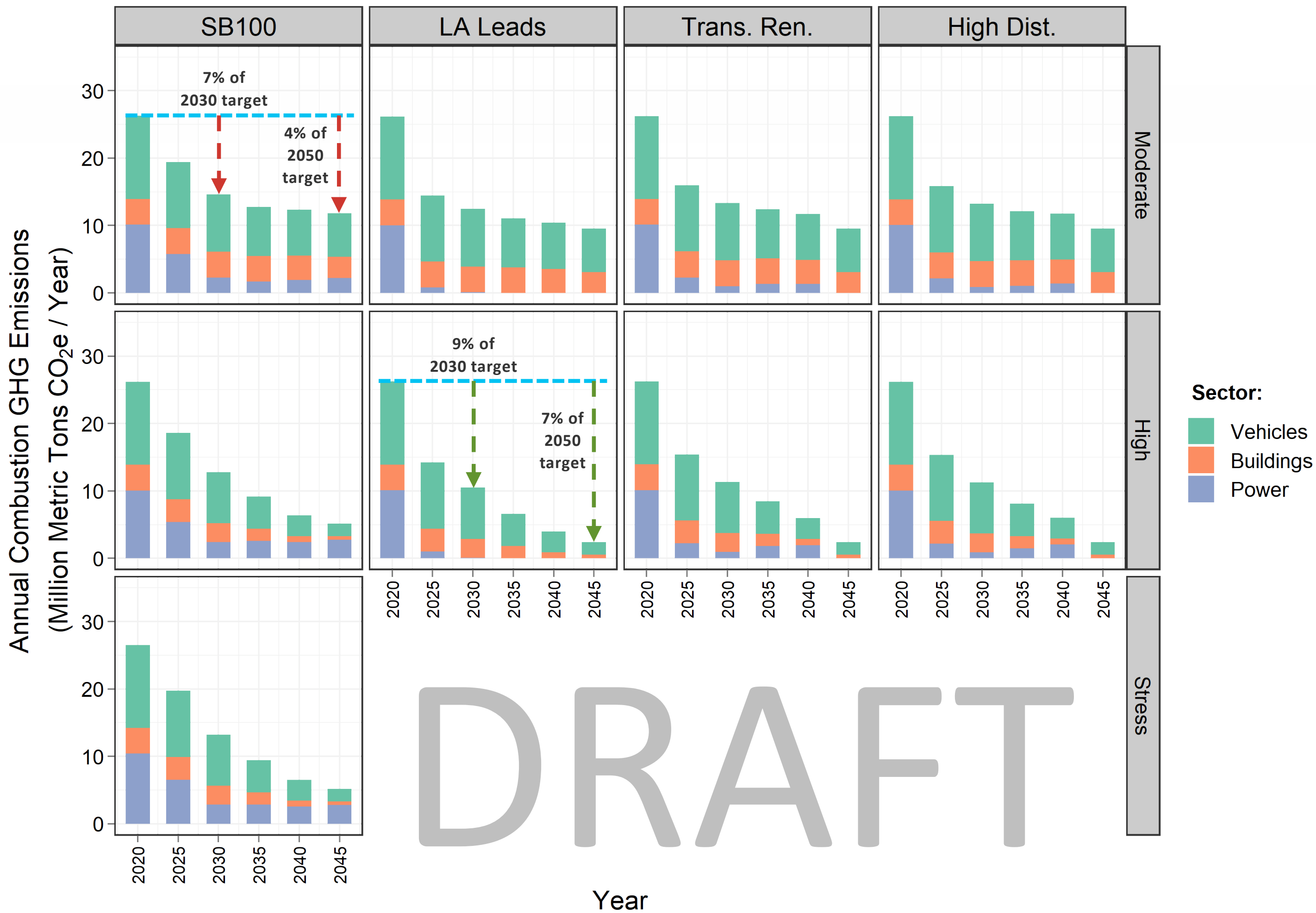
- By 2045, LA Leads – High scenario exhibits the **lowest** annual life-cycle GHG emissions attributable to LA100-affected sectors, at about 5 MMT CO_2e/year
- The SB100 – Moderate scenario has the **highest**, at 14 MMT CO_2e/year



Combustion Greenhouse Gas Emissions, Power and Non-Power Sectors

Contributions to statewide targets (40% 2030, 80% 2050):

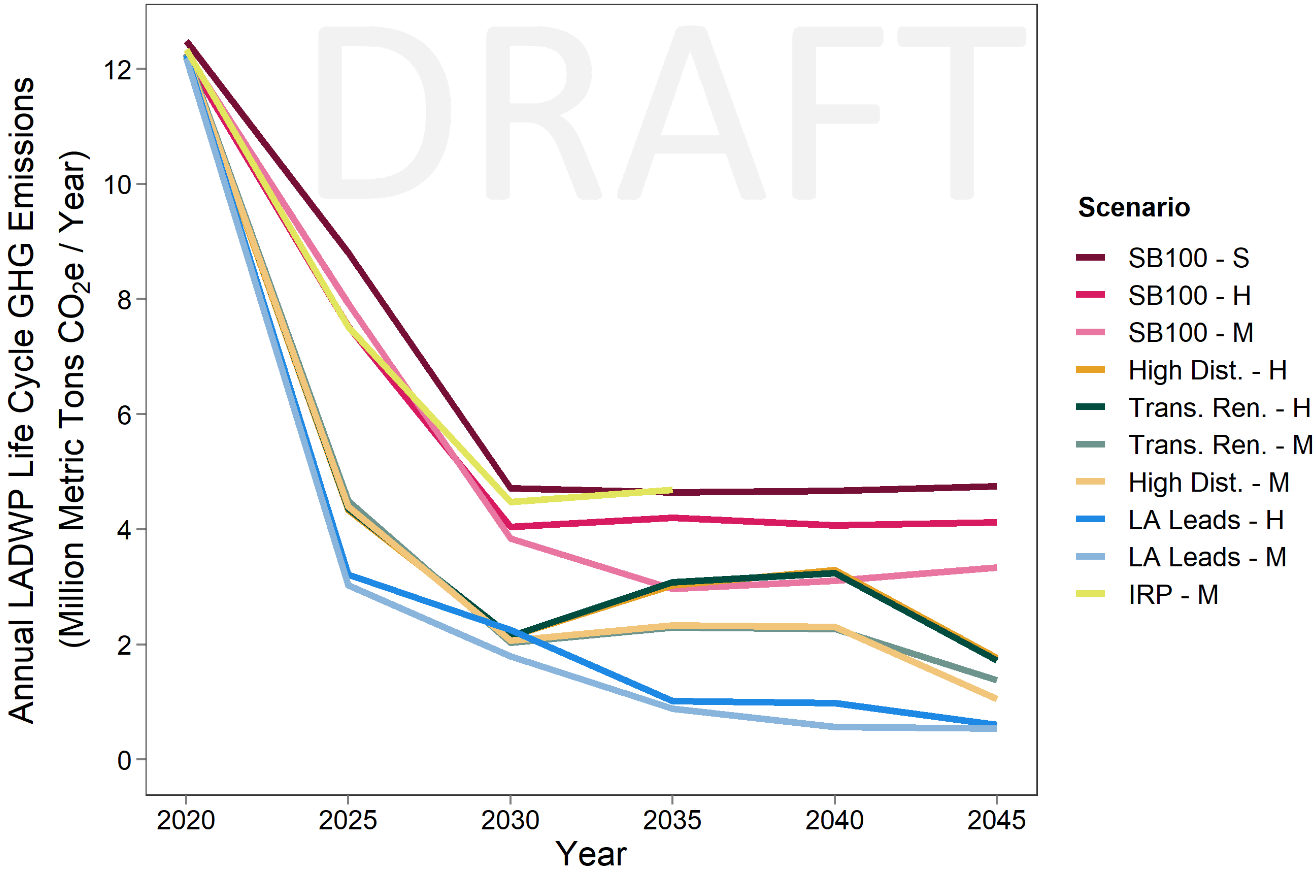
- 2030:
  - 7% in SB100 Moderate to 9% in LA Leads High
- 2050 (by 2045):
  - 4% in SB100 Moderate to 7% in LA Leads High



