



**A Methane Emissions Inventory and Analysis of Emissions Abatement
Measures for a Large State-Owned Oil and Gas Corporation: The Example
of PEMEX**

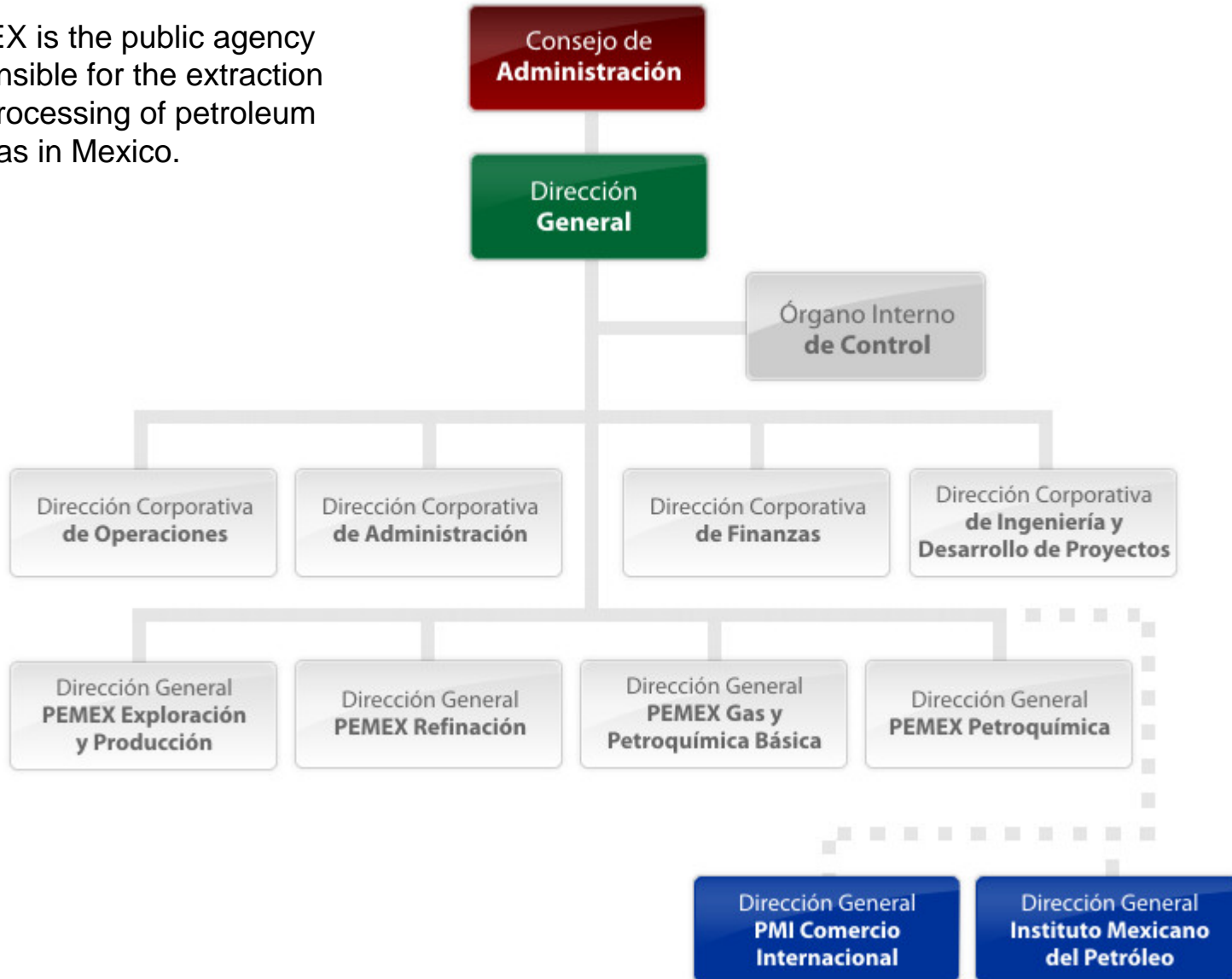
Pemex Corporate Directorate of Operations
Office of Environmental Protection

