PG&E Natural Gas System

Managing Non-CO_2 GHG Emissions

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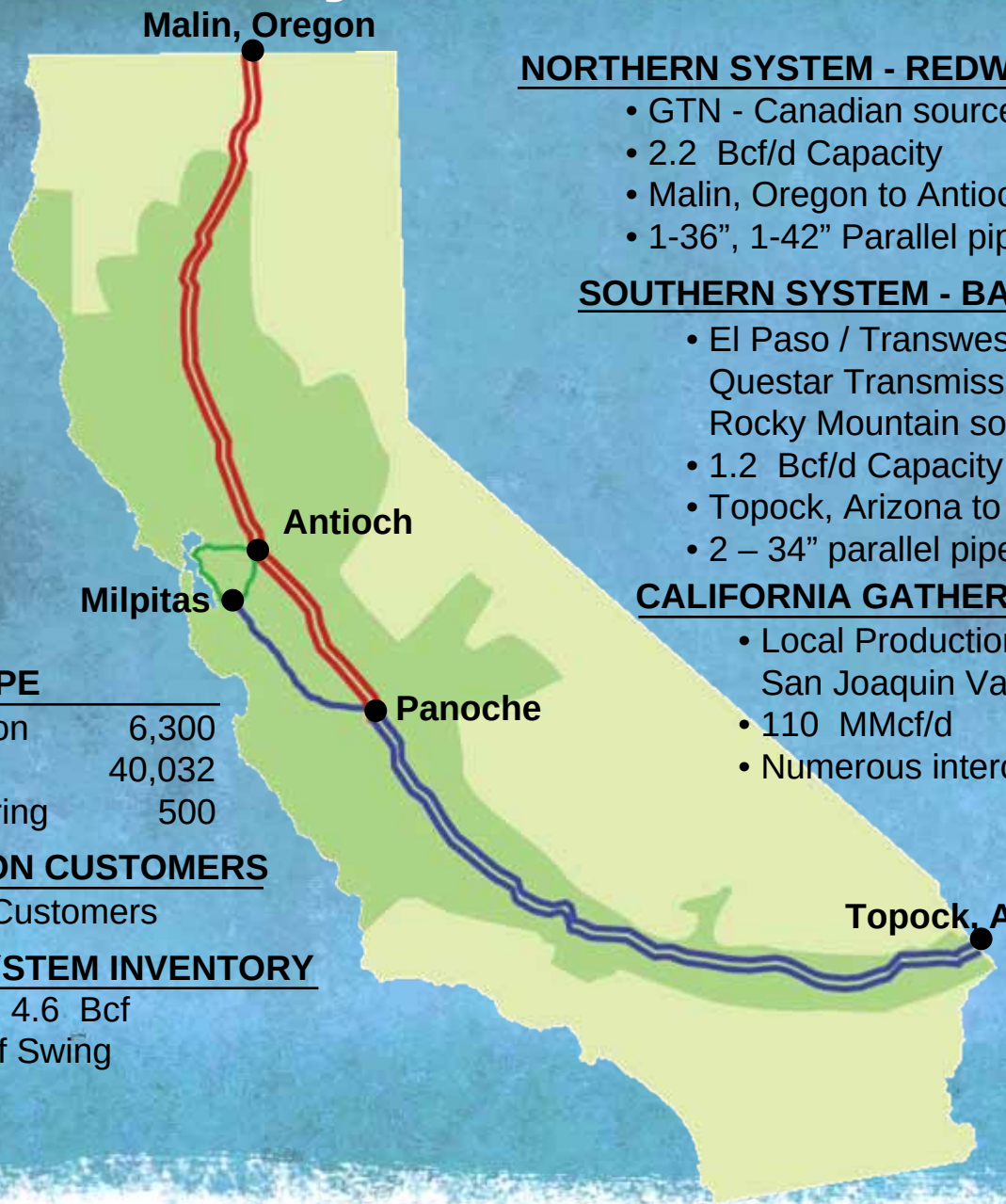
Natural Gas Pipeline Network

