



# Understanding short-lived climate forcers

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# **Understanding short-lived climate forcers**

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## Introduction

Efforts to mitigate the risks of climate change have primarily focused on reducing emissions of carbon dioxide (CO<sub>2</sub>). Recent work has broadened this focus to reconsider the role of other forcing agents in changing the climate and their reduction as part of a broader mitigation strategy. Specifically, so-called short-lived climate forcers (SLCFs), which include methane, black carbon and hydrofluorocarbons (HFCs), have drawn the attention of researchers, governments and industry in mitigation proposals. Overall, these climate forcers may have a significant effect, even though their mass emissions are smaller, and their atmospheric lifetimes shorter, than CO<sub>2</sub>.

While real opportunities exist with the inclusion of SLCFs in climate change mitigation, uncertainties remain surrounding their sources, climate effects and strategies to manage their emissions. It is a difficult task to accurately quantify the sources of both anthropogenic and natural emissions of SLCFs on a global scale. Current assessments of the contribution from the oil and gas industry (activities and products) to total SLCF emissions remain divergent, with large uncertainties in certain regions. Developing future initiatives that contribute material reductions in SLCF emissions will require efforts to constrain the varied sources of emissions as well as facilitate collaborative action among stakeholders.

An IPIECA Workshop on SLCFs was held in Rome, Italy on 8–9 October 2013. The objectives of the workshop were to:

- identify and understand the effects on warming, precipitation and air quality from methane and black carbon as well as the associated uncertainty;
- assess the sources and sinks of methane and black carbon from a global perspective as well as from the oil and gas industry in particular;
- understand the role of current initiatives to measure, mitigate and manage the emissions of SLCFs; and
- discuss remaining gaps in the industry's understanding of SLCF emissions, future pathways to reduce uncertainty, and high impact pathways for reducing these emissions.

The workshop and this publication are part of IPIECA's long-term initiative to promote climate change understanding and engage in developing solutions for mitigating risks to both society and the oil and gas industry.

## Executive summary

1. **Carbon dioxide remains the predominant focus for long-term climate mitigation, though global emissions of methane and black carbon can have important, and different, effects on climate.** Because of their shorter atmospheric lifetimes and greater potency, short-lived climate forcers (SLCFs) offer opportunities for emissions reductions to have a greater impact on reducing warming than CO<sub>2</sub> in the near term. Key uncertainties in determining the mitigation potential of SLCFs remain, including sources and quantities of methane and black carbon emissions, and the combined radiative forcing effects of black carbon and co-emitted species.
2. **Various methodologies to estimate the contribution from the oil and gas industry to global methane emissions exist, and each has its own uncertainty and inconsistencies with the other methods.** Different approaches are important in triangulating the correct amounts, however estimates from these methodologies vary widely and work to reconcile these estimates remains. Future improvements in estimates of aggregated methane emissions, along with direct measurements from natural gas systems to estimate emission factors, will lead to further agreement and more accurate estimates overall.
3. **Recent improvements in data collection efforts have provided a wealth of information that quantitatively characterizes some sources of methane emissions from the oil and gas supply chain.** Results have shown significant variations from emission factors and activity levels used in national emissions inventories and other estimates of emissions from the oil and gas sector.
4. **Emerging data suggest that methane emissions from oil and gas production in the USA are in the order of 0.5% of total production, which is much lower than some estimates. The data also shows that conventional versus unconventional gas production do not have materially different methane emissions.** As most existing methane estimates are based on data/studies from North America where 'dispersed' oil and gas production with higher potential for methane emissions is standard, there is a need for more research beyond this region where many of the US sources do not exist and lower methane emissions are expected.
5. **Measurements of methane emissions from natural gas production are also consistent with estimates that the life-cycle greenhouse gas (GHG) emissions from electric power generation are roughly half for natural gas in comparison to coal per unit of electricity generated.**
6. **Global estimates of black carbon emissions from all sources, as well as the climate effects of black carbon (BC) and co-emitted species, continue to have substantial uncertainty.** Emissions estimates may be underestimated, particularly with respect to developing nations where the majority of emissions originate. Open biomass burning (wildfires and agricultural burning) is the largest source of BC emissions (roughly 1/3 of global total), followed by residential solid fuel, i.e. biomass and coal (~1/3), diesel engines (~1/6), and industrial sources, e.g. coal use, flaring, etc. (~1/6).



7. **Black carbon emissions from diesel engines continue to decrease in the developed world due to policies under way or implemented.** Coincident improvements in engine technology and fuel quality can lead to significant improvements in emissions in countries with few other emissions policies. Marine shipping is estimated to be a rather small contribution to both global and Arctic black carbon emissions.
8. **Black carbon emissions from upstream flaring are highly uncertain and vary significantly between flare types and gas compositions.** Improved knowledge of black carbon formation in various flare operating conditions could lead to targeted and effective pathways for reducing emissions from high emitters.
9. **Continued attention to acquiring better data, sharing of best practices, and mitigation efforts from the oil and gas industry will likely lead to further improvements in the oil and gas industry's emissions management for both methane and black carbon.** Organizations (e.g. IPIECA) and initiatives (e.g. US EPA Natural Gas STAR programme, World Bank Global Gas Flaring Reduction public-private partnership (GGFR)) provide important platforms for achieving improvements in emissions mitigation. However, opportunity costs, safety and reliability must be factored in when considering mitigation options, and there is likely no single fit-for-purpose mitigation strategy.

