Agenda

Summary of Working Group Meeting #7
Progress of Rule Development
Third Party Consultant Update
CEMS Data
SCR Cost Model Update and Revisions
Next Steps
Progress of Rule Development

Summary of Working Group #7 (4/30/19)

- Presented meetings with technology manufacturers
- Discussed U.S. EPA Selective Catalytic Reduction (SCR) Cost Model
- Proposed initial considerations for rule concepts

Since Last Working Group Meeting

- Finalizing both contracts with Norton Engineering Consultants, Inc. (Norton) and Fossil Energy Research Corporation (FERCo)
- Continued meetings and conversations with control technology suppliers
- Follow-up site visit to facilities to address additional concerns
- Completed CEMS data analysis
- U.S. EPA SCR cost model revisions/updates
  - Discussion with EPA regarding SCR cost model methodology
  - Requesting additional cost information from stakeholders
- RECLAIM staff is currently working on NSR/BACT resolution and will provide further updates
Third Party Consultant Update
Third Party Consultant Update

- Finalizing contracts with:
  - Norton
  - FERCo
- Initial meetings with each consultant scheduled in July
- Consultants will perform separate tasks

- Review staff’s BARCT analysis
- Research international low-NOx installations (achieved in practice)
- Control technologies
- Costs

- Difficult installations and/or retrofits
  - Space constraints
  - Burner technology installations
  - SCR and ammonia injection grid optimization
# Proposed Scope of Work

## Norton Engineering

<table>
<thead>
<tr>
<th>Task 1:</th>
<th>Assess the feasibility of staff’s proposed NOx limits and secondary pollutant limits for affected equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task 2:</td>
<td>Assess the cost effective estimates including, but not limited to the use of the U.S. EPA SCR cost model</td>
</tr>
<tr>
<td>Task 3:</td>
<td>Provide recommendations on the technological and/or cost feasibility of affected equipment</td>
</tr>
<tr>
<td>Task 4:</td>
<td>Communicate, when warranted, with the other consultant evaluating the potential installation challenges, or with vendors of control technology</td>
</tr>
<tr>
<td>Task 5:</td>
<td>Prepare progress status updates and final report including technology and/or cost recommendations</td>
</tr>
<tr>
<td>Task 6:</td>
<td>Present findings at meeting(s)</td>
</tr>
</tbody>
</table>

## Fossil Energy Research Corporation

<table>
<thead>
<tr>
<th>Task 1:</th>
<th>Conduct potential facility visits to make detailed on-site observations and engineering evaluations of affected equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task 2:</td>
<td>Feasibility of installation, including but not limited to, feasibility of installation of new control technologies</td>
</tr>
<tr>
<td>Task 3:</td>
<td>Determine if further optimization can be performed on currently installed NOx control systems to help achieve further emission reductions</td>
</tr>
<tr>
<td>Task 4:</td>
<td>Prepare progress status updates and final report including recommendations</td>
</tr>
<tr>
<td>Task 5:</td>
<td>Present findings at meeting(s)</td>
</tr>
</tbody>
</table>
Purpose for CEMS Data Collection

- 2018 refinery survey only included annual average emissions for each unit
  - Does not reflect day-to-day concentration variations, nor operational peak
- CEMS data provides a range of real time data that better characterizes equipment emissions
- Staff requested the following CEMS data from facilities:
  - Hourly average NOx in ppm
  - Hourly average O₂ in percent
  - Hourly average fuel flow rate and higher heating value (HHV)
- CEMS data will provide estimated operational peak NOx concentration for units with no permit limit
  - Most units >40 MMBTU/hr do not have a NOx concentration permit limit
- Operational peak NOx concentration will be used to calculate emission reduction potential and cost-effectiveness for each unit
CEMS Data Evaluation

- Evaluate CEMS data to eliminate anomalies that can skew data
- Excluded obvious outlying data such as missing, negative, and very high values
- Established “normal” operational parameters to help identify other outlying data points
- Normal operational parameters were determined from:
  - Fuel flow rate trends
  - Measured O₂ trends
  - Length of time that trends occur
- Data points outside normal parameters may indicate “abnormal” conditions
CEMS Data Parameter Considerations

