

# The Global Energy Challenge: Reviewing the Strategies for Natural Gas

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## Natural Gas Industry Study to 2030

Enabling Solutions for  
Energy Demand and  
Environmental Challenges



24<sup>th</sup> World Gas Conference  
ARGENTINA | 2009

5-9 October

Natural Gas Industry  
Study to 2030

## ABOUT THE INTERNATIONAL GAS UNION

The International Gas Union (IGU), established in 1931, is a worldwide non-commercial, non-political and non-governmental organisation with over 100 members from all continents. IGU's members are national gas associations and companies, which may encompass producers, transporters, distributors, technological and scientific institutes, and appliance manufacturers. Together, IGU's members cover around 95 percent of marketed world gas production. As a result of the advance of natural gas in the world's energy balance and the increasing number of countries where gas is being used or emerging, IGU's network is expanding with more participation from developing countries. The IGU also cooperates with many other global energy organisations.

IGU's activities cover all domains of the gas industry from exploration and production of natural gas on- or off-shore, pipeline, and piped distribution systems to customers' premises and combustion of the gas at the point of use.

The main objective of IGU is to promote the technical and economic progress of the gas industry emphasising environmental performance worldwide, mainly by facilitating the exchange of information of both a technological nature and of a more general, business-oriented nature.

To this end it organises the World Gas Conference and Exhibition and currently manages nine Working and Programme Committees that study all aspects of the gas industry from the wellhead to the burner tip. Special Task Forces are established by the Presidency according to the topics that are considered in need of particular attention or focus at the time. The Committees report at the World Gas Conference every three years.

The World Gas Conference occurs every three years, and in the 24th World Gas Conference in October 2009 in Buenos Aires, Argentina, the central theme is "The Global Energy Challenge: Reviewing the Strategies for Natural Gas". The main objective of these conferences is to increase the value to the membership by promoting exchange of knowledge and information. The next World Gas Conference is scheduled to take place in Kuala Lumpur in 2012.

More information on the IGU's Missions and Objectives, memberships, and activities can be found on the IGU website: [www.igu.org](http://www.igu.org)

The Global Energy Challenge:  
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for Natural Gas**

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## FOREWORD

In its 2006–2009 Triennial Work Programme, the Argentine Presidency of IGU stated that the developments of the global energy scenario were inducing the diverse players involved in the natural gas industry around the world to pose and answer a basic strategic question: Where is the gas sector positioned and in which direction should it evolve?

This reflection gave way to the first of the three strategic guidelines on which the programme was founded: “The Global Energy Challenge: Reviewing the Strategies for Natural Gas to 2030.”

This document is one of the main deliverables of the World Gas Conference 2009, which deals with this theme, and aims to become a key reference for policy and corporate decision-makers.

It is also the result of the combined knowledge and talent of a committed group of people who funnelled the information from the IGU technical committees, which consisted of over 750 technicians and expert members dispersed around the globe.

The work is therefore the first comprehensive study conducted by the global gas industry that analyses the key energy and natural gas industry challenges and the alternative ways to tackle them, highlighting those issues that require greater attention from representative stakeholders.

In the energy agenda, the world is facing a number of challenges, several of which cannot be addressed—particularly in the medium and long term—following the same strategies used until today.

Indeed, the growing demand for energy is currently at odds with society’s claims for lower emissions affecting climate change. Further, while some of the traditional energy sources are facing resistance or limitations to expansion, the world is eyeing renewables as a solution, though most of these technologies still need a long time to gradually develop into a reliable source.

Natural gas is available and abundant, as well as competitive, flexible, and clean. It is in a clear position to enable some of the solutions needed to address these challenges.

But even with a general consensus on the above, the road will not be easy. Claims for security of supply will continue to be mirrored by similar requests for security of demand to ensure a workable return for the large investments needed. The remoteness of supply sources; transit and transmission agreements; and the complex geopolitical, social, and security issues are some of the major hurdles to be sorted by the energy industry in general, and particularly for the global natural gas industry to achieve a successful and timely expansion.

As declared in IGU’s first Strategic Statement issued in 2008, a shared understanding among all stakeholders in the gas industry—particularly between corporate and policy decision makers—is therefore mandatory as the structural driver of market promotion and the foundation of the right context, laying the ground for both clear rules and clear roles for those involved.

In line with its Vision, IGU will actively continue to foster this dialogue. We sincerely hope this work provides a helpful tool to that effect.



Roberto Brandt  
IGU Coordination Committee Chairman



Ernesto Lopez Anadón  
IGU President

## ACKNOWLEDGEMENTS

This report is the result of a collective effort and has benefited from input and feedback from all IGU Working Committees (WOC), Programme Committees (PGC) and Task Forces (TF). This network comprises over 750 experts from more than 50 countries distributed over five continents. The information flow was funnelled through Programme Committee B (Strategy, Economics, and Regulation) which led the committees in this project and provided timely and comprehensive data analysis and projections. The designated focal points and contributors from each committee who submitted this vital information are listed under their respective headings in Annex 3.

The report was prepared under the coordination of a Management Team headed by Roberto Brandt and Andres Kidd, respectively Chair and Secretary of IGU's Coordination Committee. The project's Management Team also included the leaders of PGCB: Pedro Moraleda and Francisco Sichar from Spain (Chair and Secretary), and Colin Lyle from the United Kingdom (Vice-Chair), to whom goes a special recognition for his perseverance in following up and coordinating all the diverse information that nurtured this work, as well in supporting the preparation of the report. The group was completed by Jaap Hoogakker from The Netherlands (leader of Study Group B.1), who had the challenge of assembling the regional estimations of supply and demand under diverse assumptions, and Runar Tjersland from Norway (leader of Study Group B.2), who was responsible for analysing the gas pricing models across the world.

The report's primary author was Sylvie D'Apote, Associate Director with IHS Cambridge Energy Research Associates (IHS CERA), who assisted the IGU throughout the whole process. She also oversaw the editing and final production of the report. She counted on the advice and contribution of several colleagues of IHS CERA's Global Gas Group, in particular Simon Blakey, Senior Associate; Michael Stoppard, Managing Director; Shankari Srinivasan, Managing Director; and Robert Ineson, Senior Director. Special thanks go to Vivian MacKnight, of the IHS CERA Rio de Janeiro office, who provided assistance with research and drafting, as well as help with statistical data and graphics.

The high quality of the results achieved would not have been possible without the advice, guidance, and challenge of the project's Steering Committee, chaired by the IGU President Ernesto Lopez Anadón and comprising a selected number of industry experts from around the world. They are: Coby van der Linde (The Netherlands), Director of the Clingendael International Energy Programme; Tim Eggar (United Kingdom), Chairman, Nitel Solar; Rajendra Pachauri (India), Chairman, Intergovernmental Panel of Climate Change, deputised by Jayant Sathaye (USA), Senior Analyst of Climate Change & Sustainable Development Issues, Lawrence Berkley Laboratories; Daniel Yergin (USA), Chairman, IHS CERA, deputised by Simon Blakey (United Kingdom), Senior Associate; Nobuo Tanaka (Japan), Executive Director of the International Energy Agency (IEA), deputised by Ian Cronshaw (Australia), head of Energy Diversification Division Directorate of Energy Markets and Security; Shigeru Muraki (Japan), Chief Executive of Technology Development, Tokyo Gas, deputised by Ryo Fukushima (Japan), General Manager, Business Development; Bert Panman (The Netherlands), former IGU Coordination Committee Chairman (his work was supported by Dick de Jong, from the same country, a Fellow of the Clingendael International Energy Programme); Roman Samsonov (Russia), General Director of VNIIGAZ – Gazprom; Torstein Indrebø (Norway), IGU Secretary General; and Ho Sook Wah (Malaysia), IGU Coordination Committee Vice-Chair.