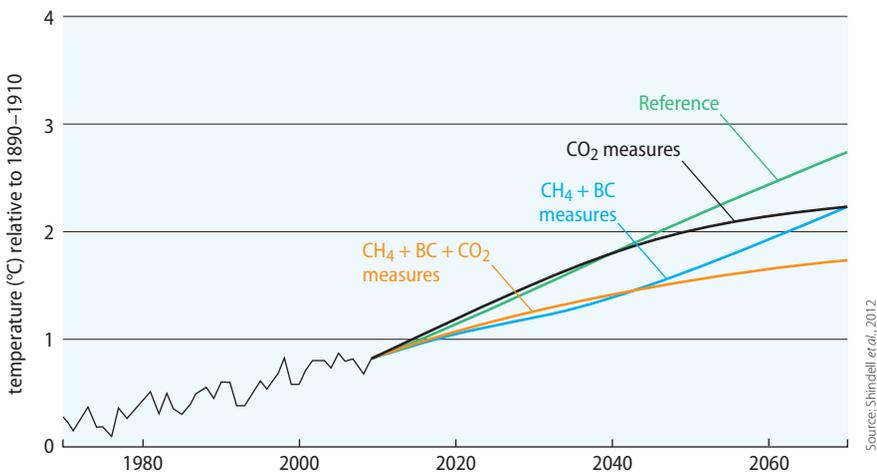
## Overview of short-lived climate forcers

Short-lived climate forcers principally comprise black carbon (BC), methane (CH<sub>4</sub>—the main component of natural gas) and HFCs<sup>1</sup>. These SLCFs are present in the atmosphere and are estimated to have an important contribution to warming (IPCC, 2013; Shindell *et al.*, 2012). Therefore, reducing their presence can partially mitigate the risks of climate change.

Recent assessments suggest that current concentrations of methane and black carbon in the atmosphere together contribute about as much radiative forcing as CO<sub>2</sub>, though there is substantial uncertainty about black carbon's

contribution (IPCC, 2013). However, a key difference is that a fraction of emitted CO<sub>2</sub> can stay in the atmosphere for centuries, while SLCFs are either removed from the atmosphere or transformed to CO<sub>2</sub> relatively quickly (i.e. a few weeks for BC to about 12 years for methane). This difference in atmospheric lifetime is important for several reasons. First, for BC, the effects tend to be local or regional, rather than global. Second, given their shorter atmospheric lifetime, coupled with their higher radiative forcing per kg, compared to CO<sub>2</sub>, mitigating SLCFs could more rapidly decrease positive<sup>2</sup> climate forcing and hence climate

**Figure 1** Compared to CO<sub>2</sub>, mitigating SLCFs could more rapidly decrease positive climate forcing and hence climate warming



<sup>1</sup> Sulphur oxides are another type of short-lived climate forcer that generally leads to cooling of the atmosphere (negative forcing), hence their emissions are not included in typical SLCF assessments for climate mitigation. Emissions from certain sources have already been significantly reduced through environmental regulation, for example the International Maritime Organization's (IMO's) agreement will reduce sulphur levels in marine fuels globally from 3.5% to 0.5% (by 2020 or 2025)

<sup>2</sup> Radiative forcing is a measure of the effect a species or process has in altering the energy balance in the Earth-atmosphere system (see IPCC, 2013). When more energy is absorbed by the atmosphere, this phenomenon is called 'positive forcing'.



warming, and be a complementary approach to a climate mitigation strategy focused on CO<sub>2</sub> alone (see Figure 1).

## Black carbon

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Black carbon is a carbonaceous component of soot, and is mainly produced through the incomplete combustion of biomass, biofuels and fossil fuels. BC contributes to global warming because it strongly absorbs incoming solar radiation when it is in the atmosphere, and also by changing the reflectivity of the surface (albedo) when it is deposited on light-coloured surfaces such as snow and ice. Different sources of BC also co-emit other aerosol species which may be warming or cooling agents in the atmosphere, hence it is important to consider the total emissions profile of a given source to assess its contribution to warming. In addition, the presence of BC in the atmosphere can influence cloud formation and rainfall (precipitation).



Much of the uncertainty around the climate effects of BC result from unknowns in its vertical distribution in the atmosphere.

In addition to its effects on climate change, BC may influence human health. Particulate matter (PM), of which BC is a component, can affect the respiratory system. The UN has assessed that indoor air pollution from biomass combustion has a particularly important negative health effect in the developing world, where cooking, heating and lighting still rely heavily on the use of biomass (UNEP/WMO, 2011).

