Air Quality Impacts of Electrification

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Overview

- This presentation focuses on two electrification studies:
  - EPRI-NRDC 2015 study on the air quality and greenhouse impacts of electric transportation
    - Air quality analysis focused on a scenario of potential transportation electrification projection to 2030
  - Aggressive electrification:
    - Air quality impacts estimated from a scenario of aggressive electrification of all amenable end-use sectors projected to 2050 (preliminary results)
    - Supported by California Energy Commission (CEC)
Light-duty sales at about 1 million vehicles
Customer choice increasing with 108 116 EVs by 2023
97 counties in 16 states have > 2.0% EV sales (through June 2018)

- San Juan, WA (6.0%)
- Jefferson, WA (5.6%)
- King, WA (4.6%)
- Multnomah, OR (4.0%)
- Sonoma (8.1%)
- Marin (11.1%)
- San Francisco (8.6%)
- Alameda (11.3%)
- Santa Clara (14.8%)

White = 1.36% (national average)
Public DC fast charging infrastructure is increasing
Per-vehicle greenhouse gas emissions results (present day)
EPRI-NRDC 2015 Study:
Near-term (2030) Impacts of Transportation Electrification
Transportation Sector Modeling (Passenger Vehicles)
Transportation Sector Modeling (Passenger Vehicles)
EPRI-NRDC Study: Percent Electric Vehicle Miles Traveled by 2030
## EPRI-NRDC Study: Examples of Electrified Non-Road Equipment

<table>
<thead>
<tr>
<th>Lawn and Garden</th>
<th>Industrial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chain Saws</td>
<td>Agricultural Pumps</td>
</tr>
<tr>
<td><em>(units ≤6 horsepower)</em></td>
<td><em>(units ≤175 horsepower)</em></td>
</tr>
<tr>
<td>Chippers/Shredders</td>
<td>Aircraft Auxiliary Power Units</td>
</tr>
<tr>
<td><em>(units ≤6 horsepower)</em></td>
<td><em>(units ≤25 horsepower)</em></td>
</tr>
<tr>
<td>Commercial Turf Equipment</td>
<td>Airport GSE</td>
</tr>
<tr>
<td><em>(units ≤25 horsepower)</em></td>
<td><em>(units ≤175 horsepower)</em></td>
</tr>
<tr>
<td>Leaf Blowers</td>
<td>Dredging Craft</td>
</tr>
<tr>
<td></td>
<td><em>(units ≤175 horsepower)</em></td>
</tr>
<tr>
<td></td>
<td>Forklifts</td>
</tr>
<tr>
<td></td>
<td><em>(units ≤25 horsepower)</em></td>
</tr>
<tr>
<td>Push Lawn Mowers</td>
<td>Port Cranes</td>
</tr>
<tr>
<td>Riding Lawn Mowers</td>
<td>Shoreside Power</td>
</tr>
<tr>
<td><em>(units ≤40 horsepower)</em></td>
<td>Sweepers / Scrubbers</td>
</tr>
<tr>
<td>Snow Blowers</td>
<td><em>(units ≤25 horsepower)</em></td>
</tr>
<tr>
<td><em>(units ≤3 horsepower)</em></td>
<td>Switching Locomotives</td>
</tr>
<tr>
<td>Trimmers/Edgers</td>
<td>Transportation Refrigeration Units</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Recreational</strong></td>
<td></td>
</tr>
<tr>
<td>ATVs</td>
<td>Motorcycles</td>
</tr>
<tr>
<td></td>
<td>Special Vehicle Carts</td>
</tr>
<tr>
<td>Golf Carts</td>
<td><em>(units ≤25 horsepower)</em></td>
</tr>
</tbody>
</table>

Only electrified the “low-hanging fruit” technologies already “primed” for electrification
For passenger vehicles, transportation electrification increases the reduction in transportation GHG emissions between 2015 and 2050 from 32% to 57%
Without electrification, the Base GHG Scenario projects most new load being met with renewable generation, with some additional combined cycle natural gas (CCNG).

The marginal transportation load is met by a combination of CCNG and renewables, with increasing amounts of coal with carbon capture and storage (CCS) in the post-2040 timeframe.
There are modest, but widespread air quality benefits, i.e. reduced ozone concentrations.

~1 ppb benefits are widespread and benefits are higher in urban areas.
• There are also reductions in fine particulate matter, PM$_{2.5}$, mostly concentrated in urban areas
Aggressive Economy-wide Electrification in 2050
California Case Study
(supported by California Energy Commission)
Emissions Inventory: Reference (Overall)
Emissions Inventory: Electrification Scenario

[Bar chart showing emissions reduction across different sources and pollutants.]
## Electrification Assumptions 2050 (On-Road)