Greenhouse Gas Emissions, Power Sector

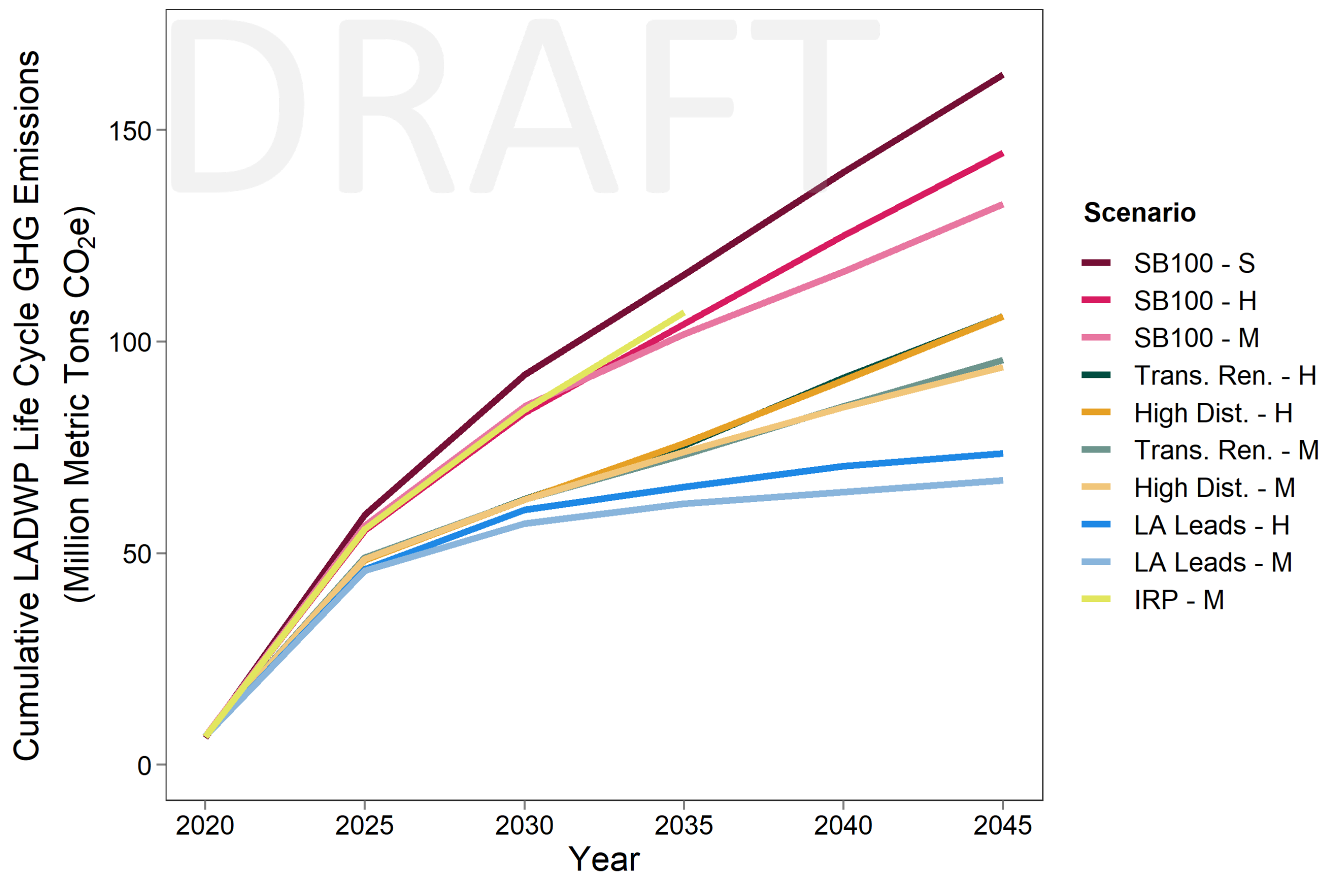
Life-Cycle Greenhouse Gas Emissions, Power Sector

The LA Leads set of scenarios has the **lowest annual life-cycle GHG emissions in 2045**, at 0.5–0.6 MMT CO_2e/year, or about 85% lower than those of the SB100 set



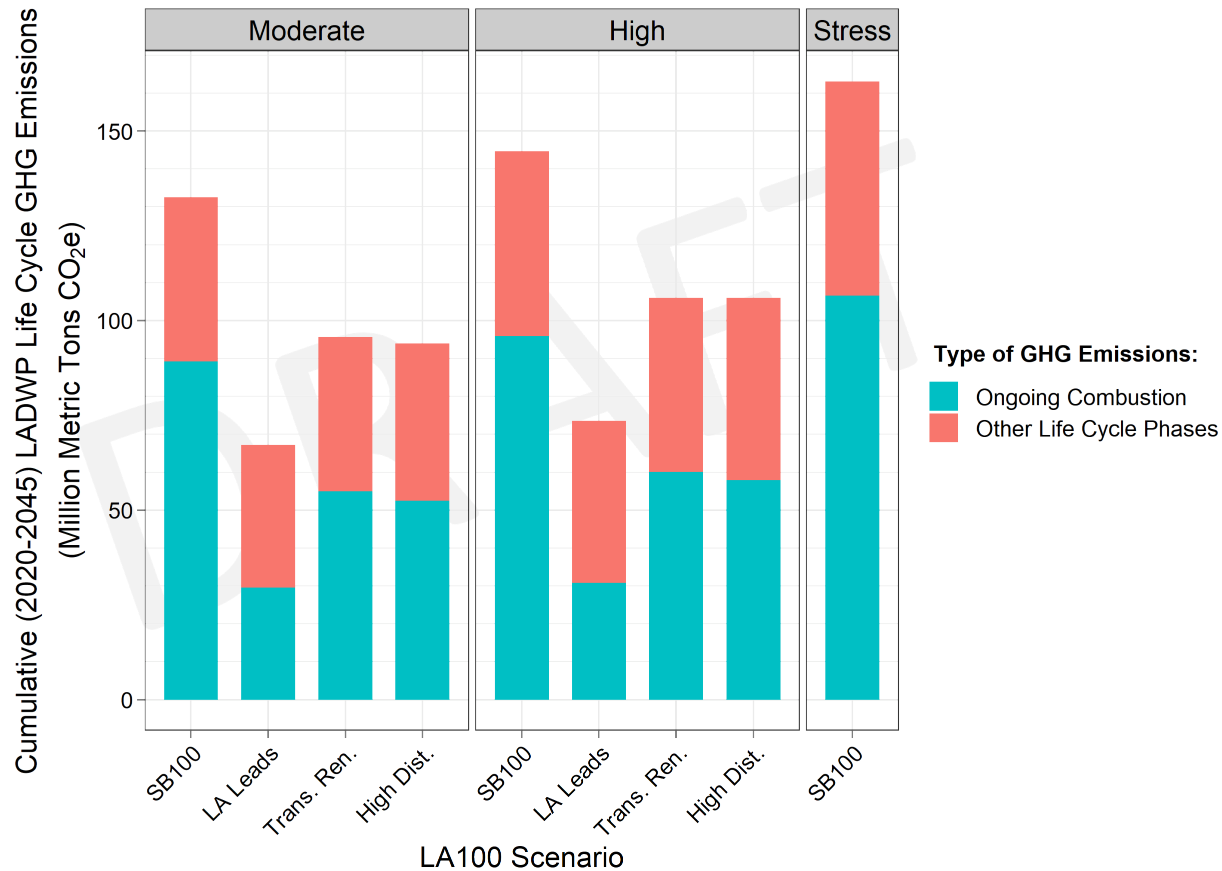
Cumulative Life-Cycle Greenhouse Gas Emissions, Power Sector

