PG&E Natural Gas System

Managing Non-CO₂ GHG Emissions

Jack Dunlap
Manager, Gas System Operations, PG&E
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Natural Gas Pipeline Network

1. Pacific Gas and Electric Company - California Gas Transmission
2. Alliance Pipeline L.P.
3. Colorado Interstate Gas Company
4. El Paso Natural Gas Company
5. Foothills Pipe Lines Ltd.
6. Kern River Gas Transmission Company
7. KN Energy, Inc.
8. Mojave Pipeline Company
9. North Baja Pipeline, LLC
10. Northern Border Pipeline Company
11. Northwest Pipeline Corporation
12. Trailblazer Pipeline Company
13. Paiute Pipeline Company
14. Questar Southern Trails Pipeline Company
15. San Diego Gas & Electric
16. Southern California Gas Company
17. TransCanada's - GTN System
18. TransCanada's - Alberta System
19. TransCanada's - B.C. System
20. TransCanada's - Canadian Mainline
21. Transwestern Pipeline Company
22. Tuscarora Gas Transmission Company
23. Kinder Morgan
24. Westcoast
25. Terasen Gas

Pipelines delivering to the PG&E System
PG&E Gas System

NORTHERN SYSTEM - REDWOOD PATH – Line 400/401
- GTN - Canadian source gas
- 2.2 Bcf/d Capacity
- Malin, Oregon to Antioch and Panoche
- 1-36”, 1-42” Parallel pipes with full remote capability

SOUTHERN SYSTEM - BAJA PATH – Lines 300 A/B
- El Paso / Transwestern / Kern River / Questar Transmission - Southwest and Rocky Mountain source gas
- 1.2 Bcf/d Capacity
- Topock, Arizona to Milpitas
- 2 – 34” parallel pipes with semi-remote capability

CALIFORNIA GATHERING - SILVERADO PATH
- Local Production - Sacramento & San Joaquin Valleys
- 110 MMcf/d
- Numerous interconnects

MILES OF PIPE
- Transmission 6,300
- Distribution 40,032
- Gas Gathering 500

DISTRIBUTION CUSTOMERS
- 4.2 Million Customers

PIPELINE SYSTEM INVENTORY
- 4.0 Bcf to 4.6 Bcf
- 600 MMcf Swing
PG&E STORAGE – MISSION PATH
Fields – McDonald Island, Los Medanos, Pleasant Creek
- 2010 Mmcf/d Withdrawal
- 450 Mmcf/d Injection

LODI STORAGE
- 500 Mmcf/d Withdrawal
- 450 Mmcf/d Injection

WILD GOOSE STORAGE
- 700 Mmcf/d Withdrawal
- 450 Mmcf/d Injection
Market Demands - 2007

- Non-core Off-system: 7%
- Electric Generation: 22%
- Core Market: 35%
- Non-core On-system: 36%

2,668 MMcf Average Daily Demand

Gas Supply Sources - 2007

- Redwood: 59%
- Baja: 36%
- Silverado: 5%
Major Stations

Controlled and monitored by PG&E Gas System Operations

- Tionesta
- Burney
- Gerber
- Delevan
- Antioch
- Brentwood
- Bethany
- Panoche
- Kettleman
- Irvington
- Milpitas
- Compressor Station

- L400/L401 Redwood Path
- L300 Baja Path
www.pge.com/pipeline

- Gas Composition Data
- Historical Supply and Demand
- Supply and Demand Forecast
- Storage Activity
- Physical Pipeline Capacity
Natural Gas is a Mixture of Gases

- Mixture varies depending on source
- Primarily methane
- Usually less than 1% CO₂
- Satisfactory appliance operation requires limiting variability

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>BTU</td>
<td>1020.2</td>
</tr>
<tr>
<td>Sp_Gr</td>
<td>0.5788</td>
</tr>
<tr>
<td>N2</td>
<td>0.96%</td>
</tr>
<tr>
<td>C02</td>
<td>0.63%</td>
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<tr>
<td>Methane</td>
<td>95.81%</td>
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<tr>
<td>Ethane</td>
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<tr>
<td>Propane</td>
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<tr>
<td>I_Butane</td>
<td>0.02%</td>
</tr>
<tr>
<td>N_Butane</td>
<td>0.02%</td>
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<tr>
<td>I_Pentane</td>
<td>0.01%</td>
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<tr>
<td>N_Pentane</td>
<td>0.01%</td>
</tr>
<tr>
<td>C6</td>
<td>0.01%</td>
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</table>
Natural Gas System GHG Emissions

