



Methane to Markets

PEMEX Methane Emissions Inventory and Marginal Abatement Cost Analysis

Javier Bocanegra

PEMEX Corporate Directorate of Operations
United States Environmental Protection Agency (USEPA)

September 16, 2009

Overview

- PEMEX – M2M Collaboration
- Context for Climate Change in Mexico
- PEMEX GHG Reduction Efforts
- PEMEX - M2M Study
- Methane Emissions Inventory
- MAC Analysis Results
- M2M – PEMEX: Next Steps
- Summary

Methane to Markets Resources

- Resources to advance cost-effective oil & gas sector methane emission reductions:
 - General technology transfer, training, and capacity building
 - Technical documents and research outlining over 80 mitigation options, including analyses of economic, environmental and operational benefits
 - Workshops and Conferences
 - Study tours
 - Individual assistance to help companies identify and assess project opportunities
 - Estimated methane emission inventories
 - Pre-feasibility and feasibility studies
 - Measurement studies



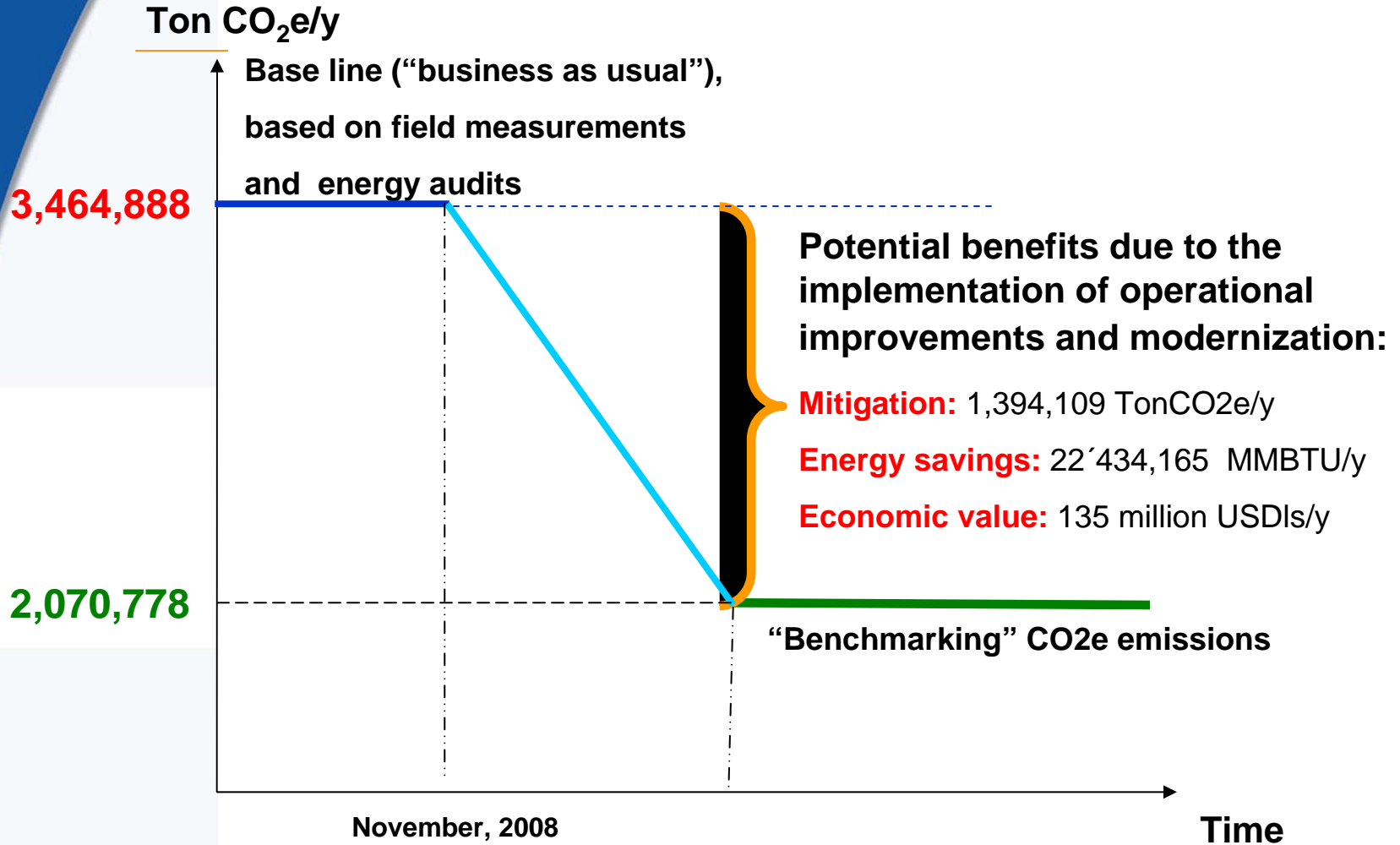
PEMEX – M2M Collaboration

- August, 2006 – PGPB Ciudad Pemex Gas Processing Center (GPC)
Compressor fugitive emissions measurement study (baseline)
- August 2006 – PGPB Cactus, Ciudad Pemex and Nuevo Pemex GPC's
Process fugitive emissions screening and measurement
- February 2007 – Corporate Directorate of Operations (DCO)
Preliminary Methane emissions inventory for selected sources at PEMEX
- October 2007 – PGPB Ciudad Pemex GPC
Compressor project emissions study (new dry gas seals installation)
- October 2007 – PGPB Cactus, Ciudad Pemex and Nuevo Pemex GPC's
Post repair fugitive emissions measurement study
- October 2007 – PGPB Gas Pipelines, Tabasco
Leak screening, maintenance procedures revision
- October 2007 – PGPB Nuevo Pemex GPC