Because LA Leads reaches the 100% target 10 years earlier, this scenario has the **lowest cumulative life-cycle GHG emissions for the power sector** in the study period, at 67–74 MMT CO_2e, or about half those of the SB100 set



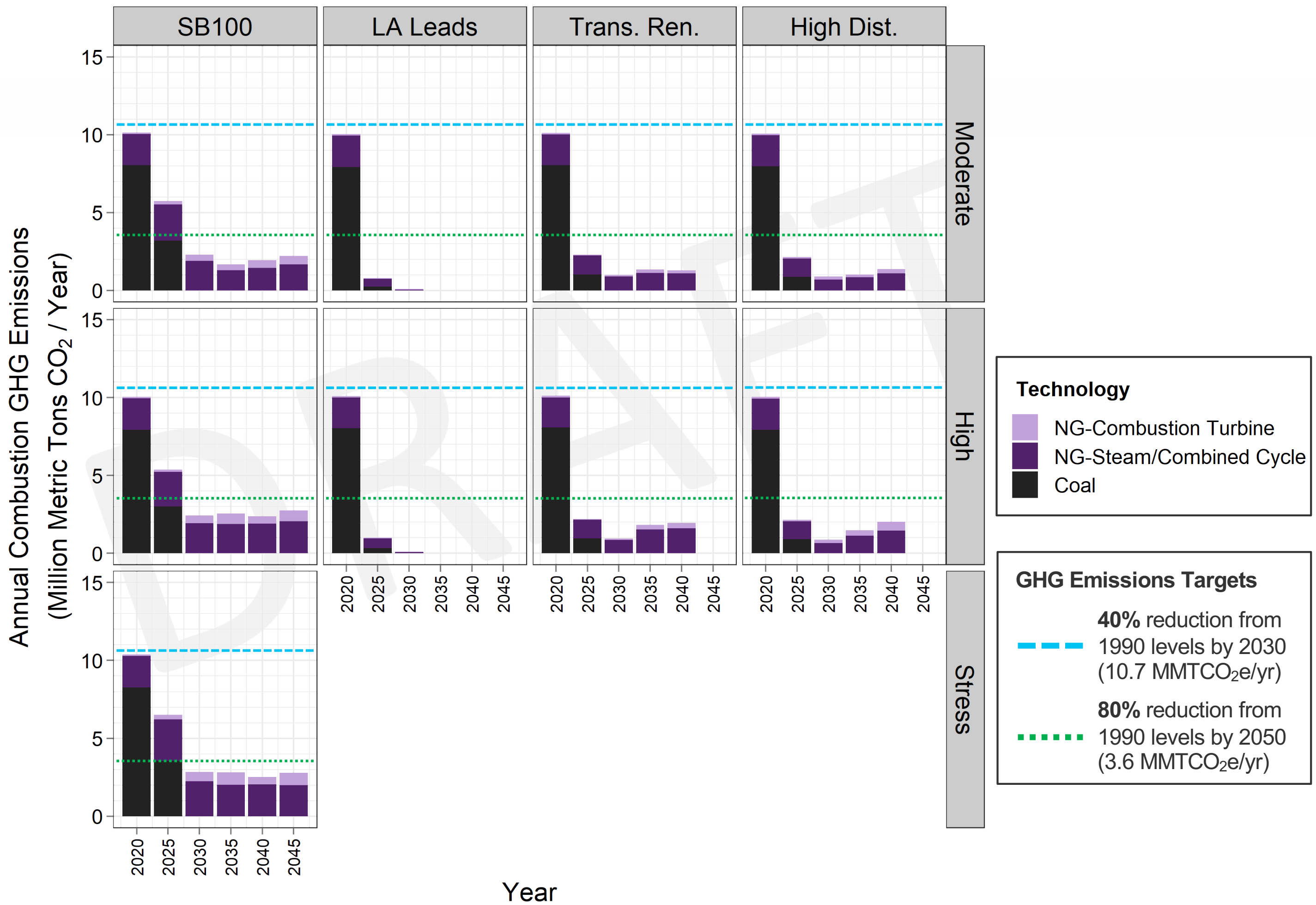
Cumulative Life-Cycle Greenhouse Gas Emissions, Power Sector

Power sector GHG emissions from **activities outside of fossil fuel combustion** which include construction, decommissioning, and ongoing non-combustion (such as maintenance of generator facilities and fuel extraction) account for between 33% and 58% of cumulative (2020-2045) emissions



Annual Combustion Greenhouse Gas Emissions, Power Sector

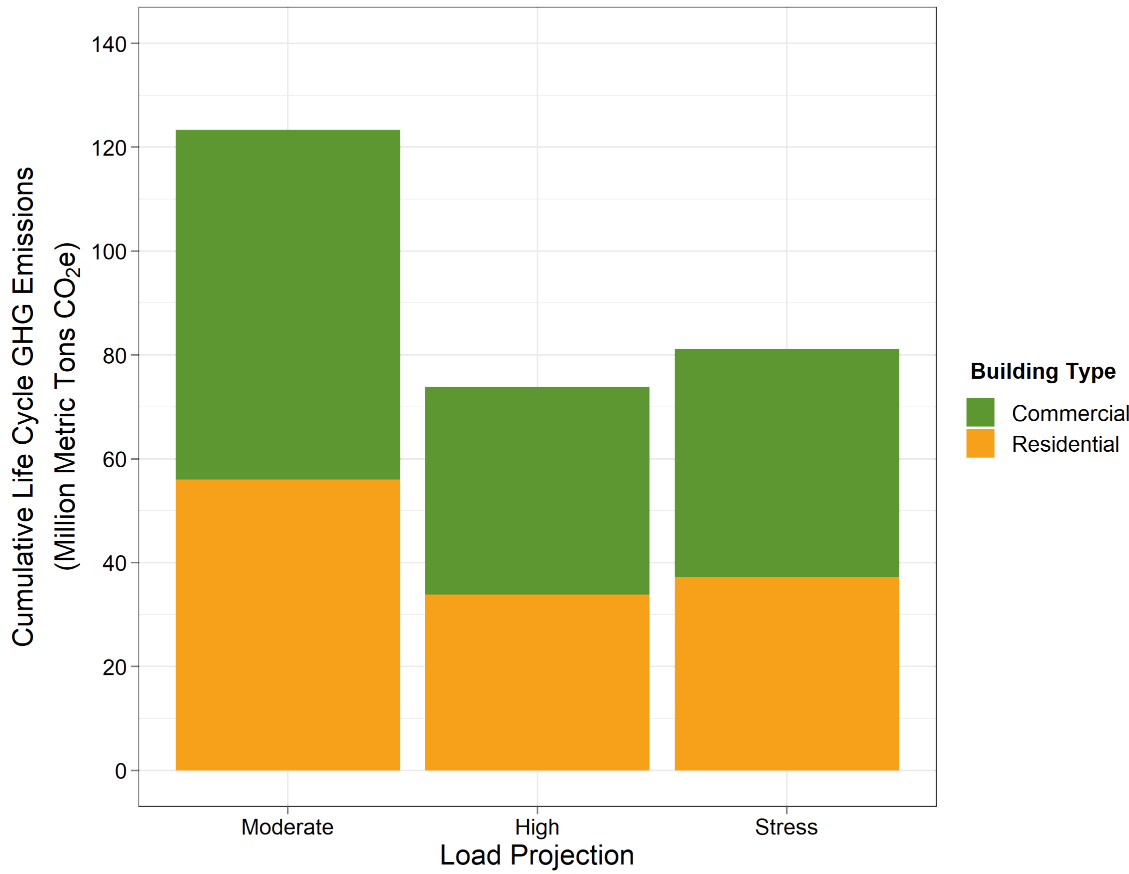
- Coal initially dominates in all scenarios, yet drop off after 2025
- Natural gas-fired plants accounts for combustion emissions from 2030 onward
- In all LA100 scenarios, LADWP's assets **exceed** commensurate contribution to the statewide 40% and 80% GHG reduction targets for 2030 and 2050, respectively.



