



Recent global trends and policy considerations

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– Michael F. Farina (January 2011)

v. flared, flar·ing, flares

- 1. To flame up with a bright, wavering light.
- 2. To burst into intense, sudden flame.

Flar-ing of associated gas

- 1. a multi-billion dollar waste
- 2. a local environmental tragedy
- 3. a global environmental issue
- 4. an energy problem that can be solved



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Recent trends and policy considerations

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ssociated gas flaring is one of the most challenging energy and environmental problems facing the world today. Approximately 150 billion cubic meters of natural gas are flared in the world each year, representing an enormous waste of natural resources and contributing 400 million metric tons of CO₂ equivalent global greenhouse gas emissions. Environmental degradation associated with gas flaring has a significant impact on local populations, often resulting in loss of livelihood and severe health issues.

The technology to address the problem exists today and the policy reforms required are largely understood. However, deeper issues regarding infrastructure development and market design hinder progress in the places where gas flaring is most rampant. Many constructive efforts to reduce flaring are underway, yet on the current path it will likely take a decade or more to minimize this wasteful practice. However, with greater global attention and concerted action, largescale gas flaring can be largely eliminated in as little as five years.

The gas-flaring problem is a classic case of failing to account for the real costs of

energy production on local populations coupled with failures in government policy that have allowed the issue to continue. Governments with non-transparent policies and weak environmental regulations are particularly likely to flare large amounts of gas. The problem is exacerbated through policy distortions related to subsidized hydrocarbon and electricity pricing, as well as ineffective oversight and enforcement measures.

There has been forward movement over the last decade producers have shifted away from large-scale flaring as an accepted practice, leading to progress in gathering and using their associated gas streams. Today, most countries are exploring how they can avoid flaring gas and put a valuable resource to productive use. Many new oil developments, such as those in Angola or Kazakhstan, explicitly deal with associated gas production as part of the overall project plan. But more needs to be done. Many smaller and isolated flares at older sites continue to burn across the world, equal in emission terms to the annual emissions from 77 million cars, released for no useful purpose.

Gas Flaring in Perspective Size of the problem

150 billion cubic meters per year of flared gas is roughly equivalent to ...

- Gas use in all US residences for a year
- 5% of global natural gas production
- 23% of US natural aas use
- 30% of EU natural gas use
- US\$10 Billion lost revenue at \$2.00 per MMBtu
- 2.4 Million barrels of oil equivalent per day

Climate impact

400 million tonnes per year of CO_2 is roughly equivalent to ...

- Annual emissions from 77 Million cars (34% of US fleet)
- 2% of global CO₂ emissions from energy sources
- US\$6 Billion carbon credit value at \$15.00 per Metric Tonne
- 20% of global steel industry CO₂ emissions
- 35% of global cement industry CO₂ emissions
- Output from 125 medium-sized coal plants about 63 gigawatts (GW)
 - 63 GW is ~20% of the current US coal fleet
 - 63 GW is ~67% of India's current coal fleet

Figure 2: Gas flaring in perspective Source: GE Eneray









Figure 1b: Gas flaring countries and trends Source: NOAA/GGER

"Unbalanced approaches only reduce investment, oil production, and revenues in a way that weakens the resolve of governments to eliminate flaring."

Technology and policy solutions differ by region

A lack of technology solutions is not the problem; gas flaring can be dealt with today through a variety of existing technologies at reasonable cost. Depending on the region, power generation, gas re-injection to enhance oil recovery, gathering and processing, pipeline development, liquefied natural gas (LNG) and a variety of distributed energy solutions can be deployed. However, often regional political complexities and lack of gas infrastructure systems drive the decision to flare gas.

It is becoming increasingly clear that the next phase of flare gas eradication will require a major, coordinated effort from central and regional governments, oil and gas producers, technology providers, and the international community. The role that each party plays differs by region. Experience has demonstrated a need to have proper alignment between punitive and incentive based approaches to reduce global gas flaring. Strict penalties are often ineffective if there are institutional constraints on developing new outlets for associated gas. Unbalanced approaches only reduce investment, oil production, and revenues in a way that weakens the resolve of governments to eliminate flaring.

In Russia, the largest flaring nation by some data measures, alignment between the Russian government, Gazprom (the state-owed gas monopoly), power utilities, processors, and independent oil producers on key issues such as pipeline access, processing investment, and pricing is critical. Improved oil and gas accounting and flare monitoring are an important first step, to be followed by better coordination between industry players while tackling inefficiency in the system. A good example is the recent joint ventures between the oil producers and the Russian petrochemical giant, SIBUR, that have been instrumental in reducing flaring despite growing oil output. While the Russian government is attempting to tackle the problem, plans for investment in gas processing have been hampered by the global economic downturn. Frequent calls by Russia's senior leadership to stop the wasteful practice have not gained much momentum. For example, a plan to increase penalties for flaring for firms that fail to increase associated gas utilization to 95 percent by 2012 is being postponed to 2014. The delays reflect tension between the government's need for oil revenue and the upstream infrastructure challenge in remote producing areas.

In Nigeria, a multi-decade legacy of flaring has been a flashpoint for conflict in the Niger Delta region. Repeated postponements of government deadlines, the most recent in

Gas flaring: a cycle of waste



Figure 3: Cycle of waste Source: GE Energy

2008, for a phase out of gas flaring have diminished expectations for a lasting solution. The challenge in Nigeria, and in other parts of West Africa, is to enact effective policies that simultaneously build a dynamic energy sector, foster local economic development, improve security, and enhance government commitment to regulation and enforcement all while finding a way to develop new infrastructure to connect dispersed sites. In this region, external financing solutions, expansion of public-private partnerships, and political will to advance policy reform will be critical to drive flare reductions.

In the Middle East, domestic pricing policies distort the economics of gas flaring projects especially at older brownfield sites. In some cases, there are high levels of contaminates, such as hydrogen sulfide and heavy liquids, within natural gas that drive up gas gathering and processing costs. If gas is sold at fixed prices in the marketplace well below the costs of associated gas gathering it creates a dilemma for gas producers. As a result, it is not uncommon to see development of "sweeter" less costly non-associated gas while "sour" associated gas is flared, despite the existence of nearby areas with a strong demand for additional gas. In places such as Iraq and Iran, where physical conditions should support gas infrastructure construction, political issues and security concerns have delayed the needed investments. In these regions it is the governments that must lead; recognizing the negative externalities associated with flaring and incorporating associated gas strategies in their oil industry policies.

In the Americas and parts of Asia, the challenge will be to keep gas infrastructure investments in synch with oil developments especially in remote offshore settings. Space and weight constraints can limit gas-processing options in offshore settings once the platform has been designed, so gas utilization needs to be considered explicitly with the oil developments. Brazil, for example, will face this challenge in development of its substantial pre-salt deepwater oil reserves.

Depending on the region, proven technologies such as distributed power generation, large-scale efficient commercial power generation, re-injection, gathering and processing, liquefied natural gas (LNG) and micro gas-to-liquids (GTL) will all have their place. GE believes that with good government policy and effective corporate governance technology, solutions to flaring can almost always be found. However, some national oil companies need to become more adept at managing natural gas resources and foster a better understanding of the value of gas within the culture of the company. The perception that associated gas is not worth the effort needs to be challenged. Beyond national borders, the role of the international community will be to accelerate the process, acting as a catalyst for change to achieve practical outcomes that create value, generate social benefits, and increase environmental protection.

International commitments need strengthening

A decade has passed since the gas flaring issue emerged as an international concern, coinciding with growing awareness of the climate impact of fossil fuel use. Yet flaring levels have not been reduced dramatically. Flaring should be a priority target because there is a significant alignment between local and global interests. Flare reduction investments can have a meaningful impact on the quality of life and economic progress in specific countries while making





measureable impacts on reducing global greenhouse gas emissions.

International organizations such as the World Bank's Global Gas Flaring Reduction Initiative (GGFR), the International Energy Agency (IEA), and the G8 have highlighted the issue while active campaigns by many environmental organizations have raised awareness on the social impacts. In response, greater action by producer nations and the international oil companies (IOCs) is evident in many places. A number of countries, including Indonesia, Angola, and Syria appear to be making significant progress in limiting disposal flaring. In other countries, including Kazakhstan or Kuwait, strict anti-flaring regulations and increased enforcement has set the stage for flare reductions. Overall, many countries are beginning to adopt successful practices used by Canada, the United Kingdom, or Norway. However, a more concerted effort is required to eliminate flaring.

Many of the flare reduction projects sanctioned over the last decade leverage existing nearby gas infrastructure. For this reason, less progress has been made at remote locations. Furthermore, in places such as Venezuela, Uzbekistan, Ecuador, Iraq, and Libya, gas flaring appears to be increasing. Governments in new frontier oil regions of Africa, such as Uganda or Liberia, need in particular to consider associated gas options early in the oil development process before flaring becomes a major issue. A critical challenge, however, is that the short-cycle investment process of the oil industry is at odds with the long-cycle nature of the gas business. This puts a spotlight on the role of state to invest in gas infrastructure, but often there are insufficient resources and expertise to launch capital and technology intensive gas projects. This dynamic highlights the need for external

support and financing, especially in the developing world.

While some financing tools exist from both public and private sources, there is a shortage of direct initiatives to develop countries' gas infrastructure backbone. Offsets programs like the Clean Development Mechanism (CDM) have demonstrated only limited success. Critical investments and pipeline, processing, and storage are required to make it economically feasible to gather the supply and foster gas use. Various forms of credit enhancement, including partial risk guarantees, are one way to support investment while policy reforms are underway. Other options such as targeted technology funds and carbon partnerships or funds show promise as a way to facilitate projects.

The CDM program, established under the United Nations Framework Convention on Climate Change, has only sparingly been used in associated gas flaring projects. In fact, between 2005 and 2010, only nine out of more than 2,000 CDM projects have been focused on large-scale associated gas flaring reductions. One of the thornier challenges related to receiving CDM credits is proving that flare reduction projects would not have been done as a part of normal oil and gas development activities. To receive CDM financing, project developers not only need to provide detailed methodologies to demonstrate baselines and the volumes of gas flaring reduced, they also need to demonstrate that flare gas reduction projects would not move ahead without carbon financing the so-called "additionality" test. This requires capabilities and monitoring that are often unavailable in some developing nations.

Given the challenges outlined above, four broad recommendations appear necessary to accelerate the pace of flare gas reductions:

Advance local solutions

Successful gas flaring projects have indicated that localization efforts are key factors in driving success. These include:

• Understand the value of gas in the local economy.

Lowering emissions and increasing efficiency from electricity generation, driving petrochemical opportunities, freeing oil for transportation uses or export are just a few examples of gas value that is not always properly considered when establishing pricing or sanctioning investments.

Make the case to end flaring.

Convincing governments and developers that with focus and policy reforms, there are financial benefits and cost reductions that will emerge from the effort.

Secure support of regional government officials and local regulators.

Local officials can be valuable partners with the central government to assist in monitoring and enforcement of flaring regulations.

Develop local capabilities.

With proper training and guidance, local companies can be equipped to set up, operate, and service distributed power generation or small liquids gathering systems. Joint venture arrangements can allow parties to pool resources so that one company does not face the full burden of overcoming the economic challenges that surround flare gas reduction projects. This can have particular benefit in regions where local economic development is a priority and regional tensions make access by external contractors problematic. However, care must be taken not to solely focus on driving local content at the expense of using

the right technology and more costeffective solutions.

Local governments are likely to see many of the benefits of reduced pollution or increased energy access that result from successful flare gas reduction efforts. Engaging local officials in addition to the central government can be critical to move projects forward. Likewise, empowering local officials to make decisions and enforce laws and regulations can help reduce flaring, if regulatory systems are set up properly and transparently. Engagement of local utilities is especially critical in power projects.

Expand access to flare and venting reduction financing mechanisms

Even if localization efforts can bring together stakeholders and launch a project at legacy flaring sites, lack of capital can stop projects. Governments or producers may be reluctant to commit funds within the structure of the country's petroleum industry. In such scenarios, carbon financing can play a critical role. As noted above, international mechanisms have not been effective in driving the deployment of capital for gas flaring reductions.

Some options to boost threshold economics in riskier environments include:

- Streamline and expand the eligibility criteria for flare gas reductions within the existing CDM program.
- Ensure that flaring reductions are made a part of U.S. and other emerging carbon emission offset programs
- Establish lean technology funds that target pipes and wires projects or flaring reduction with favorable rates and conditions

Executive Summary: Gas flaring in focus

Encourage effective national regulatory and legislative solutions

Developing a dynamic and robust natural gas industry is a challenging process. Governments play a critical role in finding the reform strategies that align producer and consumer interests for their country. Using both the "carrot" and "stick" can encourage compliance with regulation while promoting additional energy investment and economic development.

