2020 Locomotive Emissions Inventory
Air Quality Planning & Science Division
Public Workshop
September 3, 2020
What is an emission inventory?

• An emission inventory represents *total emissions* from an equipment category (i.e. locomotives, ships, trucks, etc.)

• Emission inventories are generally based on total *activity* or *fuel usage*
  ✓ *Equipment age* is very important, as newer equipment are generally cleaner

• Emission inventories help determine sources for statewide air quality issues, and informs the need for, and effectiveness, of different emission reduction strategies.

*California’s rail system is vital to the freight network, yet it also contributes a significant portion of the state’s emissions at railyards and regionally.*
Locomotive Types

California’s locomotive emission inventory is composed of 4 categories:

1. **Line-haul**
   - Categorized as Class I freight rail, operated in California by BNSF and UP

2. **Switcher**
   - Move railcars in or around rail yards, limited to those operated at BNSF and UP railyards

3. **Short line**
   - Categorized as Class III rail
   - Local and regional railroads haul freight and provide switching, but report lower revenue than Class I, and operate over a small network. (Class III switching is captured here, not w/ Switcher)

4. **Passenger**
   - Commuter, intercity and interstate passenger rail lines

**Note**
- COVID19 has had and will have impacts on freight movement and passenger rail activity
- CARB is collecting and reviewing monthly data to determine and reflect impacts for 2020 and beyond
Line-haul locomotive emission inventory
## Data Sources

<table>
<thead>
<tr>
<th>Inventory Variable</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>South Coast MOU Data from 2010 to 2018</td>
</tr>
<tr>
<td>Activity (Megawatt Hrs)</td>
<td>Provided by UP and BNSF for 2018</td>
</tr>
<tr>
<td>Location/Distribution</td>
<td>Provided by UP and BNSF for 2018</td>
</tr>
<tr>
<td>Age and/or Tier Distribution</td>
<td>Both South Coast MOU data and those provided for non-SC regions by UP and BNSF for 2018</td>
</tr>
<tr>
<td>Emission Factors</td>
<td>US EPA Locomotive Emission Factors</td>
</tr>
<tr>
<td>Growth</td>
<td>Primarily Freight Analysis Framework (comparison with other sources)</td>
</tr>
</tbody>
</table>
### Background information

<table>
<thead>
<tr>
<th>Tier</th>
<th>NOx (g/bhp-hr)</th>
<th>PM10 (g/bhp-hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Tier 0</td>
<td>13.0</td>
<td>0.32</td>
</tr>
<tr>
<td>Tier 0</td>
<td>8.6</td>
<td>0.32</td>
</tr>
<tr>
<td>Tier 0+</td>
<td>7.2</td>
<td>0.20</td>
</tr>
<tr>
<td>Tier 1</td>
<td>6.7</td>
<td>0.32</td>
</tr>
<tr>
<td>Tier 1+</td>
<td>6.7</td>
<td>0.20</td>
</tr>
<tr>
<td>Tier 2</td>
<td>4.95</td>
<td>0.18</td>
</tr>
<tr>
<td>Tier 2+</td>
<td>4.95</td>
<td>0.08</td>
</tr>
<tr>
<td>Tier 3</td>
<td>4.95</td>
<td>0.08</td>
</tr>
<tr>
<td>Tier 4</td>
<td>1.0</td>
<td>0.015</td>
</tr>
</tbody>
</table>

- **Importance of Engine Tiers**
  - Standards for new engines got progressively cleaner over time
  - Tier 4 engines achieve NOx reductions of 93%, PM reductions of 95% when compared to an uncontrolled engine

- Tier 0+ / 1+ / 2+ mean remanufactured* engines

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*Remanufacturing is a process to increase the life of the locomotive. Through this process, locomotives are disassembled to the frame and their components are replaced as needed.*
Modeling Concept

- Work / energy (MWhrs)-based emissions inventory
- Primary goals are
  1) Understanding current Tier mix, and which Tiers are being retired vs. Tier groups that are increasing
  2) Using this to project future Tier mix based on last decade of rail visits and remanufacturing behavior.
    - Engines are not only replaced but remanufactured to different Tier standards → MWhrs flows across different Tiers