March 2010

- PEMEX
 - Context for Climate Change in Mexico
 - PEMEX GHG Reduction Efforts
 - PEMEX - M2M Study
 - Methane Emissions Inventory
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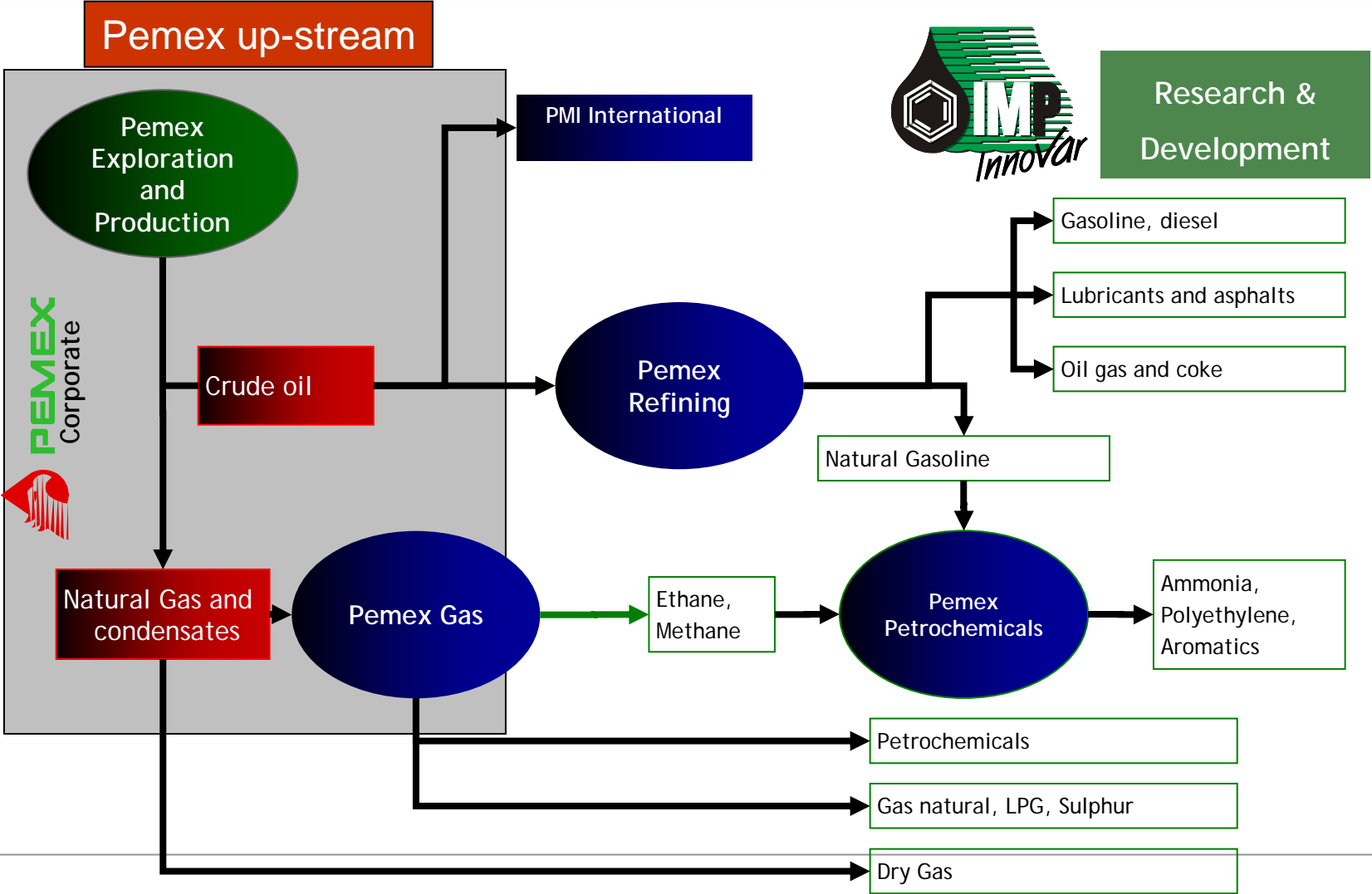
PEMEX Organizational Structure

PEMEX is the public agency responsible for the extraction and processing of petroleum and gas in Mexico.



PEMEX Organizational Structure

- The up-stream sector of Pemex is operated by Pemex Exploration and Production (PEP) and Pemex Gas (PGPB).



