

**Version: Septiembre 8**  
**Precio: US\$4.0/MMBTU**



***Mitigation of methane and black carbon in the oil and gas production, distribution and storage***

**Eng. Luis Fernando Betancourt**  
**Vice-Chairman Safety, Health and Environment Protection**  
[luis.fernando.betancourt@pemex.com](mailto:luis.fernando.betancourt@pemex.com)

**Technical Workshop on Science and Policy of  
Short-lived Climate Forcers (SLCF)**

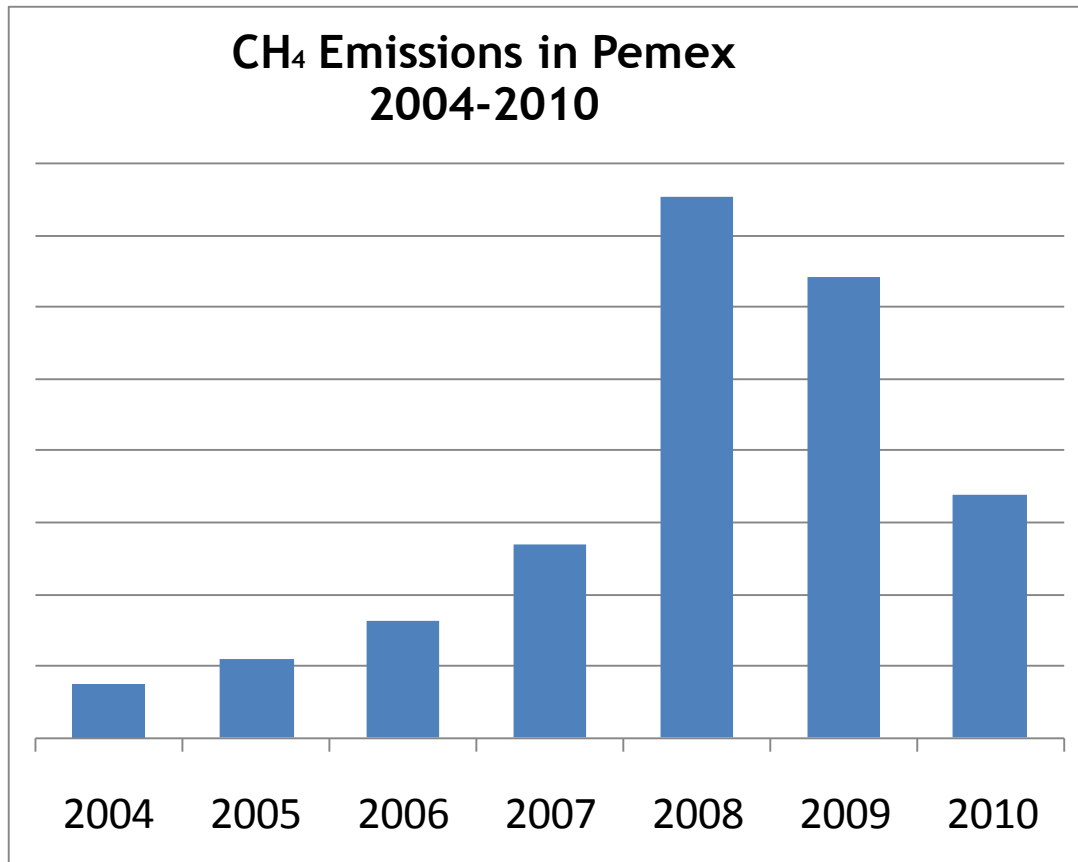
**September 9, 2011**

- Introduction
- Mitigation of methane fugitive emissions
  - Measurement campaigns
  - Methane emissions inventory
  - Methane Abatement Cost Analysis (MAC)
- Measurement of flaring efficiency and *Black Carbon*
- Next steps

- In addition to methane and carbon dioxide as major greenhouse gases, black carbon or soot has recently been implicated as a powerful climate forcer
- Methane emissions from oil and natural gas systems are primarily the result of normal operations and system disruptions. These emissions can be cost-effectively reduced by upgrading technologies or equipment, and by improving operations
- There is recognized concern over the amount of black carbon (BC) that is being emitted from flares worldwide, due to hydrocarbon carry over and poor flare combustion efficiency. BC has been proved to cause significant health hazard implications due to its small particle size
- Since 2006, Pemex has been working along with Global Methane Initiative (GMI) and, more recently, with Global Gas Flaring Reduction (GGFR) to train technical personnel to measure and mitigate CH<sub>4</sub> and BC in several facilities of its subsidiaries Pemex Gas (PGPB) and Pemex Exploracion y Producción (PEP).