Increasing Tier groups (ITGs) tier Transition Patterns

Only 4% Tier 4

Rebuilding process: https://www.assemblymag.com/articles/94429-ge-stays-on-track-by-rebuilding-locomotives
Current and Historical Data & Trends

<table>
<thead>
<tr>
<th>Data</th>
<th>Year</th>
<th>Used For</th>
</tr>
</thead>
<tbody>
<tr>
<td>'98 South Coast MOU Reporting Data</td>
<td>2010-2018</td>
<td>Understanding Activity &amp; Workload by Engine Tier</td>
</tr>
<tr>
<td>Ever-Visited South Coast Population</td>
<td>2015-2018</td>
<td>Looking at Remanufacturing Behavior &amp; Tier Transition Pattern (can monitor locomotives by tracking number, observe remanufactures)</td>
</tr>
</tbody>
</table>

- Additional factors;
  - Tier 4 locomotive purchases have been steadily decreasing since the standards went into effect in 2015, with no 2019 Tier 4 locomotive purchases as of May 31, 2019
  - Tier 0 and Tier 1 locomotives might be parked and can be pulled back into service
Combing Growth, Tier Transition and Retirement into Forecasting Steps

**STEP 1**

Increasing & Decreasing Tier groups based on Tier Transition Patterns

**STEP 2**

Retiring of units after several remanufacture cycles (i.e., limit on total service life)

**STEP 3**

Baseline MWhrs growth due to increased freight movement (2.19% YOY)

**STEP 4**

Determine Tier of Locomotives that will backfill retirements and growth needs (Potential for many parked Tier 0+ /1+ units brought back into service to fill gap)
Forecasting Steps – BAU scenario

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Step 1: Calculation of incremental MWhrs of Increasing Tier Groups by using Tier Transition Patterns

MWhrs flow

Pre-Tier 0

Tier 0

Tier 0+

Tier 1+

Tier 1

Tier 1

Tier 2+

Tier 2

Tier 2

Tier 3

Tier 3

Previous Tier groups

Previous Tier groups

Present Tier groups

Present Tier groups

x1%

x2%

50%

b1%

b2%

z1%

z2%

y1%

y2%

48%

97%

c3%
Step 1: Calculation of incremental MWhrs of Increasing Tier Groups by using Tier Transition Patterns

- Pre-Tier 0, Tier 0, Tier 1, and Tier 2 (Decreasing Tier Groups) will be phased out at their observed rate of decline from 2010 to 2018.

- Decreasing Tier Groups activity will be absorbed by other Tier groups, based on observed MWhrs flow pattern (shown in graphic).

**Example:** Tier 1+ will absorb 50% of decreased MWHrs in Pre-Tier, 48% of MWHrs from decreasing Tier 0, 97% of MWHrs from decreasing Tier 1.
Step 1: Results of Tier Transition Only

<table>
<thead>
<tr>
<th>Tier</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
<th>2035</th>
<th>2040</th>
<th>2045</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRE-TIER 0</td>
<td>7.0E+05</td>
<td>6.0E+05</td>
<td>5.0E+05</td>
<td>4.0E+05</td>
<td>3.0E+05</td>
<td>2.0E+05</td>
<td>1.0E+05</td>
<td>0.0E+00</td>
<td></td>
</tr>
<tr>
<td>TIER 0</td>
<td>6.0E+05</td>
<td>5.0E+05</td>
<td>4.0E+05</td>
<td>3.0E+05</td>
<td>2.0E+05</td>
<td>1.0E+05</td>
<td>0.0E+00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TIER 0+</td>
<td>5.0E+05</td>
<td>4.0E+05</td>
<td>3.0E+05</td>
<td>2.0E+05</td>
<td>1.0E+05</td>
<td>0.0E+00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TIER 1</td>
<td>4.0E+05</td>
<td>3.0E+05</td>
<td>2.0E+05</td>
<td>1.0E+05</td>
<td>0.0E+00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TIER 1+</td>
<td>3.0E+05</td>
<td>2.0E+05</td>
<td>1.0E+05</td>
<td>0.0E+00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TIER 2</td>
<td>2.0E+05</td>
<td>1.0E+05</td>
<td>0.0E+00</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>TIER 2+</td>
<td>1.0E+05</td>
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<td></td>
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<tr>
<td>TIER 3</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TIER 4</td>
<td>0.0E+00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Step 1 only: Not the actual long-term forecast of Tiers
Forecasting Steps – BAU scenario