Greenhouse Gas Emissions, Buildings Sector

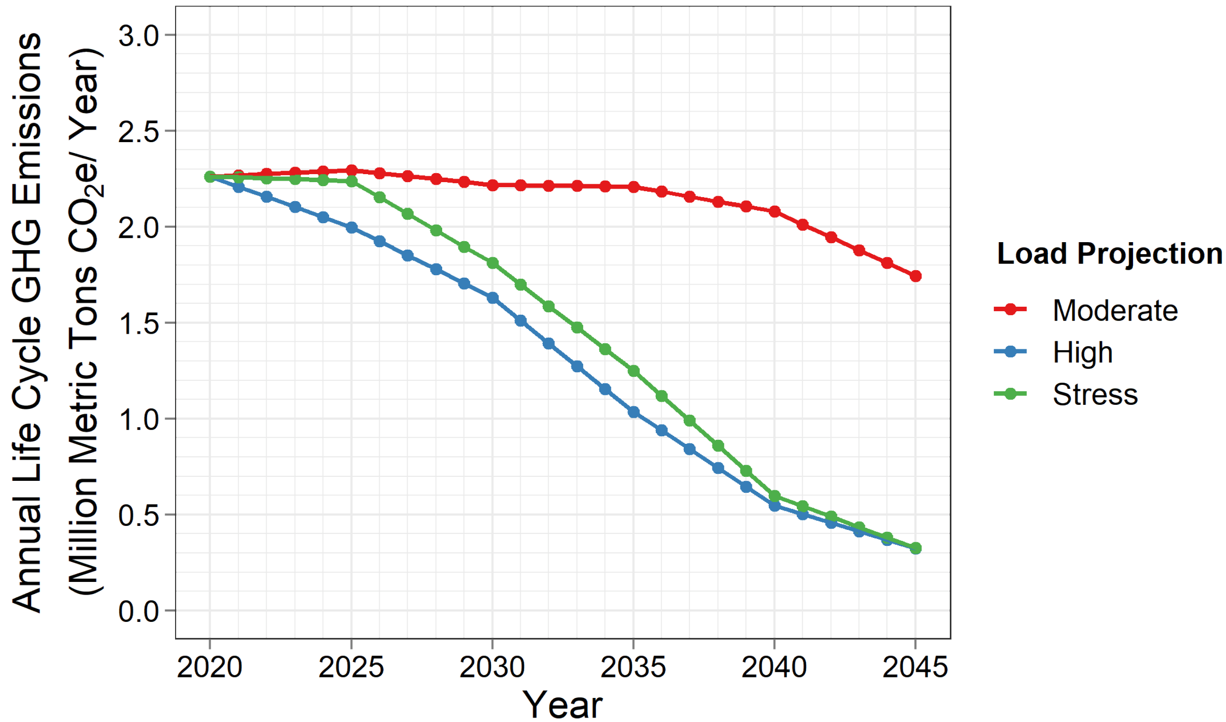
Cumulative Life-Cycle Greenhouse Gas Emissions, Buildings Sector Natural Gas Use

- Due to higher levels of end-use electrification, life-cycle GHG emissions associated with natural gas consumption in the building sector in the High load projection are **significantly lower** than in the Moderate
- This reduction is equivalent to about **28 times** the annual emissions generated by the LA residential sector's 1.17 million dwelling units in 2020



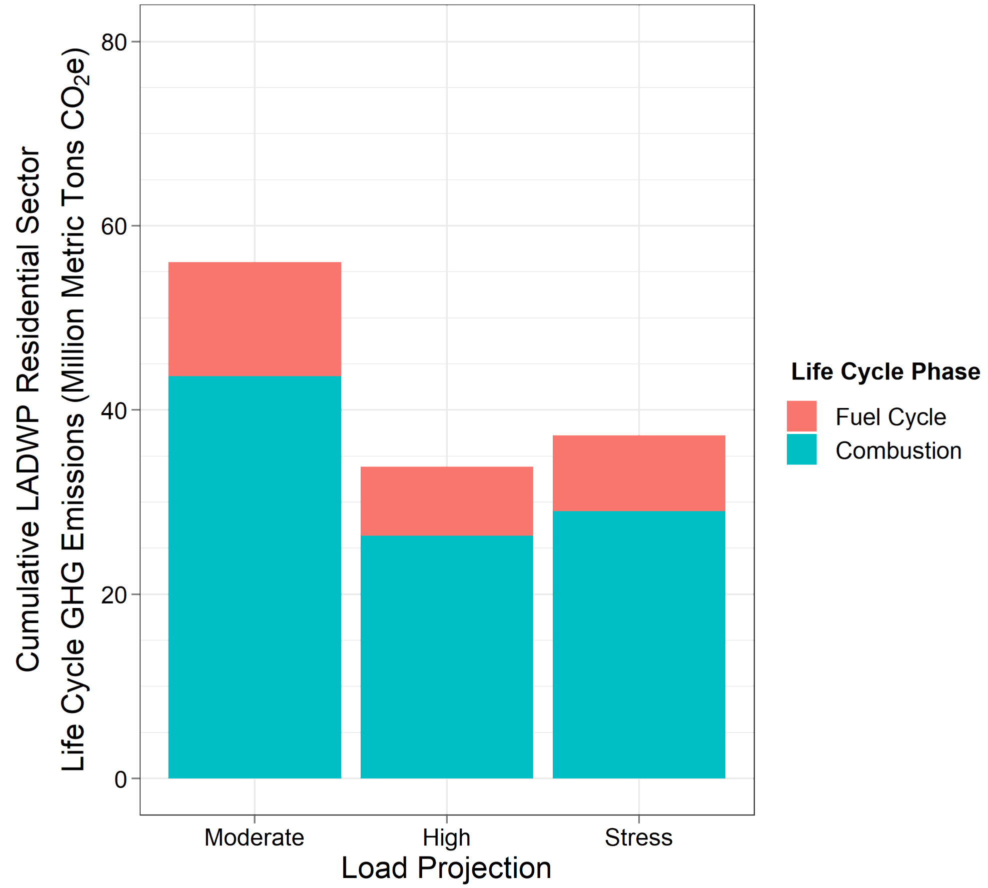
Life-Cycle Greenhouse Gas Emissions, Buildings Sector Natural Gas Use

- Reductions in natural gas usage in residential buildings in the High and Stress load projections = **~86% reduction** in annual GHG emissions from 2020 to 2045
- Commercial building results are similar