Some options include:

- Reform of pricing for gas and electricity
- Contractual reform where pre-emptive rights to associated gas limit project development
- Transparency on revenues within the oil sector
- Effective monitoring, penalty, and enforcement mechanisms

- Tax or royalty relief for qualified projects
- Low carbon emissions standards for petroleum imports into developed countries
- Security measures to protect pipelines and electricity transmission

Governments should especially examine cases where subsidies on imported liquid fuels can be redirected to incent internal flare capture projects. This reduces outflow of foreign exchange to import liquid fuel, creates the resource pool to pay for gas development, and can often save the country money.

Establish a new international sector agreement on gas flaring

One option to accelerate flare reduction is for the international community to launch a new sectoral agreement focused specifically on global gas flaring reduction. The voluntary program currently sponsored

5% of global gas production ... wasted

by the World Bank's Global Gas Flaring Reduction initiative (GGFR) offers a model.¹ Signatories to such a new global effort could be required to undertake commitments to reduce gas flaring, while developed countries could assist with technology transfer, best practice sharing, and financing. The structure could be organized within existing international institutions or through new high-level partnerships. The countries that undertake such commitments could be offered preferential access to new environmental and greenhouse gas mitigation funds, including any that may be focused on flare gas reduction. For example, portions of the Copenhagen accord funding, or the World Bank's Clean Technology Fund, could be earmarked for flare reduction.

Utilizing such international agreements and funding, large blocks of carbon reductions could be achieved from flaring problems in specific countries. To be effective, the effort would require active engagement with the governments and robust controls to accurately develop baseline emissions, monitor progress, and avoid perverse incentives.

The agreement could also provide for international advice on effective flare gas reduction regulation and enforcement, analysis of the economics of flare gas reduction, dissemination of information on technologies available to put flare gas to productive uses, and other technical assistance.

The next big energy and environmental success story

Gas flaring reduction has the potential to be one of the great energy and environmental success stories, and it has the potential to be achieved within the next five years.



For the oil and gas industry, environmental scrutiny is only going to increase in the nearterm as a result of the recent oil spill in the Gulf of Mexico. Finding the right partnerships to eliminate legacy flaring and minimize new flaring is a chance for the industry to take a leadership role on sustainable resource development and energy efficiency.

For producer governments, flare reduction is an opportunity to create value from a wasted resource and enable wider access to energy, improved environmental conditions, and economic development for local populations. Successful efforts to reduce flaring will benefit local communities, provincial and national governments, and the entire planet. "We are now certain that gas flaring reduction has been most successful where there is country ownership, high-level support and an effective local partnership between government and industry."

Somit Vatma Director, Oil, Gas, Mining. and Chemicals Department World Bank Group

1. Introduction

G as flaring is one of the most challenging and important energy and environmental problems facing the world today. When discussed publicly, gas flaring elicits comments like "extravagant squandering" or "monstrous and unnecessary." The fact is, approximately 150 billions of cubic meters of natural gas are flared in the world each year, representing a 15 to 20 billion dollar waste of resources and a 260 to 400 million metric ton contribution to global greenhouse gas emissions.



Annual global flaring is equivalent to about 30 percent of the total yearly gas requirements of the entire European Union, or the annual residential gas consumption in the United States. Even more troubling, in some cases flaring negatively affects the livelihood and quality of life for local populations, often raising political stakes for governments and petroleum production companies.

The gas flaring issue first received global attention a decade ago, coinciding with growing awareness of the climate impact of fossil fuel use. Previously, gas flaring had been more often thought of as a human rights issue in the developing world rather than a global energy problem. While human rights issues are still of paramount concern, perceptions of the problem are widening. Concerns about the scarcity of oil and gas resources and high prices since 2005 have galvanized interest in flare solutions as the value of the commodity has increased.

The issue is large-scale flaring of natural gas associated with oil, not routine and transient flaring for operational or safety reasons. Natural gas flaring occurs in places where remoteness or economic considerations have driven governments and producers to burn off gas in order to produce the oil associated with it. And the issue is global, not local. While some countries, such as Russia, Nigeria, and Iran are often singled out for criticism, significant levels of flaring and venting occur on every continent, and global failures in both governmental policy and industry practice have allowed the issue to remain unresolved. Governments with non-transparent policies and weak environmental regulations are particularly likely to flare large amounts of gas. The problem is exacerbated through policy distortions and ineffective oversight and enforcement measures.

1. Introduction

Fortunately, a host of technologies including GE-manufactured gas turbines, compressors, and Jenbacher engines are available to combat flaring. For large concentrated deposits, traditional gas technologies are suitable. However, at smaller, remote sites, new distributed, modular, and mobile options are required.

Unfortunately, commercialization of more novel approaches has been slow. Small, leading companies are often challenged by lack of capital and credibility in the industry to drive growth. As a result, discussions within industry and policy circles are too often replete with phrases such as "uneconomic alternatives" or "technical complexity" or "lack of government support."

Despite global attention, absolute levels of associated gas flaring have remained fairly constant for a decade growing from 2000 to 2005 and then generally trending down. From one perspective this can be considered a modest success given the growth in oil production over the same period. But holding flaring constant, while good, is not the appropriate goal. The wave of projects sanctioned in the middle of the last decade will make an impact over the next few years, but it is not enough to fully resolve the problem. It is more uncertain how the second wave of more challenging flare reductions will happen.

While the challenges are daunting, there is reason to remain optimistic. A number of large oil producing countries such as Indonesia, Norway, Saudi Arabia, and Canada have made important progress in gathering and using their associated gas streams. Many more countries are now focusing on how they can avoid flaring gas. In fact, most new oil developments, such as those in Brazil, Angola, and Kazakhstan, incorporate associated gas gathering, or re-injection, as part of the overall development plan. Yet more needs to be done in the developed and developing world.

Gas flaring reduction has the potential to be one of the great energy and environmental success stories, and it has the potential to be achieved within the next five years. For the oil and gas industry, environmental scrutiny is only increasing in the near-term as a result of recent events like the spill in the Gulf of Mexico. Finding the right partnerships to eliminate legacy flaring and minimize new flaring is a chance for the industry to take a leadership role on sustainable resource development and energy efficiency. For producer governments, flare reduction is an opportunity to create value from a wasted resource and an enable wider access to energy, improved environmental conditions, and economic development for local populations. Successful efforts to reduce flaring will benefit local communities, provincial and national governments, and the entire planet.

GE Energy has developed this white paper to highlight some of the key issues around the gas flaring debate. The paper begins with a review of the magnitude and difficulties in understanding the true scale of the flaring problem. While a complete picture from the available data is elusive, the global scale, the substantial environmental impact, and the immense waste of resource are clear. Next, the paper turns to regional considerations, economics, and technology options. The section features recent trends in the major flaring countries and how various technologies and new commercial models are being used to address gas flaring today. Finally, the last section discusses economic challenges, potential policy options, and commercial structures, and makes policy recommendations for achieving the next wave of flare gas reductions.

2. Gas Flaring: Geography and magnitude

G as flaring has been part of the oil industry from its inception. Associated gas, or solution gas, separates from the oil as a result of the pressure change between the oil producing formation and the surface. The amount of gas released from each barrel of oil is determined by the gas-to-oil ratio (GOR). The GOR can vary dramatically in different oil fields and can change in the same field over time.

Furthermore, associated gas is typically not as pure as pipeline or utility gas, which is almost entirely methane. The proportion of methane in associated gas is typically between 60 to 80 percent, while pipeline gas is typically 90 percent methane.²

Associated gas also contains heavier (volatile) hydrocarbons, mainly ethane, propane, butane, and pentanes. These heavier hydrocarbons can be condensed and have a higher heat value; thus associated gas is considered "wet" or "hot" gas. In addition, associated gas may contain water vapor, hydrogen sulphide (H2S), CO₂, helium, nitrogen, and other compounds. These components and impurities cannot be handled and transported easily and, moreover, in high volume they make the gas unfit for commercial consumption

Gas is flared in oil operations for obvious safety reasons. Flaring systems are designed to protect personnel and equipment during emergencies or processing disruptions. However, in some cases, the lack of immediate and economic options for the associated gas, coupled with the desire to accelerate and maximize oil production, drives significant amounts of gas flaring. Some of the largest wasted gas streams occur in remote areas where the lack of outlets and small volumes of gas often do not justify the expense of gathering.

A practice similar to gas flaring is methane venting, or the direct release of methane or CH4 into the atmosphere.³ Leakage of methane from existing gas systems, coal mines, or inefficient flaring technologies likewise represents a significant policy and environmental challenge especially since the greenhouse gas potential of methane is roughly 21 times that of carbon dioxide.

Lack of monitoring equipment and limited oversight make it difficult to quantify the



Figure 4: Spectrum of waste gas issues

Associated gas flaring is one of the key sectors for waste gas reductions *Source: GE Energy*

2. Gas Flaring: Geography and magnitude

scale of gas flaring around the world. For example, in Russia, only half of the flares in the Khanty-Manski region have flow monitors. 4

In addition, many countries do not publicly report gas flaring volumes, leading to significant uncertainty regarding the magnitude of the problem.⁵ In fact, to avoid scrutiny, it may be in the producer's or government's interest to limit access to data on gas flaring levels. Much of the official information on the amount of gas flaring comes from environmental ministries or statistical agencies within various governments. However, during the last decade, increased use of military satellites and sophisticated computer programs has been used to measure gas flaring. These efforts seek to correlate light observations with intensity measures and flare volumes to produce credible estimates of global gas flaring levels.

2.1 What does the data say about gas flaring?

Maximum Estimate

BCM per Year

200

Precise data on the magnitude of the gas flaring issue is elusive. Over the last decade,

the amount of gas disposed of through flaring has trended down modestly despite a sizeable increase in crude oil production. This is an encouraging sign that companies are governments have started focusing on the value of associated gas. However, the scale of waste in aggregate remains substantial.

In order to assess the geographic distribution and magnitude of gas flaring, GE examined multiple data sets and collected anecdotal information from various sources. Two data sets are available that cover approximately 98 percent of estimated gas flaring.

The first data set is a compilation of Cedigaz, EIA, and IEA data that broadly captures the reported levels of gas flaring.⁶ No single agency had global data coverage so a hybrid compilation of data was developed from these sources and is referenced as the reporting agencies data set.

The second data set was prepared for the World Bank's Global Gas Flaring Reduction Initiative (GGFR) by the U.S. National Oceanic Atmospheric Administration (NOAA) based on satellite tracking. The satellite data has excellent global coverage but also has

"Lack of monitoring equipment and limited oversight make it difficult to quantify the scale of gas flaring around the world"



GGFR – Satellite 150 **Reporting Agency Sources** 100 Minimum Estimate 50 0 '01 '0[']2 ʻ03 ʻ04 ʻ05 '06 ʻ07 '08 '09 100

Satellite Data from 2000 to 2009 indicate global gas flaring levels have remained fairly constant at around 150 Bcm per year.

> Estimates on 2009 flaring indicate an increase to 146 Bcm per year (~15 Bcf per day) from 142 Bcm in 2008

Figure 5: Comparison of global gas flaring data estimates 2000-2008

Source: GE Energy, GGFR, EIA, Cedigaz, IEA. Reporting agency data for 2009 was not available. Notes: Maximum and minimum estimates based on highest or lowest data points for each country from any of the data sets.

2. Gas Flaring: Geography and magnitude

several sources of uncertainty, including variation in flare intensity, inclusion of processing plant flaring, misidentification of flares, inability to track gas venting, and the difficulty in distinguishing flares from other urban lighting sources.

When the various data sources are viewed in tandem, the global perspective on the flaring problem starts to become clearer. Estimates suggest that more than 150 billion cubic meters (Bcm) per year of gas is flared each year. At the upper end of the scale, the problem is estimated to be in the range of 200 Bcm per year, or about 20 Bcf per day. The lower end estimate is closer to 120 Bcm per year. The scale of the problem clearly is considerable. The most recent information from the satellite data from GGFR in November 2010 indicates that global flaring levels are 146 Bcm per year.⁷

Estimates based on agency reported data sources indicate that level of gas flaring is increasing. The reported estimates may be increasing as countries and producers have been forced to reconcile the sometimes sizable differences between the internal and external (satellite) data sources. A

good estimate for global flaring seems to be around 150 Bcm per year, but there are some large uncertainties at the country and regional level.