We would also like to extend our appreciation to all those people who helped with the countless logistic and organisational details throughout the nearly three years it took for the preparation of this report.

## EXECUTIVE SUMMARY

### Natural Gas: The Enabling Fuel

The world energy system is in a critical and uncertain phase, with severe economic, environmental and security challenges to face. This study shows that the natural gas industry can make a very strong contribution towards meeting these local, regional, and global challenges. Natural gas is an enabler fuel to help meet our aspirations and a critical ingredient of any strategy to ensure a secure, affordable, and environmentally friendly energy system.

However, the future role of natural gas should not be taken for granted. During the next 25 years natural gas demand and production will continue to grow, but it will not be easy to replicate the formidable increase of natural gas's share in global energy of the past 25 years. The resources exist, but the level and timing of the long-term investments needed to bring these resources to the final consumer will be possible only if critical policies are put in place, including a proactive drive to address climate change. The correct alignment between private and public investment is required and an appropriate policy framework is needed for gas to contribute its full potential to meeting global energy needs in an economic and sustainable manner.

The key conclusions from this report are

- **Natural gas is an abundant fuel.** In addition to extensive conventional gas reserves, technological developments for exploiting unconventional gas are further raising the prospect of ample, commercially viable gas resources. Unlike oil, gas resource potential is not a concern on a global basis.
- **Natural gas will continue to play a substantial role in global energy demand for many decades:** demand from traditional sectors and uses (such as power generation, heating/cooling, feedstock, etc.) will continue to increase, thereby contributing environmental improvements through increased efficiency and low carbon content. In addition, natural gas will also play a new role as a complementary fuel to renewables by enabling increased deployment of energy supply from intermittent renewable technologies.
- **Through these two roles, natural gas will play a key role in helping to meet environmental targets** related to both local pollution reduction and climate change mitigation. Gas is an essential part of a sustainable global solution.
- **Market conditions are right for international trade of natural gas—and especially of liquefied natural gas (LNG)—to expand,** linking additional resources to fast growing markets. However, the growth will depend critically on the support for trade and investments from national and international policies and regulations.
- **The natural gas industry can and must invest through the current economic cycle** if it is to reach its full potential and bring economic and environmental benefits to humankind.
- **Political and geopolitical issues can threaten the continuous optimum economic development of the gas industry.** International agreements and solutions are needed to ensure that required investments in key parts of the gas chain are not delayed or impeded.

Assuming that the right conditions are created and the appropriate decisions are taken, the global natural gas market is expected to grow from its current annual size of 3 trillion cubic metres (Tcm) to over 4.3 Tcm by 2030, implying a compound annual growth rate of 1.8 percent. If, however, more challenging local environmental and climate mitigation policies are put in place, as is assumed in the IGU Green Policy scenario, the gas market could grow to nearly 4.8 Tcm, implying an average annual growth rate of 2.2 percent and boosting gas's share in the global energy mix to 28 percent from today's 21 percent.

### An Increasingly Abundant Resource

Natural gas reserves are sufficiently abundant from a geological perspective to support the assumption that gas will make an increasingly significant contribution to the global energy challenge. Recent technological developments and higher energy prices over the past several years are transforming previously technical reserves into commercial ones.

Current estimates of conventional gas reserves suggest that these are more than sufficient to meet the range of needs through to 2030 that are projected in this report. Moreover, the upstream natural gas industry outside of North America, Europe, and parts of Asia remains a relatively young business—certainly compared to oil—and many of the world’s geological basins are relatively under-explored for gas. Arctic regions, especially in Russia, present opportunities for sustainable gas supply for decades. Deeper prospects also offer vast undiscovered potential throughout the world.

Besides conventional reserves, recent developments to exploit unconventional gas—tight sands gas, coal-bed methane (CBM), and shale gas—as well as frontier resources, such as ultra-deep offshore gas or sour gas, suggest that commercially viable gas resources may be both significantly more prolific and more widespread across the globe than has generally been recognised. Unconventional gas—and particularly shale gas—has led to large revisions for prospectivity in North America, the world’s most mature and explored region. Indeed North America was the fastest growing region in production additions in 2008, faster even than Qatar. Likewise, there is a significant upward reevaluation of Australian gas reserves based on CBM activity. The potential for unconventional gas in other parts of the world is significant, although unproven.

Biogas will play an increasing role but remain a relatively small additional source of supply—and a renewable one. Finally, gas hydrates are a vast potential resource that can contribute to gas supply in the longer term.

Overall, the possibilities for sourcing gas reserves will expand. Although a large proportion of global gas production will continue to come from conventional gas reservoirs, by 2030 gas supply will be coming from an increasing variety of sources and will be produced and supplied by a greater variety of companies involved in indigenous gas production and international trade. Given recent developments in natural gas exploration and development, the IGU believes that world natural gas production can be expanded to meet expected demand growth. Higher demand growth will of course imply an earlier and more aggressive development of unconventional gas resources and higher investments in transportation and distribution.

## The Environment and Sustainability

The delivery of clean, efficient, affordable, and secure energy is critical ingredient of economic growth, social development and environmental sustainability. Natural gas is cleaner and more efficient than any other fossil fuel. The natural gas industry has the scale, technology, and resources to help to mitigate emissions today—in contrast to zero-emission energy technologies such as renewables that will need some years to scale up. The debate between natural gas and zero-emission technologies is misguided. It is not a case of ‘either/or’ regarding renewables and natural gas, but rather ‘both/and’.

Replacing oil or coal with natural gas has clear environmental advantages. In addition, gas is the ideal complementary fuel to renewables; its use as a ‘partner’ fuel will allow increasing deployment of intermittent renewable technologies. The share of biogas in total gas supply is also expected to increase.

The move to a more environmentally conscious world should be positive for natural gas at least to the year 2030. Natural gas can contribute both to the reduction of greenhouse gas (GHG) emissions and to improvements in energy efficiency.\*

This study looks into the future with the help of two scenarios, a base-case scenario named IGU Expert View developed by combining regional perspectives using reference assumptions implying a continuation of current policies, and a more environmentally focussed view, the IGU Green Policy scenario that would require a global climate change agreement implemented by a high cost on carbon dioxide (CO<sub>2</sub>) emissions. Our expectation under the IGU Expert View scenario is that global GHG emissions will continue to rise, while under the IGU Green Policy scenario CO<sub>2</sub> emissions would start decreasing after 2015, and in 2030 they would be 35 percent lower than in the IGU Expert View scenario. Natural gas plays a key role—alongside nuclear, renewables, and abated coal. Global primary energy consumption (PEC) would be lower in this IGU Green Policy scenario and gas would attain 28 percent share of the energy market by 2030, as compared with 21 percent today. Increased use of natural gas can be consistent with decreasing GHG emissions, and it enables renewable energy to achieve a pre-eminent position in the fuel mix without compromising economic sustainability.