Total GPC methane emissions measurement study

PEMEX – M2M Collaboration

- February 2008 – PGPB Poza Rica GPC
Process fugitive emissions screening and measurement
- October 2008 – PGPB Ductos
Fugitive emissions at compressor and pumping stations in Veracruz and Monterrey - Burgos main gas pipeline systems
- December 2008 – PGPB Burgos GPC
Process fugitive emissions screening and measurement
- December 2008 – PEP Cunduacan compressor station
Fugitive emissions measurement study and Energy Efficiency Audit.
- April – July 2009 – DCO
Baseline Methane emissions inventory and Marginal Abatement Cost Analysis (MAC)
- July 2009 – PPQ Cosoleacaque Petrochemical Complex (Ammonia)
Fugitive emissions measurement study and Energy Efficiency Audit.

Potential mitigation of CO₂e emissions in Nuevo Pemex, Poza Rica and Burgos GPCs



PEMEX Methane Emissions Inventory

- A coherent Climate Change Strategy starts by building a GHG emissions baseline.
- PEMEX – M2M collaboration agreement: PEMEX and M2M agreed to work together to establish an emissions baseline for methane, to complement parallel PEMEX efforts on the CO₂ emissions baseline.
- This work is relevant for all interested parties:
 - PEMEX has a methane emissions inventory carried out by M2M in 2006. Inventories have also been made by INE as part of Mexico's national inventory. With M2M methodology and detailed information from PEMEX, these inventories can be significantly improved to contribute to a comprehensive PEMEX inventory.
 - M2M has special interest in updating and improving the desktop estimations performed several years ago for the Mexican O&G sector
 - PEMEX needs a comprehensive inventory to complete its Climate Change Strategy
 - PEMEX is one of the biggest O&G companies worldwide and its impact as a sectoral leader is important.