## Methane

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Methane is a simple molecule which exists as a gas in the atmosphere and arises from thermogenic, biogenic and pyrogenic sources. These sources of methane emissions may result from natural processes (e.g. natural seeps, wetlands) and human activities (e.g. oil and gas production, agriculture). Methane is a

GHG with an estimated important contribution to radiative forcing (see Figure 2); its global warming potential has recently been estimated at around 28 times greater than CO<sub>2</sub> over 100 years (IPCC, 2013).

In addition to the GHG effect of methane on atmospheric warming, the presence of methane can also increase the amount of ozone in the lower atmosphere. Higher ozone concentrations at surface levels are associated with adverse effects on crop yields and human health.

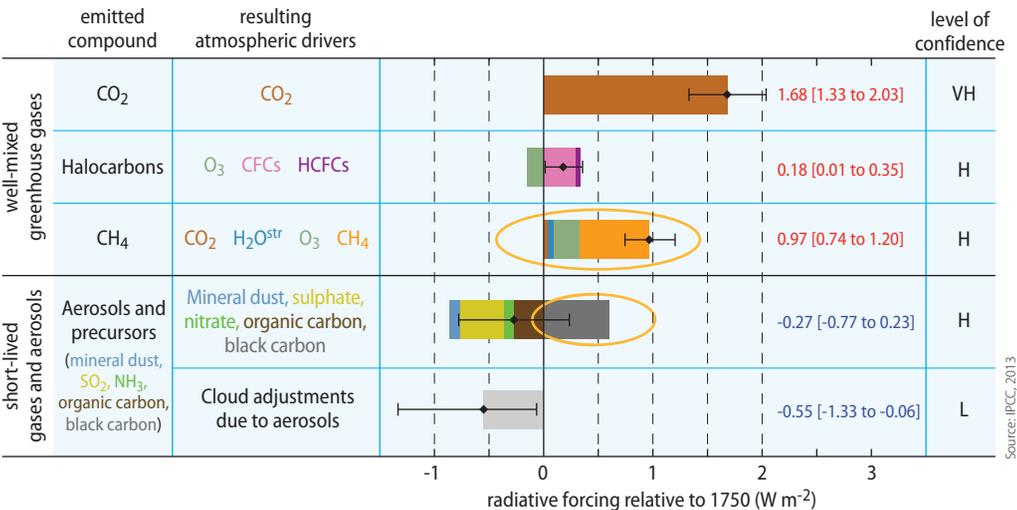
### Hydrofluorocarbons

Hydrofluorocarbons (HFCs) are organic compounds that have a strong radiative forcing per unit of mass compared to CO<sub>2</sub>. They are used extensively in refrigeration, and also have industrial uses such as in foam blowing and as solvents. The use (and releases) of HFCs

has grown considerably since the UN Montreal Protocol on Substances that Deplete the Ozone Layer began encouraging the replacement of chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) with HFCs (which do not react with ozone) in refrigeration and air conditioning. As the demand for these systems continues to increase, particularly in developing countries, HFC emissions will also continue to rise.



**Figure 2** Radiative forcing by emissions and subsequent atmospheric component



Source: IPCC, 2013

## Global sources

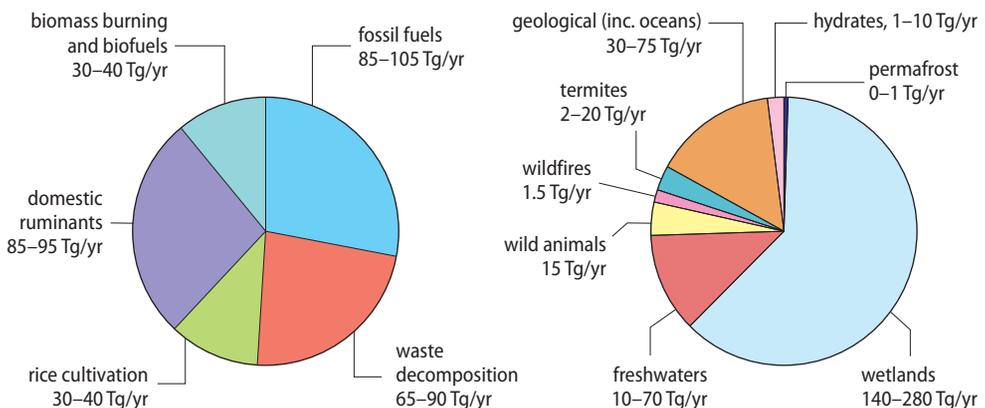
With the increasing focus on SLCFs as a potential route to mitigate climate change in the near term, it is important to better understand and quantify the sources and magnitudes of these emissions. Although many researchers, governments and industries have compiled various estimates of emissions, there can be a wide variation in reported figures for both BC and methane. Methods for estimating SLCF emissions are often characterized as ‘bottom-up’ or ‘top-down’ methodologies. Bottom-up methods calculate emissions by multiplying an emission factor (EF) (such as kg of GHGs per litre of fuel consumed) by an activity at the emission source (such as litres of fuel consumed). EFs are developed by taking measurements of representative emission sources or modelling emissions and extrapolating the data to the number of such emission types that exist. In most cases the number of individual emission measurements taken, or model runs conducted, is small compared to the total number of similar sources. The resulting estimate is therefore

highly dependent on how representative the samples taken/models conducted are when compared with the whole population of sources. Top-down methods rely on atmospheric observations along with transport and inverse models to estimate emissions sources and magnitudes. Both types of methodologies are useful and complementary, but both are subject to significant uncertainty and may generate different results for the same emission type.