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\*See the IGU report “Natural Gas Unlocking the Low Carbon Future” for a comprehensive analysis of what could technically be done today (with existing technology) to reduce GHG with the help of natural gas.



## Exhibit 1

## Key Quantitative Results of the Study

	Primary Energy Demand (million tons of oil equivalent per annum)	Gas Demand (Bcm per annum)	Gas Demand (Tcf per annum)	Gas Share in Primary Energy Demand (percentage)	CO <sub>2</sub> Emissions from All Fuels (million tons per annum)
<b>IGU Experts View Scenario, 2030</b> (continuation of current policy trends)	16,500	4,300	153	23	41,600
<b>IGU Green Policy Scenario, 2030</b> (global agreement, high cost of CO <sub>2</sub> )	15,000	4,800	168	28	27,200
<b>The World Today</b> (for comparison)	12,000	3,000	106	21	30,000

Source: IGU.

## Trade and Interconnection

International gas trade, by pipeline and LNG tanker, is already well established. In 2008 delays in the commissioning of new production and liquefaction capacity exacerbated by the demand decline caused by the economic downturn led to a decrease in global LNG trade for the first time in 27 years, but international pipeline trade continued to expand.

We expect the growth in LNG to return, providing benefits to producing and consuming countries alike because of its inherent flexibility. As LNG volumes grow and as contracting practices become more flexible, LNG will be directed toward markets where it is most needed and most valued.

By 2030, LNG and long-distance gas pipeline deliveries will have grown rapidly and will underpin a gas market in which the local conditions can influence gas price formation and trade flows in whole regions, or even across the globe. We can expect that

- Gas demand growth and declining reserves in established markets will require more long-distance pipelines to deliver reserves from remote production areas to new and established markets. This will require long-term cooperation between gas producers and consumers, including trade and transit agreements, investment protection agreements, etc.
- Continued strong prospects for LNG will lead to more trade between continental blocks.
- Interconnections between more localised markets will increase as governments and companies strive for the benefits of closer cooperation and regional integration.
- Increasing technology transfer between nations will maximise efficiency.
- This development in global trade will both require and gradually help forge constructive bilateral and multilateral government relations to ensure that growing interdependence does not add to the increasing concerns about security of supply and security of demand.

## Geopolitics, Economics, and Investments

The most important challenges to natural gas industry growth are not geological: they are above ground and affect the whole of the gas chain. The gas industry is highly capital-intensive and large-scale long-term investments are required through the entire value chain to produce and deliver natural gas to end consumers. Gas projects very often involve a multiplicity of stakeholders, both public and private, across different countries. Careful alignment of interests is critical for long-term success. Governments

are frequently stakeholders in several parts of the gas chain, with differing and sometimes conflicting objectives. As a result, political and geopolitical issues will continue to arise, affecting not only decisions about new resources and infrastructure, but also the continuing operation of existing supply routes.

As global gas trade and interdependence between producer and consumers countries increase, concerns about security of supply and security of demand will become progressively more important. Furthermore, as the regional gas markets become more integrated globally, regional events will increasingly have global effects. Governments seeking diversification or enhanced flexibility in supplies as a means to manage geopolitical risk will tend to encourage LNG projects and other shuttle ways of gas delivery that are in development.

Increasingly, multilateral agreements and intergovernmental solutions will be needed to support or bring forward new infrastructure, to jointly explore and exploit new gas reserves, and to help establish robust and secure markets to the benefit of all parties.

Another above-ground risk is related to the economy and the availability of finance. The credit crunch associated with the 2008/09 economic crisis is likely to have long-term effects on the gas industry. The scarcity of credit is likely to mean that investors will be required to contribute higher levels of equity. International gas companies (IGCs), and perhaps even more so national gas companies (NGCs), may be financially constrained. The decisions of governments—notably in North America, in China, and to a lesser extent in Europe—to allocate funds to the energy industry as part of a fiscal stimulus programme should help ensure that the industry makes the necessary investments. Other large private players are demonstrating a commitment to persevere with investments. Debt financing—although scarce—will be available for sound commercial and well-aligned projects.

Paradoxically, although the economic downturn may appear to present major new obstacles for the industry, it actually creates an important window of opportunity. Project costs, which have surged in recent years as a result of an overheated economy, are now showing signs of easing. Global economic contraction and weak demand for energy, including natural gas, have bought the natural gas industry critical extra time to plan, gain approvals for, and develop the needed infrastructure. Imminent concerns of supply tightness have evaporated and been replaced by responses to a short-term supply surplus. It may take two to five years for global energy demand to return to its peak of 2008, depending on the length and depth of the recession and the speed of the recovery, but we expect that the global gas market will return to this level in 2010. It is imperative that the natural gas industry does not squander this opportunity but instead takes advantage of the extra time to make the required investments. All stakeholders need to recognise that large gas industry projects have long lead times. Both the public and private sectors must be prepared to invest against the cycle and recognise the long-term nature of the gas industry.

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## INTRODUCTION

In recent years, much progress has been made in many countries to replace other fuels with natural gas. This trend has brought several economic and environmental benefits to society. Gas has a lower carbon content than oil and coal and thus reduces the impact of energy consumption on the climate. Gas is also cleaner to burn than oil and coal: in a densely populated, urbanising world, gas makes an important contribution to improved local air quality. Gas is generally used in more technically advanced and energy-efficient equipment than other fuels; this means that less primary energy is needed to produce the same 'energy service' (cooking, warmth, electrical power, steam for industrial applications, etc.). Its cleanliness and convenience of use have also helped to improve the product quality and cost-competitiveness of several industries.

These attractive economic and environmental characteristics have resulted in a significant increase of the share of gas in the energy mix worldwide. Today gas provides more than one fifth of the world's energy, whereas a generation ago, in 1980, it accounted for just 17 percent. Wherever it is available, gas has become a fuel of regional importance. Worldwide, however, use of natural gas still ranks behind both oil and coal; hence, there is still room for major environmental gain by substituting lower-carbon natural gas for the higher-carbon fuels.

Proven natural gas reserves have grown in tandem with natural gas demand and production. The reserves-to-production ratio has remained remarkably stable in the past two to three decades, at around 60–65 years. Although geopolitical challenges related to access and transportation remain, natural gas reserves are sufficiently abundant from a geological perspective to serve a much larger gas market. The recent developments to exploit unconventional gas—tight sands, CBM, and shale—located near large consuming markets suggest that commercially viable gas resources may be both significantly more prolific and more widespread across the globe than previously believed.

Natural gas is widely traded between nations—and even across continents—by high pressure pipelines. Until recently, ship-borne trade of LNG accounted for a much smaller share of international gas trade. Most gas was used in the country or continent where it was produced, and most trade was regionally focussed. But the way that gas is being traded and used is changing. LNG trade is becoming a much larger part of the story. The gas industry is globalising. Gas trade is attracting political attention, and sometimes today has political overtones. In line with rising oil prices (and other commodity prices), gas prices increased to record levels in 2008 and are perceived to be more volatile. The growing LNG trade is providing intercontinental gas price linkages that increasingly influence patterns of gas trade between the regions of the emerging global gas market.