GHG Reduction Efforts - PEMEX

- In recent years, PEMEX has focused a number of activities on greenhouse gas reduction projects:
 - Cogeneration
 - Methane emission reductions
 - Improved gas recovery and reduced flaring of CO₂
 - Energy efficiency improvements
 - CDM project development
 - Climate Change Strategy

- Since 2006, a key GHG initiative of PEMEX has been its collaboration with Methane to Markets (M2M) to develop methane emissions reduction projects:
 - Field measurements of methane emissions in 5 gas processing complexes, and compressor stations
 - Pilot compressor seal installation project, including post-implementation measurement
 - Training activities

PEMEX—M2M Study Overview

PEMEX and M2M have undertaken the first detailed inventory of PEMEX methane emissions and their mitigation potential.

- **Objectives**

- Prepare a comprehensive baseline CH₄ emissions inventory
- Estimate abatement potential that is technologically feasible.
- Quantify the costs and benefits of achieving incremental reductions.
- Provide a basis for PEMEX to set targets for methane emission reductions as part of its climate strategy.

- **Study Period**

- April – July 2009

- **Results**

- PEMEX baseline CH₄ emissions inventory: 36.1 MtCO₂e/y
- Estimate of savings from cost-effective CH₄ reductions: \$23 million USD/yr
- Full analysis of 16 mitigation measures
- Technical and economic model of PEMEX methane emissions and emission reduction projects

PEMEX Methane Emissions Inventory: Assumptions and Considerations

- Official PEMEX information on equipment and component counts was used where available. Initial information was obtained from the PEMEX SISPA database.
- PEMEX Environmental Protection staff complemented this information with other available data, including specific requests from various operating areas.
- Tier 1 analysis was carried out in general, using either IPCC, API or already used emissions factors in similar EPA reports and studies.
- When no equipment count disaggregated information existed, all devices in that category were given the same treatment with regard to emission factors.
- Tier 2 analysis allowed PEMEX-specific data in some PGPB gas processing facilities due to measurement work performed under M2M
- When 2008 data were not available at time of reporting, then 2007 data were used (this is considered to be conservative, as operations were of higher intensity in 2007).

Inventory - Findings

- Total CH₄ emissions estimate: 36.1 MtCO₂e/y
- PEP accounts for 96% of total emissions.
- Uncombusted methane from flares is largest single source, accounting for 78% of total emissions.

PEMEX Subsidiary	Annual Emissions (tCH ₄)	Annual Emissions (MtCO ₂)	% of Baseline Emissions
PEP	1,654,798	34.75	96.3%
<i>Flaring System</i>	1,350,085	28.35	78.6%
PGPB	60,772	1.28	3.5%
<i>Gas Transmission</i>	30,421	0.64	1.8%
PREF	2,826	0.06	0.16%
PPQ	211	0.00	0.01%
Total Annual CH₄ Emissions	1,718,607	36.09	100%