### Global methane emissions

The concentration of methane in the atmosphere has increased from around 750 parts per billion (ppb) in pre-industrial times to around 1750–1800 ppb today. Increases and decreases in the atmospheric concentration of methane are the result of the difference between methane source emissions rates and its uptake or destruction (i.e. sinks). Anthropogenic emissions of methane account for about half of the total CH<sub>4</sub> emissions (see Figure 3). The main sources of

**Figure 3** Estimated global methane sources: anthropogenic (left) and natural (right) (1 Teragram = 1 million tonnes)



Source: Global Carbon Project, 2013; based on data from Kirschke et al., 2013

anthropogenic methane emissions are oil and gas systems<sup>3</sup>; agriculture, including enteric fermentation, manure management and rice cultivation; landfills; wastewater treatment; and emissions from coal mines. Methane is the primary component of natural gas, with some emitted to the atmosphere during its production, processing, storage, transmission and distribution. The main mechanism for the destruction of methane in the air is the chemical reaction with atmospheric OH free radicals. Over the past two decades, the net flux of methane to the atmosphere (sources minus sinks) can swing from positive to negative on an annual basis, with changes in

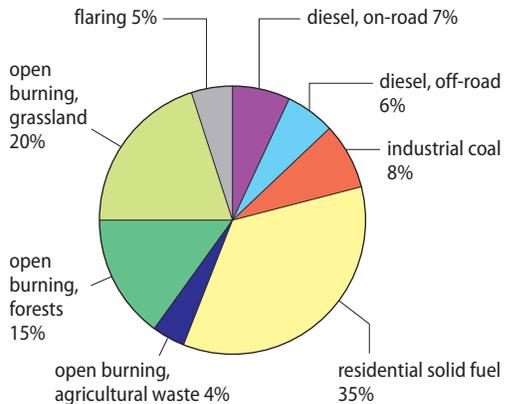
emissions from wetlands being attributed as the likely category contributing to the observed variability. In 2013, for example, the sources of methane were about 8% higher than the sinks, leading to an increase in atmospheric concentration.

### Global black carbon emissions

The main sources of black carbon are: open burning of forests and savannas (~1/3); residential solid fuel (coal and biomass) use (~1/3); industrial uses, e.g. coal burning, brick production and gas flaring (~1/6); and diesel vehicle exhausts (~1/6) (see Figure 4).



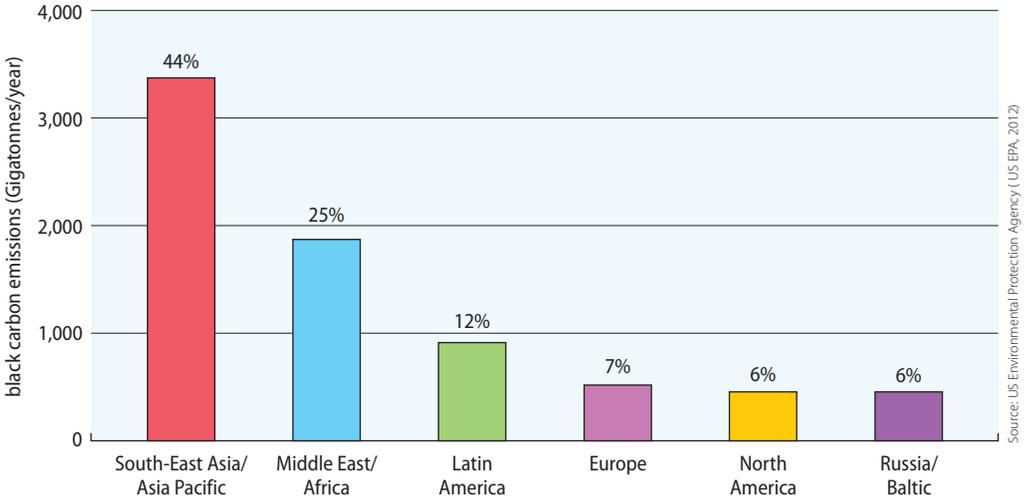
Figure 4 Estimated black carbon sources (2000s, 8 TgC/year)



Source: IIPASA GAINS, 2013.

<sup>3</sup> *Natural Gas Systems* and *Petroleum Systems* are the categories in the IPCC inventory system that apply to the oil and gas industry. The two categories collectively cover the entire industry except petrochemicals.