Cumulative Life-Cycle Greenhouse Gas Emissions, Buildings Sector Natural Gas Use

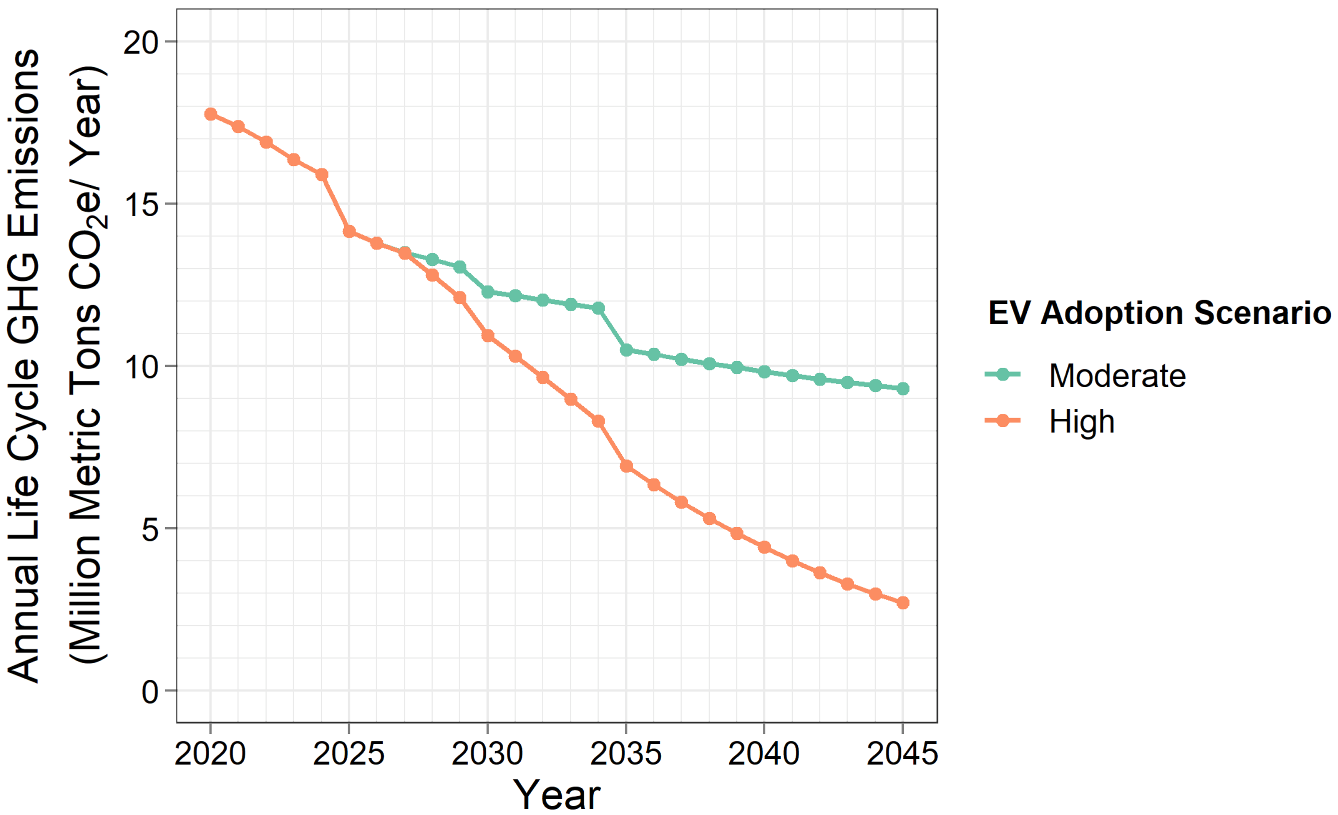
- Across all three load projections, **combustion emissions** account for approximately 78% of the cumulative life-cycle GHG emissions from fuel use in the residential building sector
- The remaining 22% is attributed to the **fuel cycle** (extraction, processing and transport of fuels)
- Commercial building results are similar



Greenhouse Gas Emissions, Transportation Sector

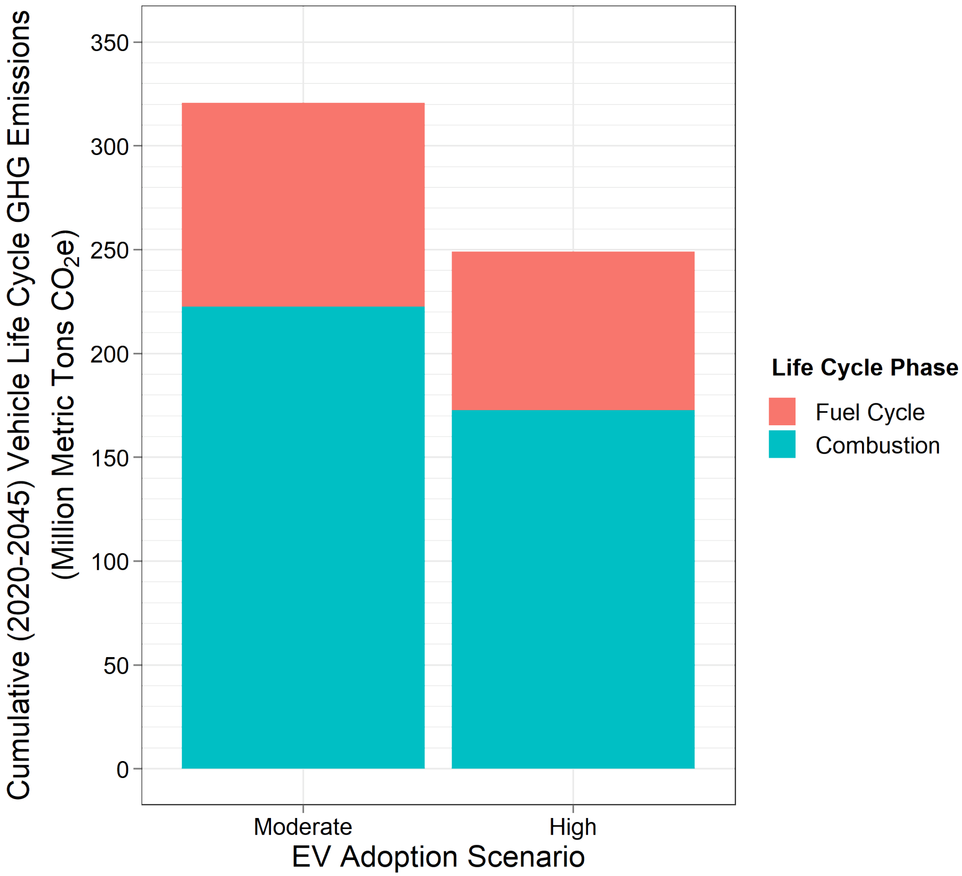
Life-Cycle Greenhouse Gas Emissions, Transportation Sector Fuel Use

- Compared to 2020, the Moderate EV projection reduces annual life-cycle GHG emissions from fuel used in light-duty vehicles and buses by 48% in 2045
- High EV projections reduce GHG emissions by 85% in 2045 relative to 2020
- These reductions are equivalent to those generated by the consumption of 1.0 and 1.7 billion gallons of gasoline, respectively