The most striking discrepancy is in Russia, where satellite estimates of more than 40 to 50 Bcm were nearly three times greater than the government reported levels of gas flaring. Other estimates include the 20 Bcm per year figure widely quoted by Vladimir Putin in 2007, and those from consultant PFC Energy of 38 Bcm per year based on analysis of gas-to-oil ratios.⁸ As a practical matter, the actual level of gas flaring in Russia is going to remain uncertain until more monitoring capability is installed

In the Americas, the level of flaring reported by energy agencies exceeds what is indicated by satellite imagery perhaps an indication that a greater amount of gas venting is occurring in the region. In this case, the inability of satellites to clearly distinguish flare sources from other onshore sources of light emissions, particularly in the United States, Canada, and Mexico probably creates underreporting.

Gas Flaring GGFR – Satellite													
BCM per Year													
Region	'00	'01	'02	'03	'04	'05	'06	'07	'08	'09			
World	165	162	153	174	167	175	165	155	142	149			
Russia	40.6	41.9	44.5	53.4	50.6	59.0	50.6	52.0	40.6	46.1			
Caspian	6.6	7.3	10.0	10.0	9.8	10.5	10.8	9.0	9.8	8.2			
Africa	50.0	48.8	40.4	44.9	43.3	41.7	39.0	33.9	31.8	31.9			
Middle East	38.6	35.5	33.2	39.6	38.4	38.7	39.4	36.1	34.4	36.1			
L. America	10.4	9.6	8.2	8.0	7.5	8.0	7.6	7.9	9.0	9.5			
SE Asia													
North Asia													
N. America	4.2	4.2	3.8	4.1	3.4	3.5.	3.7	3.9	4.1	3.9			
Europe	4.6	4.4	4.1	4.2	4.0	3.8	3.7	3.3	3.1	3.2			

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Figure 6.1: Regional gas flaring trends 2000 to 2009 from two data sources Source: GE Energy, GGFR/NOAA, EIA, Cedigaz, IEA.

Gas Flaring GGFR – Satellite



2. Gas Flaring: Geography and magnitude

Despite some of the uncertainties in the satellite-based flare tracking, the data does provide an external source of information to gauge the scale of the problem and the effectiveness of reduction efforts. Satellite data trends in the top 20 flaring nations have been generally stable between 2000 and 2007. In early 2009, the GGFR reported that satellite data from 2008 indicated a decline in levels of total flared gas to 138 Bcm from 2007 levels of 151 Bcm. However, in mid-2010, recently published satellite data on flaring in 2009 indicated an increase to 146 Bcm.

These estimates will only improve as additional satellite and industry data sources are cross-referenced. For example, there was a recent release of public data from Japan's Gosat Greenhouse Gases Observing Satellite "IBUKI." The satellite has the capability to collect infrared information and detect CO₂ and methane emissions, which should increase resolution on the flaring problem.⁹ What the data broadly shows today is that despite recent efforts the level of gas flaring has been fairly stable over the last decade.

However, it should be recognized that over the same period, crude oil production has increased by around 7 percent to about 80 million barrels per day (see figure 7.0).¹⁰ To get a better understanding of flare reduction relative to oil production, an annual ratio index of oil production to the level of gas flared was calculated and the percentage changes were applied to base year of 2000 as the reference point. Globally, the flare reduction index shows about a 20 percent decline in gas flaring relative to oil production, with most of the declines occurring after 2005.

Regional results are mixed but nonetheless interesting. The Africa and Caspian regions have shown the biggest improvements with declining flare gas indices despite large increases in crude oil production. For both regions gas flared per barrel produced is about 40 percent of what it was in 2000. Russia had been showing improvement even with exceptional growth in oil supply through 2008, but the latest satellite data for 2009 shows an uptick in gas flaring.

Flaring levels in the Middle East region remain relatively high. In Latin America, the flare index has turned upwards even with lower oil production due to increases in

ous hunning hepoticu sources (IEA-EIA-ceulguz)															
BCM per Year	BCM per Year														
Region	'00	'01	'02	'03	'04	'05	'06	'07	'08						
World	112.6	101.0	1.6.6	110.7	112.3	134.5	135.4	136.0	141.3						
Russia	10.0	7.1	11.1	11.1	14.7	15.0	14.1	16.7	20.0						
Caspian	6.8	7.5	10.5	10.4	10.4	11.0	11.0	9.9	10.5						
Africa	36.1	35.2	34.6	36.1	36.6	41.8	41.5	38.2	37.6						
Middle East	17.1	13.2	13.9	18.2	18.2	30.0	34.7	34.1	34.6						
L. America	17.9	15.3	14.7	12.5	11.9	15.7	13.7	18.4	20.2						
SE Asia	12.8	11.1	10.2	10.6	9.0	8.9		7.0	7.0						
North Asia		2.4			2.8	2.9	2.9	2.6							
N. America	5.0	4.9	5.0	4.9	47	5.3	5.8	6.2	6.4						
Europe	4.5	4.3	4.2	4.0	4.0	4.0	3.9	3.0	2.8						

Gas Flaring Reported Sources (IEA-EIA-Cedigaz)

Figure 6.2: Regional gas flaring trends 2000 to 2008 from two data sources Source: GE Energy, GGFR/NOAA, EIA, Cedigaz, IEA.

Gas Flaring Reported Sources (IEA-EIA-Cedigaz) BCM per Year



2. Gas Flaring: Geography and magnitude



Figure 7.1: Regional gas flaring relative to crude oil production Source: GGFR/NOAA, BP Statistical Report, GE Energy. flaring reported in Mexico, Venezuela, Ecuador, and most recently in Brazil. North Asia, primarily China, has relatively low flare rates, while the more remote and offshore oil projects of Southeast Asia have a higher flaring rate. As might be expected, given the regulatory focus on emissions, North America and Europe have low flaring rates relative to oil produced.

The industry's ability to hold flaring levels relatively constant even as oil supply has grown is something of an accomplishment. On an energy equivalent basis, globally 150 Bcm of annual gas flaring is the same as almost 2.4 MMB/d of oil production 3 percent of global crude production. Waste at this scale seems hard to justify as a cost of oil extraction. Clearly, holding flaring constant is not a good enough result given the scale of waste and lost value to host governments. This is even more of a concern when global environmental impact is considered.

2.2 How big are the environmental impacts from gas flaring?

While the size of the flaring problem is to some degree uncertain, there is almost unanimous agreement that systematic large-scale gas flaring is a source of enormous negative environmental externalities. The impact on the global community in terms of greenhouse gas emissions is substantial. Environmental impacts at the local level differ depending on the region. However, there are clear cases where flaring has been highly damaging to local populations and ecosystems. The problem is most acute in places where intense oil development overlaps with local communities. While the troubling impacts on the Niger Delta are well documented, Kazakhstan and many other regions face similar challenges.11

Notes: Gas flaring data converted to Bcf per day so it can be charted with oil. To roughly convert to BCM per year multiply by 10. Flare index was constructed by taking the annual ratio MMB/d of oil produced per BCM of gas flared converted into percentage change relative to the year 2000.









Figure 7.2: Regional gas flaring and crude oil production Source: GGFR/NOAA, BP Statistical Report. GE Energy.

2. Gas Flaring: Geography and magnitude

The cost of gas flaring can be measured in terms of greenhouse gas emissions, and the value of avoiding those emissions in evolving carbon markets. There is also a significant and measurable economic cost in terms of lost revenue that otherwise could be generated if flared natural gas was captured and sold into whatever end-use outlets exist in that region. Calculating costs in terms of health impact on local populations or lost output from degraded agricultural output and fisheries are somewhat more difficult.

Environmental groups make the case that the unrecognized costs of development often far exceed the value of the oil.¹² Still, others focus on sustainable development approaches that can unlock the value of the resources while reducing costs on communities. In most cases, change starts with a fuller accounting of environmental impacts, sound regulation, and more transparency on oil production revenues and costs.¹³

... on the global commons

Based on the flaring estimates presented above, 350 to 400 million metric tons (MMT) of CO₂ equivalent comes from associated gas flaring and venting of methane at flare sites. This represents about 1.2 percent of global CO₂ emissions from primary hydrocarbon sources (coal, oil, and gas). Based on the 2008 data, the 361 MMT of CO₂ emissions coming from gas flaring is roughly equal to 44,000 MW of electricity or roughly 62 medium-sized 700 MW coal plants. Put another way, assuming that 1.0 million average cars and trucks produce 4.6 million tons of CO₂ equivalent per year, eliminating gas flaring would be equivalent to taking 77 million cars off the road annually.¹⁴ Seventy-seven million cars is approximately equal to 32 percent of the U.S. car and light truck vehicle fleet of about 240 million vehicles.¹⁵ Gas flaring is also large in context of other major energy intensive operations. As an example, in 2009, greenhouse gas



	Oil Production by Region													
Million Barrels per Day														
Region	' 00	'01	'02	'03	'04	'05	'06	'07	' 08	'09				
World	74.9	74.8	74.4	77.0	80.3	81.1	81.5	81.4	81.8	79.9				
Russia	6.5	7.1	7.7	8.5	9.3	9.6	9.8.	10.0	9.9	10.0				
Caspian	1.3	1.5	1.7	1.8	2.0	2.1	2.4	2.7	2.8	3.0				
Africa	7.8	7.9	8.0	8.4	9.3	9.8	10.0	10.3	10.3	9.7				
Middle East	23.5	23.0	21.6	23.4	24.8	25.3	25.5	25.2	26.2	24.4				
L. America	10.3	10.3	10.2	10.1	10.5	0.7	10.5	10.1	9.8	9.7				
SE Asia	4.6	4.5	4.5	4.3	4.3	4.2				4.2				
North Asia				3.4	3.5	3.6			3.8	3.8				
N. America	10.5	10.3	10.5	10.4	10.3	9.9.	10.0	10.2	10.0	10.4				
Europe	7.1	6.9	6.9	6.6	6.3	5.9	5.4	5.2	4.9	4.6				

Gas Flaring Reported Sources (IEA-EIA-Cedigaz) BCM per Year



Figure 8: Crude oil production by region

Source: BP Statistical Review of World Energy, June 2010

2. Gas Flaring: Geography and magnitude

"While burning flare gas in an application still likely releases greenhouse gases into the atmosphere, there is significant value in eliminating venting and putting the gas to beneficial use." emissions from the Canadian oil-sands region were estimated to total 40 MMT equal to roughly one-tenth the emissions from global gas flaring.¹⁶ While burning flare gas in an application still likely releases greenhouse gases into the atmosphere, there is significant value in eliminating venting and putting the gas to beneficial use. In summary, the gas flaring issue is of enormous consequence in terms of carbon emissions impact.

... on local environments

Beyond the impact of gas flaring on the atmosphere, local environmental impacts of flaring can be substantial at large-scale flare sites. Flaring natural gas creates particulate emissions (soot), fugitive methane emissions, nitrogen oxides, sulfur dioxide, and a number of other harmful emissions. Assessments show larger concentrations of nitrogen oxide (NO_x) are found within one to three km of flaring sites. Sulfur Dioxide (SO2), Carbon Monoxide (CO) and various unburned hydrocarbon emissions can be present within five to 15 km from flare sites.¹⁷ Sulfur and nitrogen emissions are known to create acid rain problems that can poison watersheds and vegetation, and corrode buildings.¹⁸

In addition to atmospheric pollution, gas flaring creates thermal and noise pollution near the flare. Heat from flares can damage soil and vegetation within 10 to 150 meters around the flare site, while light pollution from actual flares is also creating places "where the sun never sets."

Solutions that address the global challenge Improving lives

2. Gas Flaring: Geography and magnitude

Based on the large body of research and reporting about the environmental impacts of flare gas, the conclusion most often reached is that industry has failed to account for the externalities of energy production on local populations and the global community. Local populations are bearing a disproportionate share of the costs, while the benefits in terms of oil products or revenue accrue elsewhere.¹⁹ Furthermore, the CO₂ equivalent emissions from flaring are greater than 5 percent of total energy sector emissions in many key oil and gas regions. A concentrated effort to reduce flaring in these regions can dramatically reduce the carbon footprint of individual countries, while improving quality of life for local populations.

A global problem built on a foundation of complex regional factors

As this survey of the geography and magnitude of the problem shows, associated gas flaring is a global problem characterized by a host of unique regional, national, and local issues. The economics of natural gas are almost always complex and project specific. The quantity and quality of raw gas streams are wide ranging. Locations vary from jungle, swamp, and desert to mountains, arctic, and deep offshore. The availability and proximity to existing gas infrastructure and the structure of the gas industry is different in each case. Government energy leasing and pricing policies are a huge factor in the ability to attract gas investment. Furthermore, the availability of equipment, access to technology, skilled labor, and financing also vary dramatically across the world. The next section explores these issues.