**Low fuel flow**
- Could be start-up/shutdown conditions
- Only pilots are running
- May show extremely high NOx or low (negative) NOx emissions

**High Higher Heating Value (HHV)**
- May result in higher NOx emissions (*not necessarily a outlier*)

**Low heater capacity or utilization**
- BTU fired below 25% probably not normal operation

**Range of measured O₂**
- >19% O₂ with low fuel flow may indicate only pilots are running (start-up/shutdown)
- >15% O₂ further evaluation needed
- >10% O₂ with all other parameters in range, could indicate leaking firebox (*did not exclude*)
- <10% O₂ typical heater operation

**Reasons for outliers**
- Possible maintenance activity or turnaround conditions
- Possible processing unit upset conditions or start-up/shutdown conditions
Staff evaluated CEMS data for 134 heaters and boilers

Graphed NOx ppm data, corrected to 3% O$_2$

Identified obvious outliers

Estimated “Normal Operational Parameters” based on fuel flow, O$_2$, and heater capacity

Eliminated NOx data points outside of Normal Operational Parameters
Example Analysis for 52 MMBtu/hr Heater

<table>
<thead>
<tr>
<th>Date/Time</th>
<th>Hourly O2 Conc. (%)</th>
<th>Hourly NOx Conc. (PPM)</th>
<th>Hourly NOx Conc. (PPM @3% O2)</th>
<th>Fuel Flow Rate (MSCF)</th>
<th>HHV of the Fuel (BTU/SCF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 1, hour 0</td>
<td>6</td>
<td>26</td>
<td>32</td>
<td>29</td>
<td>1326</td>
</tr>
<tr>
<td>Day 1, hour 1</td>
<td>6</td>
<td>26</td>
<td>31</td>
<td>29</td>
<td>1331</td>
</tr>
<tr>
<td>Day 1, hour 2</td>
<td>6</td>
<td>26</td>
<td>32</td>
<td>29</td>
<td>1323</td>
</tr>
<tr>
<td>Day 1, hour 3</td>
<td>6</td>
<td>26</td>
<td>32</td>
<td>29</td>
<td>1351</td>
</tr>
<tr>
<td>Day 1, hour 4</td>
<td>6</td>
<td>26</td>
<td>31</td>
<td>29</td>
<td>1369</td>
</tr>
<tr>
<td>Day 1, hour 5</td>
<td>6</td>
<td>26</td>
<td>31</td>
<td>29</td>
<td>1340</td>
</tr>
<tr>
<td>Day 1, hour 6</td>
<td>6</td>
<td>26</td>
<td>31</td>
<td>29</td>
<td>1323</td>
</tr>
<tr>
<td>Day 1, hour 7</td>
<td>6</td>
<td>27</td>
<td>32</td>
<td>28</td>
<td>1399</td>
</tr>
<tr>
<td>Day 1, hour 8</td>
<td>6</td>
<td>27</td>
<td>32</td>
<td>28</td>
<td>1384</td>
</tr>
<tr>
<td>Day 1, hour 9</td>
<td>6</td>
<td>27</td>
<td>33</td>
<td>27</td>
<td>1402</td>
</tr>
<tr>
<td>Day 1, hour 10</td>
<td>6</td>
<td>27</td>
<td>32</td>
<td>27</td>
<td>1405</td>
</tr>
<tr>
<td>Day 1, hour 11</td>
<td>6</td>
<td>27</td>
<td>32</td>
<td>26</td>
<td>1406</td>
</tr>
<tr>
<td>Day 1, hour 12</td>
<td>6</td>
<td>27</td>
<td>32</td>
<td>27</td>
<td>1395</td>
</tr>
<tr>
<td>Day 1, hour 13</td>
<td>6</td>
<td>27</td>
<td>32</td>
<td>27</td>
<td>1390</td>
</tr>
<tr>
<td>Day 1, hour 14</td>
<td>6</td>
<td>26</td>
<td>32</td>
<td>27</td>
<td>1361</td>
</tr>
<tr>
<td>Day 1, hour 15</td>
<td>6</td>
<td>26</td>
<td>31</td>
<td>26</td>
<td>1416</td>
</tr>
<tr>
<td>Day 1, hour 16</td>
<td>6</td>
<td>26</td>
<td>31</td>
<td>26</td>
<td>1434</td>
</tr>
<tr>
<td>Day 1, hour 17</td>
<td>6</td>
<td>25</td>
<td>30</td>
<td>27</td>
<td>1413</td>
</tr>
<tr>
<td>Day 1, hour 18</td>
<td>6</td>
<td>25</td>
<td>29</td>
<td>28</td>
<td>1374</td>
</tr>
<tr>
<td>Day 1, hour 19</td>
<td>6</td>
<td>25</td>
<td>29</td>
<td>28</td>
<td>1361</td>
</tr>
<tr>
<td>Day 1, hour 20</td>
<td>6</td>
<td>25</td>
<td>30</td>
<td>28</td>
<td>1373</td>
</tr>
<tr>
<td>Day 1, hour 21</td>
<td>6</td>
<td>25</td>
<td>30</td>
<td>28</td>
<td>1368</td>
</tr>
<tr>
<td>Day 1, hour 22</td>
<td>6</td>
<td>25</td>
<td>30</td>
<td>28</td>
<td>1363</td>
</tr>
<tr>
<td>Day 1, hour 23</td>
<td>6</td>
<td>26</td>
<td>31</td>
<td>27</td>
<td>1377</td>
</tr>
</tbody>
</table>