In summary, the gas industry has gone through significant change in the past few years:

- Natural gas demand responded to strong economic growth and investment, commodity prices reached all-time highs, and environmental concerns also increased.
- Regional gas markets expanded, and international trade and global price interactions increased. Concerns about gas price volatility and security of supply and demand brought gas onto the political agenda.
- Unconventional gas sources surged in some developed markets, particularly in North America, and are expected to have significant impacts in the medium term on regional wholesale prices and global LNG trade patterns.

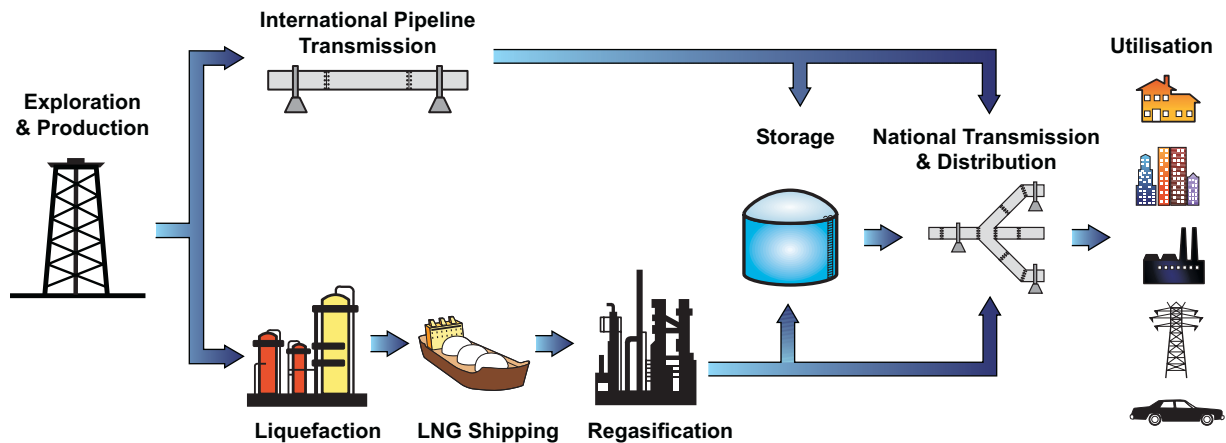
Then, in summer 2008 commodity prices started to fall sharply from the impact of the global economic downturn. Gas prices started to fall as well, though more slowly, especially in regions where lags are embedded in oil price-linked contracts.\* Lower industrial output significantly reduced gas demand for the first time in decades, and there now appears to be an oversupply of gas. In 2009 it is unclear how long the world will remain in recession, whether governments will intervene further in the financial and energy markets, and whether there will be a new (post-Kyoto) global agreement on climate change.

The energy industry is in a state of transition, but where is it headed? What will be the regional and global implications for the global gas supply-demand balance and regional gas price formation? Which government policies and regulations will most influence each part of the gas chain and lead to success or failure of economic and environmental objectives? What should decision makers do to ensure that gas is developed, delivered, and used to support economic growth at a time of environmental challenges and economic uncertainties?

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\*Such as in Europe or South America.

## Exhibit 2 The Gas Industry Value Chain



Source: IGU.  
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These questions and developments offer signposts to the future for the gas industry. The challenge is to promote continuous innovation in the technologies for finding, transporting, and using natural gas. The gas industry will seek in parallel

- to pursue the economic substitution of higher-carbon fuels with gas, and of electric appliances with gas appliances, winning new customers in established markets and in new uses
- to support technological innovation that continually improves the efficiency with which gas is used
- to develop ways in which gas can complement and work alongside carbon-free fuels, especially to help with the intermittency of wind and solar power

### Purpose and Structure of the Report

The objective of this study is to review the perspectives and strategies for the natural gas industry in the period up to 2030. Looking into the future is critical for the gas industry, considering the magnitude and long-term nature of the gas chain investments. The report addresses the questions and issues that will affect the position and evolution of the gas sector. The report also seeks to provide corporate and policy decision makers with a 'checklist' that will inform the discussion about the role of natural gas in a more sustainable energy future.

Building on the collective expertise of the IGU working groups, the report offers a prospective quantitative and qualitative analysis of how the natural gas industry might develop up to 2030. The IGU explored two possible futures among many. The IGU Expert View is a business-as-usual scenario that assumes the continuation of current policies and the partial fulfilment of current climate change commitments. The IGU Green Policy scenario looks at the possible consequences for the world's energy balance of introducing a 'cost of carbon' and combining this with appropriate government policies that will favour investment and technology innovation.

The quantitative analysis is a tool rather than a result. It is designed to provide a sound basis for the more qualitative discussion about key drivers, challenges, and opportunities for the gas industry and the interactions necessary between the private sector, policymakers, and international organisations to achieve the desired economic, social, and environmental objectives.



The structure of the report is as follows:

The first section (NATURAL GAS: A GROWING ROLE IN A CHANGING ENERGY WORLD) describes the point of departure for the study, examining the main trends and drivers that have shaped the gas industry in the recent past and have led to gas's growing role in the energy mix.

The second section (A LOOK INTO THE FUTURE: THE IGU 2030 IGU EXPERT VIEW SCENARIO) presents the IGU Expert View scenario to 2030 for natural gas demand, production, and trade. It also provides a critical assessment of pricing mechanisms and changes in business models.

The third section (ENABLING A LOW-CARBON FUTURE: THE IGU GREEN POLICY SCENARIO) draws out the effects of the IGU Expert View supply mix outlook on emissions, and then analyses broadly how some key policy changes may affect the supply and demand trends, resulting in an alternative IGU Green Policy scenario.

The fourth section (MAKING IT HAPPEN: CHALLENGES AHEAD) analysis the effect of limiting factors such as investment and financing, geopolitical issues, human resources and technology.

Finally, the last section (CONCLUSIONS) draws the main conclusions of the study, highlighting in particular the role of key actors: private industry, governments, international organisations; the steps that the gas industry could take to achieve a more favourable outcome; the desirable policies that would help and complement industry initiatives; and the role that the IGU could play to contribute effectively to these objectives.

## NATURAL GAS: A GROWING ROLE IN A CHANGING ENERGY WORLD

In the past two decades gas's share in the global energy mix has increased substantially, from 17 percent in 1980 to about 21 percent today.

This increase has been the result of significant new technological developments and evolving policies. In particular, the environmental and climate drivers have greatly supported gas substitution for other, more polluting and higher carbon fuels. Gas is cleaner to burn than oil and coal, thereby helping to improve local air quality. Gas also has a lower carbon content than oil and coal, so its use reduces the impact of energy use on climate change. Gas is generally used in more technically advanced and energy-efficient equipment than other fuels; this means that less primary energy is needed to produce the same 'energy service' (cooking, warmth, electrical power, steam for industrial applications, etc.).