Pipelines delivering to the PG&E System

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

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

Storage Systems

PG&E STORAGE – MISSION PATH

Fields – McDonald Island, Los Medanos, Pleasant Creek

- 2010 Mmcf/d Withdrawal
- 450 Mmcf/d Injection

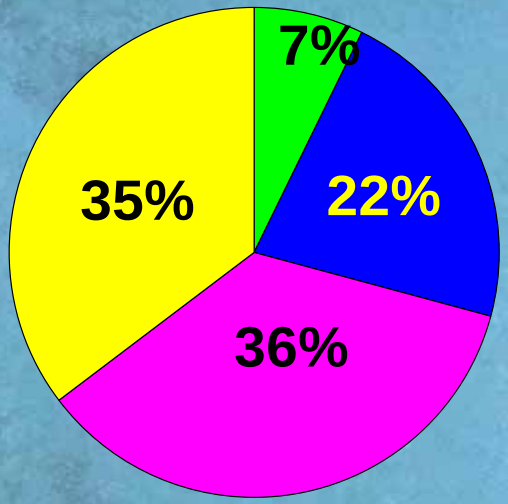
LODI STORAGE

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

WILD GOOSE STORAGE

- 700 Mmcf/d Withdrawal
- 450 Mmcf/d Injection

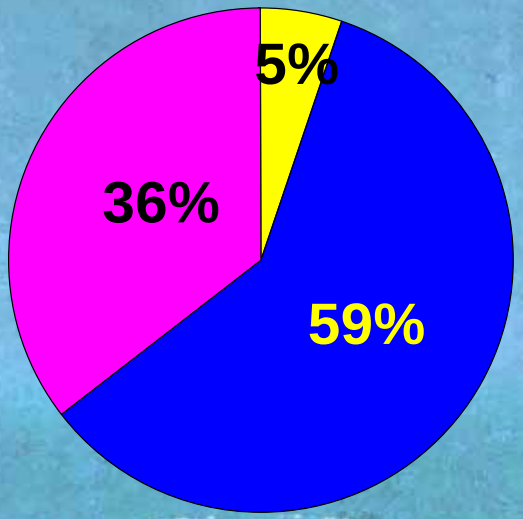
Market Demands - 2007



- *Non-core Off-system*
- *Electric Generation*
- *Core Market*
- *Non-core On-system*