- **Corrected NOx ppm data to 3% O₂**
- **Plotted NOx ppm @ 3% O₂**
- **Range of Data**
  - Corrected NOx: -510,016 to 239,842,232 ppm
  - Fuel flow rate: 0 to 37 MSCFH
  - Measured O₂: 2 to 21%
  - HHV: 993 to 2016 BTU/SCF
Example Analysis for 52 MMBtu/hr Heater (con’t.)

Day 299
NOx: 239,842,232 ppm
Measured O$_2$: 20.9 %
Fuel flow rate: 0 MSCFH
Heater capacity: 0%
Conclusion: outlier

Day 302
NOx: 197,268,519 ppm
Measured O$_2$: 20.9 %
Fuel flow rate: 0 MSCFH
Heater capacity: 0%
Conclusion: outlier

Conclusion
O$_2$ is ambient and no fuel flow, heater is down.
Excluded these data points.
Example Analysis for 52 MMBtu/hr Heater (con’t.)

Day 286 to Day 323
NOx: -510,016 to 114,208 ppm
Measured O₂: > 20 %
Fuel flow rate: 0 to 5 MSCFH
Heater capacity: 0 to 12%
Conclusion: outliers

Conclusion
This data point has low fuel flow rate, ambient O₂, and <12% heater capacity. Perhaps start-up/shutdown condition. Excluded data points.
Once all obvious outliers are eliminated, data is now more representative of normal operation parameters.
Estimating Normal Operational Parameters

- Staff evaluated 8,784 data points to determine 7,920 normal operational parameters after eliminating obvious outliers.
- Averaged revised data set (with obvious outliers removed) and calculated standard deviation.
- Normal Operational Parameters based on fuel flow, percent $O_2$, HHV, and heater capacity.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Average</th>
<th>Standard Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Flow (MSCFH)</td>
<td>23.6</td>
<td>8.3</td>
</tr>
<tr>
<td>NOx (ppm)</td>
<td>24.3</td>
<td>8.3</td>
</tr>
<tr>
<td>% $O_2$</td>
<td>5.6</td>
<td>1.1</td>
</tr>
<tr>
<td>HHV (Btu/SCF)</td>
<td>1,388.6</td>
<td>84.9</td>
</tr>
<tr>
<td>Heater Capacity (%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Normal Operational Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Flow (MSCFH)</td>
<td>15.3 - 31.9</td>
</tr>
<tr>
<td>NOx (ppm)</td>
<td>16.0 - 32.6</td>
</tr>
<tr>
<td>% $O_2$</td>
<td>4.5 - 6.7</td>
</tr>
<tr>
<td>HHV (Btu/SCF)</td>
<td>1,303.1 - 1,456.1</td>
</tr>
<tr>
<td>Heater Capacity (%)</td>
<td>38 - 91</td>
</tr>
</tbody>
</table>
Day 137
NOx @3%O₂: 65 to 159 ppm
Fuel flow rate: 3 to 16 MSCFH
Measured O₂: 13 to 17%
Heater capacity: 8 to 36%