**STEP 1**
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Retiring of units after several remanufacture cycles (i.e., limit on total service life)

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Determine Tier of Locomotives that will backfill retirements and growth needs (Potential for many parked Tier 0+/1+ units brought back into service to fill gap)
Step 2: Major Turnover Year per Tier (Retirement)

- 25 years of total service life (years)
  - Data from 2010 to 2018 shows a significant drop in population and activity at 25 years of age
  - Not guaranteed to continue, reality is maintaining locomotives past a certain age carries increased cost, balanced against increased cost of Tier 4 engines
- 2016 (Base year) + Remaining useful life + future remanufacturing period = Major turnover timing (Retiring year of the locomotives)
  - Remaining useful life = Average service life – Average age in 2016
  - Future remanufacturing period: 9~12 years depending on Tier

<table>
<thead>
<tr>
<th>Tier</th>
<th>Major Turnover Timing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Tier 0</td>
<td>2029</td>
</tr>
<tr>
<td>Tier 0</td>
<td>2029</td>
</tr>
<tr>
<td>Tier 0+</td>
<td>2029</td>
</tr>
<tr>
<td>Tier 1</td>
<td>2029</td>
</tr>
<tr>
<td>Tier 1+</td>
<td>2032</td>
</tr>
<tr>
<td>Tier 2</td>
<td>2031</td>
</tr>
<tr>
<td>Tier 2+</td>
<td>2033</td>
</tr>
<tr>
<td>Tier 3</td>
<td>2035</td>
</tr>
<tr>
<td>Tier 4</td>
<td>2039</td>
</tr>
</tbody>
</table>
Example: Major Turnover Year of Tier 0+

- Average reman cycle (Average service life) of Tier 0+: 9 years
  - Average age of Tier 0+: 5 years
  - Remained operating time: 4 years
- Avg total service life of Tier 0+: 18 years
  - Likely to be remanned earlier than the average total service life
  - Remained service lifespan: 13 years (18yrs – 5yrs)
- # of Reman likely: Average of 1.44 time (=13 yrs / 9 yrs of ARC)
Example: Major Turnover Year of Tier 1+

- Average reman cycle (Average service life) of Tier 1+: 6 years
  - Average age of Tier 1+: 2 years
  - Remained operating time: 4 years
- Avg total service life of Tier 1+: 25 years
  - Remained service lifespan: 23 years (25yrs – 2yrs of avg. age)
- # of Reman available: At least twice, reman up to 3.83 times (=23 yrs / 6 yrs of ARC)

![Graph showing major turnover timing and reman availability](image-url)
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Step 3: Baseline Activity Growth Rate of Total MWhrs

- Base activity growth rate is based on the relationship between the freight movement growth rates at different time points.
- MWhrs forecast to grow at fixed rate, 2.19%

<table>
<thead>
<tr>
<th>Data sources</th>
<th>Time frame</th>
<th>AVG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Distillate Sales/Deliveries to Railroad Consumers (Thousand Gallons) [1]</td>
<td>2013 – 2018</td>
<td>1.82%</td>
</tr>
<tr>
<td>2019 The Budget and Economic Outlook: GDP (Billions of dollars) [5]</td>
<td>2013 - 2018</td>
<td>4.70%</td>
</tr>
<tr>
<td>Rail growth used for SCAG Regional Transportation Planning [6]</td>
<td>2012 - 2040</td>
<td>3.30%</td>
</tr>
<tr>
<td>Class I Rail Freight Fuel Consumption and Travel (million gallons) [7]</td>
<td>2010 – 2012</td>
<td>1.51%</td>
</tr>
<tr>
<td>Seasonally-adjusted Rail Freight Intermodal Traffic [7](BTS &amp; AAR)</td>
<td>2010 - 2018</td>
<td>3.17%</td>
</tr>
<tr>
<td>Port of Long beach container counts (TEUs) [8]</td>
<td>2010 – 2019</td>
<td>2.20%</td>
</tr>
<tr>
<td>Port of LA container counts (TEUs) [9]</td>
<td>2010 – 2019</td>
<td>2.00%</td>
</tr>
</tbody>
</table>