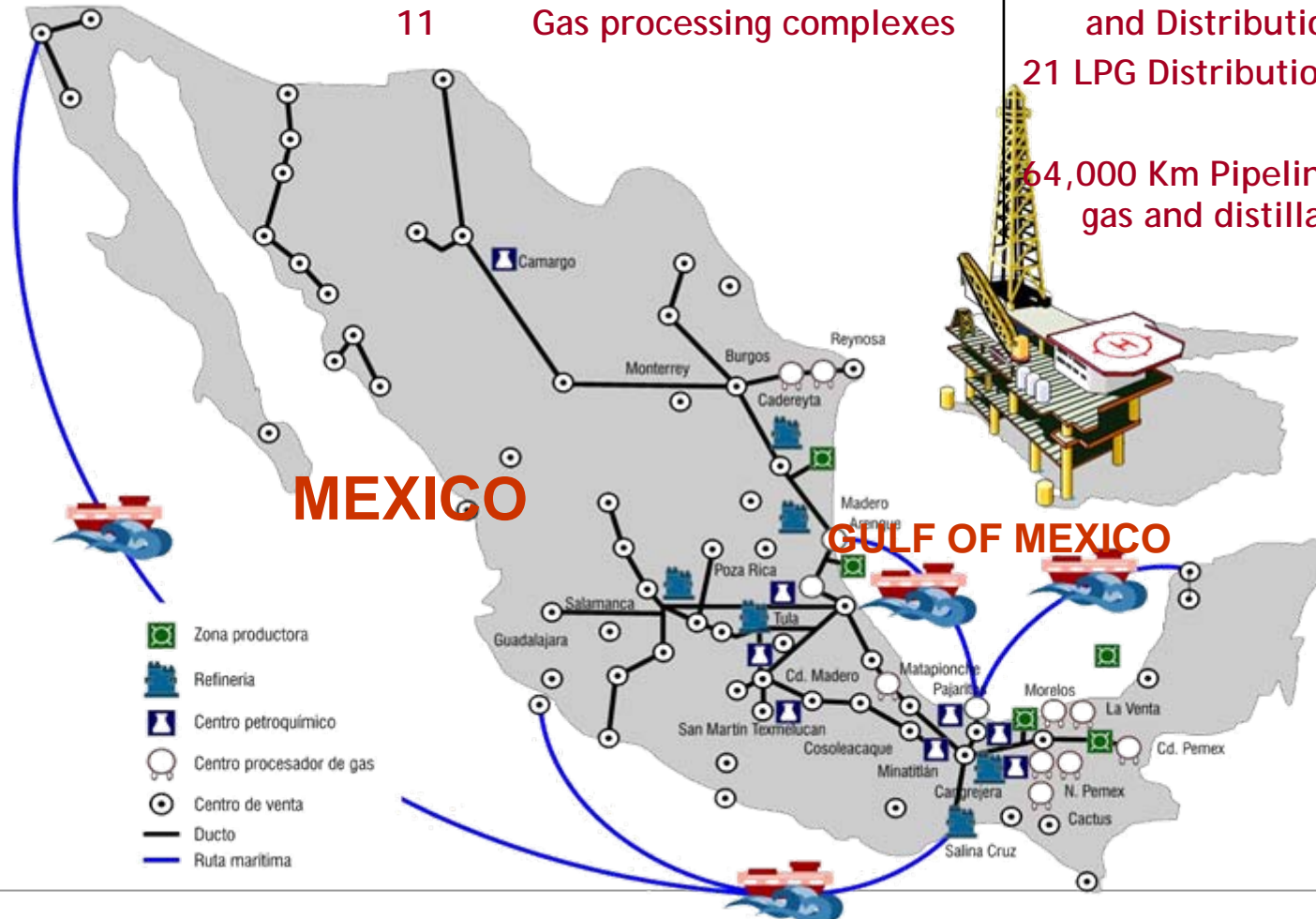
PEMEX Main infrastructure

USA

- 344 Production fields
- 6,247 Production wells
- 225 Off-shore Platforms
- 11 Gas processing complexes

- 6 Refineries
- 8 Petrochemical Complexes
- 77 Distillates products Storage and Distribution Terminals
- 21 LPG Distribution Terminals

64,000 Km Pipelines (crude oil, gas and distillates)