<table>
<thead>
<tr>
<th>Fuel use category</th>
<th>Electrification share</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>combination long-haul</td>
<td>80%</td>
<td>LTES heavy duty adoption</td>
</tr>
<tr>
<td>combination short-haul</td>
<td>80%</td>
<td>LTES heavy duty adoption</td>
</tr>
<tr>
<td>intercity bus</td>
<td>88%</td>
<td>LTES bus adoption</td>
</tr>
<tr>
<td>light commercial truck</td>
<td>85%</td>
<td>TAC suggestion</td>
</tr>
<tr>
<td>motor home</td>
<td>80%</td>
<td>LTES heavy duty adoption</td>
</tr>
<tr>
<td>motorcycle</td>
<td>93%</td>
<td>LTES light duty adoption</td>
</tr>
<tr>
<td>passenger car</td>
<td>93%</td>
<td>LTES light duty adoption</td>
</tr>
<tr>
<td>passenger truck</td>
<td>93%</td>
<td>LTES light duty adoption</td>
</tr>
<tr>
<td>transit bus</td>
<td>88%</td>
<td>LTES bus adoption</td>
</tr>
<tr>
<td>refuse truck</td>
<td>80%</td>
<td>LTES heavy duty adoption</td>
</tr>
<tr>
<td>school bus</td>
<td>88%</td>
<td>LTES bus adoption</td>
</tr>
<tr>
<td>single unit long-haul</td>
<td>66%</td>
<td>LTES medium duty adoption</td>
</tr>
<tr>
<td>single unit short-haul</td>
<td>66%</td>
<td>LTES medium duty adoption</td>
</tr>
</tbody>
</table>

LTES - “Long-Term Energy Scenarios In California” performed by Energy and Environmental Economics (E3) for CEC (project EPC-14-069).
## Electrification Assumptions 2050 (Non-Road)

<table>
<thead>
<tr>
<th>Fuel use category</th>
<th>Electrification share</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>agricultural</td>
<td>15%</td>
<td>TAC suggestion</td>
</tr>
<tr>
<td>aviation</td>
<td>10%</td>
<td>TAC suggestion</td>
</tr>
<tr>
<td>construction and mining</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>forklift</td>
<td>100%</td>
<td>Assume aggressive adoption</td>
</tr>
<tr>
<td>ground support equipment</td>
<td>100%</td>
<td>Assume aggressive adoption</td>
</tr>
<tr>
<td>lawn and garden</td>
<td>100%</td>
<td>Assume aggressive adoption</td>
</tr>
<tr>
<td>marine</td>
<td>10%</td>
<td>TAC suggestion</td>
</tr>
<tr>
<td>marine (port)</td>
<td>100%</td>
<td>Assume aggressive adoption</td>
</tr>
<tr>
<td>other non-road</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>rail</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>rail (yard)</td>
<td>100%</td>
<td>Assume aggressive adoption</td>
</tr>
<tr>
<td>recreational equipment</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>recreational marine</td>
<td>25%</td>
<td>TAC suggestion</td>
</tr>
<tr>
<td>refrigeration</td>
<td>100%</td>
<td>Assume aggressive adoption</td>
</tr>
<tr>
<td>terminal tractor</td>
<td>100%</td>
<td>Assume aggressive adoption</td>
</tr>
<tr>
<td>truck apu</td>
<td>100%</td>
<td>Assume aggressive adoption</td>
</tr>
</tbody>
</table>
## Electrification Assumptions 2050 (Various Sectors)

<table>
<thead>
<tr>
<th>Sector</th>
<th>Fuel use category</th>
<th>Electrification share</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial</td>
<td>boiler</td>
<td>98%</td>
<td>LTES commercial water heating adoption</td>
</tr>
<tr>
<td>Industrial</td>
<td>chemical manufacturing</td>
<td>0%</td>
<td>No electrification assumed</td>
</tr>
<tr>
<td>Industrial</td>
<td>heat</td>
<td>60%</td>
<td>EPRI assumption</td>
</tr>
<tr>
<td>Industrial</td>
<td>motion</td>
<td>100%</td>
<td>Very high adoption assumed</td>
</tr>
<tr>
<td>Industrial</td>
<td>other</td>
<td>0%</td>
<td>No electrification assumed</td>
</tr>
<tr>
<td>Industrial</td>
<td>solvents</td>
<td>0%</td>
<td>No electrification assumed</td>
</tr>
<tr>
<td>Industrial</td>
<td>space heat</td>
<td>80%</td>
<td>LTES commercial space heating adoption</td>
</tr>
<tr>
<td>Petroleum</td>
<td>boiler</td>
<td>90%</td>
<td>Petroleum use reduction</td>
</tr>
<tr>
<td>Petroleum</td>
<td>heat</td>
<td>90%</td>
<td>Petroleum use reduction</td>
</tr>
<tr>
<td>Petroleum</td>
<td>other</td>
<td>90%</td>
<td>Petroleum use reduction</td>
</tr>
<tr>
<td>Residential</td>
<td>heating</td>
<td>99%</td>
<td>LTES residential water heating adoption</td>
</tr>
<tr>
<td>Residential</td>
<td>space heating</td>
<td>83%</td>
<td>LTES residential space heating adoption</td>
</tr>
<tr>
<td>Residential</td>
<td>wood heating</td>
<td>100%</td>
<td>Complete replacement of wood heating assumed</td>
</tr>
</tbody>
</table>
Preliminary CEC Study Air Quality Impacts:
July 2050