[1] U.S. Energy Information Administration, Sales of Distillate Fuel Oil by End Use
Forecasting Steps – BAU scenario

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Future Tier Mix (%)
- Tier 1+
- Tier 2+
- Tier 3
- Tier 4

ARC: Average Reman. Cycle

MW-hrs Deficits

Replacements
Market growth and Tier replacement

- Locomotive units will gradually be scrapped, parked, or converted to switchers (useful life is not infinite, even for increasing Tier groups)
- In most models, replacements would be new equipment, however (1) ongoing changes in purchasing habits, (2) lack of current or planned Tier 3 or 4 purchases, (3) parking large amounts of older locomotives that may be used again suggest that future replacements will primarily be Tier 1+ or Tier 2+ with only moderate Tier 3 and Tier 4 purchases
Step 4: Replacement

Step 4. Distribution of MWhrs deficits to target tier groups

**Tier Allocation of Replacement in Business-as-Usual scenario**

<table>
<thead>
<tr>
<th>Tier</th>
<th>Workload share (%) for the past 9 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tier 1/1+</td>
<td>30%</td>
</tr>
<tr>
<td>Tier 2/2+</td>
<td>30%</td>
</tr>
<tr>
<td>Tier 3/4</td>
<td>25%</td>
</tr>
<tr>
<td>Tier PT0/T0/0+</td>
<td>15%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tier</th>
<th>Percent of Deficit MWHrs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Until 2030</td>
</tr>
<tr>
<td>Tier 1+</td>
<td>35%</td>
</tr>
<tr>
<td>Tier 2+</td>
<td>35%</td>
</tr>
<tr>
<td>Tier 3</td>
<td>15%</td>
</tr>
<tr>
<td>Tier 4</td>
<td>15%</td>
</tr>
</tbody>
</table>

- The focus on T1+ / T2+ is based on current trends where T4 purchases are at or near zero
- MWHrs for Tier 1+/2+ are the primary increasing Tier groups
- Parked locomotives present an opportunity to be pulled back into service, would allow T4 to be phased in instead of purchased in huge quantities (which is unlikely based on current trends)
BAU (Business-As-Usual) Scenario

- BAU scenario Tier distribution

<table>
<thead>
<tr>
<th>Pre-Tier 0</th>
<th>Tier 0</th>
<th>Tier 0+</th>
<th>Tier 1</th>
<th>Tier 1+</th>
<th>Tier 2</th>
<th>Tier 2+</th>
<th>Tier 3</th>
<th>Tier 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,200,000</td>
<td>1,000,000</td>
<td>800,000</td>
<td>600,000</td>
<td>400,000</td>
<td>200,000</td>
<td>0</td>
<td>2010 2015 2020 2025 2030 2035 2040 2045 2050</td>
<td></td>
</tr>
</tbody>
</table>

Megawatts-hours

- Base MWhrs growth

Tier 4
Tier 3
Tier 2+
Tier 1+
Tier 1
Tier 2
Tier 0
Tier 0+
South Coast NOX Emission Result (BAU scenario)
South Coast PM Emission Result (BAU scenario)
Scaling up South Coast MWhrs to CA MWhrs

- MOU data only covers locomotive activities in the South Coast Air Basin area, and it also include switcher activity.
- The model had to separate switchers’ impact from the MOU data and scale up SC line-haul MWhrs to the CA level.
- CA GTM data, OFFROAD2017, 2016 SIP, and switcher emission inventory

CA locomotive activity (Megawatts-hours)
Statewide NOX Emission Result (BAU scenario)

<table>
<thead>
<tr>
<th>Tier</th>
<th>g/bhp-hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Tier 0</td>
<td>13</td>
</tr>
<tr>
<td>Tier 0</td>
<td>8.6</td>
</tr>
<tr>
<td>Tier 0+</td>
<td>7.2</td>
</tr>
<tr>
<td>Tier 1</td>
<td>6.7</td>
</tr>
<tr>
<td>Tier 1+</td>
<td>6.7</td>
</tr>
<tr>
<td>Tier 2</td>
<td>4.95</td>
</tr>
<tr>
<td>Tier 2+</td>
<td>4.95</td>
</tr>
<tr>
<td>Tier 3</td>
<td>4.95</td>
</tr>
<tr>
<td>Tier 4</td>
<td>1.0</td>
</tr>
</tbody>
</table>