**Figure 5** Black carbon emissions by region (estimated uncertainty is 50% to 100%)



Black carbon emissions vary significantly among regions (see Figure 5). Recent assessments also highlight that total black

carbon emissions may be higher than current estimates, particularly in Southeast Asia.



## Oil and gas industry emissions

Emissions of SLCFs from the oil and gas industry include: BC emissions through flaring (~1% to ~5% of global BC emissions) (US EPA, 2012; IIASA/GAINS, 2013) and, indirectly, through the use of its fuels (~13% globally) (IIASA/GAINS, 2013), and methane emissions from the production of oil and gas. It is important to note however that estimated emissions vary from study to study, and continued work to better understand emission sources will help to identify meaningful actions for emissions reduction.

### Black carbon from oil and gas

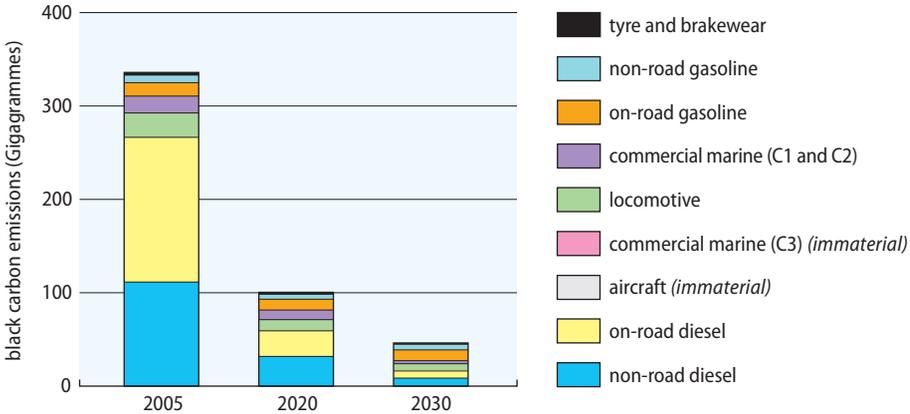
Oil and gas industry flaring, from both upstream and downstream operations, can be a source of BC emissions. The amount of BC produced varies considerably from flare to flare, primarily as a function of how effective the flare system is at

achieving complete gas combustion. Direct field measurements of black carbon emissions are difficult to conduct and subsequently quantify. A technique to estimate field emissions known as 'Sky-LOSA' measures the absorption of radiation by BC particles in a gas flare which is then used to estimate particulate composition and mass (Johnson *et al.*, 2012); this method or other future techniques may prove useful for quantifying and identifying particularly large emitters of BC while in the field. As the industry continues to reduce total flaring, the amount of co-emitted BC will also be reduced. Where flaring is still necessary, improvements to the flare systems will also reduce the amount of BC emitted from these flares.

The BC mitigation potential associated with transport fuels will depend on a number of factors. New technology diesel engines,



**Figure 6** Black carbon emissions from US transport



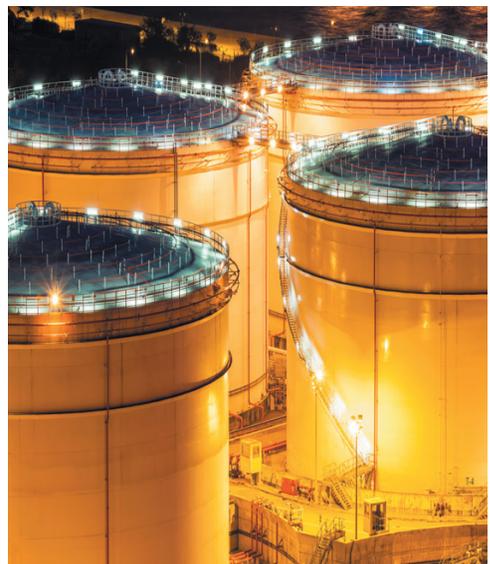
Source: from Eddy Van Bovel presentation; US EPA Report to Congress on Black Carbon, March 2012

combined with low-sulphur fuels and after-treatment systems such as diesel particulate filters (DPFs), have virtually eliminated BC from exhaust products, and the decline will continue with land fleet turnover (see Figure 6). As the use of these fuels and vehicles spreads from North America and Europe to greater worldwide use, both the climate and health impacts of BC will be substantially reduced, especially in urban environments. On the other hand, the International Council on Combustion Engines (CIMAC) recently published a study on marine fuels, concluding that, if heavy fuel oil is replaced by low-sulphur marine distillate, there would be almost no change in the level of BC emitted.