- The reduction of methane emissions during the period 2004-2010 is the result of the improvements implemented by PEP to increase the utilization of natural gas, mainly in the Cantarell complex.



|      | (Tons*)   |
|------|-----------|
| 2004 | 152,855   |
| 2005 | 219,027   |
| 2006 | 324,754   |
| 2007 | 535,810   |
| 2008 | 1'506,727 |
| 2009 | 1'279,796 |
| 2010 | 677,167   |

\* Estimated. AP-42/SISPA.

- The Global Methane Initiative (GMI) creates a framework for international cooperation to reduce methane emissions to increase energy security, enhance economic growth, improve air quality, improve industrial safety and reduce greenhouse gases
- The GMI Oil and Gas Subcommittee, Pemex is a co-chair, is responsible for guiding the oil and gas sector activities and engaging all representatives of the private, public and non-governmental arenas in those activities. The Subcommittee's first concerns are:
  - Identify methane recovery opportunities and describe available technologies and best practices
  - Identify key barriers and issues for project development
  - Discuss country-specific needs, opportunities, and priorities
  - Identify possible joint activities to increase methane recovery and use in the sector
  - Identify project finance opportunities and mechanisms



In recent years, PEMEX has focused a number of activities on greenhouse gas reduction projects:

- Methane emission reductions
- Improved gas recovery and reduced emissions of CO<sub>2</sub>

Since 2006, a key initiative of PEMEX has been its collaboration with Global Methane Initiative (GMI) to develop methane emissions reduction projects:

- Field measurements of methane emissions in:

|      |  |
|------|--|
| PEP  | <ul style="list-style-type: none"> <li>- Cunduacan gas compression facility</li> <li>- Nejo 1 O&amp;G production field</li> <li>- Atasta gas compression facility</li> <li>- Abkatum-D Platform</li> </ul> |
| PGPB | <ul style="list-style-type: none"> <li>- Cactus, Ciudad PEMEX, Nuevo PEMEX, Poza Rica and Burgos gas processing facilities)</li> <li>- Cárdenas gas pipeline sector</li> </ul>                             |
| PPQ  | <ul style="list-style-type: none"> <li>- Cosoleacaque Petrochemicals complex</li> </ul>  |



- CPG Poza Rica – Potential economic savings: US\$ 2.4 Million/year**

| Source                 | Gas losses (1000 m3/y) | GHG Emissions (tCO <sub>2</sub> e/y) |
|------------------------|------------------------|--------------------------------------|
| Combustion             |                        | 28,570                               |
| Flaring                | 9,125                  | 20,292                               |
| Fugitives              | 650                    | 9,268                                |
| Venting in compressors | 7,487                  | 82,431                               |
| Sulphur recovery       |                        | 9,227                                |
| <b>Total</b>           | <b>17,262</b>          | <b>149,788</b>                       |

- CPG Nuevo PEMEX– Potential economic savings: US\$ 6.6 Million/year**

| Source                 | Gas losses (1000 m3/y) | GHG Emissions (tCO <sub>2</sub> e/y) |
|------------------------|------------------------|--------------------------------------|
| Combustion             |                        | 224,104                              |
| Flaring                | 43,983                 | 83,036                               |
| Fugitives              | 405                    | 5,765                                |
| Venting in compressors | 3,021                  | 23,210                               |
| Sulphur recovery       |                        | 490,547                              |
| <b>Total</b>           | <b>47,409</b>          | <b>820,942</b>                       |

- Burgos Compression Facility**—Potential economic savings: US\$ 4.6 Million/year

| Source         | Gas losses (1000 m3/y) | GHG Emissions (tCO <sub>2</sub> e/y) |
|----------------|------------------------|--------------------------------------|
| Combustion     |                        | 10,163                               |
| Flaring        | 13,965                 | 29,440                               |
| Fugitives      | 32                     | 410                                  |
| Heath recovery |                        | 24,293                               |
| <b>Total</b>   | <b>13,997</b>          | <b>64,306</b>                        |

- Cunduacán Compression Facility**—Potential economic savings: US\$ 30.0 Million/year

| Source         | Gas losses (1000 m3/y) | GHG Emissions (tCO <sub>2</sub> e/y) |
|----------------|------------------------|--------------------------------------|
| Combustion     |                        | 64,763                               |
| Pneumatics     | 68                     | 645                                  |
| Fugitives      | 742                    | 7,800                                |
| Heath recovery |                        | 280,124                              |
| <b>Total</b>   | <b>810</b>             | <b>354,138</b>                       |



PEMEX and GMI have undertaken a detailed inventory of PEMEX methane emissions and their mitigation potential (2008 data).