NOx Emission Factor (US EPA, 2009)

- Tier 0: 8.6 g/bhp-hr
- Tier 0+: 7.2 g/bhp-hr
- Tier 1: 6.7 g/bhp-hr
- Tier 1+: 6.7 g/bhp-hr
- Tier 2: 4.95 g/bhp-hr
- Tier 2+: 4.95 g/bhp-hr
- Tier 3: 4.95 g/bhp-hr
- Tier 4: 1.0 g/bhp-hr

Tier 0: 4.95 g/bhp-hr
Tier 0+: 4.95 g/bhp-hr
Tier 3: 4.95 g/bhp-hr
Tier 4: 1.0 g/bhp-hr

2020-2050 NOx emissions (tpd)
Switcher Rail Yard emission inventory
What Data Did UP/BNSF Supply?

CEA submitted data on behalf of UP/BNSF in 2019

1. Combined statewide tier distribution for both companies

2. Number of full-time-equivalent (FTE) engines per railyard

   • FTE = number of engines operating = \( \frac{\# \text{ engines} \times \text{activity (hr/yr)}}{24 \text{ hr/day} \times 365 \text{ day/yr}} \)

   • On average, a yard locomotive consumes 82,490 gal/yr (Source: U.S. EPA)

   • Fuel (annual gal/yard) = (# FTE per yard) \times (82,490 gal/yr)
Model Assumptions

CEA Assumptions
• Tier distribution applied equally to all yards
• CEA assumes fuel consumption according to U.S. EPA conversion rate

CARB Assumptions
• Calendar Year 2017 data
• 2.19% fuel growth rate matches freight growth assumptions in the new line haul Inventory
• No forced turnover or engine purchases/trades, except phase-out of Pre-Tier 0 in 2030

** Lack of turnover is supported by a study of South Coast locomotives between 2010 and 2018, and their observed turnover practices
Base Year Statewide Tier Distribution

- Tier 0: 26%
- Tier 0+: 49%
- Tier 2: 14%
- Tier 3: 3%
- Tier 4: 2%
- Pre-Tier 0: 6%

2017 Percent of FTE Engines
### Base Year FTE and Fuel by Air Basin

<table>
<thead>
<tr>
<th>Air Basin</th>
<th>Number of yards (BNSF:UP)</th>
<th>Number of FTE</th>
<th>Annual Fuel (gallons)</th>
<th>Percent of Fuel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mojave Desert</td>
<td>1:0</td>
<td>8.17</td>
<td>674,161</td>
<td>8%</td>
</tr>
<tr>
<td>Sacramento Valley</td>
<td>0:3</td>
<td>8.04</td>
<td>662,782</td>
<td>8%</td>
</tr>
<tr>
<td>San Diego</td>
<td>1:0</td>
<td>1.38</td>
<td>114,040</td>
<td>1%</td>
</tr>
<tr>
<td>San Francisco Bay Area</td>
<td>1:5</td>
<td>9.19</td>
<td>758,823</td>
<td>9%</td>
</tr>
<tr>
<td>San Joaquin Valley</td>
<td>4:3</td>
<td>14.61</td>
<td>1,204,789</td>
<td>15%</td>
</tr>
<tr>
<td>South Coast</td>
<td>5:5</td>
<td>57.51</td>
<td>4,743,834</td>
<td>58%</td>
</tr>
</tbody>
</table>

Annual Fuel = FTE x 82,490 gal/yr

![Pie chart showing 2017 Percent Fuel distribution: Mojave Desert 8%, Sacramento Valley 8%, San Diego 2%, San Francisco Bay Area 9%, South Coast 58%, San Joaquin Valley 15%.]
Statewide FTE Population by Tier