- Zona productora
- Refinería
- Centro petroquímico
- Centro procesador de gas
- Centro de venta
- Ducto
- Ruta marítima



- Mexico is the 2nd largest emitter of GHG in Latin America
 - PEMEX contributes 8.2% of Mexico's GHG emissions
 - In 2008, PEMEX total GHG emissions grew by 25% to 54.9 MtCO₂e.
 - June 2009 - President Calderon announcement
 - Mexico's voluntary commitment to reduce GHG emissions by 50 MtCO₂e by 2012.
 - PEMEX expected to make an important contribution to the emissions reductions.
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- In recent years, PEMEX has focused on 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
 - 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
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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

- 10 ● **Expected Results**

- PEMEX baseline CH₄ emissions inventory
 - Estimate of savings from cost-effective CH₄ reductions
 - Full analysis of different mitigation measures
 - Technical and economic model of PEMEX methane emissions and emission reduction projects
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PEMEX Methane Emissions Inventory

- A coherent Climate Change Strategy starts by building a GHG emissions baseline.
 - PEMEX and M2M agreed to work together to establish a methane emissions baseline, as detailed and as accurate as possible.
 - This work is relevant for all interested parties:
 - It presents an opportunity to improve the previous PEMEX methane emissions inventory carried out by M2M in 2006, and inventory estimates made by INE as part of Mexico's national GHG 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.
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PEMEX Methane Emissions Inventory: Assumptions and Considerations

- Official PEMEX information on equipment and component counts was used where available, primarily 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 emissions factors from IPCC or API, or from previous EPA reports and studies.
 - Tier 2 analysis allowed PEMEX-specific data in some PGPB gas processing facilities due to results of measurements performed under M2M.
 - When no equipment count disaggregated information existed, all devices in that category were given the same treatment with regard to emission factors.
 - Based on 2008 data, except 2007 where more recent data were not available.
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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%

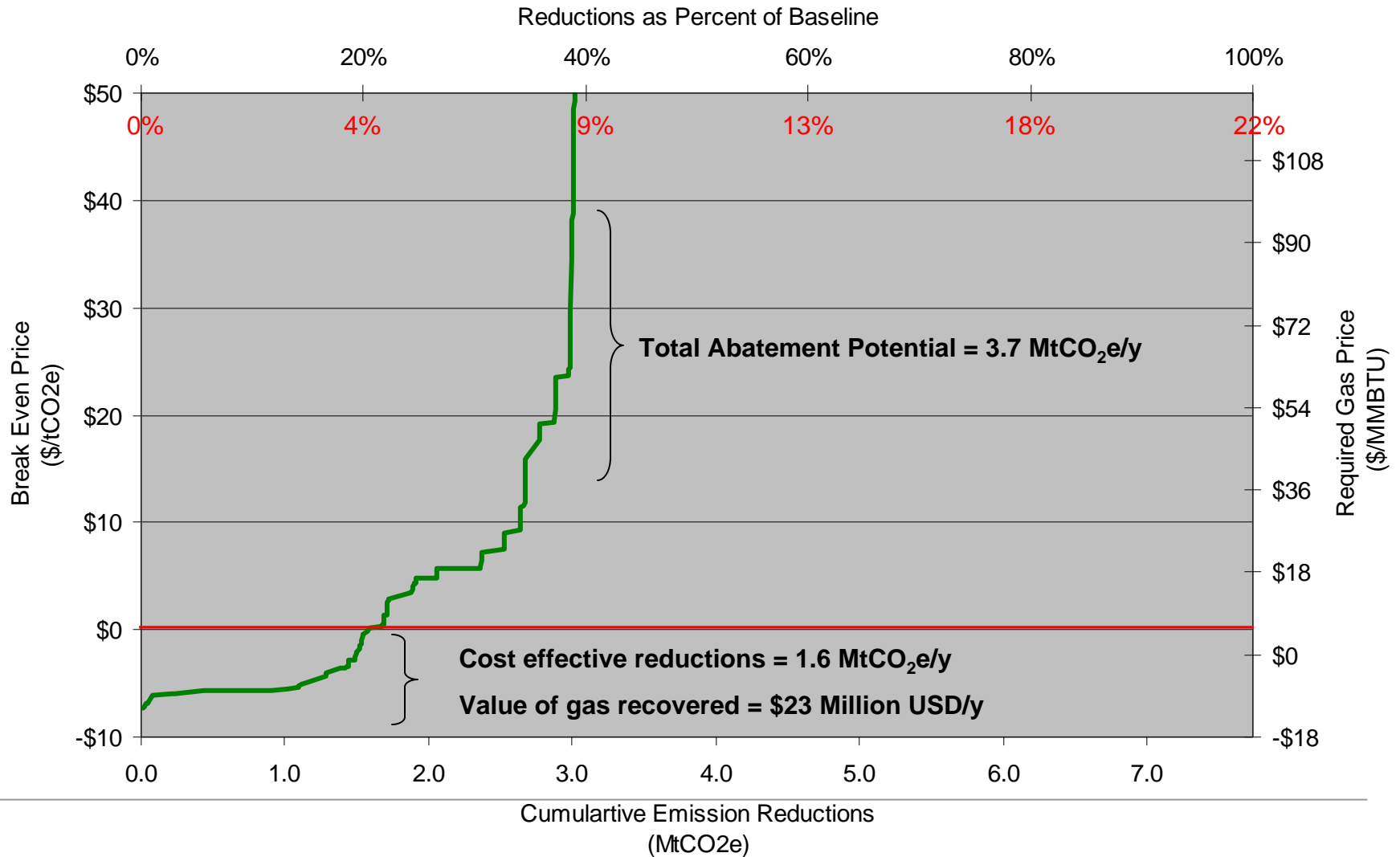
Use of Inventory Results to Quantify Emissions Reduction Measures