## Objectives:

- Prepare a comprehensive baseline CH<sub>4</sub> 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

## Results:

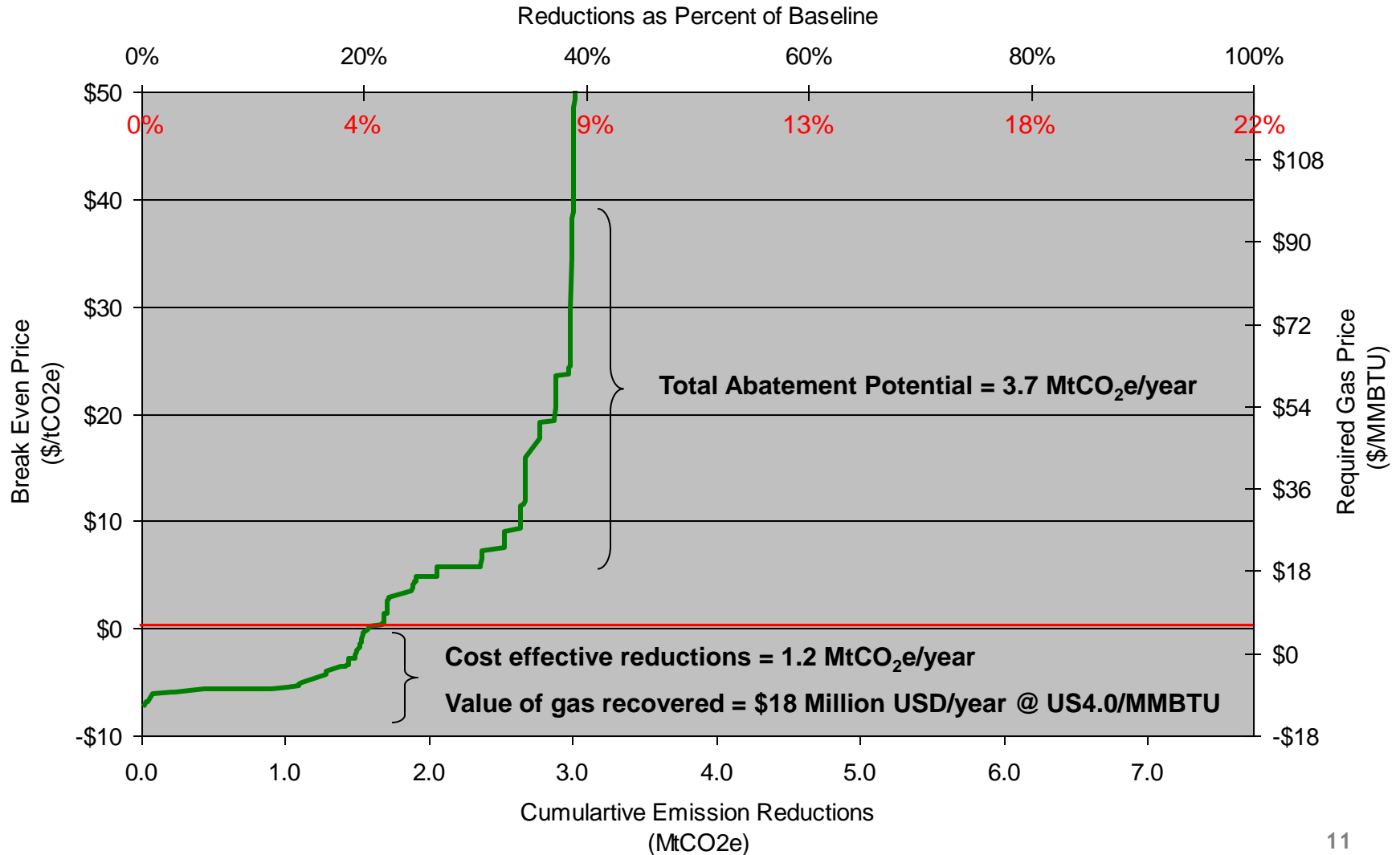
- PEMEX baseline CH<sub>4</sub> emissions inventory: Aprox. 36.1 MtCO<sub>2</sub>e/year
- Estimate of savings from cost-effective CH<sub>4</sub> reductions: UD\$ 18 million/year @4.0 USDIs/MMBTU
- Full analysis of 16 mitigation actions
- Technical and economic model of PEMEX methane emissions and emission reduction projects