In the temperate developed world, where there are extended distribution networks, gas has traditionally been widely used in buildings for space heating and cooking purposes and in industries where its clean burn and convenience are essential for product quality and cost-competitiveness. In several countries, cheap domestic gas production has helped develop a thriving petrochemical industry. The widespread use of gas in the power sector is a more recent development which is linked to the introduction of highly efficient combined-cycle gas turbine (CCGT) technology.

### Growing Penetration of Gas in Primary Energy Demand

Between 1980 and 2006 global primary energy demand increased from 7.2 billion tonnes of oil equivalent (btoe) to 11.7 btoe, an annual average growth of 1.9 percent. During the same period, world primary demand for natural gas grew at a much faster rate—2.6 percent per year on average. As a result, gas participation in the global energy mix grew from 17 to 21 percent, taking market share mostly from oil. Coal largely maintained its share in the global primary energy mix during the period, but this was actually the result of a more pronounced trend of coal substitution by gas in Europe and the Commonwealth of Independent States (CIS) being offset by increasing use of coal in Asia.

This trend was not uniform across the globe. As shown in Exhibit 3, the regions which have today the highest gas penetration are the CIS (52 percent) and the Middle East (44 percent). On the other hand, Asia and Asia Pacific are the regions where gas participation is the lowest (5 percent and 17 percent, respectively).<sup>\*</sup> Gas's share in total primary energy increased in all regions except North America, where gas lost a few percentage points to coal between 1980 and 1990 and never recovered them.

### Main Drivers of Gas Demand Growth

#### *Macroeconomic Drivers*

Economic growth is by far the most important driver of energy demand growth in general, and of gas demand growth in particular. Before the economic crisis of 2008, the world economy registered over a decade of strong growth. Gross domestic product (GDP) grew at 3.5 percent per year between 1990 and 2006. The region with the fastest GDP increase was Asia (8.1 percent average per year), followed by the Middle East (4.1 percent). GDP in Europe and North America grew 2.2 percent and 3.0 percent, respectively.

Population growth is another important determinant of energy demand. Between 1990 and 2006, world population grew 1.4 percent—significantly lower than the 1.7 percent average growth in 1980–90. Population growth is expected to fall gradually over the outlook period to an average of 1 percent for 2007–30. There are of course substantial differences between developed and developing countries.

#### *The Gas-to-power Driver*

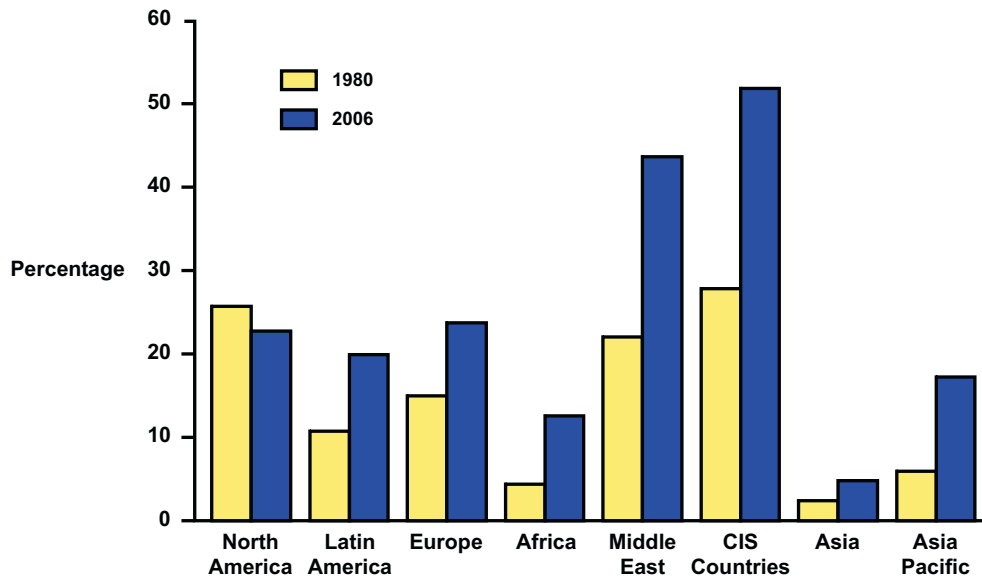
The most important driver of gas demand growth in the past two decades has been the remarkable increase in gas use in the power generation sector. In 1980 gas accounted for a mere 12 percent of world power generation; in 2006, it was 20 percent. Although there are still substantial differences across regions, the upward trend is consistent across all regions (see Exhibit 4).

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<sup>\*</sup>The country composition of the IGU regions is described in Annex 1.

**Exhibit 3**

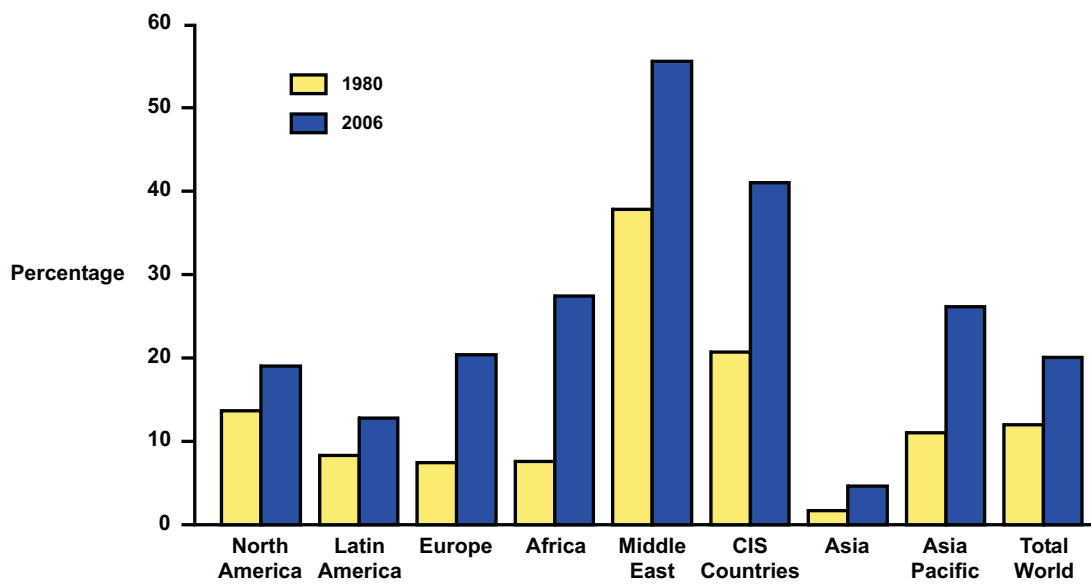
**Share of Gas in Primary Energy Demand, 1980 and 2006**



Source: International Energy Agency.  
90813-1

**Exhibit 4**

**Share of Gas in Power Generation, 1980 and 2006**



Source: International Energy Agency.  
90813-2

Of the several reasons why gas has become the preferred fuel for new power generation capacity in those regions, the most important are