<table>
<thead>
<tr>
<th>Tier</th>
<th>Turnover Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Tier 0</td>
<td>in 2030, replace with Tier 2</td>
</tr>
<tr>
<td>Tier 0</td>
<td>before 2000, all to Pre-Tier 0</td>
</tr>
<tr>
<td>Tier 0+</td>
<td>before 2001, all to Pre-Tier 0</td>
</tr>
<tr>
<td>Tier 2</td>
<td>before 2005, all to Pre-Tier 0</td>
</tr>
<tr>
<td>Tier 3</td>
<td>before 2013, all to Pre-Tier 0</td>
</tr>
<tr>
<td>Tier 4</td>
<td>before 2016, all to Pre-Tier 0</td>
</tr>
</tbody>
</table>

FTE Engine Distribution

- 25% Tier 0
- 50% Tier 0+
- 20% Tier 2
- 2.9% Tier 3
- 2.1% Tier 4
Switch Emission Factors

Switch Emission Factors \( \times \) Conversion Factor = Emissions Factor
\( \text{(g/bhp-hr)} \) \( \text{(bhp-hr/gal)} \) \( \text{(g/gal)} \)

Switcher Emission Factors (g/gal)

- NOx g/gal
- PM g/gal

Pre-Tier 0 Tier 0 Tier 0+ Tier 1 Tier 1+ Tier 2 Tier 2+ Tier 3 Tier 4

https://nepis.epa.gov/Exe/ZyPDF.cgi/P100500B.PDF?Dockey=P100500B.PDF
Air Basin Emissions

Switcher BAU NOX Emissions by Air Basin

Switcher BAU PM Emissions by Air Basin

CARB

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Short Line Rail emission inventory
What is Short Line Rail?

• Local or regional rail lines that haul freight and provide switching (Class 3)
• Lower revenue than line haul (Class I)
• No reporting obligations
Short Line Rail Summary

Rail companies voluntarily submitted data in 2017
- 25 rail companies – Commercial, switching, and recreational rail lines

Data
- Locomotive model year, tier, and horsepower
- Fuel consumption data is for 2015

Growth
- Assumed to be constant – no available future plans

Turnover
- Assumed no turnover – companies do not make long-range business plans
- Average age is 43 years old
  (Engines have been bought, sold, leased, and traded over and over again)
Short Line Tier Distribution

Short Line Engine Distribution

- Pre-Tier 0: 66%
- Tier 3: 10%
- Tier 4: 3%
- Genset: 21%
Passenger Rail Emission Inventory

Passenger Rail

• Commuter, intercity and interstate passenger rail operating within the state of California.

History

• Commuter rail is relatively newer in California, with service beginning in 1991
• Amtrak intercity and interstate lines are significantly older.
Passenger Rail Summary

Rail companies voluntarily submitted data
  • Base Year 2017
  • Six rail companies

Data
  • Locomotive model year, tier, and horsepower
  • Fuel Consumption

Fuel
  • Fuel consumption is averaged over several years, by rail company (data provided fuel per engine)
  • Fuel growth is assumed to be constant – no plans for additional routes or other operational changes

Turnover
  • Turnover based on individual rail company’s plans
Passenger Rail Statewide NOx

Statewide Passenger NOx

- ~2018
  - Metrolink replaced Pre-Tier engines with 40 Tier 4s
  - Pacific Surfliner replaced Pre-Tier engines with 18 Tier 4s

- ~2021
  - Caltrain plans to replace Pre-Tier engines with Electric
Total Locomotive NOx Emissions Inventory and Mobile Source Strategies (MSS)
Locomotive NOx Emissions

South Coast NOX

Statewide NOX

NOX (tons per day)

2020 2025 2030 2035 2040 2045 2050

NOX (tons per day)

2020 2025 2030 2035 2040 2045 2050
2020 Mobile Source Strategy (MSS)

- MSS considers technology mixes for mobile source sector that are needed to meet mid-term air quality goals and mid-century climate goals
- MSS scenarios are developed to illustrate the extent of transformation needed to achieve the clean air goals
- Extensive additional work would be needed to translate these scenarios into measures
- Additional information can be found at: https://ww2.arb.ca.gov/resources/documents/2020-mobile-source-strategy
## Line Haul Scenarios Considered