Normal Operational Parameters
Fuel Flow Rate: 15 to 31 MSCFH
Measured O₂: 4.5 to 6.6%
Heater Capacity: 38 to 91%

Conclusion
Compared to “normal operation parameters”, fuel flow rate is at reduced rate, high O₂, and heater capacity is less than normal range

Excluded NOx data.
Example Analysis for 52 MMBtu/hr Heater (con’t.)

Peak 1 (Day 44)
NOx: 43.8 ppm
Fuel Flow Rate: 20 to 21 MSCFH
Measured O₂: 5 to 7%
Heater Capacity: 50 to 52%
Conclusion: include

Peak 3 (Day 323)
NOx: 57 ppm
Fuel Flow Rate: 5 to 10 MSCFH
Measured O₂: 17 to 19%
Heater Capacity: 8 to 10%
Conclusion: exclude

Normal Operational Parameters
Fuel Flow Rate: 15 to 31 MSCFH
Measured O₂: 4.5 to 6.6%
Heater Capacity: 38 to 91%
Example Analysis for 52 MMBtu/hr Heater (con’t.)

Peak 2
\[\text{NOx @3\%O}_2: \ 41 \text{ to } 55.3 \text{ ppm}\]
Fuel flow rate: 31 MSCFH
Measured O\(_2\): 4.4 to 4.6 %
Heater capacity: 73 to 75%
Conclusion: include

Normal Operational Parameters
Fuel Flow Rate: 15 to 31 MSCFH
Measured O\(_2\): 4.5 to 6.6%
Heater Capacity: 38 to 91%

Conclusion
56 ppm will be considered the operational peak

Excluded peak 3 data point because it did not meet Normal Operational Parameter
Example Analysis for 52 MMBtu/hr Heater (con’t.)

<table>
<thead>
<tr>
<th></th>
<th>Survey Annual Average</th>
<th>Operational Peak (CEMS Evaluation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOx (ppm @ 3% O₂)</td>
<td>23.3</td>
<td>56</td>
</tr>
<tr>
<td>Fuel Flow (Mscf/hr)</td>
<td>201</td>
<td>207</td>
</tr>
<tr>
<td>HHV (MMBtu/scf)</td>
<td>1330</td>
<td>1289</td>
</tr>
</tbody>
</table>
CEMS Data Evaluation Conclusions

CEMS data shows operational variations in each unit.

Can be used to identify outliers, define normal operation conditions, and estimate an operational peak.

Operational peak defined as highest concentration, with outliers removed.

Operational peak will be used for cost-effectiveness and emission reduction calculations.
U.S. EPA SCR Cost Model
Stakeholders expressed concern that U.S. EPA SCR* cost model does not reflect the refining industry because it does not reflect:

- Increased costs associated with California Senate Bill 54
- Increased costs associated with space constraints or plot space limitations
  - Increase construction cost
  - Increased duct work

U.S. EPA SCR cost model derived from cost to replace boilers at electricity generation facilities

- Determines costs based on MW to MMBTU conversion
- May underestimate SCR size and costs for refining industry

SCR Cost Model – Applications

- U.S. EPA SCR cost model is most comprehensive tool available to estimate the cost-effectiveness of an SCR installation
- Methodology based “The Rule of Sixth-tenths”
  - Approximate costs can be obtained based on unit with different size or capacity
  - Uses cost indices to adjust to current total capital investment price
- Model is used and applied to many other industries
- Widely used for regulatory purposes
- Model tends to overestimate SCR installation costs for most industries
- Unique challenges at refineries increases costs
SCR Cost Model – Rule of Six-tenths