	С	O ₂ En Ga	nissior s Flar	ns froi ing	m	Flaring Share of Energy Sector CO ₂ Emissions						
	Millio	n Metr	ic Toni	nes pei	r Year	Percentage						
Region	04 05 06 07 08 04 05 06 07								'08			
World	424	445	419	394	361	1.5	1.5	1.4	1.3	1.2		
Russia	129	150	129	132	103	7.3	8.4	7.1	7.4	5.6		
Caspian	25	27	27	23	25	5.9	6.2	6.1	5.2	5.3		
Africa	110	106	99	86	81	10.3	9.8	9.1	7.8	7.3		
Middle East	98	98	100	92	87	7.0	6.6	6.5				
L. America	19	20	19	20	23	1.3	1.3	1.2	1.2	1.4		
SE Asia	18	18	19	17	18	0.7	0.6	0.6	0.5	0.5		
North Asia						0.1	0.1	0.1	0.1	0.1		
N. America	9	9	9	10	11	0.1	0.1	0.1	0.1	0.2		
Europe	10	10	9	8	8	0.2	0.2	0.2	0.2	0.2		

CO₂ Emissions from Gas Flaring





Figure 9: CO2 emissions from gas flaring and share of energy sector emissions: 2004-2008

Sources: GGFR/NOAA, EIA

Notes: Energy Sector includes CO2 from coal, oil, gas, and Gas Flaring Includes calculated CO2 from flaring and estimated venting at flare sites.

3. Regional gas flaring trends

ountries that have deliberately focused on development of their gas industry have usually been able to dramatically reduce gas flaring. As industry structures, infrastructure, and regulatory processes mature, previously flared gas tends to be used. However, this is not always the case. Gas flaring is most serious in places where investment is difficult (Nigeria, Iraq, Iran), especially at brownfield sites and where oil projects are extremely remote (West Siberia, Deep Offshore, and so on). A wide range of technology options exists to eliminate flaring, but each country or region has slightly different issues.

Examined broadly, five key industry trends appear to be most responsible for recent progress on flare reduction.

1. Energy security:

Flare reductions have been driven by a combination of concerns at the beginning of the decade over the reliability of the gas supply in Europe and North America and over relatively high North American gas prices. These forces, for example, were a key factor in sanctioning of the associated gas liquefied natural gas (LNG)projects in West Africa for the Atlantic basin.

2. Policy reform:

Oil and gas policy reforms in key producer nations ranging from new pricing policies to new regulations have set the stage for large flare reductions. Examples include pricing policy for associated gas and the petrochemical business in Russia and emerging regulations and energy policy changes in Indonesia, Kuwait, and Kazakhstan.

3. Public-private partnerships:

Increased openness from national oil companies and their host governments for public–private joint ventures has allowed companies to share risks in the midstream sector. This is important given the capital intensity of gas projects and the need to establish new outlets for gas.

4. Corporate social responsibility:

Corporate practice has also increasingly moved away from gas flaring. Commitments by international oil majors to eliminate disposal flaring have been made and executed in many new projects. Efforts by the World Bank's Global Gas Flaring Reduction Initiative (GGFR) and NGOs to raise public awareness probably influenced some of these changes in corporate policy.

5. Resource accounting:

Over the last decade, governments have been more proactive in delineating and classifying their natural resources. This has often been a result of a stronger and more independent regulatory body within the host country. In the hydrocarbon industry, governments need resource assessments to attract foreign investment and a byproduct of this research is a raised awareness regarding the amount of resources wasted by flaring and venting.

6. High oil prices:

For national oil companies, the steady increase in oil prices throughout the last decade has probably been the biggest driver of flare reduction. Higher oil prices increase the value of using gas domestically so that oil can be exported. The higher cost of the substitute (oil) expands the value of using flare gas for oil in domestic power generation or industry and in upstream operations. In particular, flare gas can be a substitute for diesel fuel in small-scale power generation.

As shown below, these five drivers emerge repeatedly when flaring issues in the top countries and regions are examined, and they will continue to be key drivers in achieving the next wave of flare gas reductions.

3. Regional gas flaring trends

3.1 Russia

In Russia, gas flaring in Siberian oil fields has been occurring for decades. Remote oil fields full of liquids-rich low-pressure gas, low domestic gas prices, limited regulation, and constraints on pipeline access all have contributed to the Russian flaring problem. In the broadest sense, rampant flaring is the result of coordination problems and conflicting interests.

As noted above, the absolute scale of flaring is uncertain (15 to 50 Bcm per year), but company efforts to reduce flaring have intensified after Prime Minister Vladimir Putin brought focus to the issues in a 2007 presidential address. In response, the Russian energy and environmental ministries crafted a series of proposals to reduce flaring. The government approaches proposed so far have been largely punitive. Current plans are for a steep increase in

penalties in 2014.²⁰ However, in November 2009, Putin reaffirmed the government commitment to 95 percent associated gas utilization by 2012. Reuters quoted Putin as saying: "Oil companies that do not meet this requirement will pay huge fines.'21

While new penalties are likely forthcoming, some incentives to reduce flaring have also been advanced. The process of fuel price reforms for domestic end-use is ongoing. The government has liberalized associated gas prices allowing parties to negotiate terms. In addition, a program is in place to increase domestic gas sales prices across all sectors. More recently, the government has allowed preferred access to the electricity grid for power generated from flare projects.²² With Russian oil producers now facing potentially sharp increases in flaring penalties, many are exploring options to reduce flaring.

Scrutiny on aas flaring increases

2001	Draft law on APG submitted by Russian Gas Society is rejected by Duma
2006	 Results from satellite data indicate high levels of flaring > 50 Bcm per year
2007	 Apr-2007: Putin raises gas flaring issue in his presidential address Sep-2007: package of measures and 95% associated gas utilization by 2011. Russian Industry and Energy and Natural Resource ministries disagree on flare gas approach Rostekhnadzor calls for escalating flaring penalties starting 2008*; Seeks alignment with increased Russian consumer energy prices
2008	Feb-2008: APG pricing is liberalized ends Sibur monopoly for feedstock gas
	 FAS submits recommendations third party access to Gazprom pipes
2009	 Jan-2009: Russian ministries recommend delay from '12 to '14 for 95% deadline Decree #7 stipulates 95% utilization by 2012** Putin: "Oil companies that do not meet this requirement will pay huge fines"*** Allows preferred access to the electricity grid for power from flare projects
2010	APG utilization top priority for government's high-priority Yamal and Taimyr-Okrug oil program

GE's role in Rosneft's Vankor APG solution is key example of an international approach Reinjection and distributed power generation are crucial in the new oil frontiers



Figure 10: Russian Gas Flaring Policy Trends

Notes: APG: Associated produced gas; FAS: Russian Federal Anti-monopoly service

^{**} Government Decree #7, January 8, 2009 "On measures to stimulate reduction of atmospheric air pollution with associated gas flaring products"; From WWF-Russian Academy of Sciences report August 2009. *** November 10, 2009, Reuters Environmental Online Report

3. Regional gas flaring trends

One of the most significant options has been the establishment of joint venture (JV) gas processing plants between TNK-BP, Roseneft, Gazpromneft, and SIBUR, the Russian petrochemical giant.²³ JV structures create an outlet to use the associated gas and partners share revenues from oil product (LPG) sales. In total, SIBUR is planning on increasing gas throughput from about 15 Bcm per year today to over 21 Bcm by 2011, up from about 13 Bcm in 2005.²⁴ However, the economic crisis may slow these plans as LPG and petrochemical product markets have been squeezed both inside and outside Russia. Existing constraints can limit access to the Gazprom pipeline system, even for gas produced from processing plants. The Khanti-Mansiysk oil region is closest to the gas mainlines that run between Urengoy and Chelabinsky. However, these pipelines have capacity constraints that limit the ability for gas to enter the system.

These constraints can be physically linked to capacity availability and gas quality specifications or they can be regulatory related to third-party access rules.²⁵ Recent reports indicate that Gazprom is progressing on pipeline enhancements and allowing third party gas pipeline access. These efforts will be critical to eliminating flaring.²⁶

Another area of focus has been the development of gas-fired power to displace the use of onsite diesel fuel or expensive on-grid power sources. In the maturing fields of Western Siberia, the scale of flaring is such that local power generation can only absorb a portion of flare gas. Furthermore, the remoteness of many of the oil fields can make it challenging to manage gathering costs to bring supply to a processing plant. New concepts involving smaller scale gas-to-liquid (GTL) or liquified natural gas (LNG) plants are emerging, but the technologies are still advancing. Policy incentives for new technologies and perhaps tax relief for new associated gas projects are possible avenues toward achieving flare reductions without the specter of large-scale oil shut-ins as flaring fines increase. The Russian government will face a difficult balancing act of trying to maintain oil revenues while driving additional flare reductions.





3.2 Nigeria

In Nigeria, a multi-decade legacy of gas flaring has been a flashpoint for conflict in the Niger Delta region. The origins and complexities around eliminating gas flaring in Nigeria are well documented²⁷ While much still needs to be done, the Nigerian government and international producers have succeeded in cutting flaring by 28 percent from 2000 levels. A number of factors have driven investment to reduce flaring, including: higher oil prices, increased government stability, additional regulatory oversight, pressure from NGOs, and international focus on sustainability practices of the regions oil companies. However, the path toward reductions has been painfully slow.

Detailing why progress on flaring has been so slow is beyond the scope of this report, but ineffective regulation, immature gas and electricity markets, producer underinvestment in regional infrastructure, lack of government funding of JV projects, corruption, militancy, sabotage, and human rights issues all play a role. Numerous government targets for the elimination of gas flaring in Nigeria have come and passed, most recently in 2008, leaving little confidence among local populations that progress will occur. The physical challenge of developing infrastructure in the Niger Delta also creates constraints. In some cases, waterways are too shallow to effectively use barges for shipping, while in other cases the ground is too soft to anchor pipelines. Overcoming all these factors to develop gas projects defines the Nigerian challenge.

Plans outlined a decade ago are only now being fully realized. A few of the most significant of these have been the Bonny Island LNG export terminal, the West Africa Gas Pipeline (WAGP), and the gas processing infrastructure associated with the Escravos GTL project. More recently, a number of flare gas to power projects have begun feeding the severely short Nigerian power sector.²⁸

President Goodluck Jonathan succinctly captured the power issue in recent comments, "Today less than half of our citizens have access to electricity. We expend about \$13 billion every year

Nigerian Gas Flaring by Company 2000-2009													
Billion Cubic Meters per Year													
Company	'00-'03	'03-'05	'06	'07	'08	' 09							
Grand Total	24.8	25.7	23.0	19.0	17.8	14.9							
Shell (SPDC)	7.9	7.1	4.6	2.7	2.8	2.1							
ExxonMobil	3.6	5.1	5.7	5.3	3.8	4.1							
Chevron		4.0	5.6		4.6	3.4							
Total	1.2	2.5	1.8	1.0	1.0	1.0							
ENI (NAOC)	5.5												
Addax-Sinopec	0.8	0.9	1.3	1.7	2.1	1.6							
Others	0.7	1.4	0.8	0.6	0.8	0.5							

Nigerian Gas Flaring by Company BCM per Year



Figure 12: Nigerian Gas Flaring by company 2000-2008 Source: Nigerian National Petroleum Corporation (NNPC) statistical bulletins

3. Regional gas flaring trends

"sanctioning of new pipe and processing projects is a good signpost for further progress on flare reduction." providing power from diesel generators when we require only about \$10 billion per year of investment over the next few years to develop our generation, distribution and transmission capacities."²⁹

Recognizing the inefficiency of the current system, the Nigerian Federal government is encouraging independent generation development by oil majors and others. Shell recently committed \$2 billion to reduce gas flaring at 24 sites across the delta.³⁰ These projects have been under development for many years, but have been delayed. One of the larger efforts, the Gbaran-Ubie project, will use flare gas to feed a power project in Bayelsa state.³¹ In addition, Chevron is investing in its 3A and 3B gas processing plants in the Escravos region. These will double processing capacity by 2013 and should reduce flaring in the western parts of the Delta.³² In the offshore regions of Nigeria, gas is captured and brought to the Bonny LNG facility or re-injected. Exxon has increasingly relied on offshore processing. They strip associated gas for heavier hydrocarbons and then lean gas

is re-injected into the oil field to maintain reservoir pressure.