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Average Reman Cycle (ARC)</th>
<th>MWhrs deficit allocation (Unit replacement of RR) (T1+ : T2+ : T3 : T4)</th>
<th>Note</th>
</tr>
</thead>
</table>
| **BAU**   | No reman limit policy     | - Until 2030 40% : 40% : 10% : 10%  
- Until 2050 0% : 0% : 10% : 90% | • Tier 1+ and Tier 2+ will be the majority by 2030 which is the predicted major turnover timing of the locomotives in the CA operation.  
• Tier 4 (possibly including T5) will take over the workload of its predecessors. |
| **MSS**   | Twice-remanned units are not operated in CA operations | 0% : 0% : 0% : 100% | • Tier 5 adoption scenario  
- All old Tiers except for Tier 4 are almost phased out by 2035  
- MWhrs of Tier 5 increases from 2028 to 2050 at 35% per year. → 100% of activity share by 2050 |
MSS (Mobile Source Strategy) Scenario

• MSS scenario Tier distribution

[Image of a graph showing the distribution of different tiers over time, with bars indicating the megawatt-hours for each tier from 2010 to 2050.]
SC NOx emission projections

- SC BAU scenario
- SC MSS scenario
- 2016 SC SIP inventory

NOx emissions (Tons per Day)

- 2020: 11.3
- 2024: 7.2
- 2028: 8.4
- 2032: 4.8
- 2036: 3.1
- 2040: 3.0
- 2044: 3.0
- 2048: 2.8
- 2050: 1.9

Values for 2016 SC SIP inventory:

- 2020: 11.2
- 2024: 12.0
- 2028: 12.6
- 2032: 13.2
- 2036: 12.9
- 2040: 11.0
- 2044: 9.6
- 2048: 7.8
- 2050: 6.9

Values for SC BAU scenario:

- 2020: 11.0
- 2024: 9.6
- 2028: 7.8
- 2032: 6.9
- 2036: 5.2
- 2040: 4.1
- 2044: 3.0
- 2048: 2.8
- 2050: 1.9

Values for SC MSS scenario:

- 2020: 9.3
- 2024: 7.2
- 2028: 8.4
- 2032: 4.8
- 2036: 3.1
- 2040: 3.0
- 2044: 3.0
- 2048: 2.8
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Values for NOx emissions (Tons per Day):

- 2020: 11.2
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### Switcher Scenarios Considered

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>2017 Tier Mix (PTO:TO:T0+:T2:T3:T4)</th>
<th>2030 Tier Mix (PTO:TO:T0+:T2:T3:T4)</th>
<th>Notes</th>
</tr>
</thead>
</table>
| BAU       | 0% : 26% : 49% : 20% : 3% : 2%     |                                   | • No purchases/turnover  
• Turnover Pre-Tiers to Tier 2 in 2030. |
| Optimistic| 6% : 26% : 49% : 14% : 3% : 2%     | 0% : 0% : 0% : 95% : 3% : 2%       | • Turnover all Pre-Tier, Tier 0,  
  Tier 0+ turnover over to Tier 2  
  by 2030. |
| Aggressive| 0% : 0% : 0% : 20% : 30% : 50%     |                                   | • Turnover all Pre-Tier, Tier 0,  
  Tier 0+ by 2030.  
• Only Tier 2, Tier 3, Tier 4, with  
  primarily Tier 4. |

*ARB is reviewing zero emission battery technology for switchers and planning to incorporate them in future MSS scenarios this year*
Scenarios: NOX

Switcher Scenario - Optimistic

Switcher Scenario - Aggressive

Pre-Tier Tier 0 Tier 0+ Tier 2 Tier 3 Tier 4
Pre-Tier Tier 0 Tier 0+ Tier 2 Tier 3 Tier 4

BAU NOX Optimistic NOX

Aggressive NOX

CARB
Scenarios: PM

Switcher Scenario - Optimistic

Switcher Scenario - Aggressive
Emissions Inventory and Health Impact

- Emissions inventory is significant part of health risk analyses.
- Cancer risk characterization near railyards
- Mortality and Illness from locomotive emissions
- Health Impacts from locomotive emissions will be updated during Fall Locomotive Regulation Webinar.
Questions and Contacts

• Questions, comments and feedback are encouraged and welcome

• To address comments and reflect any changes, please submit comments and any supporting data by October 1, 2020

Health Risk and Regulatory Related Questions

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Thank you