PG&E 2007 Natural Gas System GHG Emissions
(metric tons CO2e, including de minimis emissions)

- Stationary Combustion Emissions: 297,162 (23%)
- Process Emissions: 731,219 (57%)
- Fugitive Emissions: 258,957 (20%)
Major Sources of Emissions

• Vented (Process) Emissions
  • Pipe blow downs for maintenance and construction
  • Controllers and operators in remote locations

• Fugitive Emissions
  • Distribution and transmission pipe leakage
  • Gas meters and fittings
  • Compressor stations
  • Metering and regulator stations

• Combustion at Compressor Stations
Mitigation Strategies

- Reduce venting for maintenance and construction
  - Use pipeline drafting procedures
  - Cross-compression
- Replace high bleed controllers and operators with low bleed or electric driven controllers
- Thermal oxidizers on glycol dehydration systems to oxidize methane and other hydrocarbons
- Reduce fugitive emissions - prioritize by safety and then by volume/savings
Calculation/Estimating Methods

**Good**

Based on incidents and statistically valid data

- Main and services leakage data
- Pipeline venting
- Controllers and operators

**Not So Good**

Based on activity such as # meters or mileage

- Meter leakage
- Meter/regulator station leakage
Good Information Already Available

- Leak Repair Costs and Methods
- Tools to Calculate Costs/Effectiveness

Good Information Needed

Leakage Rate Data Per Incident

- Customer meter sets
- Meter and regulator stations
- Main and services leakage data
Good Calculations/Estimates are Critical

- Understand overall Gas System impact
- Establish priorities for attention
- Estimate cost effectiveness of mitigation strategies
- Measure effectiveness of mitigation strategies
Appendix
Scenario 1
Blow-Down without Drafting or Cross-Compressing

386 MeTnCO2e/MMCF

216 MMCF
83,416 MeTnCO2e

624 psi (Average)
Reduced Venting

Scenario 2
Blow-Down with Drafting,
No Cross-Compression

216 – 115.2 = 100.8 MMCF

115.2 MMCF

UPSTREAM
CLOSED #1
354 psi (Average)
CLOSED #2
DOWNSTREAM
Scenario 3
Blow-Down with Drafting and Cross-Compression

- Supply gas to 1,450,875 homes for a day in California
- 155 NG Honda Civics in PG&E fleet—the saved NG is enough to power the Honda Civics for 23 years

216 – 26.3 = 189.7 MMCF

74 psi (Average)
Compressor
CLOSED

UPSTREAM
#1
CLOSED

#2
CLOSED
DOWNSTREAM
Methane Reduction Potentials
(Cost Effectiveness in the Current Gas System
Remains to be Verified)
Cost Effectiveness Calculation

\[
\text{Cost Effectiveness (\$/ton)} = \frac{\text{Total Cost of Mitigation (\$)}}{\text{Total tons of reduction in methane emissions (tons)}}
\]

- Determining the cost effectiveness of measures allows for prioritization of mitigation
CA Emission Reduction Potential

Figure 3: Achievable emissions reductions (MMTCO₂ Eq.) for all sources in 2020 (DR= 4 percent and TR= 0 percent)

# Options for Distribution System Reductions

<table>
<thead>
<tr>
<th>Technology</th>
<th>Lifetime (yrs)</th>
<th>MP (%)</th>
<th>RE (%)</th>
<th>TA (%)</th>
<th>Capital cost</th>
<th>Annual cost</th>
<th>Benefits</th>
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<tbody>
<tr>
<td>Electronic monitoring at large surface facilities(^1)</td>
<td>5</td>
<td>100</td>
<td>95</td>
<td>6</td>
<td>$28.07</td>
<td>$4.68</td>
<td>$11.37</td>
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<td>Replacement of cast iron/unprotected steel pipeline(^2)</td>
<td>5</td>
<td>-</td>
<td>95</td>
<td>6-10</td>
<td>$17.259</td>
<td>$0.86</td>
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<tr>
<td>Replacement unprotected steel services(^2)</td>
<td>5</td>
<td>-</td>
<td>95</td>
<td>3-4</td>
<td>$410,830</td>
<td>$82.17</td>
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<tr>
<td>Inspection and maintenance (pipeline leaks)(^1)</td>
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<td>100</td>
<td>26</td>
<td>9</td>
<td>$4.88</td>
<td>$5.76</td>
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<td>Inspection and maintenance (enhanced)(^2)</td>
<td>5</td>
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<td>66</td>
<td>1-12</td>
<td>$21.14</td>
<td>$21.08</td>
<td>$9.42</td>
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Note: MP: market penetration, RE: reduction efficiency, TA: technical applicability; costs are in year 2000 US$/MT\(_{CO_2-eq}\)
### Options for Processing & Transmission System Reductions