Increasing integration of the pipeline and processing network will be critical to realizing the master plan envisioned by the government. The government needs to find a way to be effective in funding of jointventure partnerships and insuring proper allocation of revenue to public works that build the backbone of an energy system. This opens the door for independent companies, like Oando, who have been successful in establishing gas grids and have ambitious plans to increase capacity. To support these independent efforts, partial risk guarantees like those offered by the World Bank are an important way to mitigate high financing costs and credit risks. Overall, sanctioning of new pipe and processing projects is a good signpost for further progress on flare reduction.33

Today, the country is at a crossroads. A fragile peace, forged in 2009 by the Yar'drua government and militant factions in the Niger Delta, is under stress.³⁴ The new Nigerian president, Goodluck Jonathan, is



forging ahead with a number policies that will directly impact the Delta. However, with elections on the horizon in 2011 the political climate is uncertain. Moreover, the flaring crisis in Nigeria is embroiled in larger changes occurring in the Nigerian petroleum sector. The Nigerian federal government is instituting a host of policy measures to reform the NNPC, the national oil company of Nigeria, and put the energy sector on a more sustainable path.

The path of reform taken by Nigeria is similar to that successfully pursued by Indonesia at the beginning of the last decade. The hope is that NNPC will evolve into a profitable regional player similar to Brazil's Petrobras. At the forefront of these efforts is the new Petroleum Industry Bill (PIB) that will change royalty and leasing terms for producers and reorganize the NNPC into several regulatory and operating segments. The government has also passed local content provisions that ostensibly seek to drive additional indigenous labor but, in all likelihood, will serve instead to deter foreign investment and private sector activity.

The most important policy impacting gas flaring is the ambitious Nigerian gas master plan. The NNPC gas master plan calls for development of a new series of gas processing hubs that will gather and process associated and non-associated gas for feedstock domestic power plants.

Another key element of the plan expands pipeline infrastructure to improve the connection between the western and eastern areas of the Niger Delta. Better pipeline integration should improve flare reduction options. Development of the new Brass LNG export facility and expanding pipeline networks out of the Delta region are part of the long-term plan. If gas processing pipeline plans proceed at the pace envisioned by the NNPC, Nigeria is



The "Eternal" flames of Ebocha Photo by Michael Kamber (2005)

on pace to eliminate large-scale disposal flaring by 2012. However, even if big infrastructure projects can be developed, there will be a need to integrate the small isolated flare sites. Integrating sites in the midst of mangrove forests and swamps will be difficult, leaving an important role for smaller scale distributed generation options.

The challenge in Nigeria is to enact effective policies that simultaneously build a dynamic energy sector, foster local economic development, improve security, and enhance government commitment to regulation and enforcement. In addition, there is a strong need to develop new gas infrastructure across the entire value chain, including the power sector.

Reaching investment targets will be difficult. Nigeria is a place where risk premiums on financing are high and the government's track record on driving investment has been patchy. As a result, the role that joint venture arrangements play in bringing partners together to share risk is critical.

However, the players in the Nigerian oil and gas industry are changing. Independent

Nigerian operators will potentially be playing a much larger role in the onshore region. In addition, China, through Sinopec, has recently bought a large stake in the Nigerian oil business with its acquisition of Addax Petroleum.³⁵ Russia's Gazprom has also expressed interest in helping develop gas infrastructure. The commitment of these new players to flare reduction is unknown. In addition, smaller independent players could increasingly play a role in onshore operations.³⁶ These companies may be more agile in operating in the region, but may lack resources to effectively manage flare reductions at brownfield sites.

Clearly, the situation in Nigeria is complex. The chaotic path of the last decade makes many pessimistic and dismissive of the potential for change. However, there is reason to be hopeful that Nigeria is on the verge of real progress to eradicate flaring and toward the next wave of gas industry development. The keys to Nigeria's success will be good governance, better security, operational best practices, new partnerships, and commitment to investment.





Figure 13: Gas Infrastructure in the Niger Delta region Sources: GE Energy based on SPDC, NNPC, and other sources.

3.3 West Africa

While attention and concern over gas flaring focuses on Nigeria, it is also an issue in other parts of West Africa, including Angola, Equatorial Guinea, Gabon, Congo, and Cameroon. In 2009, these five countries collectively flared around 10 Bcm per year 65 percent of the Nigerian total. These countries are working steadily to bring forward new projects and adjust policy to reduce flaring in the near future. At the same time, interest in offshore development from Liberia to Ghana and Cameroon to the Congo is growing, while Angola is continuing its path toward becoming the largest oil producer in West Africa. This makes trends on gas flaring in the region unclear. Recent data from the satellite source shows flaring generally declining, while reporting agencies data indicates an upward trend. 37

From a gas flaring perspective, Angola can probably be regarded as a success story. The country has been one of the fastest growing oil producers over the last decade. Oil production has climbed from under 0.75 MMb/d in 2000 to nearly 2.0 MMb/d in 2010.

Currently, 75 percent of the associated gas produced in Angola is being flared. However, strong pressure from the government to reduce gas flaring in 2004 and 2005 led to sanctioning of a US\$4 billion LNG export monetization plan using associated gas that will be fully operational by 2012. Critical factors that appear to have driven this outcome were alignment of partner interests, supportive global LNG market conditions, and government policy. Angola's enormous deepwater potential, coupled with the remoteness of development, drove international producers (Chevron, ENI, Total, BP) in the region toward a LNG project. In addition, Atlantic basin LNG prospects were good with solid expectations to sell gas into Europe or the United States.³⁸

The Angola government was moved by concerns that flaring was getting out of control as production increased and consequently instituted a no-flare policy. Many of the project partners were already confronting flaring issues in Nigeria and had made company commitments to eliminate routine flaring. In Angola, all of the produced gas is owned by the state.³⁹ Sonagol, the state

West A	West Africa (Excluding Nigeria) Gas Flaring													
Billion Cubic Meters per Year														
Company	'00-'03	'03-'05	ʻ06	'07	' 08	'09								
Grand Total	13.0	12.4	11.4	10.2	9.2	9.8								
Angola	5.5	5.0	4.2	3.7	3.1	3.6								
Gabon	2.6	2.6	2.0	1.6	1.5	1.7								
Congo (Braz.)	1.6			1.6										
Cameroon	1.4	1.2	1.2	1.2	1.2	1.0								
E. Guinea	0.5	0.5	0.4	0.5	0.4	0.4								
Congo (DRC)	0.5	0.5	0.4	0.5	0.4	0.4								
Others	0.3	0.3	0.4	0.3	0.3	0.3								

Figure 14: Gas flaring and crude oil production in West Africa (excluding Nigeria) Sources: GGFR/NOAA, IEA, BP Statistical Report 2010

West Africa (Ex Nigeria) Flaring and Crude Oil Production





West Africa: Cameroon-E.Guinea-Gabon



Figure 15: West Africa: major oil and gas development areas (Angola, Cameroon, Equatorial Guinea, Gabon)

Source: GE Energy based Rigzone, BMI, Exxon, Total, AAPG, and various sources.

oil and gas company, is largely responsible for gas infrastructure development. The state then compensates partner companies for capital expenditure on associated gas projects.⁴⁰ This structure puts the responsibility on the government to expand infrastructure and find demand for gas.

Government tax incentives have spurred economic development around Soyo on the Northwest coast of Angola. The hope is that development of the LNG plant and new gas infrastructure will open the way for new petrochemical plants and other industrial developments. With many deepwater and ultra-deepwater opportunities still available, prospects for gas development are good. A logical next step may be a gas pipeline to Luanda to expand electricity access. Today, many Angolans (80 percent) use bio-mass from the forests as their primary source of energy.⁴¹

Further to the North in Gabon, the government is pursuing efforts to ban associated gas flaring by 2011 and expand public-private partnerships in the gas sector.⁴² Total, Shell, and Addax (now owned by Sinopec) are the largest oil producers in Gabon, although several other smaller independents are increasing production. While much of the country's oil fields are mature, redevelopment efforts and exploration of deepwater and sub-salt reserves are occurring. In addition, producers are exploring in the southern parts of the country. As production expands in the Etama region, far away from existing gas pipelines, new gas infrastructure or re-injection options will needed to control flaring.

In Cameroon and Equatorial Guinea, gas possibilities are also expanding. In 2007, Marathon and its project partners, including the National Oil Company of Equatorial Guinea, brought the Equatorial Guinea LNG plant on Bioko Island into service.⁴³ Similar to the Angola story, the EG LNG project advanced quickly with nearby availability of large associated gas and non-associated gas reserves from the Alba field. Infrastructure to produce propane (LPG) and methanol from liquids-rich gas is also on the island, but flaring still occurs at Zafiro and other nearby fields. This is a case where low cost, non-associated gas developments create the opportunity to tie in near-by associated gas that otherwise would have been flared. The proximity of Bioko Island to offshore Nigeria and Cameroon make it a viable hub location, but both of those countries are keen to focus on local options.

In the last few years, more oil and natural gas have been discovered in offshore Douala basin, and the Rio Muni basin on the coast of continental Equitorial Guinea has potential. Associated gas will be re-injected or flared in the near-term, but an expansion of the existing EG LNG plant and other new LNG or power generation options on the continent are possible.

In Ghana, the focus is on fast tracking gas development to keep pace with one of the most rapidly developing deepwater offshore projects ever. At the Jubilee development in offshore Ghana, project partners (Anadarko, Tullow, Kosmos, GNPC) are looking to move from discovery to first oil in five years. However, Ghana has a no-flare policy and using the associated gas as major oil production volumes start to rise will be critical. Gas will be re-injected in the initial phases of the project. However, new pipeline, gas processing and power generation investments will be required to build outlets for associated gas.

With good policy and investment the prospects for the gas market in the region are promising. The oil and gas potential of the entire offshore region from Liberia to Ghana is good. In addition, with Chevron's

Escravos projects in Nigeria coming online over the next few years in the east, and Ghana's offshore growth in the west, the West Africa gas pipeline will have two major sources of gas. Commitment to gas infrastructure early in the process gives hope that mistakes made in Nigeria will not be repeated. It is conceivable that the future could hold improved electricity access, economic development, and displacement of oil generation with efficient gas power, but this will take good planning, producer commitment, and policy.

3.4 Caspian

The Caspian region includes the key oil producing countries of Azerbaijan, Kazakhstan, Turkmenistan, and Uzbekistan. In recent years, Kazakhstan has been an industry focal point for its giant yet complex oil reservoirs. Oil production has increased substantially, but high levels of toxic hydrogen-sulfide (H2S) have made associated gas projects especially challenging. The resulting acid gas from smaller operations was flared. However, it was recognized early last decade that potential growth from the giant Karachaganak, Tengiz and Kashagan oil fields would drive the scale of flaring to unacceptable levels.

In 2005, the Kazakhstan government took a strong stance to end flaring. The policy was ambitious, but the ban on flaring was not accompanied with a fully articulated utilization policy. In addition, operators were inexperienced in the necessary technologies to handle complex and often sour gas streams. As a result, industry could not deploy capital fast enough, and provisions for extended implementation timelines needed to be developed.⁴⁴

In other parts of the Caspian region, Azerbaijan's offshore oil developments have been associated with high levels

of gas flaring. Country level data from the International Energy Agency (IEA) and satellite surveys show large differences in flaring levels 0.4 and 1.0 Bcm per year, respectively. The trend from both data sources shows little change over the decade. However, there are public reports of reduction efforts. BP reported eliminating 0.25 Bcm per year of flaring at the Chirag field complex in 2005 through the development of a pipeline to integrate low-pressure flare gas into an existing compression water injection platform. Development of the Azeri-Chirag-Guneshli (ACG) fields and the nearby Shah Deniz oil and gas field offer more opportunities to bring offshore flare gas into the existing gas infrastructure.

Data on associated gas flaring is less available in places like Uzbekistan and Turkmenistan. Satellite data shows increasing flaring levels in both nations. In Uzbekistan, the World Bank's Global Gas Flaring Reduction Initiative (GGFR) recently reported it has worked with the government to identify gathering and re-injection projects that could eliminate 0.68 Bcm per year of flare gas more than half the satellite reported volumes.⁴⁵ In addition, the Uzbek government, along with Malaysia's Petronas, the state oil and gas company Uzbekneftegaz, and South Africa's Sasol are planning to establish a 1.3 million metric ton/year (38,000 BB/day) gas-toliquids (GTL) plant. Feedstock sources are uncertain, but there may be potential for integration of flare gas from nearby field operations. The region has growing gas infrastructure options as new pipelines are built from Turkmenistan to China on top of a vast network of legacy Soviet era infrastructure. A focus on monetizing wasted gas from flare projects and large new gas pipeline projects should reduce flaring in the region.





3.5 Middle East

Flaring issues in the Middle East are as varied as the countries in the region. The largest volumes of gas flaring occur in Iran and Iraq. However, Saudi Arabia, Kuwait, Qatar, and other parts of the region have flaring issues.