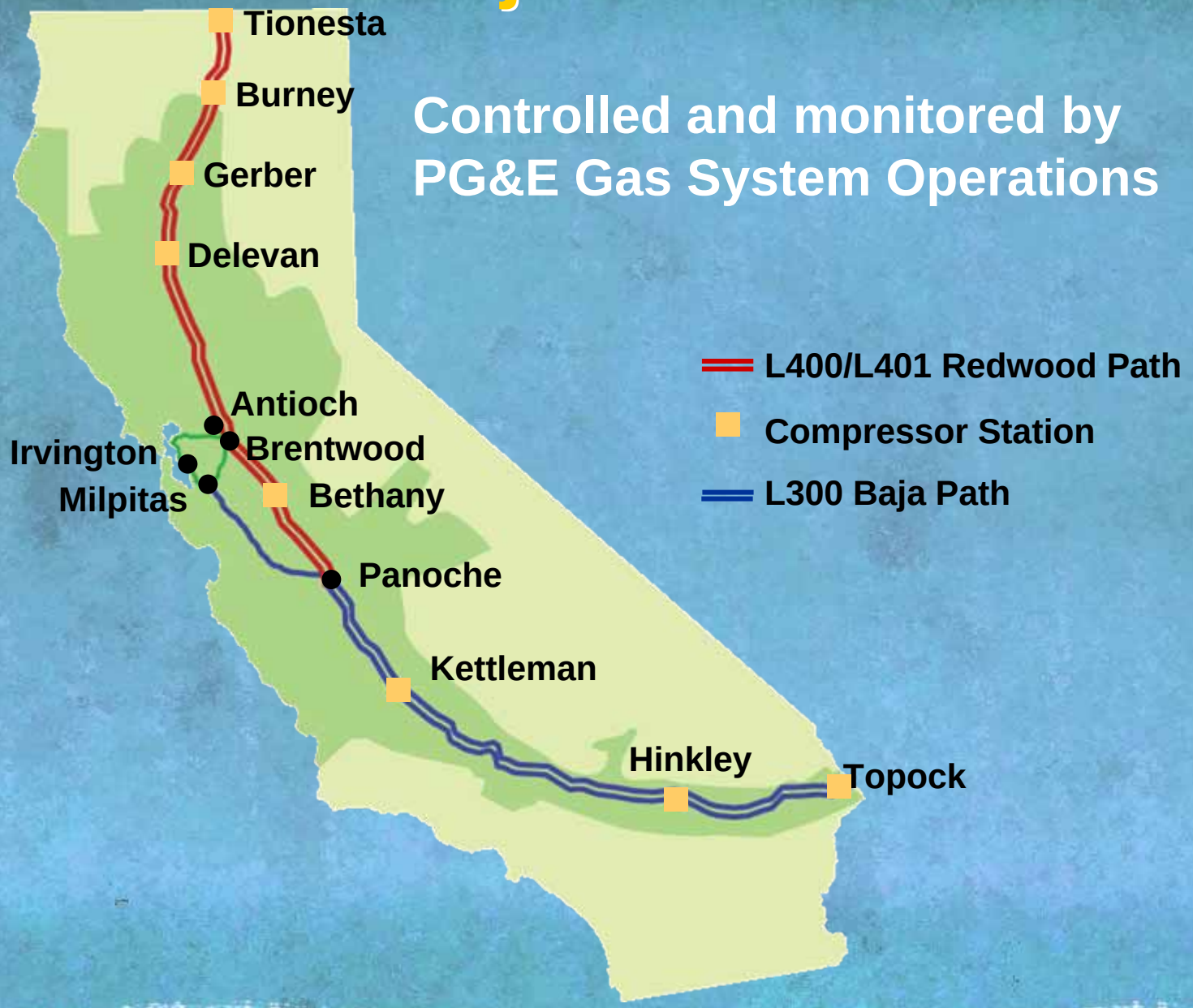
2,668 MMcf Average Daily Demand

Gas Supply Sources - 2007

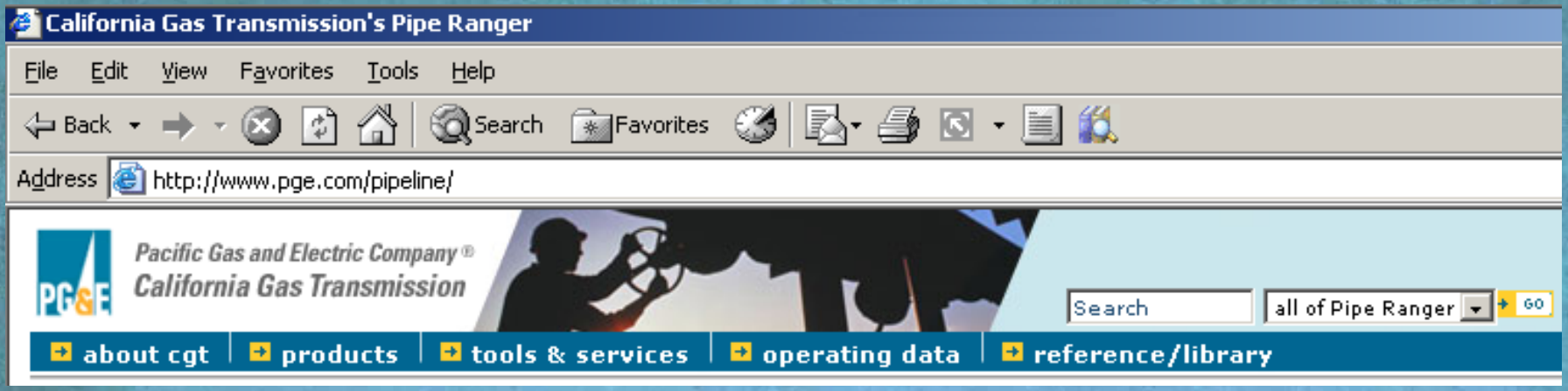


- *Redwood*
- *Baja*
- *Silverado*

Major Stations



Controlled and monitored by PG&E Gas System Operations



www.pge.com/pipeline

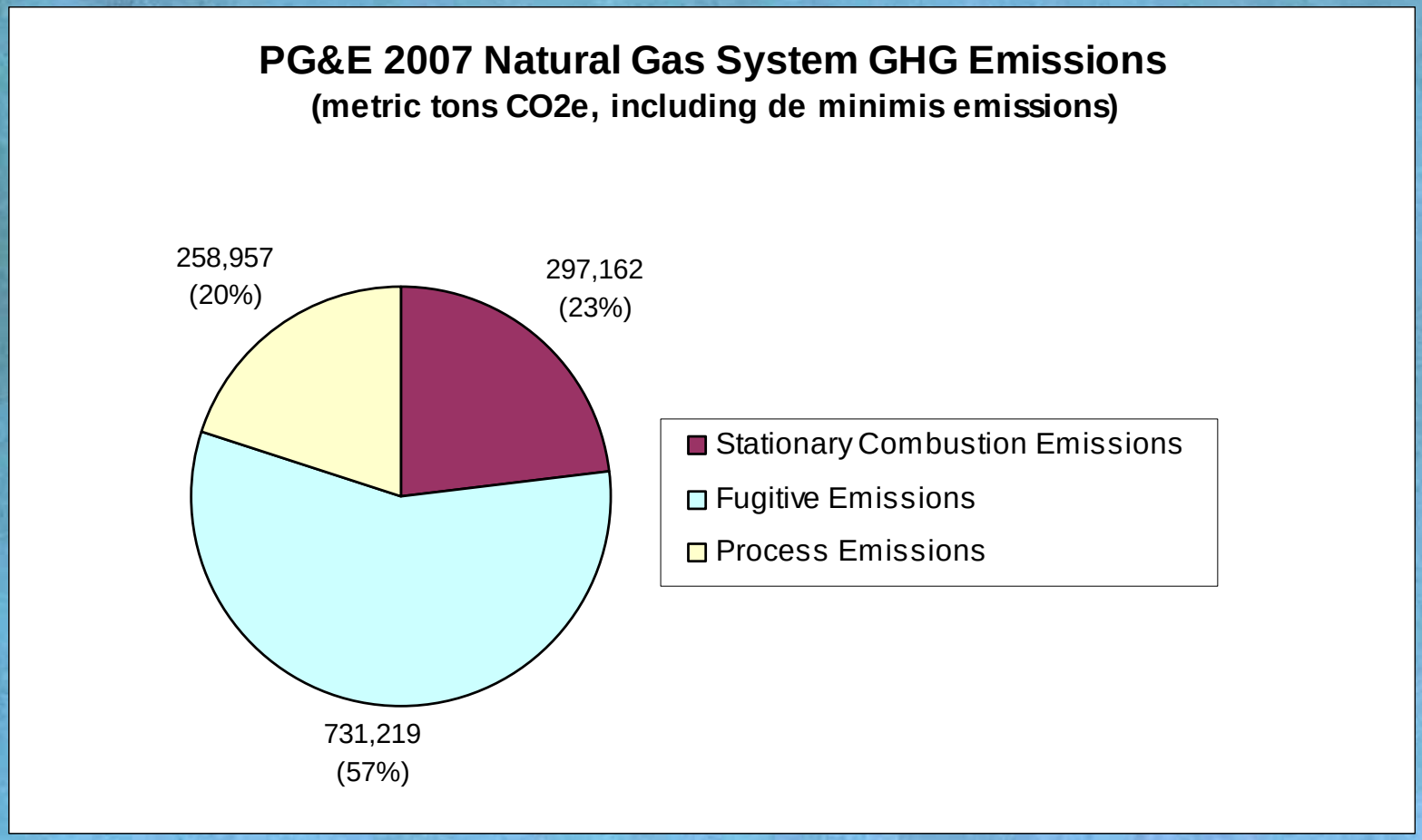
- Gas Composition Data
- Historical Supply and Demand
- Supply and Demand Forecast
- Storage Activity
- Physical Pipeline Capacity

Natural Gas is a Mixture of Gases

- Mixture varies depending on source
- Primarily methane
- Usually less than 1% CO_2
- Satisfactory appliance operation requires limiting variability

BTU	1020.2
Sp_Gr	0.5788
N2	0.96%
C02	0.63%
Methane	95.81%
Ethane	2.40%
Propane	0.15%
I_Butane	0.02%
N_Butane	0.02%
I_Pentane	0.01%
N_Pentane	0.01%
C6	0.01%