Use of Inventory Results to Quantify Emissions Reduction Measures

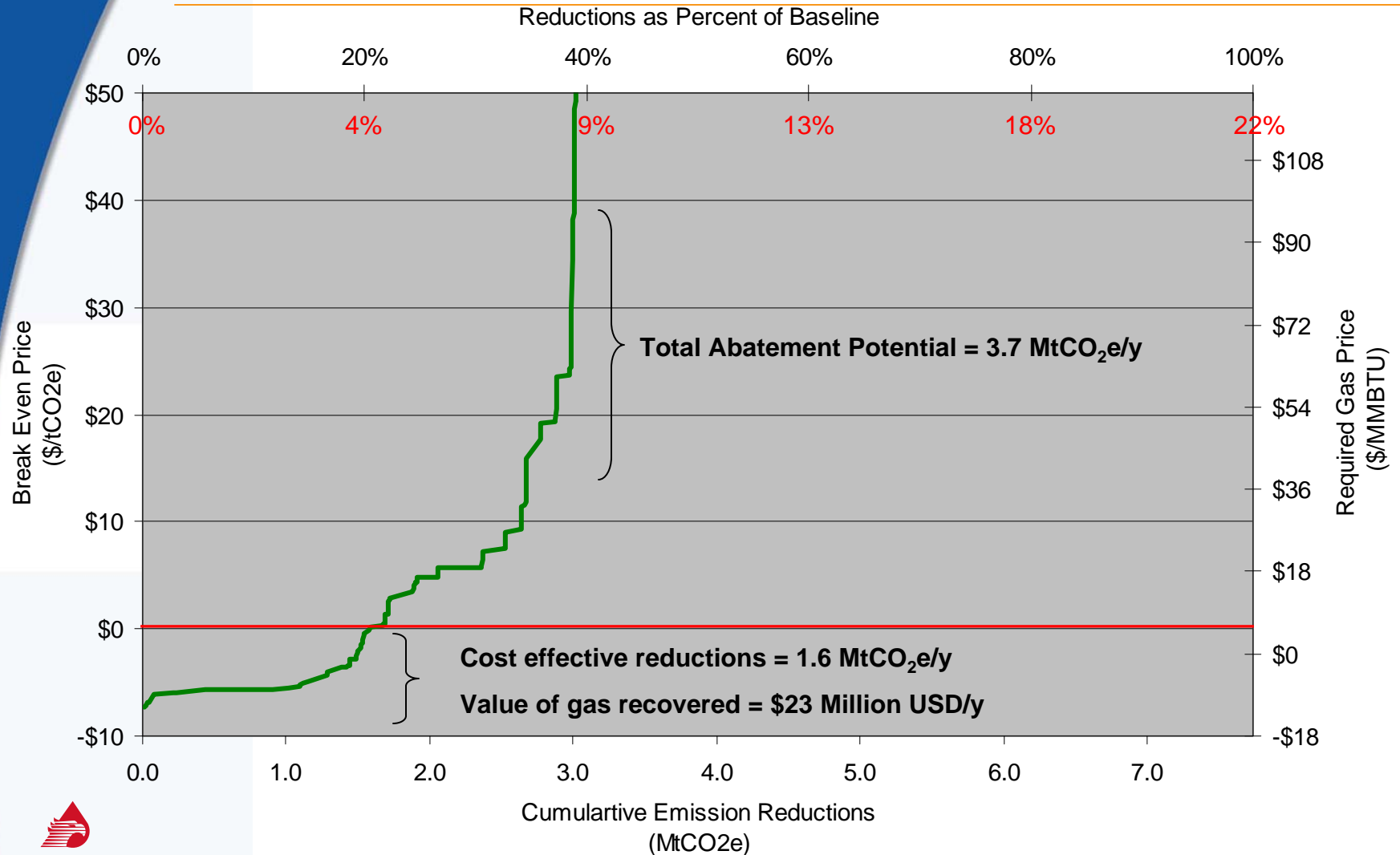
- Many of the emissions identified in the inventory can be mitigated or reduced through specific technologies, better maintenance and operational changes.
- The costs of abatement for 16 typical methane emissions reductions measures are applied to different inventory sources, resulting in nearly 200 emission sources with mitigation or abatement cost data.
- Implementation costs are based on experience with such measures in the U.S. and internationally, and are adjusted to the Mexican context.
- Inventory sources and abatement data have been incorporated into a PEMEX-specific model, which calculates marginal abatement costs (MAC).
- The results identify the cost-effective methane emissions reductions measures for PEMEX to implement, and are fundamental to the development of the PEMEX Climate Change Strategy,

Marginal Abatement Cost (MAC) Methodology

- Breakeven prices (BEP) are calculated for the nearly 200 emissions sources.
 - Solve for the GHG price that sets the NPV of the project to zero.
 - Inputs to the calculation include:
 - current natural gas price - \$6/MMBtu
 - real discount rate - 12%
 - tax rate – 45%
 - annualized costs and benefits for each measure
 - A BEP of \$0/tCO₂e equals the market price of natural gas
 - Negative BEP - abatement measures that are cost-effective at current prices.
 - Positive BEP – equals the additional incentives above the current gas price PEMEX would need to receive to breakeven.