The essence of the flaring issue in the Middle East is not a lack of expertise on oil and gas, or in many cases infrastructure, but how governments either directly or indirectly set the price of gas at very low levels. In most countries in the region, the delivered price of gas is below \$1.00 per MMBtu.⁴⁶ The low value placed on natural gas stems from several factors. Associated gas gathering has been practiced for decades at the supergiant oil fields of Saudi Arabia, Iran, Iraq, Kuwait, and other parts of the GCC.⁴⁷ In many cases, the large concentration of associated gas reserves could be developed at low cost as a co-product of oil production.

Governments have encouraged gas use for industrial petrochemicals and power generation. Saudi Arabia in particular has been very successful in harnessing its associated gas for domestic industry. In the Kingdom, the desire for industrialization coupled with higher energy prices in the 1970s supported the decision to invest in the master gas system mega-project. At the time, it was one of the largest gas projects in history. The first phase was online in 1982 and today it gathers almost 10 Bcf per day (100 Bcm per year) of gas, and is touted as the world's largest single hydrocarbon network. Approximately half of the gas supply for the system comes from associated gas that was previously flared.

However, in Saudi Arabia, and in other parts of the Middle East, gas prices were held low to diversify the economic base, and predictably, demand for gas has expanded sharply across the region. For example, over the last five years, gas demand in the region has been expanding by more than 6 percent per year. Gas shortages are emerging, particularly for new projects. This has set up a tension between maintaining access to low cost gas for end-users, while needing to invest in higher cost gas sources.

The variation in types of gas supply available and limited interregional trade drive each country to approach the flaring issue differently.⁴⁸ In addition to the vast associated gas reserves in the region, some countries, like Qatar and Iran, have enormous concentrated supplies of non-associated gas that can also be produced at relatively low cost. The issue for flare gas reduction is prices are typically administered at an average level based on the average costs of the giant concentrated gas resources. However, at sites where gas is sour, or at isolated smaller sites, gas gathering and processing costs are higher than average. As a result, often it has been more economical to flare hard-to-handle gas than to develop it into gas systems.49

In Iran, the mandated low price of gas, under investment in gas infrastructure, and international sanctions are driving gas flaring. The country is in the process of expanding pipeline infrastructure to better connect isolated locations. In addition, Iran will likely need to increase its use of re-injection and power in the oil field to drive pumps and compression to offset natural decline in its larger oil fields. However, until the issues around Iran's nuclear program are resolved, access to advanced gas technology will likely be limited.

Iraq has the pricing issues of other regions, but the security situation and devastation accompanying the war have hurt the situation. Even before the U.S. invasion, data indicated Iraqi gas flaring was at high

levels. Both satellite and reported data sources indicated seven to 10 Bcm per year of gas flaring. After the war, damage to gas processing sites in the south was extensive and remains unaddressed. Iragi oil production is concentrated in the Kurdish provinces to the north and in the southeast portion of the country near Basra. Gas processing capacity is limited at key sites where oil production exists and is expected to grow rapidly. Today, estimates point to over 2.3 Bcm per year of flaring at newer oil developments in the south of West Qurna and Missan.⁵⁰ In addition, the massive North and South Rumaila oil fields are flaring 1.2 Bcm per year. Combined, these fields are producing about 2.0 MMb/d of crude oil. However, operator plans indicate that production could climb to 5.0 MMb/d by 2015. This will result in a sharp increase in associated gas production and potentially increased gas flaring. Failure to address the necessary associated gas infrastructure could drive flaring to 20 Bcm per year, close to Nigerian levels, by 2015.

In 2008, Shell proposed a major project, the Basrah Gas company, to repair damaged infrastructure and gather associated gas in the south for domestic power production, industrial uses, and eventually an LNG export project. Today, the project is currently moving slowly waiting for resolution of Iraqi elections and enactment of a long-awaited Iraqi hydrocarbon industry bill. Shell has reported a number of quick "wins" in reducing flaring that have captured around 135 MMcfd of previously flared gas along with associated liquids. In addition, recent news points to a formal agreement in the near future.⁵¹ Critics in the Iragi parliament voice concern that Shell will be given a virtual monopoly over gas exports from the Basra oil fields. However, Shell and its partners appear ready to invest over US\$4 billion to rebuild and expand gas

infrastructure.⁵² Given the scale of investment required to gather and process gas, selling a portion of gas internationally may be necessary to justify the economics on a stand-alone basis. Alternatively, associated gas can be considered a negative externality oil development and a portion of the oil revenues would be directed toward eliminating flaring. Yet another choice is to slowly alter domestic gas pricing so associated gas can eventually be sold in the country at prices that underwrite investments. A combination of all three choices may be possible as well. Iraq appears to be leaning toward allowing private investment in the upstream gas segment, while developing the pipeline system as a state asset.⁵³ In the end, if Iraq fails to synchronize oil and gas field development with viable options for associated gas, the flaring problem in Iraq can be expected to expand significantly. The result will be enormous direct costs in-terms of wasted resources and corresponding social and environmental costs.

"If Iraq fails to synchronize oil and gas field development with viable options for associated gas, the flaring problem in Iraq can be expected to expand significantly"

3. Regional gas flaring trends



Other regions

The gas flaring issue is not restricted to these key oil-producing regions. In fact, 45 Bcm per year or about 30 percent of the global total occurs in places outside of the countries and regions discussed previously. Flaring has been rising in Latin America in particular. Mexico has shown a large increase in flaring over the last few years despite falling crude production. The problem largely stems from insufficient gas processing capacity to handle nitrogenrich associated gas from the Cantarell reinjection program.⁵⁴ This problem expected to be resolved over the next few years as new processing plants are brought into service highlights the need to anticipate and synchronize oil and gas investments. Further south, as crude oil production has increased in Brazil, offshore flaring has increased. The Brazilian regulator ANP has been imposing rules on producers, primarily Petrobras, to address the problem and a number of associated gas concepts, including floating LNG and GTL, are being tested to handle growing output from their prolific sub-salt fields.

Even in the United States and Canada where regulatory focus on emissions is high, gas flaring remains a problem at times. In remote oil fields in the western United States, like the Bakkan fractured oil shale play, and in parts of Wyoming, gas flaring has increased sharply. Gas processing and gathering pipeline capacity has not been able to keep up with booming drilling activities.⁵⁵

Gas flaring is also a problem in Asia, especially at offshore sites and in remote onshore locations. Indonesia has been a clear success story as reform of the petroleum sector at the beginning of the decade has fostered development of a competent regulator in the form of BP Migas, and an increasingly savvy national oil company, Pertamina. In Indonesia, local and federal partnerships coupled with effective gas value chain investments and external financing have reduced flaring. Challenges will continue as new oil projects in Indonesia will be in the more remote Kalimantan, Sulawesi, and Irian Jaya (Papu) regions further from existing gas and power networks being expanded on Java and

Gas Flaring in Latin America and North America

BCM per Year												
Region	' 00	'01	'02	'03	'04	'05	'06	'07	ʻ08	'09		
Americas	14.6	13.8	12.0	12.2	10.9	11.5	11.2	11.7	13.1	13.4		
Venezuela	3.1	2.6	2.0	2.0	2.2	2.2	2.1	2.2	2.6	2.8		
Mexico	1.9	1.6	1.2	1.3	0.9	1.0	1.2	1.8	2.6	2.0		
Brazil				1.0	1.0	1.6		1.0		1.6		
Ecuador	1.0	1.1	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.3		
USA		2.4		2.6	2.0		2.0	2.0		2.0		
Canada	1.9	1.8	1.4	1.6	1.4	1.3	1.6	1.8	1.8	1.8		
Columbia	0.7	0.8	0.8	0.6	0.5	0.4	0.4	0.4	0.4	0.5		
Argentina	1.3	1.3	1.3	1.2	1.1	1.0	0.9	0.9	0.8	1.0		
Others	1.1	1.0	0.9	0.9	0.7	0.7	0.6	0.5	0.5	0.4		

Gas Flaring in the Americas BCM per Year



Figure 16: Gas flaring in the Americas Source: GGFR/NOAA

Sumatra. China has some offshore gas flaring, but the bulk of flaring is likely the result of a lack of gas infrastructure in the western and northern regions of the country. In general, more gas infrastructure is a key enabler of reduced flaring across the region. However, there is typically a need for government support to underwrite development of these new gas grids.

What will drive the next wave of flare reductions?

As can be seen from these regional overviews, the gas flaring problem is complex and nuanced. Progress has been made where regulations have been tightened, policies have been modified, or viable outlets could be established. However, additional investments and increased government commitment needs to occur. At new greenfield oil sites, such as in Uganda, the government needs to address associated gas early in the process by developing reasonable policies to eliminate waste and minimize pollution. At brownfield sites, the next wave of reductions will be more challenaing as project economics are poor or sites are in remote locations where investment is hardest. The question becomes, what will drive the next wave of flare reductions? The next section explores some indications on technology choices, costs of flaring reduction, and how policy and partnerships offer a way forward.

	Gas Flaring in Asia													
BCM per Year														
Region	' 00	'01	'02	'03	'04	' 05	'06	'07	'08	'09				
Asia	10.5	10.7	9.3	10.1	10.0	9.9	10.4	9.2	9.3	9.5				
Indonesia	4.0	4.2	3.5	3.4.	3.1	2.9	3.1	2.5	2.3	2.7				
Malaysia	1.6	1.6	1.4	1.8	1.7	1.8	1.9	1.8	1.9	1.7				
Vietnam	0.7	0.7	0.5	0.6	0.6	0.6	0.5	0.6	0.5	0.6				
China	2.3	2.4	2.3	2.7	2.8	2.9	2.9	2.6	2.3	2.4				
Australia	0.6	0.5	0.4	0.5	0.5	0.4	0.4	0.4	0.4	0.4				
Thailand	0.1	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2				
India	0.6	0.6	0.5	0.6	0.5	0.5	0.6	0.7	0.8	1.0				
Brunei Darus	0.1	0.2	0.1	0.1	0.1	0.1	0.2	0.2	0.4	0.2				
Others	0.3	0.3	0.3	0.2	0.4	0.5	0.5	0.5	0.6	0.3				

Gas Flaring in Asia BCM per Year



Figure 17: Gas flaring in Asia Source: GGFR/NOAA

4 Technology and Economic Options

ssociated gas recovery projects are particularly challenging. The economics can be marginal and the options to sell gas are often limited. Furthermore, since associated gas is a byproduct of crude oil or condensate recovery, costs and contract terms around oil development, and ultimately potential oil revenues, dictate investment economics. If gas infrastructure does not exist, associated gas is, at best, a nuisance and, at worst, a serious hazard in the oil field. In most cases, the gas is rich with heavy hydrocarbons and contaminants that require special technologies for treatment, driving up

mitigation costs. Perhaps most damaging to investment economics is how associated gas depletes with the oil over the project life, potentially leaving underutilized capacity hindering investment schemes.

Traditionally, in remote non-associated gas projects, the high capital intensity of developing gas is managed by multi-decade development plans that insure steady load factors for gas equipment. This is harder, but not impossible, to achieve in associated gas projects. For example, if existing gas infrastructure exists, flaring at smaller onshore fields can often be integrated with modest gathering and processing

Unique solutions for different types of flare problems in different regions



Figure 18: Unique solutions for different types of flare problems in different regions Source: GE Energy

investments. In other cases, when little existing infrastructure exists, mobile power generation and processing solutions offer compact solutions allowing equipment to move from site to site as production decreases.

Offshore fields pose a different set of issues. Space constraints and remote operations make this one of the toughest challenges from a technology perspective especially when gas recovery was not part of the original platform design. In such circumstances, NGL recovery and re-injection for enhanced oil recovery is often the first choice to reduce flaring. Using gas for upstream power systems is also a good option. However, when gas streams are larger than needed for local power generation, new floating LNG and smaller scale GTL approaches are an option if there are not significant resources to drive a pipeline project.

Even after upstream issues are overcome and gas is gathered and processed for sale, outlets must be identified and developed so the full value chain for the gas supply can be established. Given the complexities, it is clear why it is often so difficult to get stakeholders to see the value of using flare gas.

4.1 What are the costs of flare reduction?

Recognizing that gas project economics are always site specific, it is useful to look at a few public examples of project costs versus regional conditions to examine the economic challenge. The conclusion is often that the costs of gathering and processing associated gas are higher than can be recouped in the marketplace. When this is the case, host governments should look for policy solutions. If the producer government is dedicated to eliminating flaring, the key question is how should regulations be

structured? What level of subsidies or penalties is required to drive change? Or, if policy options are limited for a specific country for other reasons, what level of international support may be required to create reductions? In most cases, details of flare projects economics are proprietary, but detailed information is publicly available as part of the submissions for Clean Development Mechanism (CDM) carbon credits and from a few other public economic studies.⁵⁶ It is instructive to look at economic questions around flaring in Russia as well information on gas processing costs and information from the CDM submissions to help put perspective on the larger economic challenge.

