White Paper Overview

• Role of VOCs in ozone and PM2.5 formation
  – Technical analysis
  – Atmospheric chemistry
  – VOC to NOx ratios
  – Major sources

• Implications of alternative strategies
  – Potential detrimental effects
  – Rationale for NOx and VOC control strategy

• Potential approaches under consideration
Overall Goal: Attainment of Federal Standards

Ozone Trend

- **Ozone**
  - Current Standard 8-hour average – 75 ppb
  - Attain by 2032

PM2.5 Trend

- **PM$_{2.5}$**
  - Current Standard – 12 µg/m3
  - Attain by 2020-2025
Role of VOCs: Ozone Formation

- Ozone levels a function of VOC/NO\(_x\) ratios*
- NO\(_x\) limited – decreasing NO\(_x\) reduces ozone; decreasing VOC has little effect
- VOC limited – decreasing VOC reduces ozone; decreasing NO\(_x\) has little effect or increases ozone

<table>
<thead>
<tr>
<th>Region</th>
<th>VOC/NO(_x) Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inland Empire/Mountains</td>
<td>NO(_x) Limited</td>
</tr>
<tr>
<td>San Gabriel Valley</td>
<td>VOC Limited (Transitional)</td>
</tr>
<tr>
<td>Central Los Angeles</td>
<td>VOC Limited</td>
</tr>
</tbody>
</table>

*Many factors, including temporal and spatial, add complexity
OZONE – 2013
Number of Days Exceeding the Federal Standard
(8-hour average > 0.075 ppm)
Role of VOCs: PM Formation

- **Primary Organic Aerosols**
  - Science more developed
  - Typically from combustion (including mobile) sources
  - Does not account for significant portion of measured particulates

- **Secondary Organic Aerosols (SOA)**
  - Generated from the oxidation of organic gases in the atmosphere
  - SOA yield function of total organic PM available
    - More SOA produced in highly polluted environments
  - Higher carbon chain organics and aromatics form most SOA
  - Additional studies underway

Gas-phase organic compounds → Oxidation Reactions (OH, O₃, NO₃) → SOA
Intermediate (I-VOC) and Semi-Volatile (S-VOC) Organic Compounds

- Organic compounds that occur in gas phase but may not be defined as VOC
- Form ozone
- Efficient Secondary Organic Aerosol (SOA) source
- May be significant emission source
  - Evaporation still occurs, but slower evaporation rate
  - Increases in temperature lead to significant enhancement in volatility
- Recent research completed on I-VOC and S-VOC
  - Likely to be significant source of SOA

Examples
- Intermediate (C12-C23) and Semi-Volatile (C24-C27) alkanes
- Solvents used in coatings and adhesives
- Low Vapor Pressure VOC consumer product solvents
PM2.5 – 2013*
Annual Arithmetic Mean $\mu g/m^3$
(Federal Standard = 12.0 $\mu g/m^3$)

*Based on preliminary invalidated data.
VOC Sources* (2023)

Total = 481 tpd

- Consumer Products 19%
- Off-Road Vehicles 18%
- On-Road Vehicles 14%
- Biogenic 16%
- Cleaning and Surface Coatings 10%
- Industrial Processes 3%
- Petroleum Production and Marketing 7%
- Architectural 4%
- Waste Disposal 3%
- Fuel Combustion 3%
- Others 0%
- Misc. Processes* 3%
- RECLAIM Sources 0%

Regulated by SCAQMD
Regulated by CARB
* Excludes LVP-VOC contribution
Source: 2012 AQMP – (excluding biogenic)
Top 10 VOC Source Categories*

Does not include LVP-VOCs

- Regulated by SCAQMD
- Regulated by CARB

* Excludes LVP-VOC contribution

Source: 2012 AQMP – 2023 Top Ten Emitter Categories

VOC Emissions (tons/day) vs. Source Categories:

1. Consumer Products
2. Off-Road Equipment
3. Petroleum Marketing
4. Coatings & Related Process Solvents
5. Recreational Boats
6. Light-Duty Trucks
7. Passenger Cars
8. Architectural Coatings
9. Medium-Duty Trucks
10. Degreasing