### Methane from oil and gas

There have been numerous estimates and measurements of methane emissions from the oil and gas production industry made by government bodies, academic researchers, industry, and other stakeholders. Using a

bottom-up approach the International Energy Agency (IEA) has estimated total CH<sub>4</sub> emissions of 90 million tonnes per year from the oil and gas industry with about half of them (45 million tonnes) coming from the production segment. Comparable data from the industry,



collected and aggregated by the International Association of Oil and Gas Producers (OGP), suggests a figure of 9 million tonnes per year. In Europe, the Joint Research Centre (JRC), which is the in-house science service of the European Commission, is undertaking work to quantify emissions for a range of substances, including CH<sub>4</sub>, CO, NO<sub>x</sub>, SO<sub>x</sub>, VOCs, NH<sub>3</sub>, PM and BC. It develops the Emissions Database for Global Atmospheric Research (EDGAR) which is independent from other EU emissions data. Comparing the estimates from EDGAR to those from the UNFCCC on a regional basis suggests that large variations may exist in the estimate of methane emissions from the oil and gas industry (See Table 1).

A recent study directly characterizing the emissions from various components of the upstream production phase of onshore natural gas wells in the USA was carried out by a

**Table 1** Estimates of oil and gas industry methane emissions by country (Tg CH<sub>4</sub>/yr) (UNFCCC vs. EDGAR emission inventories)

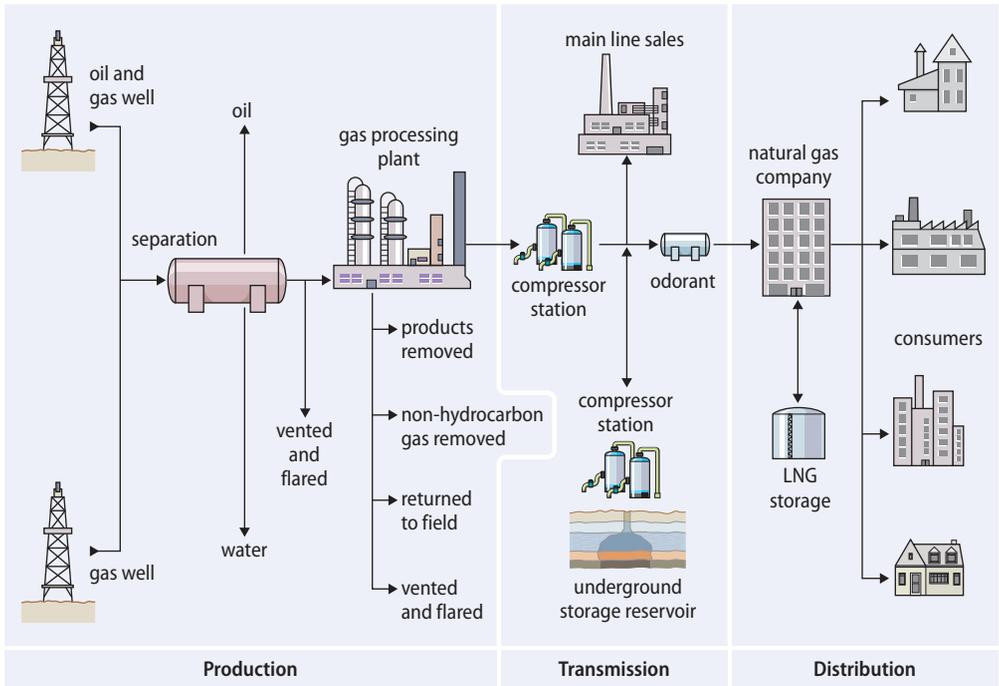
Emission inventory	UK	France	Germany
UNFCCC	0.32	0.09	0.35
EDGAR	0.67	1.43	0.39

Source: JRC (averages: 2001–2006)

team from the University of Texas (UT) (Allen *et al.*, 2013). This study, in partnership with nine natural gas producers and the Environmental Defense Fund (EDF), measured emissions associated with: the flow-back of wells following hydraulic fracturing (31 measurements, 27 new wells and 4 work-overs); well venting for liquids unloading (9 measurements); pneumatic controllers (instruments); and equipment leaks (190 wells) (See Figure 7).



**Figure 7** The natural gas production, transmission and distribution system



Source: US Energy Information Administration

Allen *et al.* (2013) concluded that there is little difference in CH<sub>4</sub> emissions between gas fields using conventional techniques and those using hydraulic fracturing since emissions from well flowback were comparatively small. When coupled with US EPA data for other sources not measured and extrapolating to total US gas production, the results indicate that emissions of methane are about 0.42% of the total US natural gas production, which compares favourably with the EPA's estimate of about 0.47%. In the context of power generation, if the other losses from processing and transmission are taken into account, the estimated total lost gas is just above 1.0%. In

determining whether coal or natural gas has a climate emissions benefit in power generation, it has been calculated that the balance point for gas leakage, regardless of the time frame, is about 3.2% (Alvarez *et al.*, 2012). This suggests that using natural gas instead of coal for electricity production results in a reduction in CO<sub>2</sub> equivalent emissions. Currently there are ongoing efforts to better characterize methane emissions from other parts of the oil and gas supply chain in the USA, which should lead to an improved understanding of total life-cycle emissions of methane. Future consideration of extending these types of efforts to other regions outside the USA may prove useful.