4.1.1 Russian flare reduction economics

In Russia, a variety of flare gas reduction options are economically viable today. However, as more distant and smaller associated gas projects are tackled the task will be more difficult. In 2007, the World Bank commissioned a large study by PFC Consulting to examine economic options for associated gas monetization in Russia. The study found two of the most efficient ways to monetize flare gas were electric power generation and development of gas processing plants. In addition, the authors concluded that at a netback price of around \$50/Mcm (\$1.42 per MMBtu) close to 80 percent of Russia's associated gas could be economically recovered.57

Assuming the gas price reforms discussed above are implemented, domestic gas price to industrial users in Russia is scheduled to increase from about \$70 per MCM (\$2.00 per MMBtu) in 2009 to over \$115 (\$3.30 per MMBtu) by 2012. An estimate by PFC points to gas transmission mainline charges of around \$65 per Mcm for lean dry gas delivered to the Gazprom system from



Western Siberia.⁵⁸ However, the additional gathering and processing costs to move gas to a transmission mainline will range dramatically depending on the size of the source field and the distance to the processing plant.⁵⁹ When additional costs to deliver gas from associated gas processing plants to the Gazprom system are included, the netback price from the domestic industry for sales of processed flare gas will likely be less than \$50 per Mcm by 2012. This means that price reforms, and perhaps other policy incentives, will be critical in driving additional flare reduction investments on an economic basis.

So, how much does it cost to gather or use associated gas? The Russian Academy of Sciences study estimates associated gasprocessing costs at \$47 per Mcm, excluding gathering and compression charges.

Re-injection costs presented in the study appear high relative to other regions, but less is known about the range of economics for re-injection projects in Russia because only a few real examples exist and reinjection investments are often integrated with the overall upstream project.⁶⁰ Distributed power generation is the lowest cost option for smaller sites. Small gas engines can efficiently produce oil field power with minimal processing displacing the use of diesel fuel.⁶¹ The use of efficient mobile aero-derivative turbines is another flare option. Use of mobile trailer based units allows generation to be moved to new sites as associated gas is depleted.

Commercial combined-cycle generation has also been an economic option at sites where gas could be efficiently aggregated. The economics of gas liquids are another key driver of gas processing economics.⁶² In Russia, wholesale prices for LPG are around \$186 per metric ton (\$3.80 per MMBtu equivalent), while export prices for LPG move with global conditions. In early 2009, the Russian government removed export tariffs on LPG sales to support domestic producers amid the economic crisis.

The Russian government is pushing to increase associated gas utilization to 95 percent by 2012. However, it is unclear if this can be achieved given trends in the oil and gas industry. Flaring penalties and



Generalized Costs of Associated Gas Options in Russia

 Figure 19: Generalized costs of Associated Gas options in Russia
 Fi

 Sources: CERA, IEIE 2008, Notes: Processing is simple processing for lean gas raw NGL mix. Processing costs
 So

 exclude gather costs, Current flaring penalties of around \$8-10 per Mcm assuming recent exchange rates.
 So

Indicative Associated Gas Processing Plant Economics



Figure 20: Indicative associated gas processing plant economics Source: UNFCC CDM program, PFC Consulting, PA Consulting, GE Energy calculations. Notes: Converted to nominal 2009 dollars. Most cases include basic gas processing package of compression to 30 Bar (~400psi), treatment, dehydration, and refrigeration (chilling) to create lean gas and a raw NGL mix.

increased oversight will accelerate flare gas reduction, but as noted above punitive measures alone are probably insufficient to solve the problem entirely. Attentions to export tariff policies, along with movement on domestic price reforms, are probably critical in achieving the next wave of reductions in Russia. The burden also falls on oil companies to act on the issue and consider internalizing the negative externalities of associated gas in their oil project economics.

4.1.2 Flare gas processing: a problem of scale

One of the critical flare gas issues from a technology perspective is how to justify processing expense for small volumes of low-pressure gas that decline quickly relative to traditional gas fields. Estimates from several sources conclude that basic gas processing costs for rich associated gas range between \$40 to \$80 per Mcm (\$0.90 to \$2.00 per MMBtu). This estimate assumes a basic gas-processing package of compression to 30 Bar (~435psi), dehydration, and refrigeration (chilling) to create lean gas and a raw NGL mix. The analysis shows that for traditional systems, per-unit cost starts to escalate rapidly as the size of gas stream decreases. Lower gas flow equals higher costs. Project specific processing costs range dramatically with the gas composition, size of the plant, and level of gas treatment for contaminates. Typically, basic gas processing options (refrigeration) are used for flare projects, but newer gas processing technologies are becoming well established. Cryogenic gas processing operations that use turboexpansion often are preferred for larger non-associated gas streams. Even newer technologies using membranes, solvents, or molecular sieves for gas treatment and processing are making promising in-roads

in smaller fields and in low-pressure applications.⁶³ Combining these types of new processing systems with efficient fuel flexible gas turbines is one of the technology trends that can reduce flaring.

New offshore options, such as floating liquified natural gas (LNG) terminals and small scale gas-to-liquids (GTL), are emerging as well. Floating LNG (FLNG) is creating new project options for small non-associated gas fields and may become useful in associated gas plays in certain situations. The rapid depletion profile of oil and associated gas fields, and shorter investment cycles typical of oil investments challenge FLNG deployment for flare gas reduction. However, linking an associated gas project to an FLNG anchored on the long-cycle phased development of a non-associated gas field may be an option. Small scale GTL or mini-LNG is emerging as another option for remote flare sites.

One example is related to massive sub-salt oil developments being initiated by the Brazilian state oil company Petrobras. Petrobras is looking at various technology options to monetize associated gas and eliminate flaring. Micro-reactor GTL pilot plants are being developed as one option.⁶⁴ A recent study indicates that a micro GTL option might be viable on a stand-alone economic basis when oil prices are around \$85/bbl. When other values like CO₂ are factored in, breakeven costs are lower.⁶⁵ Overall, as gas technologies continue to advance, the ability to find new options to reduce flaring will increase.

4.1.3 Economic examples from CDM programs

Other examples of the costs of flare reduction are contained in data submitted for carbon credits within the United Nations Framework Convention on Climate Change (UNFCC) CDM program. Looking at a



selection of projects ranging in size and location, several observations can be made.

First, the costs of flare reduction on a per unit basis range between \$1.60 and \$2.40 per MMcfd (\$60 and \$80 per Mcm) of flare gas captured.



Second, all submissions show flare project economics without credits that are below typical investment thresholds for oil investment. Many oil companies look for internal rate of return (IRR) thresholds of 20 percent or higher to justify expenditure depending on the risk profile of the investment. Third, the price used for certified emissions reductions (CER) has a large impact on the viability on the flare project economics. In the case of the Indonesian Tambun project, the IRRs shift from sharply negative to positive, but the project also assumes a higher CER price than most.

Fourth, although just a rough measure of CO_2 abatement costs, the capital investment per annual CO_2 equivalent reduction calculation shows a wide range: from \$52 to \$110 per annual million metric tons of CO_2 reduced.

4.1.4 Nigerian flare reduction economics

The example from Nigeria is worth looking at in more detail as it shows, similar to the Russian examples above, the important role for government policy and international support. CDM submissions for Nigerian projects paint a picture of challenging economics in an uncertain policy environment and tense security conditions.⁶⁶ Based on pro forma economics for Pan Ocean included with CDM submission, the project only achieved an 11 percent IRR even with inclusion of carbon credits. Expected low prices on gas sales, high transport costs for

			Country/Year/Name		
	Indonesia 2007 Tambun	Qatar 2007 Al-Shaheen	Nigeria 2008 PanOcean	China 2009 Tarim	Nigeria 2010 Utumu
Flare Gas Use: Bcm/y	0.1	1.6	1.3	0.2	0.2
Flare Gas Use: MMcf/d	12.6	150.0	130.0	19.7	16.0
CO2e Total Emissions Reduced: MMT	3.9	17.5	26.3	2.4	2.6
CO ₂ e Annual Emissions Reduced: MMT	0.4	2.4	2.6	0.3	0.3
Capex \$US Million	\$30	\$260	\$302	\$32	\$30
\$Capex/CO ₂ e Annually Reduced	\$77	\$106	\$115	\$110	\$117
\$/MCM Flare Gas Use	\$84	\$60	\$81	\$56	\$65
\$/MMcfd of Flare Gas Use	\$2.42	\$1.73	\$2.32	\$1.62	\$1.87
CER Price – \$US/MtCO ₂	\$15	\$6.5	\$7.5	\$10	\$11
IRR Without Credits (Post Tax)	-30.4%	9.7%	5.4%	11.8%	4.5%
IRR With Credits (Post Tax)	6.1%	16.0%	11.2%	19.7%	22.4%
Technology	Mini LPG Plant, Pipeline	Processing, NGL, and Pipeline	Processing, NGL, and Pipeline	Processing, NGL, and Pipeline	Processing, NGL, and Pipeline

Figure 21: Flare gas project economics from recent CDM submissions Source: UNFCC CDM program, GE Energy calculations.

produced LPG, conservative carbon credit assumptions, and high costs of financing projects in Nigeria all hurt the economics. The assumed low price (\$18 per Mcm; \$0.51 per MMBtu) paid by the Nigerian government for dry gas is a key factor. Recently, the government has announced plans to raise the price of gas for power generation from \$0.30 per MMBtu in 2009 to over \$1.00 per MMBtu by 2012.⁶⁷ Uncertainty in the pace of price reform explains the assumed low price in the project submission.

The price paid for LPG sales (\$34 per barrel) is expected to be low because of difficult transport logistics. The submission highlights how security risks hurt potential development of a LPG pipeline, so oil products needed to be barged or trucked away from the plant site. In addition, project economics discounted the value of certified emissions reductions (CER) to only \$4 per metric ton after 2012 given uncertainties in the next phase of the ETS program. Finally, the project submission points to the high cost of project financing.⁶⁸ Recent prime lending rates in Nigeria are above 18 percent.⁶⁹

The Pan Ocean submission is an example of a flare project with marginal economics.

However, it is interesting to explore how gas pricing policy and carbon prices can strengthen a marginal project. If economics on the Pan Ocean project are recalculated assuming a transition toward a steady \$1.00 per MMBtu for gas sales, the post tax IRR with credits increases to almost 15 percent. If price reforms are followed and a CER credit price of \$15 per metric ton can be realized after 2012 through the crediting period to 2018, the project IRR increases to over 18 percent close to typical thresholds for oil investment.

If the goal is additional flare reduction, there is a good case for the government to continue pursuing gas-pricing reform. In addition, the international community should find new ways to channel carbon-financing funds into these projects.

A clear role for policy

Based on only a small set of examples, data tend to confirm the widely held view that the base economics of associated gas flare reduction projects are marginal. The costs of incremental associated gas infrastructure often exceed the value in the region or the cost of paying assessed penalties.







Figure 22: Example of Nigerian flare gas economics

Source: GE Energy based on 2008 Pan Ocean CDM submissions. Notes: Processing includes treatment, dehydration, compression; NGLs includes separation, condensate splitting, LPG production, LPG storage etc. Base

In these cases, the gas is flared. However, the value proposition driving flare gas investments is changing.

High oil prices have driven up opportunity costs of flaring. This creates more opportunities for flare gas to displace energy from an alternative fuel source (such as oil-fired power generation). In addition, there is a need to constantly explore whether new technologies have changed economic thresholds. Nevertheless, there is a clear role for government action and policy. The availability of carbon credits is probably going to be key in getting private industry to sanction the next wave of reduction. More importantly, governments need the resolve to stay the course on many of the price reforms and policies that are underway. The next section explores broad policy options in more detail.

4.1.5 Gas Flaring Reduction ... GE Success Stories

GE Energy has been involved in a number of successful flare reduction projects. Many of these have involved reinjecting gas or gathering the gas to generate electricity or feed pipelines or LNG plants.

Russia • Flare gas reduction and electricity production with Jenbacher gas engines

GE Energy is supplying 12 Jenbacher gas engines to support Russian oil and gas producer Monolit LLC's project to reduce emissions by utilizing previously flared gas at a Western Siberian production facility. At the facility, the waste gas will be separated into liquefied natural gas and other "transportable" products (including propane, butane, and ethane) for the chemical industry. By utilizing the gas from nearby drilling fields at Shapinskoe for onsite power generation, Monolit will avoid the need to transport diesel fuel over long distances, thus delivering significant environmental benefits. Utilization of otherwise flared gas for onsite power generation will help save up to about 536,000 tons of CO_2 equivalents per year.