Maximum daily 8-hour average (MDA8) ozone
Average monthly ozone
24-hour average fine particulate matter (PM$_{2.5}$)
Average monthly PM$_{2.5}$
July 2050 Maximum MDA8 Ozone in South Coast Air Basin

- Broad reductions maximum daily average 8-hour ozone (July 2050) within 10-20 ppb
- Up to 33 ppb reduction; small area of NOx disbenefit generally within 1-3 ppb (up to 14 ppb increase near Long Beach) in region with low baseline ozone
July 2050: Monthly Average MDA8 Ozone in South Coast Air Basin

- Broad reductions in monthly average ozone within 5-10 ppb
- Up to 16 ppb reduction; NOx disbenefit near ports generally within 1-3 with a highly localized maximum 13 ppb
July 2050: Maximum 24-hr PM$_{2.5}$ in South Coast Air Basin

- Broad reductions within 1-5 $\mu$g/m$^3$
- Maximum reduction of 15 $\mu$g/m$^3$ near Long Beach; large reductions in elemental carbon and primary organic aerosol as well as other PM$_{2.5}$ constituents
July 2050: Monthly Average PM$_{2.5}$ in South Coast Air Basin

- Broad reductions within 1-2 µg/m$^3$
- Maximum reduction of 9.5 µg/m$^3$ near Long Beach; large reductions in elemental carbon and primary organic aerosol as well as other PM$_{2.5}$ constituents
National Electrification Assessment
National assessment of the potential to increase electrification by 2050

- Energy demand by sector
- Electricity load shapes
- Electric capacity and generation
- Energy prices
- CO₂, air emissions, other
- Drivers/barriers

Preview released at NARUC on Feb. 11
Full Report rolled out at National Press Club in Washington, DC on April 3, 2018
Potential for Efficient Electrification Varies by End-Use Application

US 2015 Final Energy Break-Out

Transport
- Cars and light trucks
- Heavy-duty trucks
- Aviation
- Bus / Transit / Rail
- Maritime
- Military

Buildings
- Space heating
- Cool / Light / Appl. / Elec.
- Water Heating
- Other dual-fuel buildings

Industry
- Process Heat / Cool
- Industry boilers
- Facilities / Other
- Machine Drive
- Constr. / Ag. / Min. Feedstocks

How does this look in my state?
Efficient Electrification: Reference

- **Reference**
  - GDP Growth (AEO)
  - Structural Change (AEO)
  - Efficiency Improvements
  - Electrification

- **Other Non-Electric Energy**
- **Gas**
- **Electricity**

- **Vehicles**
- **Buildings**
- **Industry**

- **Electrification**

- **GDP Growth**
  - Reference
  - 2015 → 2050: +32%

- **Electricity Demand**

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Efficient Electrification: Progressive

GDP Growth (AEO)

Structural Change (AEO)

Efficiency Improvements

Electrification

Other Non-Electric Energy

Natural Gas

Electricity

Moderate Carbon Target

+35% Growth 2015 → 2050

Electricity Demand

Buildings (before electrification)

Industry (before electrification)

Vehicles

Efficient Electrification 

(21% Electricity GDP Growth (AEO)

39% Elec Share)
Efficient Electrification: Transformation

- GDP Growth (AEO)
- Structural Change (AEO)
- Efficiency Improvements
- Electrification
- Other Non-Electric Energy
- Gas
- Electricity

+52% 2015 → 2050

- Tight Carbon Target
- Electrification
- Vehicles
- Buildings
- Industry

21% Electricity (AEO)

47% Vehicles (AEO)

Industry (before electrification)

Buildings (before electrification)

Other Non-Electric Energy (before electrification)
C&I/MD/HD EV Market Update (1 of 2)

- MAN eGTM truck (125 miles)
- SCANIA PHEV truck (18.4 kWh, 6 miles)
- DAF CF Electric truck (220 kWh, 137 miles)
- Ford autonomous truck
- DAF CF Hybrid truck
- Daimler truck
- Volvo Class 8 port truck

Photos from www.insideEVs.com and www.greencarreports.com
C&I/MD/HD EV Market Update (2 of 2)

- Mercedes eCirtaro bus (243-330 kWh)
- MAN City 12E bus (480-640 kWh, 125 miles)
- SCANIA/VW bus
- MAN/VW eCrafter van (36 kWh)
- VW I.D. Buzz Cargo (111 kWh, 342 miles)

Photos from [www.insideEVs.com](http://www.insideEVs.com) and [www.greencarreports.com](http://www.greencarreports.com)
Charging for Medium and Heavy Duty Vehicles

- High uncertainty
- Tesla Semis appear to need ~2MW per truck for fast charging
- Some applications can be even higher
- How much charging should happen at depots over night and how much during the day?
Air Quality Impacts of Electrification
Conclusions
Conclusions

- Electric sector emissions have decreased significantly due to shifts in generation and a myriad of air quality regulations.

- The EPRI-NRDC study shows that, in the near term, transportation electrification can lead to modest but widespread air quality benefits.

- Preliminary results (limited to July 2050) from a study supported by the California Energy Commission demonstrates that aggressive electrification can lead to even greater air quality benefits.
Together…Shaping the Future of Electricity