Values:
- Consumer Products: 89 tons/day
- Off-Road Equipment: 43 tons/day
- Petroleum Marketing: 31 tons/day
- Coatings & Related Process Solvents: 26 tons/day
- Recreational Boats: 21 tons/day
- Light-Duty Trucks: 18 tons/day
- Passenger Cars: 17 tons/day
- Architectural Coatings: 17 tons/day
- Medium-Duty Trucks: 14 tons/day
- Degreasing: 14 tons/day
NOx Sources (2023)

- Regulated by SCAQMD
- Regulated by CARB

Source: 2012 AQMP

Total = 328 tpd

- On-Road Vehicles 38%
- Off-Road Vehicles 40%
- RECLAIM Sources 8%
- Misc. Processes 5%
- Others 0%
- Waste Disposal 1%
- Fuel Combustion 8%
Top 10 NOx Source Categories

- Regulated by SCAQMD
- Regulated by CARB

Source: 2012 AQMP – 2023 Top Ten Emitter Categories

<table>
<thead>
<tr>
<th>Category</th>
<th>NOx Emissions (tons/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy-Duty Diesel Trucks</td>
<td>51</td>
</tr>
<tr>
<td>Off-Road Equipment</td>
<td>43</td>
</tr>
<tr>
<td>Ships &amp; Commercial Boats</td>
<td>41</td>
</tr>
<tr>
<td>NOx RECLAIM</td>
<td>27</td>
</tr>
<tr>
<td>Locomotives</td>
<td>22</td>
</tr>
<tr>
<td>Aircraft</td>
<td>16</td>
</tr>
<tr>
<td>Heavy-Duty Gasoline Trucks</td>
<td>16</td>
</tr>
<tr>
<td>Residential Fuel Combustion</td>
<td>15</td>
</tr>
<tr>
<td>Passenger Cars</td>
<td>14</td>
</tr>
<tr>
<td>Light-Duty Trucks</td>
<td>13</td>
</tr>
</tbody>
</table>
PM2.5 Sources* (2023)

Total = 71 tpd

- Point Sources: 33%
- Area Sources: 17%
- Dust: 14%
- Other: 28%
- Misc. Processes: 3%

- On-Road Vehicles: 4%
- Off-Road Vehicles: 4%

Regulated by SCAQMD
Regulated by CARB

* Excludes I-VOC and S-VOC contribution
Source: 2012 AQMP
Top 10 PM2.5 Source Categories

PM2.5 Emissions (tons/day)

- Regulated by SCAQMD
- Regulated by CARB
* Excludes I-VOC and S-VOC contribution

Source: 2012 AQMP – 2023 Top Ten Emitter Categories
## Implications of Alternative VOC Strategies

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Inland Empire &amp; Mountains (NOx Limited)</th>
<th>San Gabriel Valley (VOC Limited)</th>
<th>Central Los Angeles (VOC Limited)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOx Only</td>
<td>Ozone reduction; Limited PM reduction</td>
<td>Limited ozone increase; Limited PM reduction</td>
<td>Ozone increase; Limited PM reduction</td>
</tr>
<tr>
<td>VOC Only</td>
<td>Limited ozone reduction; Limited PM reduction</td>
<td>Ozone reduction; Limited PM reduction</td>
<td>Ozone reduction; Limited PM reduction</td>
</tr>
<tr>
<td>NOx &amp; VOC</td>
<td>Ozone reduction; Enhanced PM reduction</td>
<td>Ozone reduction; Enhanced PM reduction</td>
<td>Limited ozone reduction; Enhanced PM reduction</td>
</tr>
</tbody>
</table>
Data Limitations

• Limited data on LVP-VOCs used in consumer products
• Intermediate and Semi-volatiles not included in inventories
  – VOCs from coatings/solvents/consumer products also may address additional uncertainty
• Some inventories are dated and rely on population and rule projections
• Smaller area source and consumer/institutional users do not normally report emissions
• Fugitive emissions and non-compliance difficult to estimate
Potential Approaches