Natural Gas System GHG Emissions



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

Reduced Venting

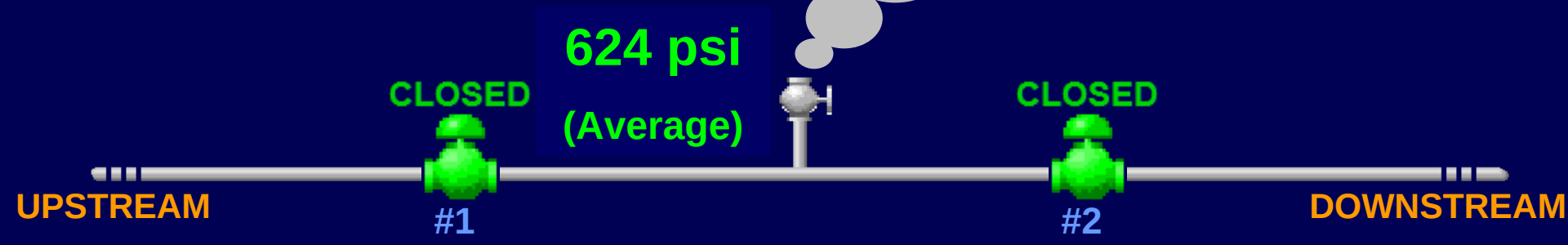
Scenario 1

Blow-Down without Drafting or Cross-Compressing

386 MeTnCO2e/MMCF

216 MMCF

83,416 MeTnCO2e

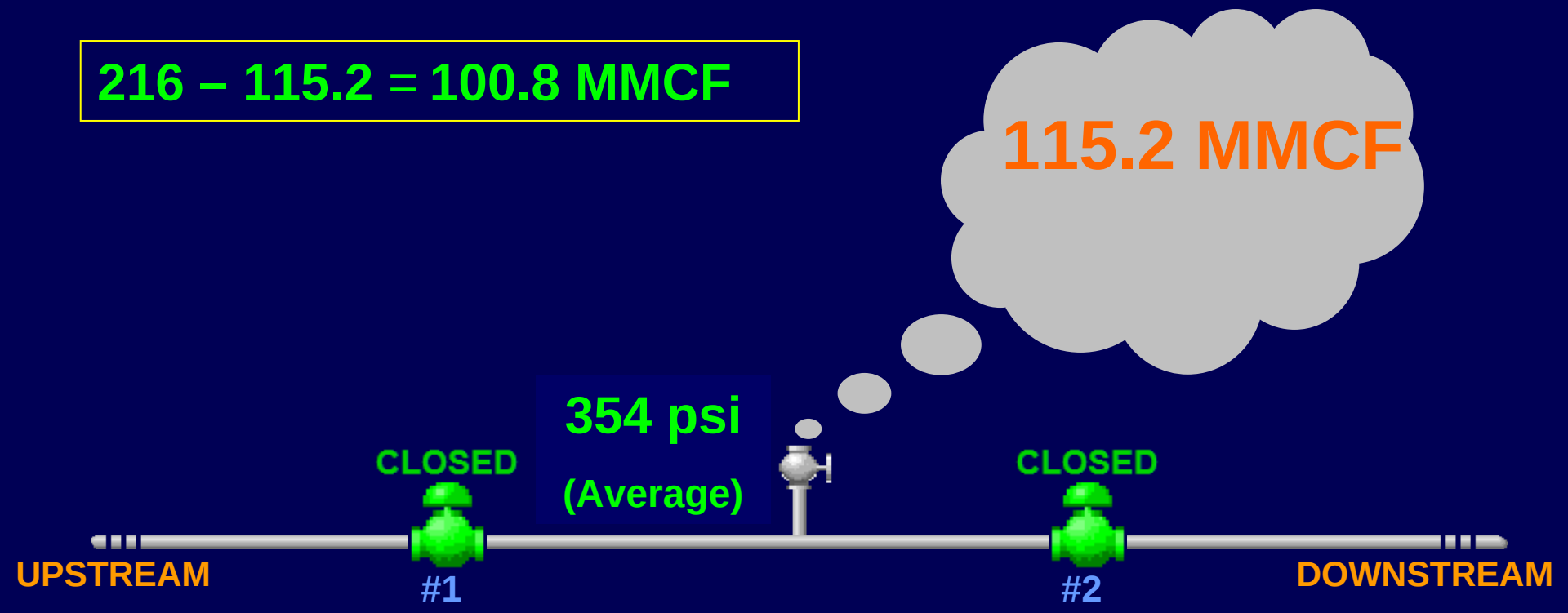


Reduced Venting

Scenario 2

Blow-Down with Drafting,
No Cross-Compression

216 – 115.2 = 100.8 MMCF



Reduced Venting

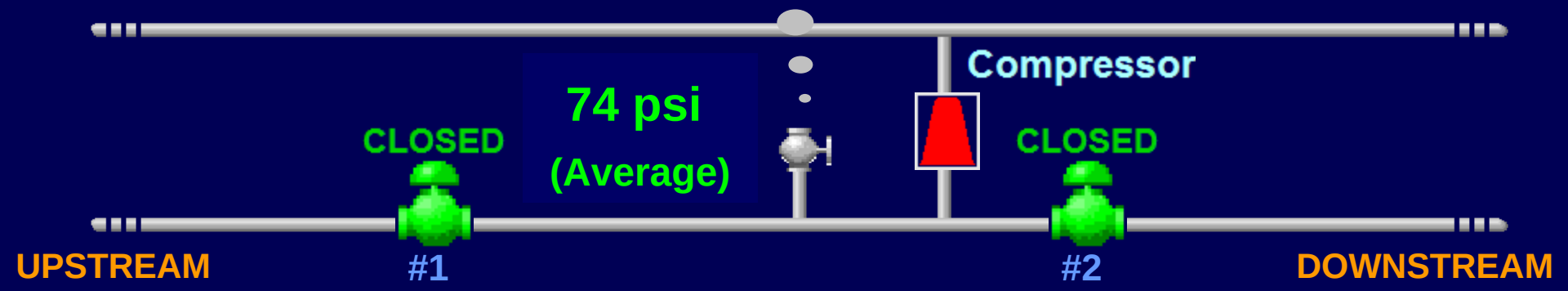
Scenario 3

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**

26.3 MMCF

216 – 26.3 = 189.7 MMCF



Methane Reduction Potentials

(Cost Effectiveness in the Current Gas System Remains to be Verified)