- Total CH<sub>4</sub> emissions estimate: 36.1 MtCO<sub>2</sub>e/year
- PEP responsible for 96% of total emissions
- Un-combusted methane from flares is the largest single source, accounting for 78% of total emissions.

| PEMEX Subsidiary                             | Annual Emissions (tCH <sub>4</sub> ) | Annual Emissions (MtCO <sub>2</sub> ) | % 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%                   |
| <b>Total Annual CH<sub>4</sub> Emissions</b> | <b>1,718,607</b>                     | <b>36.09</b>                          | <b>100%</b>             |

# MAC Analysis - Typical Findings (preliminary)

- The results will allow to identify the cost-effective methane emissions reductions measures for PEMEX to implement



**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 <sup>3</sup> ) | 1,030                | 1,030               |
| CH <sub>4</sub> Density (kg/m <sup>3</sup> ) | 0.7168               | 0.7168              |
| GVP of CH <sub>4</sub> (100yr time horizon)  | 21                   | 21                  |
| <b>Finance Parameters</b>                    |                      |                     |
| Gas Price (2008\$USD / Mcf of natu)          | \$5.83               | \$5.83              |
| Real Discount Rate (Required %IRR)           | 12%                  | 12%                 |
| Tax Rate                                     | 45%                  | 45%                 |

**Summary of Emissions Inventory by Segment**

| Oil and Gas Segment      | (tCH <sub>4</sub> ) | (MtCO <sub>2</sub> e) |
|--------------------------|---------------------|-----------------------|
| Production (Oil and Gas) | 1,677,144           | 35.22                 |
| Flaring System           | 1,350,085           | 28.25                 |
| Processing (Gas)         | 30,351              | 0.64                  |
| Transmission (Gas)       | 28,176              | 0.59                  |
| Refining (Oil)           | 2,826               | 0.06                  |
| Petrochemical (Oil)      | 211                 | 0.00                  |
| <b>Annual Emissions</b>  | <b>1,738,708</b>    | <b>36.51</b>          |

**Emissions Baseline with No Reductions (MtCO<sub>2</sub>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 effect the baseline emissions estimate in future years.

The MACA sheet provides detailed results of the MAC analysis.

**Summary Results Table**

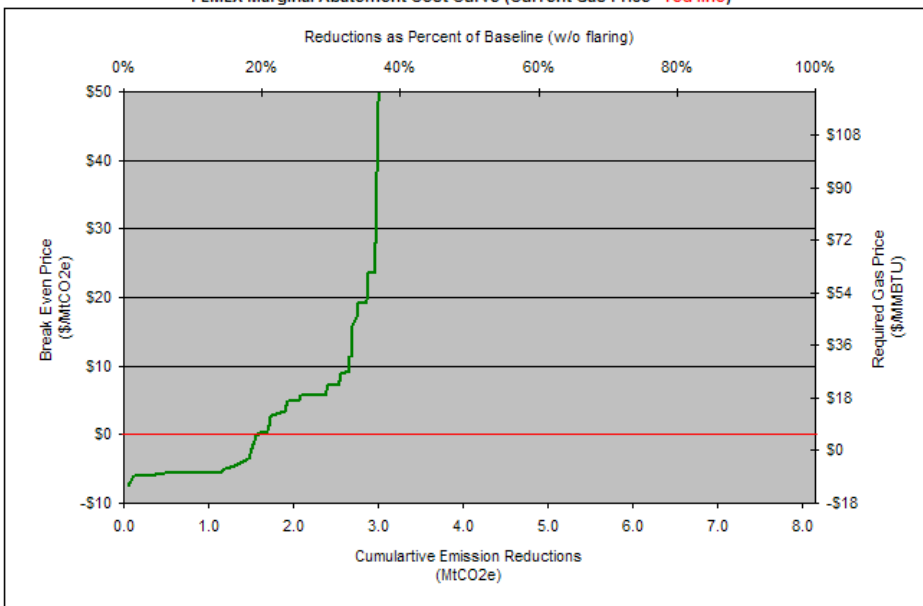
| Break Even Price (\$/tCO <sub>2</sub> e) | Emission Reductions (MtCO <sub>2</sub> e) | % of Baseline (w/o Flaring) | % of Baseline (with Flaring) |
|--|---|-----------------------------|------------------------------|
| -\$5                                     | 1.18                                      | 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 <sub>2</sub> e) | Incremental Reduction (MtCO <sub>2</sub> 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%                                   |
| D&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%                                    |
| D&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  | 13.5                         | -15%                                   |
| <b>Totals</b>  | -   | <b>1.71</b>                                 | -                            | -                                      |