- **Higher transformation efficiency.** CCGT technology introduced in the 1980s has a much higher transformation efficiency than the traditional steam turbines and single-cycle gas turbines, reducing the amount of fuel input necessary per unit of power output. CCGTs, however, can only use relatively clean fuels, such as gas or naphtha. Gas's higher efficiency in power generation is reflected in the use figures: while the electricity generated with gas grew at an average annual rate of 5.3 percent between 1980 and 2006, the corresponding gas used in power generation grew only 4.6 percent per year.
- **Lower relative capital investment and modularity.** Gas-fired CCGTs also have lower capital investment costs (relative to coal-fired power plants, for example) and can be built more quickly and in a modular way, allowing for a quicker response to demand, including intra-day changes in demand. This modularity and high ramp-up rates allow CCGTs to act more effectively as back-up generation for intermittent renewables than some other thermal generation (particularly coal units), increasing their attractiveness in a green scenario. Gas-fired power plants also have a shorter construction cycle than either coal or nuclear.
- **Ease of delivery and reduced maintenance.** The continuous delivery of gas by pipeline avoids the need for onsite storage infrastructure and the complicated delivery logistics of oil and coal.\* Because gas is a cleaner fuel, the need for maintenance is reduced, allowing for higher power plant average availability.
- **Lower pollutant emissions.** Gas-fired power stations emit much less pollutants (e.g., sulphur, particulates, etc.) than coal- or oil-fired power stations. Increasingly stringent pollution standards have been a significant determinant of the fuel choice for new power stations.
- **Lower CO<sub>2</sub> emissions.** As gas has a lower carbon content than coal and oil, its combustion generates less CO<sub>2</sub>. This advantage, which is magnified by its higher transformation efficiency, has provided gas a significant competitive advantage in the post-Kyoto world, especially in Europe where a CO<sub>2</sub> emissions cap-and-trade scheme was introduced in 2005.
- **Increased availability.** The increasing penetration of natural gas distribution networks and the increase in long-distance natural gas transportation (both by pipeline and LNG) have enabled gas to reach a larger market, fuelling power stations in locations where only coal and oil had been available previously.
- **Lower relative prices.** In many countries the competitiveness of natural gas in the power generation sector has been supported by favourable pricing and taxation policies.

### *The Main Policy Drivers*

Gas penetration in the past two decades has been influenced directly or indirectly by a number of government policies. Though there are substantial differences across countries and regions, the energy policies applied in countries where gas's share has grown the fastest fall into one or several of the following categories:

- policies that support energy security and diversification (e.g., those that mandate diversification of energy sources and/or suppliers; stimulate domestic exploration/production; mandate oil inventories; subsidise gas transportation and distribution systems; improve bilateral connections with neighbouring gas production countries; etc.)
- policies that stimulate efficiency in transformation and end use
- policies that support environmental objectives (e.g., clean air policies to reduce acid rain and local air pollution or climate-related policies)
- the privatisation/liberalisation of the EU power markets, which also led to increased gas use in power generation in the European Union (particularly in the United Kingdom, Spain, and Italy), because a wide

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\*Onsite storage may not be required, but without access to a liquid traded market, some form of storage or flexible gas supply contracts is required to cover variations in production unless the power sector has a very stable overall load factor.

range of new players entering the generating business in those liberalised markets sought the economic and environmental 'edge' that gas-fired CCGTs offered

## Gas's Contribution to Environmental and Climate Objectives

As a result of the increasing share of gas in the energy mix, its lower carbon content, and its higher conversion efficiency, the world total energy-related CO<sub>2</sub> emissions have increased at a much lower rate than primary energy demand between 1980 and 2006: 1.6 percent per year for emissions, compared with 1.9 percent per year for primary energy.

While natural gas has contributed to a much lower emissions' growth than would otherwise have occurred, the level of GHG emissions remains unsustainably high and is not close to even stabilising, much less declining. This is partly because the shift from coal to gas in Europe and the CIS was counterbalanced by a substantial increase in coal use in emerging Asia.

In order to support a reduction of the energy-related GHG emissions, the challenge for the gas industry will be to

- Reduce direct methane emissions from the whole gas chain through reduction of gas flaring, of transportation and distribution leakages, and of incomplete combustion at end use.
- Support technical innovation that continually improves the efficiency with which gas is produced, transported, transformed, and used.
- Pursue the substitution of higher-carbon fuels with natural gas, winning new customers in established markets and in new uses.
- Develop the ways in which gas can complement and work alongside carbon-free renewable fuels, therefore facilitating and speeding up the transition to a low-carbon and sustainable energy future.

## A LOOK INTO THE FUTURE: THE IGU 2030 IGU EXPERT VIEW SCENARIO

### Methodology and General Assumptions

The IGU 2030 forward-looking exercise was based on the collective expertise of hundreds of industry representatives worldwide who form a global network of IGU working groups. The challenge was to integrate the views of this global network on a consistent basis. To this end in April 2007 a Study Group within the IGU Strategy, Economics and Regulation Committee generated an initial 'reference case'. This was shared with the whole IGU global network, not only for review and challenge, but also as a framework for the technical committees to use when considering how their parts of the gas chain might change between now and 2030. This initial reference case went through several adjustments during 2007–09 that ultimately produced the IGU Expert View scenario. The final version of the IGU Expert View scenario described in this report was completed in May 2009.

The analysis of gas demand and supply was done regionally, based on country data aggregated at the regional level, then followed by a global sense check of net imports and exports. But unlike other energy outlook exercises (such as the International Energy Agency's [IEA] World Energy Outlook [WEO]), no exact reconciliation was forced at the global level to equate global demand and global supply. In this sense, the output is genuinely what well-informed industry experts in every region think will happen under a set of common assumptions. The size and direction of the difference between global gas supply and global gas demand thus indicate the tensions between supply and demand, the possible trends towards oversupply or repressed demand, and the possible effects on prices.

This is not the only possible approach. The text box 'Modelling a Global Gas Industry' provides an overview of other methodological approaches that could possibly be adopted in future IGU work.

#### Modelling a Global Gas Industry

The regional analysis of supply and demand that the IGU has carried out to support this study is one of several possible approaches to modelling the gas market. Because natural gas is supplied from discrete production zones and delivered through a network of pipes, ships, and ports to primary zones of consumption (concentrated urban areas and major industrial or power facilities), natural gas supply and demand can also be modelled using mathematical tools that involve nodal analysis.

Such modelling can be conducted for purposes of engineering or cost optimisation in the operation of a small gas network. It can also be scaled up to the level of national networks for purposes of investment planning. Gas companies and gas research institutes make use of such models to ensure cost-effective operations, to aid their own planning, or to signal to market participants and investors where future bottlenecks might develop.

In principle, such mathematical tools could be extended to help develop an understanding of gas production, gas trade, and gas consumption across the whole world.

The data requirements would be vast and the challenge to develop reliable models would be considerable, but as international trade in gas continues to grow, it will become increasingly important for the industry and for governments to understand the implications of the development of national and regional markets throughout the world. The Russian representative in the 2030 Steering Committee has suggested such modelling activity as a way forward for the IGU to help improve the quality of understanding of future international gas flows.

This proposal exceeds the focus of this report; however, we recommend that it should be assessed by IGU's incoming authorities. There may need for further consultation with IGU membership to carry such a project forward, as it may require specific resources and financing in addition to the voluntary data gathering and analytical work conducted by the IGU committees.