## Mitigation: progress to date and initiatives

The oil and gas industry has been working for many years to measure and reduce SLCF emissions through mandatory and voluntary programmes.

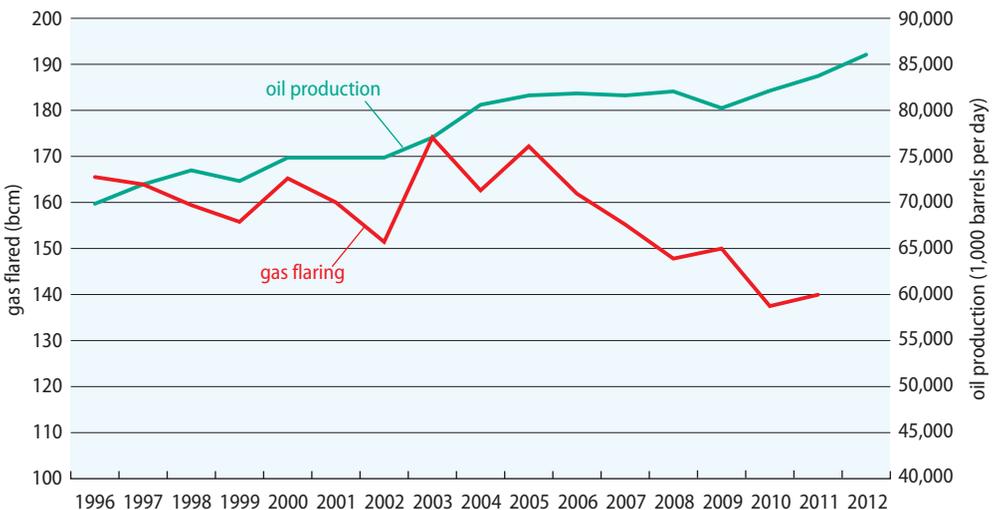
In 1993, the US Environmental Protection Agency launched its **Natural Gas STAR Program**, a voluntary methane reduction initiative focused on the oil and gas industry. In 2006, a programme covering international oil and gas operations was opened, known as '**Natural Gas STAR International**' and has now grown to include 130 US partner companies and 18 international partner companies.

The **Global Methane Initiative** (formerly the Methane to Markets Partnership) or GMI is a country-based international initiative to which companies can belong as partners in their project network. The initiative covers many sectors including oil and gas. The initiative now

has 42 partner governments and more than 850 public and private sector organizations. Their aim is to encourage reporting and reduction plans for methane and the sharing of technical good practices between partners. Currently, 600 projects are under way, adding up to 128 kt of CO<sub>2</sub> equivalent reductions in CH<sub>4</sub> emissions.

Focusing on CO<sub>2</sub> reductions rather than methane, but with additional BC benefits, the **Global Gas Flaring Reduction (GGFR) initiative** (administered by the World Bank) has partnerships with 16 global oil and gas producers as well as 3 multilateral bodies (the European Bank for Reconstruction and Development, World Bank and European Union). Global flaring is estimated to be 140 billion m<sup>3</sup>/year, with GGFR achieving a 12% reduction since the initiative started, despite a 13% increase in oil production in the same

**Figure 8** Global flaring trends (estimated from DMSP\* satellite images)



Sources: NOAA (Defense Meteorological Satellite Program) / BP Statistics

period (Figure 8). The World Bank has now adopted an aspirational target for a 30% reduction in global flaring, from 2012 levels, by 2017. In response, the GGFR has committed to assist the World Bank in achieving its target, if feasible. Additionally, work planned by the GGFR will help understanding of BC generation during flaring and enable better understanding of how to reduce BC generation when flaring occurs.

To better understand emission sources and inform policy decisions, the US EPA requires petroleum and natural gas producers with United States operations that emit more than 25,000 tonnes of GHG equivalents per year to report their emissions (using its 'Subpart W' reporting methodology). The first report for 2011 was published in 2012. The oil and gas industry, through the American Petroleum Institute (API) along with partner organizations continue to collect methane emissions data from members' natural gas operations in the USA to provide more accurate data to the EPA. In this way, the reporting of methane emissions can be improved in future.

More recently, the **Climate and Clean Air Coalition (CCAC)** to Reduce Short-Lived Climate Pollutants was formed under the sponsorship of the United Nations Environment Programme (UNEP) with a membership including 33 partner countries, the World Bank, NGOs and other organizations. Its aim is to raise awareness of SLCFs, enhance and develop new national and regional action plans, improve scientific understanding and promote reduction best practices.

The CCAC is pursuing an initial seven initiatives for rapid implementation:

1. Reducing black carbon emissions from heavy-duty diesel vehicles and engines.
2. Mitigating black carbon and other pollutants from brick production.
3. Mitigating SLCPs from the municipal solid waste sector.
4. Promoting HFC alternative technology and Standards.
5. Accelerating methane and black carbon reductions from oil and natural gas production.
6. Addressing SLCPs from agriculture.
7. Reducing SLCPs from household cooking and domestic heating.