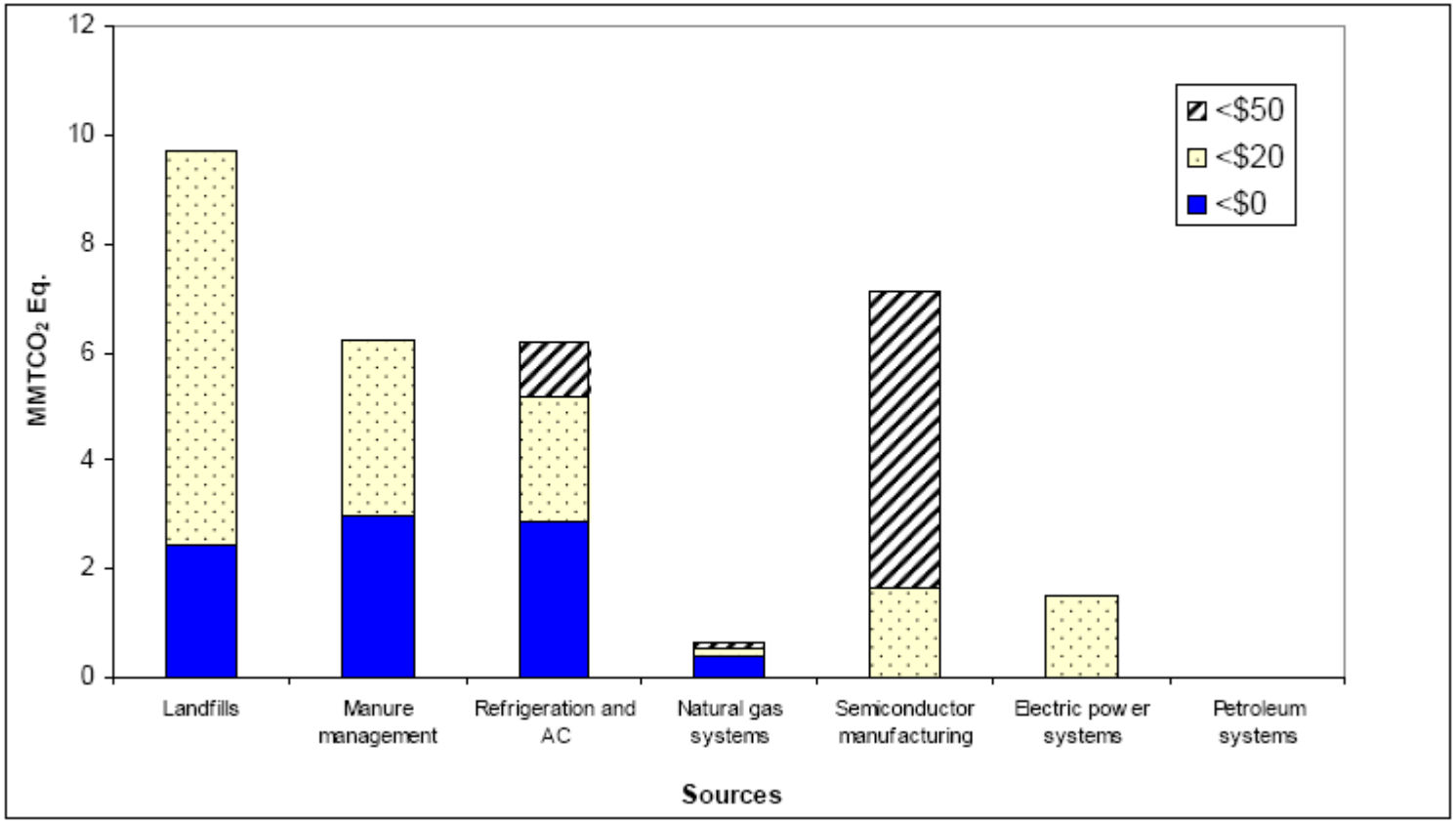
Cost Effectiveness Calculation

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

- **Determining the cost effectiveness of measures allows for prioritization of mitigation**