### Macroeconomic Assumptions

The IGU Expert View scenario is designed to depict a ‘business-as-usual’ future of ongoing but moderate economic growth, slowing population growth, and a continuation of current policy trends, with only partial achievement of climate-related commitments. However, global economic growth and energy markets have been in a volatile transitional phase during the past few years, and there is great uncertainty as to where the transition will lead. The IGU Expert View scenario has been adjusted to recognise the current realities whilst setting out the IGU’s best estimation of future trends based on the assumption that economic growth will return from 2010 onwards. The regional GDP and population growth assumptions are summarised in Exhibits 5 and 6.

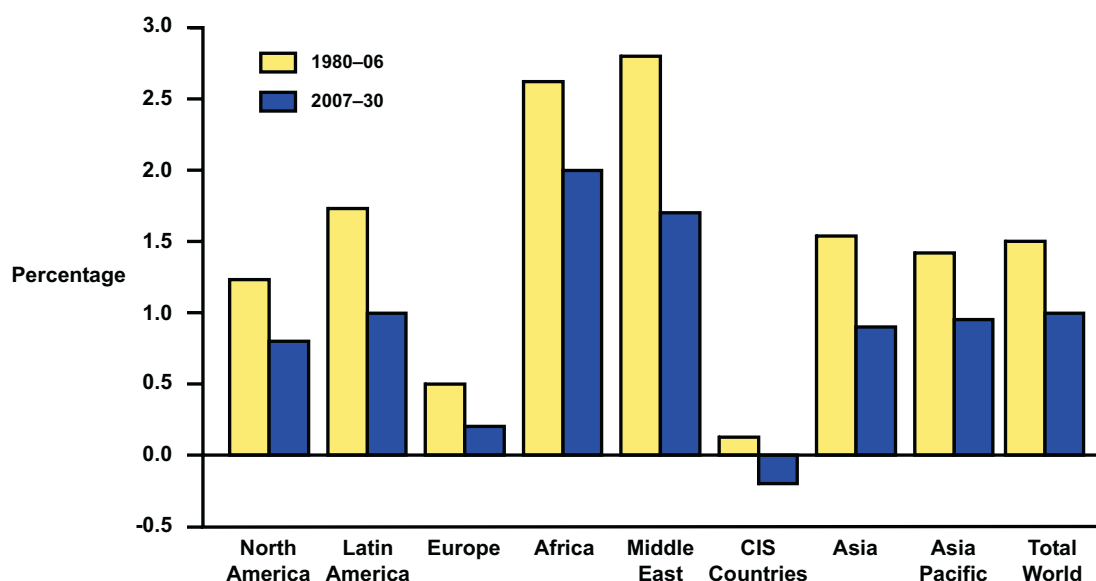
### Primary Energy Demand Assumptions

In order to frame its gas supply and demand projection within a wider energy environment, the IGU made assumptions on the evolution of total primary energy demand, consistent with the GDP, population, and policy assumptions adopted for the IGU Expert View scenario. These assumptions are loosely based on other authoritative sources (IEA, US Department of Energy, Directorate-General for Energy and Transport, and other regional and country institutions), but the IGU performed some consistency checks and sensitivities with its own gas supply and demand projections.

Total primary energy demand is projected to increase by an average of 1.9 percent per year between 2007 and 2015 and by 1.3 percent per year between 2016 and 2030, growing from 11.7 btoe in 2006 to 16.5 btoe in 2030. Exhibit 7 compares GDP, population, and primary energy growth for the period 1980 through 2030. In the longer term (2016–30), moderately strong GDP growth is expected to be accompanied by a relatively slower increase in primary energy demand. This occurs because of a combination of factors, including the increased share and higher energy efficiency of natural gas (particularly in power generation), the increasing efficiency at the point of use for all fuels, improved energy conservation, and changes in social behaviour that affect overall energy use per capita.

Total primary energy demand growth, however, varies widely across regions. Approximately, two thirds (65 percent) of the additional energy demand from 2005 to 2030 will come from developing countries (Latin America, Africa, the Middle East, and Asia). China and India, in particular, with their huge population and fast growing economies, will account for nearly half

**Exhibit 5**  
**Past and Projected Population Growth, 1980–2030**  
(average annual growth rates)



Source: International Energy Agency (historical), IGU (projections).  
90813-3

**Exhibit 6**

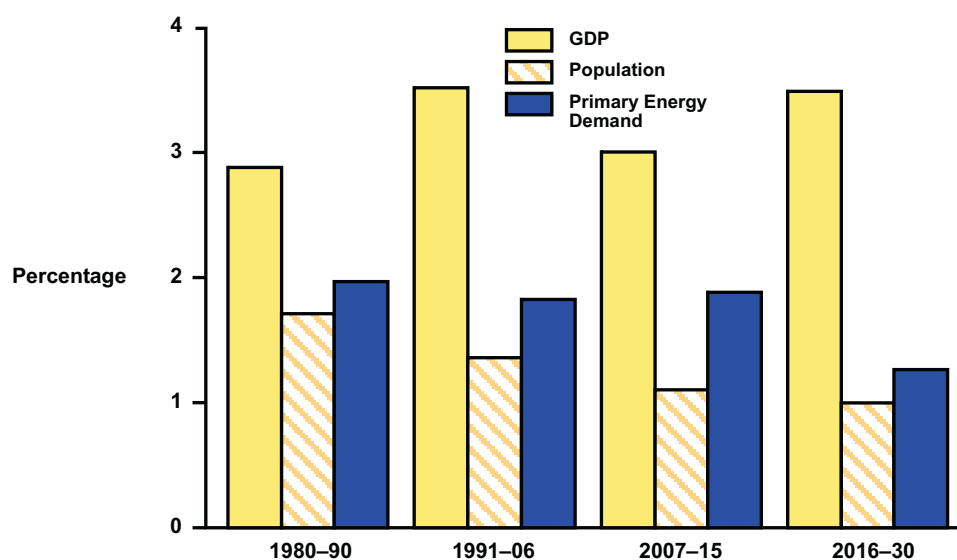
**Past and Projected GDP Growth, 1980–2030**  
(average annual growth rates)

	1980–90	1991–2006	2007–15	2016–30	2007–30
North America	3.1	3.0	2.0	2.6	2.4
Latin America & C.	1.2	3.2	3.7	3.1	3.3
Europe	2.4	2.2	0.6	2.0	1.5
Africa	2.2	3.2	2.5	4.5	3.7
Middle East	(0.2)	4.1	3.3	3.5	3.4
CIS Countries	(1.0)	(0.3)	4.9	3.3	3.9
Asia	7.2	8.1	6.0	5.1	5.4
Asia Pacific	4.5	2.9	1.3	2.1	1.8
<b>Total World</b>	<b>2.9</b>	<b>3.5</b>	<b>3.0</b>	<b>3.5</b>	<b>3.3</b>

Source: Various (historical), IGU (projections).

**Exhibit 7**

**World GDP, Population, and Primary Energy Demand, 1980–2030**  
(average annual growth rates)



Source: International Energy Agency (historical), IGU (projections).  
90813-4



of the world's additional energy demand, and thus their fuel choices will have a major impact on the world's energy demand fuel mix. Developed countries, in particular in Europe and North America, which have lower projected economic and population growth, are expected to have comparatively lower primary energy demand growth rates, as well as less significant changes in fuel mix and lower carbon impacts.