<table>
<thead>
<tr>
<th>Technology</th>
<th>Lifetime (yrs)</th>
<th>MP (%)</th>
<th>RE (%)</th>
<th>TA (%)</th>
<th>Capital cost</th>
<th>Annual cost</th>
<th>Benefits</th>
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<tbody>
<tr>
<td>Surge vessels for station/well venting&lt;sup&gt;1&lt;/sup&gt;</td>
<td>10</td>
<td>100</td>
<td>50</td>
<td>3</td>
<td>$11,216</td>
<td>$224.52</td>
<td>$8.53</td>
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<tr>
<td>Replace high-bleed with low-bleed pneumatic devices&lt;sup&gt;1&lt;/sup&gt;</td>
<td>5</td>
<td>50</td>
<td>86</td>
<td>4</td>
<td>$14.01</td>
<td>$0.00</td>
<td>$8.21</td>
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<tr>
<td>Replace high-bleed pneumatic devices with compressed air systems&lt;sup&gt;1&lt;/sup&gt;</td>
<td>5</td>
<td>50</td>
<td>100</td>
<td>4</td>
<td>$7.09</td>
<td>$62.06</td>
<td>$8.21</td>
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<tr>
<td>Reducing glycol circulation rates in dehydrators&lt;sup&gt;1&lt;/sup&gt;</td>
<td>1</td>
<td>50</td>
<td>30</td>
<td>&lt;1</td>
<td>$0.00</td>
<td>$0.87</td>
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<tr>
<td>Installation of flash tank separators&lt;sup&gt;2&lt;/sup&gt;</td>
<td>5</td>
<td>50</td>
<td>61</td>
<td>&lt;1</td>
<td>$32.59</td>
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<tr>
<td>Replace reciprocating engines with gas turbines&lt;sup&gt;2&lt;/sup&gt;</td>
<td>20</td>
<td>-</td>
<td>90</td>
<td>0-27</td>
<td>$166.52</td>
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<td>Reciprocating compressor rod packing (Static-Pac)&lt;sup&gt;1&lt;/sup&gt;</td>
<td>1</td>
<td>100</td>
<td>21</td>
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<td>$14.58</td>
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<td>Replace wet seals with dry seals on centrifugal compressors&lt;sup&gt;3&lt;/sup&gt;</td>
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<td>Alternating start-up procedure during maintenance&lt;sup&gt;1&lt;/sup&gt;</td>
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<td>Catalytic converter&lt;sup&gt;2&lt;/sup&gt;</td>
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<td>5-8</td>
<td>$91.46</td>
<td>$4.82</td>
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<td>Fuel gas retrofit for blow-down valve&lt;sup&gt;1&lt;/sup&gt;</td>
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<td>100</td>
<td>33</td>
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<td>$1.94</td>
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<td>Portable evacuation compressor for pipeline venting&lt;sup&gt;2&lt;/sup&gt;</td>
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<td>100</td>
<td>72</td>
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<td>Inspection and maintenance (pipeline leaks in transmission)&lt;sup&gt;1&lt;/sup&gt;</td>
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<td>100</td>
<td>60</td>
<td>&lt;1</td>
<td>$786.60</td>
<td>$1,180</td>
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<td>Inspection and maintenance (compressor stations)&lt;sup&gt;1&lt;/sup&gt;</td>
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<td>100</td>
<td>13</td>
<td>4</td>
<td>$0.57</td>
<td>$1.86</td>
<td>$8.53</td>
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<td>Inspection and maintenance (compressor stations - enhanced)&lt;sup&gt;2&lt;/sup&gt;</td>
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<td>20</td>
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<td>Inspection and maintenance (storage wells)&lt;sup&gt;1&lt;/sup&gt;</td>
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<td>100</td>
<td>33</td>
<td>&lt;1</td>
<td>$38.50</td>
<td>$38.50</td>
<td>$8.53</td>
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