CA Emission Reduction Potential

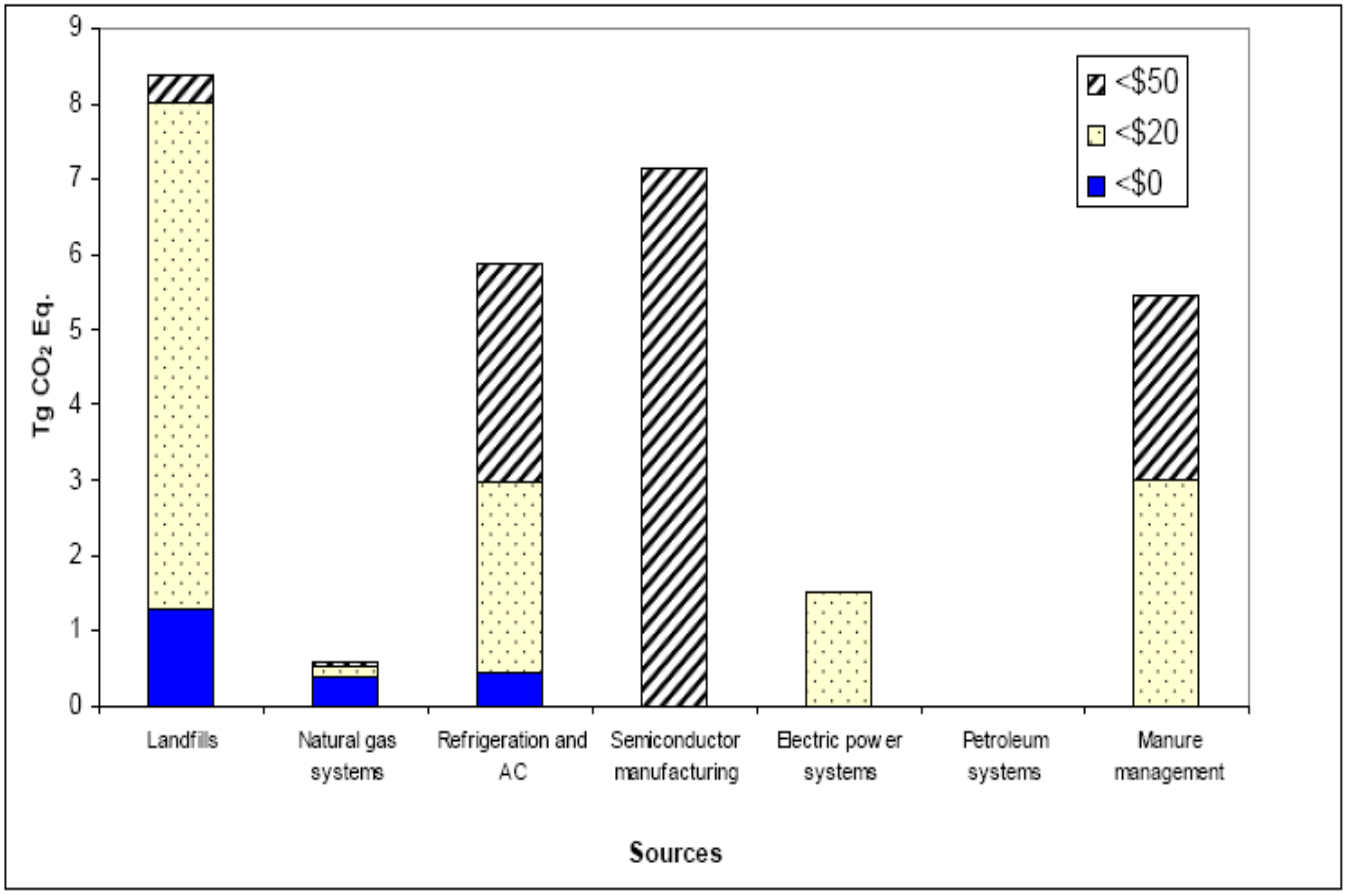
Figure 3: Achievable emissions reductions ($MMTCO_2$ Eq.) for all sources in 2020 (DR= 4 percent and TR= 0 percent)