- 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,
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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 break even.
- 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 for 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.
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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
GVP 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	-\$8.82	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	(tCH ₄)	(MtCO ₂ e)
Production (Oil and Gas)	1,677,144	35.22
Flaring System	1,269,838	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 displays the Marginal Abatement Cost Curve (MACC) for PEMEX. The x-axis represents Cumulative Emission Reductions in MtCO₂e, ranging from 0.0 to 8.0. The left y-axis shows Break Even Price in \$/tCO₂e, ranging from -\$10 to \$50. The right y-axis shows Required Gas Price in \$/MMBTU, ranging from -\$18 to \$108. A green step-like curve represents the abatement cost, starting at approximately -\$5 for the first 1.18 MtCO₂e and rising to \$50 for 3.5 MtCO₂e. A horizontal red line at \$5.83 represents the current gas price. The intersection of the red line and the green curve indicates the break-even point for the current gas price, which occurs at approximately 3.0 MtCO₂e of cumulative reductions.

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: PEMEX Corporate Environmental Protection Department

- **Review methane emissions inventory.**
 - Work with M2M to adjust, finalize
 - Make this inventory part of PEMEX official inventory
 - **Identify measures to address uncombusted emissions from flares and to reduce flaring.**
 - Work with M2M to specify reduction potential, applicability, costs, and benefits.
 - Incorporate these measures into MAC analysis and revise results.
 - **Review methane emissions abatement measures and corresponding costs.**
 - Work with M2M to adjust, finalize.
 - Use this inventory and abatement measures as a tool to help generate additional projects in PEMEX.
 - **Integrate MAC analysis into PEMEX Climate Change Activities.**
 - MAC training
 - Support to CO₂ portion of inventory
 - Follow up meetings / documentation
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- Joint PEMEX - M2M selection of PEP facilities as sample measurement sites possibly:
 - Crude oil batteries
 - Gas field equipment
 - Offshore platforms
 - Other
 - Measurement
 - Up to 3 measurement campaigns over 6-9 months
 - Identification and definition of CH₄ emissions mitigation projects
 - General
 - Training event on E&P technologies and experiences to raise awareness among decision makers
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- 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
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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 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
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PEMEX Methane Emissions Inventory: Summary

- Methane emissions reduction is both profitable and necessary under current legislation for PEMEX.
 - The CH₄ emissions inventory provides the basis for development of mitigation programs in PEMEX.
 - Methane program in PEMEX can be consolidated in the 2009 - 2010 period - special focus on PEP.
 - Involvement of top officials is needed to achieve more significant methane emissions reduction.
 - PEMEX must work to convert MAC curves and opportunities into real projects.
 - Methane emissions reductions projects can play a prominent role in PEMEX commitment to Mexican GHG emissions reductions.
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PEMEX®

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¡ Thank-You!

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