In addition to these collaborative initiatives, oil and gas companies have their own individual programmes for reducing methane emissions from natural gas extraction and black carbon from flaring. Such programmes include targets and plans to reduce flaring (both upstream and downstream), leak detection and repair (LDAR), and identifying and eliminating small leaks (fugitive emissions) of methane and other hydrocarbon gases from operating equipment.

## Conclusions and future considerations

The oil and gas industry remains focused on developing risk management strategies to promote environmental safeguards while simultaneously meeting the growing energy needs of the world. While the oil and gas industry is already undertaking many initiatives to reduce its emissions of SLCFs, it continues to consider what additional opportunities may exist. Looking ahead, it is therefore important that companies continue to work both individually and in partnership with other organizations to address further reduction initiatives where they can have a material impact.

Favourable market conditions have accelerated the adoption of natural gas for electricity generation. In the USA and other regions, natural gas is replacing coal, which has a higher carbon content. Burning gas for electricity generation produces roughly half of the CO<sub>2</sub> emissions of coal, for the same amount of energy (IPIECA, 2013).

Some energy experts forecast an annual average growth rate for natural gas of ~1.7% with gas expected to represent around 25% of total worldwide energy use by 2035 (IEA 2013). The increasing production of natural gas using hydraulic fracturing has emphasized the importance of understanding methane emissions generated during extraction, processing and distribution to consumers. Recent studies have shown that methane releases from the production and distribution processes, with or without hydraulic fracturing, do not involve substantial emissions of unburnt gas, preserving the GHG advantages of gas over coal. However, it is important that

the oil and gas industry continues to work with researchers and authorities to reconcile the significant uncertainty in methane and black carbon emission estimates.

While many cost-effective and substantial emissions reductions are possible outside of the oil and gas industry, different opportunities exist within this sector. Improved information on the composition and variability of BC in upstream flaring may help to identify the majority of potential upstream oil and gas BC sources. Further understanding the potential sources of methane emissions from the oil and gas supply chain will allow for targeted and effective reduction opportunities.



# Short-lived climate forcers

An IPIECA Workshop, Rome, Italy, 8–9 October 2013

## Workshop programme

- Welcome (*Pino Ricci, Eni*)
- Introduction (*Billy Landuyt, Workshop Chair, ExxonMobil*)
- **Session 1: Overview**  
*Session Chair: Billy Landuyt*
  - Overview of three main short-lived climate forcers (*Drew Shindell, GISS*)
  - Discussion
- **Session 2: Black carbon**  
*Session Chair: Reid Smith, BP*
  - Black carbon emissions and sources (*Markus Amann, IIASA*)
  - Climate effects of black carbon (*Gunnar Myhre, CICERO*)
  - Discussion
- **Session 3: Methane**  
*Session Chair: Djamila Amimer (Shell)*
  - Methane emissions and sources (*Ron Prinn, MIT*)
  - Climate effects of methane (*Jos Lelieveld, MPI Mainz*)
  - Discussion
- **Session 4: Emissions of the oil and gas industry**  
*Session Chair: Arthur Lee (Chevron)*
  - Methane: global oil and gas emissions (*Elisabetta Vignati, EU JRC*)
  - Methane: oil and gas emissions in the US (*Karin Ritter, API*)
  - Methane: production—UT/EDF Study (*David Allen, University of Texas*)
  - Methane: an industry perspective (*Haroon S. Ksheshgi, ExxonMobil*)
  - Discussion
  - Black carbon: operations/flaring (*Matthew Johnson, Carleton University*)
  - Black carbon: marine shipping and other fuels (*Eddy van Bouwel, ExxonMobil*)
  - Fugitive emissions monitoring—ENI's experience (*Leonardo Gelpi, ENI*)
  - Discussion

*continued ...*

## ● Session 5: Mitigation strategies

*Session Chair: Oddvar Levang (Statoil)*

- Redrawing the energy-climate map and the role of upstream methane emissions (*Timur Gül, IEA*)
- Global Methane Initiative and Natural Gas STAR (*Reid Smith, BP*)
- Global Gas Flaring Reduction (*Bjorn Hamso, GGFR*)
- CCAC oil and gas initiative (*David Turk, US State Department*)
- CCAC heavy-duty diesel engine initiative (*Mark Radka, UNEP*)
- Discussion

## Discussion Panel

*Session Chair: Laura Verduzco (Chevron)*

*Panel: Drew Shindell, GISS*

*Matthew Johnson, Carleton University*

*Anders Pederstad, Carbon Limits*

*Timur Gül, IEA*

*Mark Radka, UNEP*

*Reid Smith, BP*

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All presentations are available from the IPIECA Workshop web page:  
[www.ipieca.org/event/20130509/short-lived-climate-forcers-workshop](http://www.ipieca.org/event/20130509/short-lived-climate-forcers-workshop)

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