ICF Consulting, for the California Energy Commission Public Interest Energy Research Program. "Emission Reduction Opportunities for Non-CO2 Greenhouse Gases in California." July 2005.

CA Emission Reduction Potential

Figure 7: Achievable emissions reductions ($MMTCO_2$ Eq.) for all sources in 2020 (DR= 20 percent and TR= 40 percent)



ICF Consulting, for the California Energy Commission Public Interest Energy Research Program. "Emission Reduction Opportunities for Non-CO2 Greenhouse Gases in California." July 2005.

Options for Distribution System Reductions

Technology	Lifetime (yrs)	MP (%)	RE (%)	TA (%)	Capital cost	Annual cost	Benefits
Electronic monitoring at large surface facilities[1]	5	100	95	6	$28.07	$4.68	$11.37
Replacement of cast iron/unprotected steel pipeline[2]	5	-	95	6-10	$17,259	$0.86	$9.74
Replacement unprotected steel services[2]	5	-	95	3-4	$410,830	$82.17	$9.74
Inspection and maintenance (pipeline leaks)[1]	5	100	26	9	$4.88	$5.76	$11.30
Inspection and maintenance (enhanced)[2]	5	-	66	1-12	$21.14	$21.08	$9.42

Note: MP: market penetration; RE: reduction efficiency; TA: technical applicability; costs are in year 2000 US$/$MT_{CO2\text{-}Eq.}$

1: USEPA (2004) & CEC (2005); 2: IEA (2003) & USEPA (2004)

Kuo, Jeff, for the State of California Air Resources Board. "Reducing Anthropogenic Non-CO2 GHG Emissions from All Sectors." May 18, 2008.

Options for Processing & Transmission System Reductions

Technology	Lifetime (yrs)	MP (%)	RE (%)	TA (%)	Capital cost	Annual cost	Benefits
Surge vessels for station/well venting[1]	10	100	50	3	$11,216	$224.52	$8.53
Replace high-bleed with low-bleed pneumatic devices[1]	5	50	86	4	$14.01	$0.00	$8.21
Replace high-bleed pneumatic devices with compressed air systems[1]	5	50	100	4	$7.09	$62.06	$8.21
Reducing glycol circulation rates in dehydrators[1]	1	50	30	<1	$0.00	$0.87	$8.53
Installation of flash tank separators[1]	5	50	61	<1	$32.59	$0.00	$8.53
Replace reciprocating engines with gas turbines[2]	20	-	90	0-27	$166.52	$8.30	$0.00
Reciprocating compressor rod packing (Static-Pac)[1]	1	100	21	6	$14.58	$0.56	$8.53
Replace wet seals with dry seals on centrifugal compressors[2]	5	-	69	4-6	$96.68	-$25.38	$6.99
Alternating start-up procedure during maintenance[1]	1	100	100	3	$0.00	$0.00	$4.47
Catalytic converter[2]	10	-	56	5-8	$91.46	$4.82	$0.00
Fuel gas retrofit for blow-down valve[1]	5	100	33	21	$1.94	$0.00	$8.47
Portable evacuation compressor for pipeline venting[1]	15	100	72	3	$318.58	$2.28	$8.52
Inspection and maintenance (pipeline leaks in transmission)[1]	5	100	60	<1	$786.60	$1,180	$8.53
Inspection and maintenance (compressor stations)[1]	5	100	13	4	$0.57	$1.86	$8.53
Inspection and maintenance (compressor stations - enhanced)[2]	5	-	20	2-4	$0.40	$2.43	$7.08
Inspection and maintenance (storage wells)[1]	5	100	33	<1	$38.50	$38.50	$8.53

Kuo, Jeff, for the State of California Air Resources Board. “Reducing Anthropogenic Non-CO2 GHG Emissions from All Sectors.” May 18, 2008.