- A marginal abatement curve (MAC) is constructed by sorting the 200 abatement measures by BEP in ascending order and then plotting BEP (vertical axis) and the cumulative reductions achieved (horizontal axis).

MAC Analysis – Findings (not including flaring)



PEMEX MAC Analysis – Results

- Cost-effective abatement measures identified by the MAC analysis (not including flaring).

Abatement Measure	Avg. BEP (\$/tCO ₂ e)	Emissions Reductions (MtCO ₂ e)	Avg. Payback Period (Months)	Avg. IRR
Fuel Gas Retrofit on Reciprocating Compressors	-\$6.82	0.01	5.9	210%
DI&M - Processing plants	-\$5.59	0.01	5.2	206%
Reducing the glycol circulation rates in dehydrators	-\$5.48	0.02	3.3	a
Replace High-bleed pneumatic devices	-\$4.95	0.40	21.9	89%
DI&M - Compressor Stations	-\$3.75	0.03	2.4	382%
Installing Vapor Recovery Units on Crude Oil Storage Tanks	-\$3.21	1.03	23.9	55%
Surge vessels for station venting	-\$2.79	0.04	55.1	22%
Installation of Flash Tank Separators	-\$0.11	0.03	63.1	12%
Totals	—	1.58	—	—

PEMEX MAC Analysis – Results 2

- Abatement potential estimate: 3.7 MtCO₂e (without flaring)
- Cumulative reductions at specific BEPs

Break Even Price (\$/tCO ₂ e)	Emissions Reductions (MtCO ₂ e)	% of Baseline Emissions (without flaring)	% of Baseline Emissions (with flaring)
		7.74	36.09
-\$5	1.12	14%	3%
\$0	1.58	20%	4%
\$5	2.05	27%	6%
\$10	2.64	34%	7%
\$15	2.67	35%	7%
\$20	2.87	37%	8%
\$25	2.98	39%	8%
\$30	2.98	39%	8%
\$35	2.99	39%	8%
\$40	3.01	39%	8%
\$45	3.01	39%	8%
\$50	3.02	39%	8%
>\$60	3.68	48%	10%

PEMEX MAC Analysis - Assumptions and Considerations

- PEMEX-M2M reviewed and updated costs for each measure in the MAC model to reflect current prices in Mexico.
- Reduction potentials reported assume system-wide implementation.
- Static analysis does not account dynamic issues such as technology improvements
- Abatement potential is the sum of technologically achievable reductions for the finite set of measures in the model.
- Adding new measures, such as options for reducing flaring would increase the abatement potential.
- The MAC model can be easily updated as new information becomes available to revise reduction estimates.

PEMEX MAC Model

IN-OUT Click to Run MAC Model

Adjust model inputs in the *User Defined* column - values in GREEN
Then click **Run MAC Model** button above to update results in the summary tables.

Inputs Table		
MAC Model Inputs	Model Default Values	User Defined Values
Year of Emissions Inventory	2008	2008
Avg. Energy Intensity (btu/ft ³)	1030	1,030
CH ₄ Density (kg/m ³)	0.7168	0.7168
GWP of CH ₄ (100yr time horizon)	21	21
Finance Parameters		
Gas Price (2008\$USD / Mcf of natu)	\$5.83	\$5.83
Real Discount Rate (Required %IRR)	12%	12%
Tax Rate	45%	45%

Summary Results Table			
Break Even Price (\$/tCO ₂ e)	Emission Reductions (MtCO ₂ e)	% of Baseline (w/o Flaring)	% of Baseline (with Flaring)
-\$5	1.18	14%	3%
\$0	1.60	20%	4%
\$5	2.08	25%	6%
\$10	2.67	33%	7%
\$15	2.70	33%	7%
\$20	2.87	35%	8%
\$25	2.98	36%	8%
\$30	2.98	37%	8%
\$35	2.99	37%	8%
\$40	3.01	37%	8%
\$45	3.01	37%	8%
\$50	3.02	37%	8%
>\$60	3.50	43%	10%