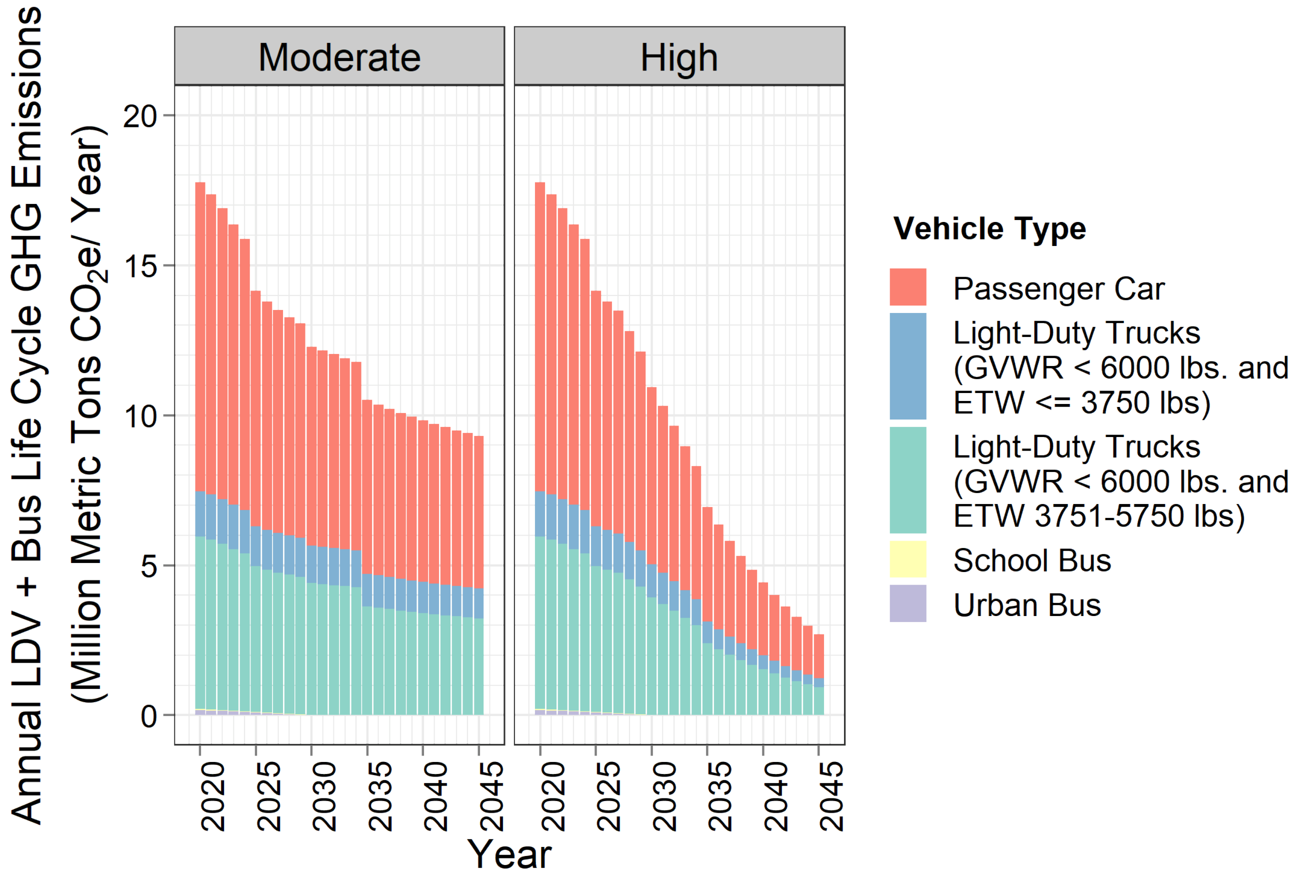
Cumulative Life-Cycle Greenhouse Gas Emissions, Transportation Sector Fuel Use

- GHG emissions from life-cycle phases **outside of fossil fuel consumption** are important to consider
- The fuel cycle accounts for about 31% of the total cumulative (2020-2045) life-cycle GHG emissions from light-duty vehicles and buses in both the Moderate and High EV adoption projections



Life-Cycle Greenhouse Gas Emissions, Transportation Sector Fuel Use

- Passenger cars and light-duty trucks account for almost all (99%) of annual life-cycle GHG emissions associated with fuel consumption from vehicles considered
- The two bus fleets contribute negligibly (1%)



Questions?

The Los Angeles 100% Renewable Energy Study

LA100

The Los Angeles 100% Renewable Energy Study

Impact of LA100 Scenarios on Air Pollutant Emissions (Update to air quality modeling methods)

Presenter: Prof. George Ban-Weiss (USC)

Collaborators: Dr. Jiachen Zhang (USC)

Yun Li (USC)

Dr. Vikram Ravi (NREL)

Dr. Garvin Heath (NREL)

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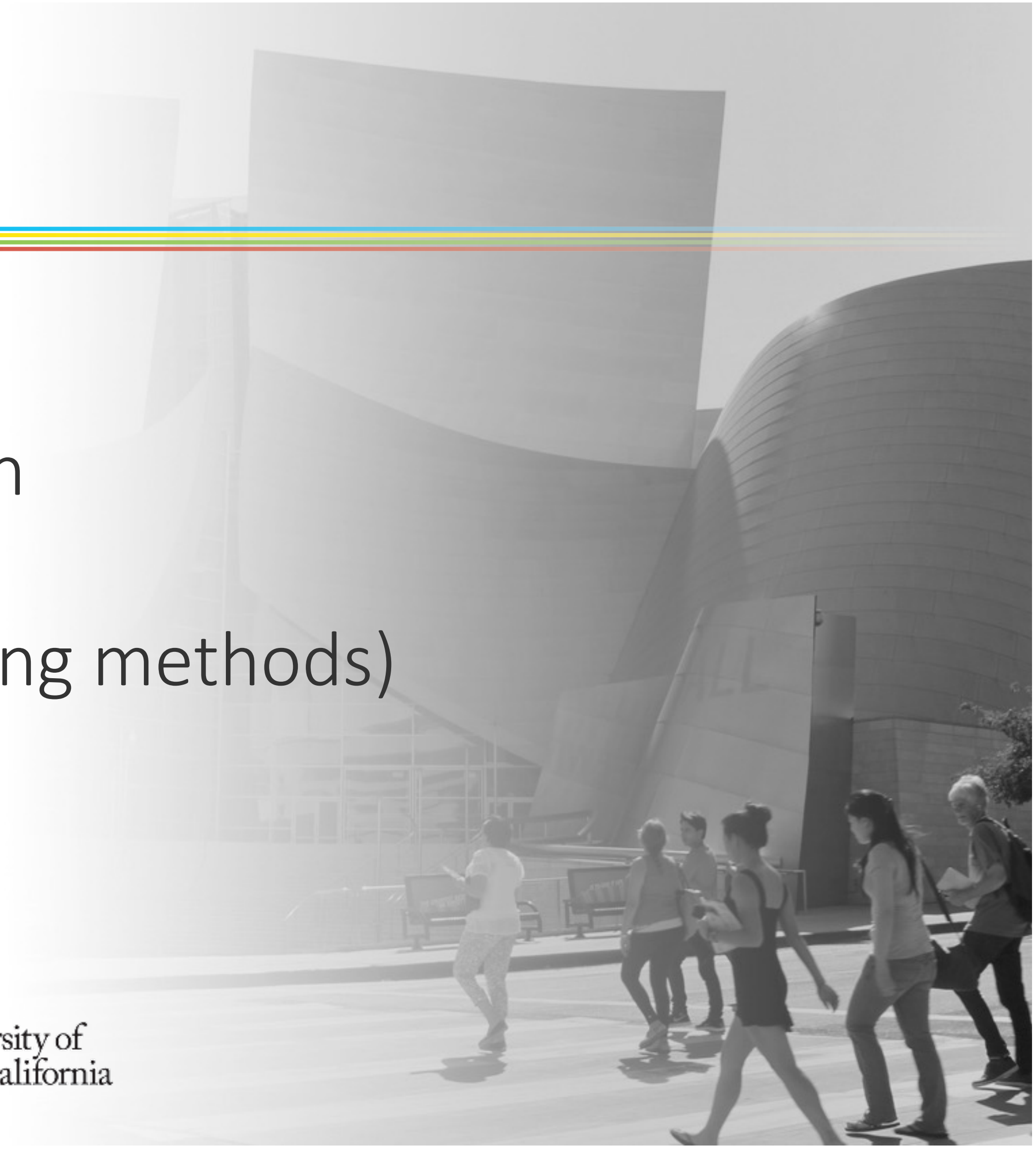