- U.S. EPA SCR cost model is based on the “Rule of six-tenths” or “six-tenths-factor” rule of thumb
- Scaling factor rule uses ratio and proportioning to estimate costs
  - If cost of a given unit at one capacity/size is known, the cost of a similar unit with “X” times the first is approximately \((X)^{0.6}\) times the cost of the initial unit

\[
C_B = C_A \left( \frac{S_B}{S_A} \right)^{0.6}
\]

\[
C_B = C_A \left( \frac{S_B}{S_A} \right)^N
\]

- \(C_B\) = approximate cost of equipment having size \(S_B\) (MMBtu/hr, hp, scfm, etc.)
- \(C_A\) = known cost ($) of equipment having corresponding size \(S_A\) (same units as \(S_B\))
- \(S_B/S_A\) = ratio size factor
- \(N\) = size exponent (varies 0.3 to >1.0, but average is 0.6)
• Staff acknowledges costs at refineries could be higher
• SCR installation costs provided by nine stakeholders in 2018 survey for 35 heaters
  • Preliminary costs varied from $500K to $36.5 MM
  • Unknown if cost estimates are order of magnitude or detailed engineering estimates
    • No itemized details on costs (e.g., engineering, material, labor, and dollar year)
• Staff requesting detailed cost estimate information for SCR installations
  • Capital cost
  • Installation costs
  • Dollar year of cost
• Actual cost estimates provided from stakeholders will be used to generate a new cost curve more representative of refining industry in California
- Updated cost information will be used to generate a cost curve based on actual costs
- Equation generated from data will be used in SCR model modification
- Solving equation will give us costs in $/MMBTU/hr
## Other Cost-Effectiveness Metrics

<table>
<thead>
<tr>
<th>Gas Turbines</th>
<th>FCCU and Coke Calciner</th>
<th>SRU/Tailgas Incinerators/Thermal Oxidizers</th>
<th>Internal Combustion Engines</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCR cost model will be used as is to determine cost effectiveness</td>
<td>SCR cost model not applicable to FCCU, NOx is determined by feed rate</td>
<td>No control technologies identified at this time</td>
<td>Only used during start-up</td>
</tr>
<tr>
<td>Installation cost can be scaled up to reflect SB54</td>
<td>Cost will be based off actual installation costs and/or vendor quotes</td>
<td>DCF method for cost-effectiveness calculation</td>
<td>Likely fall under low-use exemption</td>
</tr>
<tr>
<td>Used and applied in Rule 1134 and 1135</td>
<td>Discounted Cash Flow (DCF) method will be used to calculate cost-effectiveness</td>
<td></td>
<td>BACT limit apply to new installations</td>
</tr>
</tbody>
</table>
Next Steps

1. Update U.S. EPA Cost Model
2. Continue BARCT Assessment and Cost Effectiveness
3. Continue Facility Site Visits
4. Propose BARCT Limits
5. Final Assessment Report from Consultants
6. Finalize BARCT Limits
<table>
<thead>
<tr>
<th>Name</th>
<th>Title</th>
<th>Email</th>
<th>Phone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heather Farr</td>
<td>Program Supervisor</td>
<td><a href="mailto:hfarr@aqmd.gov">hfarr@aqmd.gov</a></td>
<td>909.396.3672</td>
</tr>
<tr>
<td>Jong Hoon Lee, Ph.D.</td>
<td>AQ Specialist</td>
<td><a href="mailto:jhlee@aqmd.gov">jhlee@aqmd.gov</a></td>
<td>909.396.3903</td>
</tr>
<tr>
<td>Sarady Ka</td>
<td>AQ Specialist</td>
<td><a href="mailto:ska@aqmd.gov">ska@aqmd.gov</a></td>
<td>909.396.2331</td>
</tr>
<tr>
<td>Michael Krause</td>
<td>Planning &amp; Rules Manager</td>
<td><a href="mailto:mkrause@aqmd.gov">mkrause@aqmd.gov</a></td>
<td>909.396.2706</td>
</tr>
</tbody>
</table>
RECLAIM Staff Contacts

Kevin Orellana  
Program Supervisor  
korellana@aqmd.gov  
909.396.3792

Gary Quinn, P.E.  
Program Supervisor  
gquinn@aqmd.gov  
909.396.3121

Michael Morris  
Planning & Rules Manager  
mmorris@aqmd.gov  
909.396.3282