• Sensitivity analysis to illustrate potential impacts
• Refine characterization of VOC sources
  • Product use surveys
  • Enhanced monitoring
• Temporal/Geographical
  • Utilize VOC/NOx ratios opportunities
• Seasonality
• Incentives
  • Permit streamlining
  • Reduced record keeping
  • Recognition/Green Business-like program
Potential Schedule/Next Steps

• Release of Draft Paper – Aug 29, 2014
• Comments on Draft Paper – Sep 26, 2014
• Additional Working Group Meeting – As needed
• Final VOC White Paper – Late 2014
Backup Slides
## VOC Sources (2023)

<table>
<thead>
<tr>
<th>SOURCE CATEGORY</th>
<th>VOC (TPD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Combustion</td>
<td>14</td>
</tr>
<tr>
<td>Waste Disposal</td>
<td>14</td>
</tr>
<tr>
<td>Cleaning and Surface Coatings</td>
<td>49</td>
</tr>
<tr>
<td>Petroleum Production and Marketing</td>
<td>36</td>
</tr>
<tr>
<td>Industrial Processes</td>
<td>16</td>
</tr>
<tr>
<td>Architectural</td>
<td>17</td>
</tr>
<tr>
<td>Others</td>
<td>2</td>
</tr>
<tr>
<td>Misc. Processes</td>
<td>16</td>
</tr>
<tr>
<td>RECLAIM Sources</td>
<td>0</td>
</tr>
<tr>
<td>Consumer Products</td>
<td>89</td>
</tr>
<tr>
<td>On-Road Vehicles</td>
<td>67</td>
</tr>
<tr>
<td>Off-Road Vehicles</td>
<td>86</td>
</tr>
<tr>
<td>Biogenic</td>
<td>75</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>481</strong></td>
</tr>
</tbody>
</table>

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* Excludes LVP-VOC contribution
Source: 2012 AQMP – 2023 Baseline (excluding biogenic)
# NOx Sources (2023)

<table>
<thead>
<tr>
<th>SOURCE CATEGORY</th>
<th>NOx (TPD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Combustion</td>
<td>27</td>
</tr>
<tr>
<td>Waste Disposal</td>
<td>2</td>
</tr>
<tr>
<td>Others</td>
<td>0</td>
</tr>
<tr>
<td>Misc. Processes</td>
<td>17</td>
</tr>
<tr>
<td>RECLAIM Sources</td>
<td>27</td>
</tr>
<tr>
<td>On-Road Vehicles</td>
<td>125</td>
</tr>
<tr>
<td>Off-Road Vehicles</td>
<td>130</td>
</tr>
<tr>
<td>TOTAL</td>
<td><strong>328</strong></td>
</tr>
</tbody>
</table>

- Regulated by SCAQMD
- Regulated by CARB

Source: 2012 AQMP – 2023 Baseline
PM Sources (Direct, 2023)

<table>
<thead>
<tr>
<th>SOURCE CATEGORY</th>
<th>PM2.5 (TPD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Combustion</td>
<td>6</td>
</tr>
<tr>
<td>Cleaning and Surface Coatings</td>
<td>2</td>
</tr>
<tr>
<td>Petroleum Production and Marketing</td>
<td>2</td>
</tr>
<tr>
<td>Industrial Processes</td>
<td>8</td>
</tr>
<tr>
<td>Solvent Evaporation</td>
<td>0</td>
</tr>
<tr>
<td>Misc. Processes</td>
<td>35</td>
</tr>
<tr>
<td>On-Road Vehicles</td>
<td>11</td>
</tr>
<tr>
<td>Off-Road Vehicles</td>
<td>7</td>
</tr>
<tr>
<td>TOTAL</td>
<td>71</td>
</tr>
</tbody>
</table>

- Regulated by SCAQMD
- Regulated by CARB

* Excludes Intermediate (C12-C23) and Semi-volatile (C24-C27) contribution

Source: 2012 AQMP – 2023 Baseline