Summary of Top 50 - Most Cost Effective Options				
Abatement Measure	Avg. Break Even Price (\$/tCO ₂ e)	Incremental Reduction (MtCO ₂ e)	Avg. Payback Period (Months)	Avg. [IRR] Internal Rate of Return (%)
Surge vessels for station venting	-\$7.44	0.04	1.1	109%
Fuel Gas Retrofit on Reciprocating Compressors	-\$6.82	0.01	5.9	210%
Dil&M - Processing plants	-\$5.59	0.01	5.2	206%
Reducing the glycol circulation rates in dehydrators	-\$5.48	0.02	3.3	#DIV/0!
Replace High-bleed pneumatic devices	-\$4.19	0.48	28.4	77%
Installing Vapor Recovery Units on Crude Oil Storage	-\$2.32	1.09	28.9	45%
Dil&M - Compressor Stations	-\$0.69	0.03	5.6	565%
Installation of Flash Tank Separators	-\$0.11	0.03	63.1	12%
Convert Gas Pneumatic Controls to Instrument Air	\$1.34	0.02	-	-15%
Totals	-	1.71	-	-

*See MACA sheet for individual results.

Summary of Emissions Inventory by Segment		
Oil and Gas Segment	(CH ₄)	(MtCO ₂ e)
Production (Oil and Gas)	1,677,144	35.22
Flaring System	1,289,888	28.28
Processing (Gas)	30,351	0.64
Transmission (Gas)	28,176	0.59
Refining (Oil)	2,826	0.06
Petrochemical (Oil)	211	0.00
Annual Emissions	1,738,708	36.51

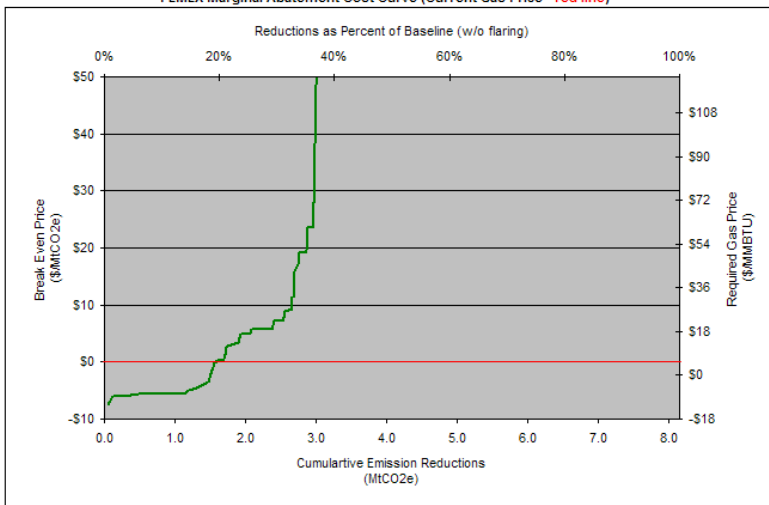
Emissions Baseline with No Reductions (MtCO ₂ e)	
Emissions Baseline (without Flaring)	8.16
Emissions Baseline (with Flaring)	36.51

Disclaimer -
The PEMEX MAC model is an analytical tool developed by U.S. EPA's Methane to Markets Program and Petróleos Mexicanos (PEMEX). The model is intended for internal use by PEMEX for planning purposes only.

The **Emissions Inventory** provides a cross-sectional snapshot of emissions in 2008. Changes in production or infrastructure and adoption of mitigation measures may affect the baseline emissions estimate in future years.

The MACA sheet provides detailed results of the MAC analysis.