Kazakhstan • Sour gas re-injection Sour gas or natural gas with high levels of H2S is lethal if dispersed into the air. GE has developed technology to handle the high pressure, high sulfur content gas associated with oil production at Karachaganak, Tengiz, and Kashagan oil fields. The associated gas is captured, compressed and re-injected into the formations to sequester the toxic gas while improving oil recovery. This approach utilizes GE's BCL300 series of centrifugal compressors. Since 2000, the deployment of this GE technology for gas re-injection has prevented more than 49 million tons of CO₂ from being released into the atmosphere each year, or the equivalent of the annual CO_2 emissions released by approximately 10 million average cars.

Argentina • Aeroderivative power generation

GE Energy developed the Chihuido Power Plant for REPSOL YPF Argentina. The project involves GE's LM2500 gas turbine equipped to operate with low BTU fuel. The project generates about 40 MW of power from the .45 million cubic meters per day of gas that was previously flared.

Nigeria • Fast track gas compression projects and power generation projects GE Oil and Gas is developing compression island approaches for various flow stations in the Niger Delta. These reciprocating compressor units will compress natural gas for delivery into local power generation or pipelines. The Ebocha compression project gathers up low and high-pressure gas from the oil and gas separation units for redelivery into the pipeline grid. Another Nigerian project used GE aeroderivative technology including LM2500 gas turbines for the Crawford Channel LPG and associated gas-gathering project. •

5.1 Flare reduction policy ... the effective pathways are largely known

s this survey of the global gas flaring landscape shows, the three main barriers to flare gas utilization are:

- 1 lack of regulatory oversight;
- 2 limited access to domestic and external gas outlets; and
- 3 financing challenges.

Government actions will be a critical factor in achieving the next wave of flare gas reductions.

As with many energy issues, flare reduction requires a difficult balance between public and private interests. Private industry is very effective in allocating resources, deploying technology, and in most cases assessing risk. GE believes that with good government policy and effective corporate governance technology solutions to flaring can almost always be found. In addition, some national oil companies need to become more adept at managing natural gas resources and foster a better understanding of the value of gas within the culture of the company. The perception that associated gas is not worth the effort needs to be challenged.

However, government must set a level playing field, develop effective legal frameworks, and offer a generally stable environment for business. Governments can also help by setting up a regulatory structure that encourages companies to internalize the environmental externalities and limit unnecessary waste from flaring. They can build capacity and engage in international bodies to enhance access to external financing and clean development funding. Governments can shape investment with tax policy and fuel price reforms, but these may be difficult to implement. The most successful countries seem to use a combination of penalties and incentives along with targeted infrastructure investments that drive up the opportunity cost of flaring associated gas, while simultaneously expanding enduse options.

A decade of work on the flaring issue has identified the most effective policy paths to eliminate flaring.⁷⁰ There are a number of foundational best practices that are often discussed in context of oil sector reform in developing nations, including:

- Transparency within the legal, financial, and regulatory structures of the oil sector;
- Competition within the economy;
- Developing industry talent; and
- Balancing oil sector and non-oil sector investments.

Once the foundation is built, the path starts with focus on and support for associated gas utilization within the fiscal terms for oil development. This is followed by development of effective regulatory oversight and a commitment to environmental monitoring and enforcement. At the same time, attention needs to be given to the full gas value chain so viable outlets can be developed. Throughout the process, leadership from the central government is critical as is support from local and regional governments. These are not new concepts and many of the largest flaring countries are making progress along the path toward eliminating flaring. However, the next three years will require execution on those project plans. As discussed above, the economics of the next wave of reductions will be more challenging and the need to produce oil from ever more remote locations will make gas utilization even more difficult.

Despite this challenge, it is reasonable to think that routine associated gas flaring could be nearly eliminated by 2015. "successful countries seem to use a combination of penalties and incentives along with targeted infrastructure investments that drive up the opportunity cost of flaring associated gas, while simultaneously expanding end-use options"



However, this will require:

- More local solutions;
- Government resolve to investigate new flare gas mitigation policies;
- Increased access to carbon financing for flare projects;
- New pubic-private partnerships;
- New private joint ventures to mitigate risk, and perhaps even;
- New international structures to accelerate large scale reductions.

In almost all cases an effective associated gas solution can be found. Technology options are expanding. Moreover, in many cases there are financial benefits, resource conservation benefits, social development benefits, efficiency gains, and environmental cost reductions that emerge over the life cycle of flare gas reduction initiatives.

5.2 Explore local solutions

Local governments are likely to see many of the benefits of reduced pollution or increased energy access, so engaging local officials in addition to the central government can be critical to secure buy-in for projects. Engagement of local utilities is especially critical in power projects.

As new oil projects emerge, governments must explicitly require that oil companies include provisions for utilization of associated gas as they submit plans for development. The governments should be aware of various technology options and, as possible, drive integrated gas and oil investments to avoid new flaring problems. Strengthening central and local government coordination is not enough. Governments must also undertake additional guarantees such as preferred access to transmission for associated gas projects in order to ease investor risk and attract external sources of capital. Joint venture arrangements can allow parties to pool resources so that one company does not face the full burden of overcoming economic challenges that surround flare gas reduction projects. This can have particular benefit in regions where local economic development is a priority and regional tensions make access by external contractors problematic.

Local contractors can also play a vital role in reducing gas flaring. With proper training and guidance, local companies can be equipped to set up, operate, and service distributed generation or small gathering systems for liquids. However, care must be taken not to solely focus on driving local content at the expense of using the right technology and more cost effective solutions. The need for education and training also is critical. This can have particular benefit in regions where local economic development and capacity building is a priority.

5.3 Encourage effective national regulatory and legislative solutions

Development of dynamic and robust natural gas industry is a challenging process. Governments play the critical role in finding reform strategies that align producer and consumer interests for their country. Using both the "carrot" and "stick" can encourage compliance with regulation while promoting additional energy investment and economic development. Some options include:

- Reform of pricing for gas and electricity;
- Contractual reform where pre-emptive rights to associated gas limit project development;
- Effective monitoring, penalty, and enforcement mechanisms;
- Tax or royalty relief for qualified projects;

- Low carbon emissions standards for petroleum imports into developed countries; and
- Security measures to protect pipelines and electricity transmission.

There is a crucial role for the government to create the right incentives. Examples from the regional overview include: moving subsidies away from diesel to power generation from previously flared gas, ensuring a fair price for flare gas derived products like LPG or electricity, and ensuring access to pipelines for captured flare gas.

Better accounting of natural resources whether they are hydrocarbon, forestry or fisheries can help countries understand the national value at risk. This is both waste associated with flaring gas, but also potentially lost value from environmental damage stemming from flaring.

Governments should especially examine cases where government subsidies on imported liquid fuels can be redirected to internal flare capture projects. This reduces outflow of foreign exchange to import diesel, creates the resource pool to pay for gas development, and can often save the country money.

5.4 Expand access for flare and venting reduction financing

Critical investments and pipeline, processing, and storage are required to make it economic to gather the supply and foster gas use. Various forms of credit enhancement including partial risk guarantees are one way to support investment while policy reforms are underway. Other options such as targeted technology funds and carbon partnerships or funds show promise as a way to facilitate projects. The Clean Development Mechanism (CDM) established under the Kyoto Protocol, while a step forward, has proved less than effective to date in driving rapid deployment of gas flaring reductions. Reasons for the ineffectiveness are manifold, but often the lack of monitoring or ambiguous regulations in producer countries makes it impossible to establish baseline scenarios or to prove investments would not happen absent CDM credits the so-called "additionality" test. Furthermore, the regulatory burden and transaction costs associated with smaller projects can discourage developers from pursuing outside financing.

However, new efforts are emerging that promise to boost threshold economics for CDM investments. These include:

- Efforts by the World Bank's Global Gas Flaring Reduction Initiative (GGFR) and others to streamline and enhance existing CDM methodologies;
- Efforts to recognize gas flare reduction in emerging U.S. carbon emission offset programs; and
- Efforts to clarify that the World Bank's Clean Technology Fund can be used to support pipes and wires projects associated with flare reduction.

These efforts should be encouraged and expanded. The GGFR is already exploring ways to better align the CDM program, or future efforts of similar intent, with the unique flaring characteristics of different regions. U.S. policy makers should examine the potential benefits of extending offsets to gas flaring projects under any future carbon mandate.

Finding the right balance between public and private involvement will be a key part of the process. Governments have shown little inclination to be proactive in moving the CDM forward. For example, many African governments did not create Designated National Authorities (local CDM body), or



created them late, and often staffed them with people who did not understand the CDM at all. Russia, for its part, took until late 2009 to develop legislation relating to joint initiative approval and green investment schemes under Kyoto Protocol and only now are the first projects emerging.⁷¹ Even in cases where the government has done a good job on capacity building, there are issues of perverse incentives.

Further examination and deeper international cooperation is required to address the challenges that are limiting the number of gas flaring reduction projects in the CDM pipeline. To date, a host of issues have limited the acceptability of the many flare reduction projects. As discussed earlier, the core of the flaring problem often stems from ambiguous or poorly enforced flaring regulations that provide exceptions that allow flaring. The policies that attach low values to flare gas, making payment of fines preferable to gas system investments, perpetuate the waste. In the international community flare projects face the stigma of being a considered hydrocarbon industry subsidy. In addition, limited monitoring often makes verifying progress impossible.

Within the existing CDM structure, there are individual submissions for each project. As a result, it has been difficult to achieve large-scale reductions. Emerging public-private sector partnerships between oil companies, power generators, carbon finance, and regional bodies are encouraging and will likely create flare gas solutions.⁷² The slow progress on project-based approaches has brought focus on various programmatic solutions that might allow for packaging of a number of projects within an overall emissions reduction program.⁷³

5.5 Role for the international community

5.5.1 The GGFR and efforts to use CDM to reduce gas flaring.

One option to accelerate flare reduction is for the international community to launch a new international sector agreement focused specifically on gas flaring reduction. The voluntary program currently sponsored by the GGFR is a model. A structure could be developed under existing international institutions or through an entirely new entity. Signatories to such a new global effort could be required to undertake commitments to reduce gas flaring in exchange for preferential access to new clean technology funds, including any that may be focused on flare gas reduction. For example, a portion of the funding identified in the 2009 Copenhagen Accord and channeled into the Copenhagen Green Development Fund could be earmarked for flare reduction. This would support commitments to pursue mitigation activities in the developing world.

The agreement could also provide for international advice on effective flare gas reduction regulation and enforcement, analysis of the economics of flare gas reduction, dissemination of information on technologies available to put flare gas to productive uses, and other technical assistance.

In the case of gas flaring, establishing a sectoral baseline would be complicated, due to multiple solutions and the complexity of flare reduction. Transparency into production and flaring data will be an important issue. Vigilance will be required to monitor the system and verify carbon reductions. Having projects generated from private entities like GE that can demonstrate actual reductions, credible economics, and proven solutions will be key.

One advantage is the ability to create large blocks of carbon reductions around flaring problems in specific countries. Active engagement with governments and robust controls to accurately develop baseline emissions, monitor progress, and avoid perverse incentives will be critical. But the scale and scope of the sector agreement could be a tool for accelerating reductions.

5.6 The next wave of flare reductions is starting now

Gas flaring reduction has the potential to be one of the great energy and environmental success stories of the next five years. For the oil and gas industry, the challenge represents a chance to take a leadership role on sustainable resource development and energy efficiency. For producer governments, it is an opportunity to create value from a wasted resource, enable wider access to energy, and mitigate social and political challenges that often accompany the issue. Furthermore, unlike longer-term greenhouse gas solutions such as carbon sequestration or wider deployment of nuclear power, gas flaring can be dealt with today through a variety of existing high-performance technologies. Depending on the region, proven technologies such as distributed power generation, large-scale efficient power generation, re-injection, gathering and processing, liquefied natural gas (LNG) and micro gas-to-liquids (GTL) will all have their place.



Figure 23: A Way Forward: policies, partnerships, and changing perceptions

Source: GE Energy.

Notes: NOC: National oil companies; IOC: International oil companies; SOE: State-owned entities; NGO: Non-governmental organizations; IPP: Independent power producers



Additional data and charts





Asia





BCM per Year



North America

BCM per Year



Figure A-1. A comparison of regional flaring data shows the dramatic differences between the reported levels of gas flaring and the levels indicated by satellite survey. Note: European estimates are broadly consistent. Source: GE Energy, GGFR, EIA, Cedigaz, IEA.

Regions Map



Figure A-1: Country – Region groups for analysis Source: GE Energy

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