\*See MACA sheet for individual results.

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



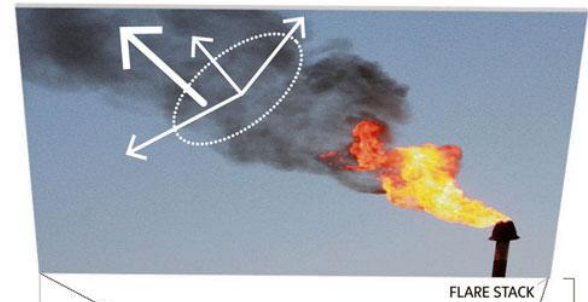
INTRO | IN-OUT | EINV | RECR | FTSD | FGR | CRPS | DSCC | IMPP | IMTS | TROT | GPCA | RHBP | VRUT | Additional Factors | Cost\_Output | **MACA** | Top50

- The World Bank's Global Gas Flaring Reduction (GGFR) partnership supports the efforts of oil producing countries and companies to increase the use of associated natural gas and therefore, reduce flaring and venting, which wastes valuable resources and damages the environment
- Given the wide variation in flare emissions associated with large variations in meteorological conditions, fuel composition, fuel flow rates, flare size, and flare design, current approaches to estimating emissions are at best grossly simplified
- There is interest in looking at flare efficiency by applying the new technical analytical method called sky-LOSA (Line-Of-Sight Attenuation) optical diagnostic measurement, which will provide estimates of soot concentration in flare plumes under field conditions
- As part of Mexico's GGFR program, Pemex is looking for technical support to estimate the performance of flare efficiency and emissions of black carbon in E&P operating facilities.



- With technical support provided by GMI and GGFR on November 2011, Pemex will conduct a methane and BC workshop.
- This workshop will help to generate additional quantitative data to support the investment decisions needed to be taken by Pemex, in order to decrease black carbon emissions, which will have positive health effects and maximize climate mitigation benefits
- This would be the first time such approach has ever been done in Latin America for an operating flare in the field. The resulting derived emission factor data would be of significant scientific and practical value, and provide quantitative data for supporting Pemex and GGFR activities.

**The Sky-LOSA method**  
Uses cameras and specially designed software to calculate how much soot is produced by a gas flare.



FLARE STACK

**How fast?**  
A high-speed movie camera measures how fast the different parts of the smoke plume are moving.



HIGH-SPEED CAMERA

**How dark?**  
A scientific-grade camera takes images of the sky and the smoke, allowing for calculations of the difference in brightness, or how dense the smoke is.



HIGH-RES CAMERA

216 M

TONIA COWAN/THE GLOBE AND MAIL | SOURCE: ENVIRONMENTAL SCIENCE & TECHNOLOGY JOURNAL

- Review and complete methane emissions inventory
  - Integrate CH<sub>4</sub> baseline and MAC analysis in the design of the Pemex's operations
  - Implement the analytical method sky-LOSA (Line-Of-Sight Attenuation) to improve the flare efficiency. Up-coming workshop in November 2011
  - Identify measures to address emissions from incomplete burning and to reduce flaring
  - Review and complete methane emissions abatement measures and corresponding costs
  - Implement operational working plans to reduce emissions of CH<sub>4</sub> and BC in other Pemex's facilities.
- 





**Mitigation of methane and *black carbon in the oil and gas production, distribution and storage***

**Eng. Luis Fernando Betancourt  
Vice-Chairman Safety, Health and Environment Protection**

[luis.fernando.betancourt@pemex.com](mailto:luis.fernando.betancourt@pemex.com)

**Technical Workshop on Science and Policy of  
Short-lived Climate Forcers (SLCF)**

September 9, 2011