PEMEX Marginal Abatement Cost Curve (Current Gas Price - red line)



The graph plots Break Even Price (\$/tCO₂e) on the left y-axis and Required Gas Price (\$/MMBTU) on the right y-axis against Cumulative Emission Reductions (MtCO₂e) on the x-axis. A red horizontal line indicates the current gas price at \$5.83. The green curve shows that at this price, approximately 3.5 MtCO₂e of emissions can be abated.

Importance of PEMEX MAC Model

- Integrated software including:
 - inventory points
 - abatement options
 - economic analysis
 - graphical and tabular outputs
- Specific to PEMEX
- Straightforward to use and understand
- Allows continual updating as additional PEMEX information and details become available
- Based on over 15 years of oil and gas industry experience
- Can serve as a model for a broader GHG analysis



Next Steps for Study

Methane Emissions Baseline Inventory

- Specific technical questionnaire on PEP emission sources to improve initial estimates based on reference emission factors or assumptions made in place of lacking data
- Field studies to determine PEMEX specific emission factors for PEP sources described above
- Validation of assumptions and emission factors for 2009 inventory
- Training on GHG inventory preparation

Mitigation potential study (MAC curves)

- Individualized MAC models for each PEMEX subsidiary
- Additional PEMEX data integration into MAC model
- Technical support on MAC model utilization

Next Steps: PEMEX DCO

- Review methane emissions inventory
- Identify potential measures for addressing uncombusted emissions from flares and reduction in flaring.
- Review methane emissions abatement measures and corresponding costs
- Integrate MAC analysis into PEMEX Climate Change Activities
- Incorporation of Canadian Government resources through M2M for Energy Efficiency Activities

Next Steps: M2M-PEP

PEP is by far the biggest source of methane emissions in PEMEX.

- Approach other PEP areas for joint activities, while consolidating current ones
- Joint PEMEX – M2M selection of PEP facilities as sample measurement sites possibly:
- Field Measurement
 - Up to 3 measurement campaigns over 6-9 months
 - Identification and definition of CH₄ emissions mitigation projects
- General
 - Short informative event for PEP staff (September 2009)
 - Training event on E&P technologies and experiences to raise awareness among decision makers

Next Steps: M2M-PGPB

PGPB should build on its excellent emissions identification work to date.

- Gas processing centers
 - Continue training initiated in June 2009 on emissions measurement equipment and energy efficiency
- Gas processing centers
 - Implement ongoing measurements with trained PEMEX staff, using M2M to support specific technical issues
- Gas transport
 - Training on M2M measures and experiences – lessons learned specific to the sector
- PGPB overall
 - Integrate methane emissions work into an overall energy management strategy

Vision for GHG Emissions Reduction in PEMEX

- **Finalize and implement Climate Change Strategy**
 - Review MAC analysis; propose projects
 - Extend analysis to energy/CO₂ emissions
 - Set emissions reductions targets
 - Develop, finance and implement GHG reduction projects

- **Obtain involvement and leadership of top PEMEX officials**
 - Disseminate Climate Change Strategy
 - Promote successful case studies in PEMEX
 - Consolidate energy efficiency and methane emissions programs
 - Create/assign a group dedicated to follow-up, implementation, monitoring and evaluation

- **Strengthen PEMEX international leadership**
 - Take advantage of prestige and image resulting from successful GHG reduction initiatives

PEMEX – M2M Collaboration: Summary

- Methane emissions reduction is both profitable and necessary under current legislation for PEMEX
- PEMEX - M2M have now nearly 3 years of successful and committed collaboration
- Methane program in PEMEX can be consolidated in the 2009 – 2010 period – special focus on PEP
- Involvement of top officers is needed to achieve more significant methane emissions reduction
- Methane projects show the company commitment with the environment
- Methane emissions reductions projects can play a prominent role in PEMEX commitment to Mexican GHG emissions reductions