Adding a SB100-Moderate Scenario for More Complete Comparison Among Future Scenarios

Scenario Name	Natural gas/RECs Biofuel (power)	ELECTRIFICATION of light-duty vehicles and buses, the Port of LA, and buildings
1. BASELINE (2012)	N/A	N/A
2. LA Leads – Moderate Load Electrification	NO	Moderate
3. LA Leads – High Load Electrification	NO	High
4. SB100 – High Load Electrification	YES	High
5. SB100 – Moderate Load Electrification (Reference case for future scenarios)	YES	Moderate

- [illegible] case given it
  [illegible] “SB100 – Moderate Load Electrification” with “[illegible] Load Electrification”
  “[illegible] Load Electrification” with “[illegible] Load Electrification”

Assumptions for SB100-Moderate Scenario in 2045

Power

Natural gas is allowed by power plants that are owned by LADWP

Residential buildings
Commercial buildings

Residential Electrification: Water heating 50%, space heating 49%, clothes drying 93% and cooking 53%

Commercial Electrification: Water heating 72% and space heating 81%

Transportation:
Light-duty vehicles and buses

Light-duty vehicles: 30% of stock is plug-in electric vehicles* (PEV)

School and urban buses: 100% electrification

THE PORT OF LOS ANGELES

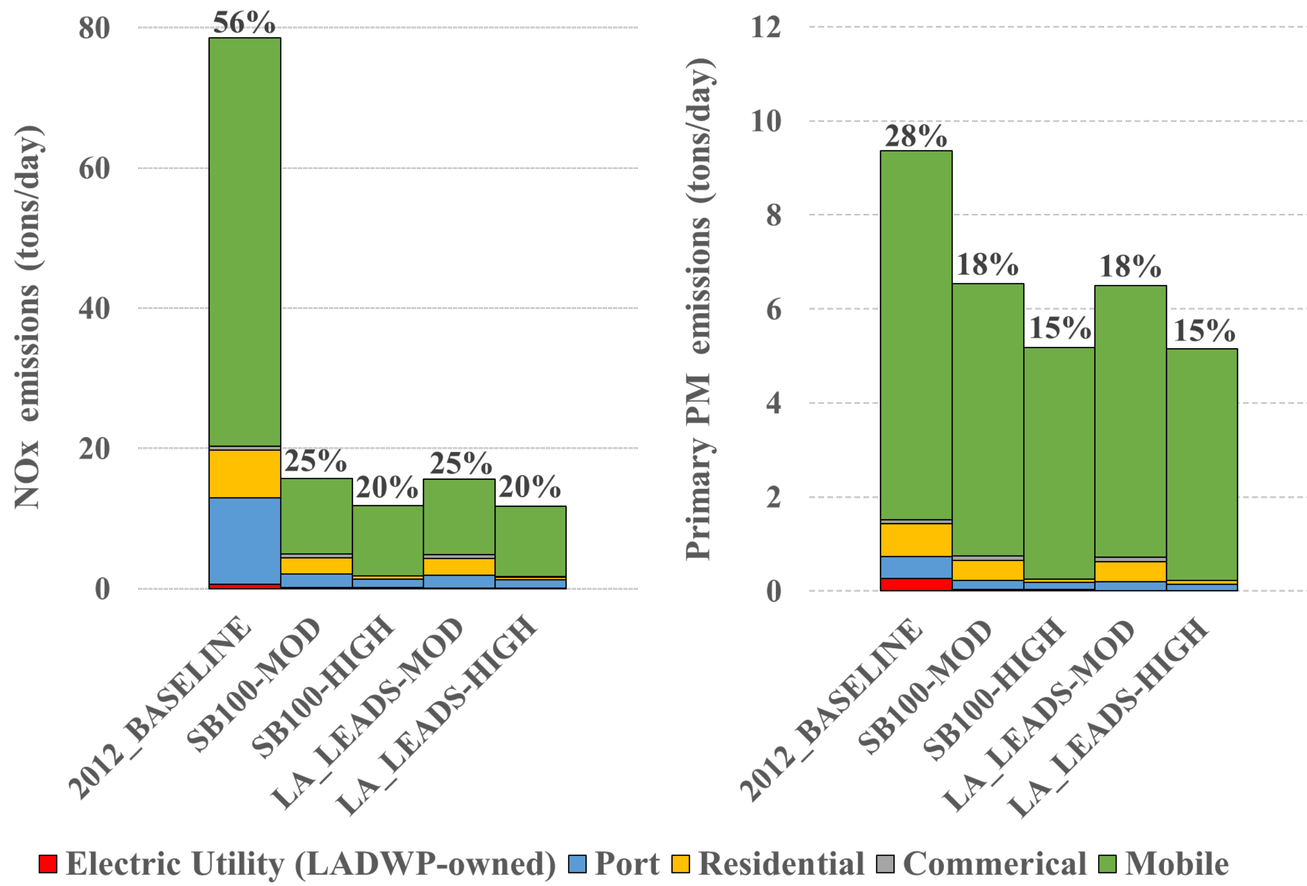
Ocean-going vessels
Cargo handling equipment
Heavy-duty vehicles

Ocean-going vessels (shore power at berth): 80%

Cargo handling equipment: 100% electrification

Heavy duty vehicles: 100% electrification

Results Update: Contribution of LA100-Related Sectors to Annual Average Emissions in the City of Los Angeles in 2045



- % represents the fraction of emissions that are from the five LA100-related sectors in the total city of LA inventory
- Non-LA100 related sources are not included in this figure
- The power sector represents LADWP-owned power plants located in the South Coast Air Basin

Results Update: Annual Total NOx Emissions for LADWP-owned Power Plants Located in the South Coast Air Basin

Fuel technology in 2045	2045 Emission factor (kg/MMBTU)	2045 SB100-HIGH (kg)	2045 SB100-MOD (kg)	2045 LA_LEADS-HIGH (kg)	2045 LA_LEADS-MOD (kg)	2012 Emissions (kg)
NG Combined cycle	0.0026 (Scattergood) 0.0034 (Valley)	30,673	30,096	0	0	198,657 (including all types of power plants)
NG Combustion turbine	0.0042 (Harbor) 0.0042 (Valley) 0.0039 (Haynes)	23,808	26,229	0	0	
NG Steam turbine	N/A	0	0	0	0	
H_2 Combustion turbine	0.0029	43	0	8,612	6,619	0

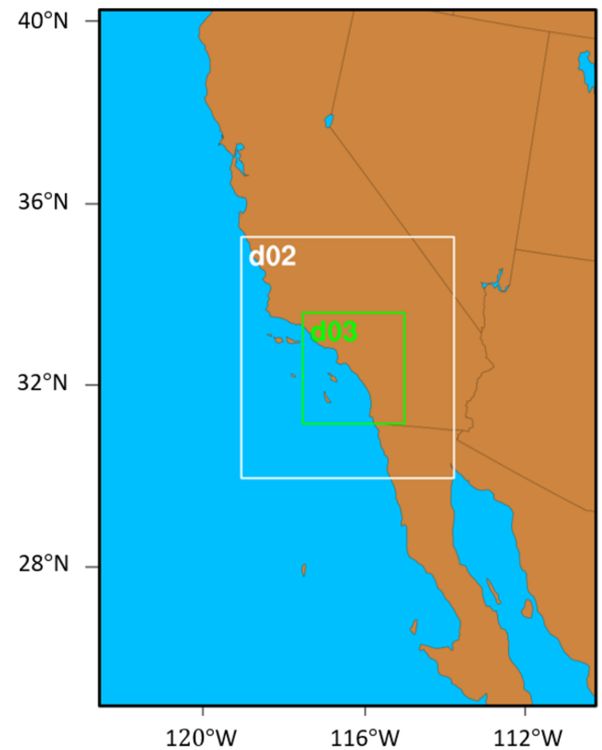
Brief Updates on Air Quality Modeling

Model setup:

- Weather Research and Forecasting Model coupled to chemistry and the Single-layer Urban Canopy Model (WRF/Chem-UCM, v3.7)
- Simulated January, April, July and October in year 2012 as representative months for calculating annual average daily $PM_{2.5}$ concentrations; July is also used as representative O_3 concentrations in Ozone season

Current status:

- Simulated $PM_{2.5}$ concentrations fit well with ground-level observations for 2012_BASELINE scenario, but O_3 concentrations in July are under-predicted
- Simulations for future scenarios are being carried out concurrently as testing for solutions to O_3 underestimation



(Model domain)

Questions?

Developing 2045 emission inventories for residential and commercial buildings

	End use	MODERATE Electrification level	HIGH Electrification level
Commercial	Water heating	72%	100%
	Space heating	81%	96%
Residential	Water heating	50%	100%
	Space heating	49%	91%
	Clothes drying	93%	100%
	Cooking	53%	100%

Developing 2045 emission inventories for the Port of LA

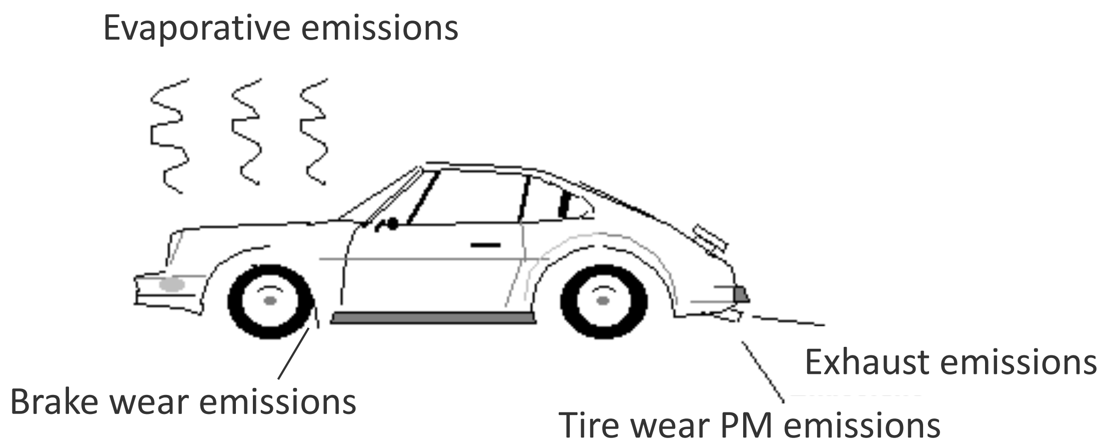
	Moderate Electrification	High Electrification
Ocean-Going Vessels (OGVs, shore power at berth)	80%	90%
Cargo Handling Equipment (CHE)	100% (45%)	100% (80%)
Heavy Duty Vehicles (HDVs)	100% (10%)	100% (25%)

(Percentages in parentheses are those used in load modeling at the Port.)

Developing 2045 emission inventories for the transportation sector

	Moderate Electrification	High Electrification
Light-duty vehicles	30% of stock is plug-in electric vehicles* (PEV)	80% of stock is PEV
School and urban buses	100%	100%

*PEVs consist of 50% plug-in hybrid vehicles and 50% battery electric vehicles



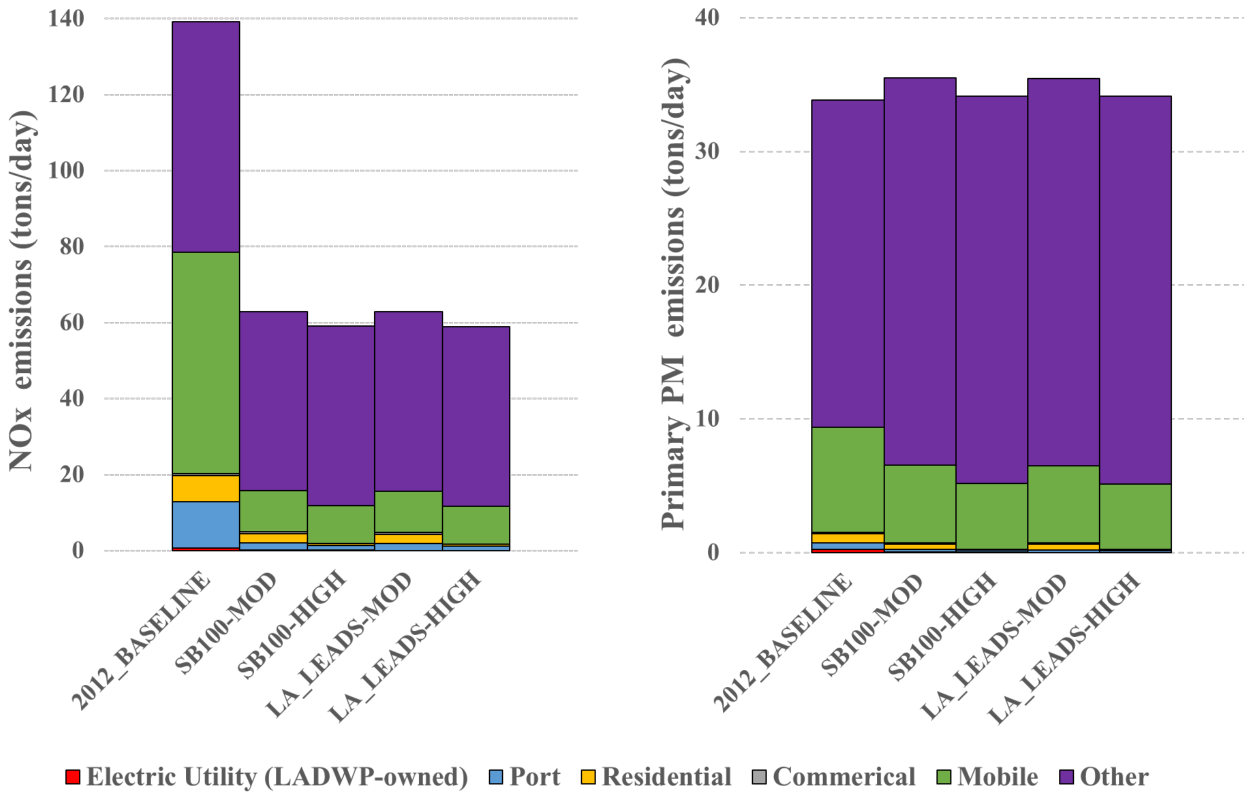
We evaluated the impact of electrification on various emission processes and sources from vehicles

Developing future emission inventories for the power sector

	SB100	LA Leads
Natural gas	Allowed	Not allowed for LADWP Allowed for other utilities
Hydrogen	Allowed	Allowed

*Note that power plants that are not owned by LADWP will follow SCAQMD 2031 projections.

Backup results: Contribution of all sources to annual average emissions in the City of Los Angeles in 2045



Examples of non-LA100 related sources shown as "Other":

- For NOx:
  - Off-road equipment
  - Trains
  - RECLAIM (large point sources)
  - Aircraft
- For Primary PM:
  - Construction and demolition
  - Industrial processes
  - Cooking
  - Off-road equipment

Cumulative Combustion Greenhouse Gas Emissions, Power Sector

- All LA100 scenarios show significant cumulative (2020-2045) combustion GHG emission declines compared to a hypothetical case where current generation and associated annual emissions are held constant.
- Reductions range from -52% reduction for SB100 Stress to -87% for LA Leads Moderate.