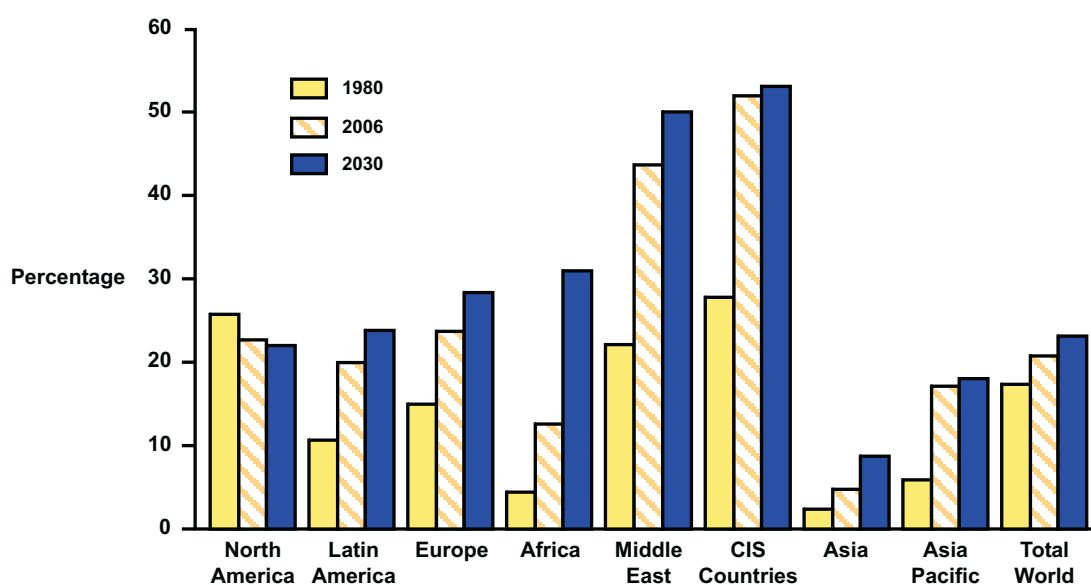
The expected fuel shares in total energy demand are not assumed to change very much in the long term under the IGU Expert View scenario, when examined at a global level. The share of gas increases a little (from 21 to 23 percent), mainly at the expense of oil (whose share falls from 33 to 30 percent) and nuclear (falling from 6 to 5 percent). The shares of coal and renewable energy remain unchanged at 29 percent and 11 percent, respectively.

However, this relative stability at a global level masks very different trends at regional levels, and at the same time the relative weights of the different regions in the world total are also evolving. In particular, the increasing importance of large coal users such as China and India counterbalance the decrease in the share of coal in other regions, such as Europe and the CIS. The share of gas in primary energy demand grows particularly in Africa, the Middle East, and Europe (see Exhibit 8).

Competition between coal and gas, which will take place principally in the power generation sector and to a lesser extent in the industrial sector, will depend on a number of factors, mainly the endowment of local coal and gas reserves, whether carbon legislation or other restrictive environmental policies are in place or will be introduced, and the relative price levels.

The position of nuclear will also vary across regions. Nuclear capacity is expected to increase in North America, Asia, and Asia Pacific. The future trend in Europe is more uncertain. There is a growing discussion of new nuclear plants in many European countries—France has just decided to build a second new plant, and there is much discussion of a whole new wave of plants in the United Kingdom. Even without additions, if all nuclear plants in Europe are kept operational (for example by not implementing the current plant closure policy in Germany), then European gas consumption would be 40 billion cubic metres (Bcm) (5 percent) lower in 2030 than currently. In the United States, problems of waste storage management and long construction lead times will limit the growth of nuclear. In Latin America, nuclear generation is expected to double by 2030, but the share will remain small, at less than 2 percent.

**Exhibit 8**  
**Share of Gas in Primary Energy Demand, 1980–2030**



Source: International Energy Agency (historical), IGU (projections).  
90813-6

Renewable energy (which includes hydropower) will increase in absolute terms, but its global share remains largely the same. The share of non-hydro renewable energy sources increases rapidly but still remains small in the period up to 2030. The position of natural gas should not be threatened by renewables, and indeed the potential combination of natural gas with some renewables will be a driver for natural gas market development in some countries and regions. This, however, is based on the assumption that there is a level playing-field for natural gas to compete with other fuels in power generation, including renewable energy.\*

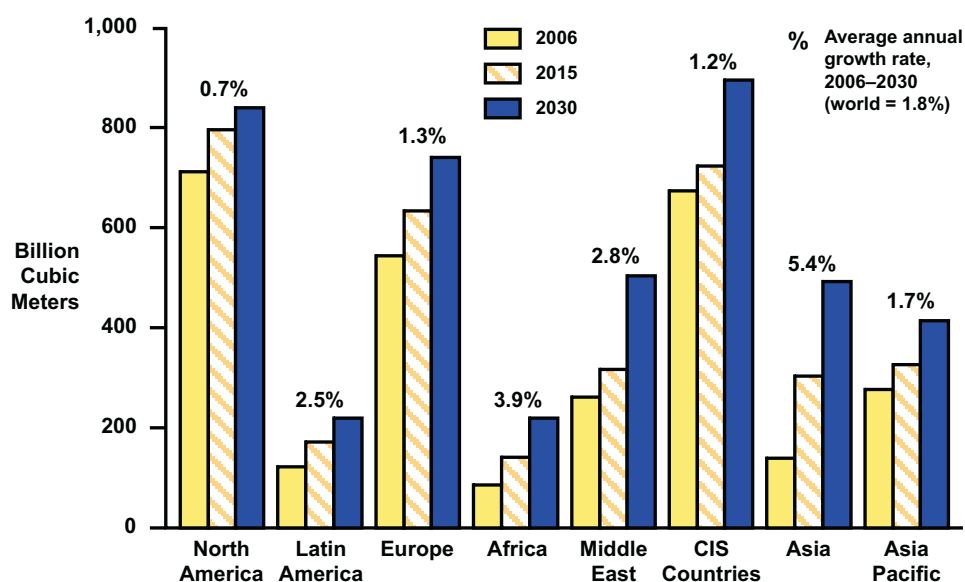
## Natural Gas Demand to 2030

### Natural Gas Demand by Region

Global natural gas demand is projected to increase at an average annual growth rate of 1.8 percent between 2006 and 2030, rising from 2.8 to 4.3 Tcm. In absolute terms, the CIS is expected to surpass North America as the major consumer of natural gas by 2030, with Europe coming in third (see Exhibit 9). In terms of growth rate, however, the most dynamic region is expected to be Asia, followed by Africa, the Middle East and Latin America. Within those regions, the expected evolution of the “frame-breaking” markets of China, India, and Brazil will have a significant impact on global gas demand trends, and therefore we examine these in more detail in a separate section below.

The main drivers influencing gas market development are summarised in Exhibit 10. A more detailed analysis of the main drivers and limiting factors for each of the regions and for each of the segments of the gas value chain is presented in Annexes 4 and 5.

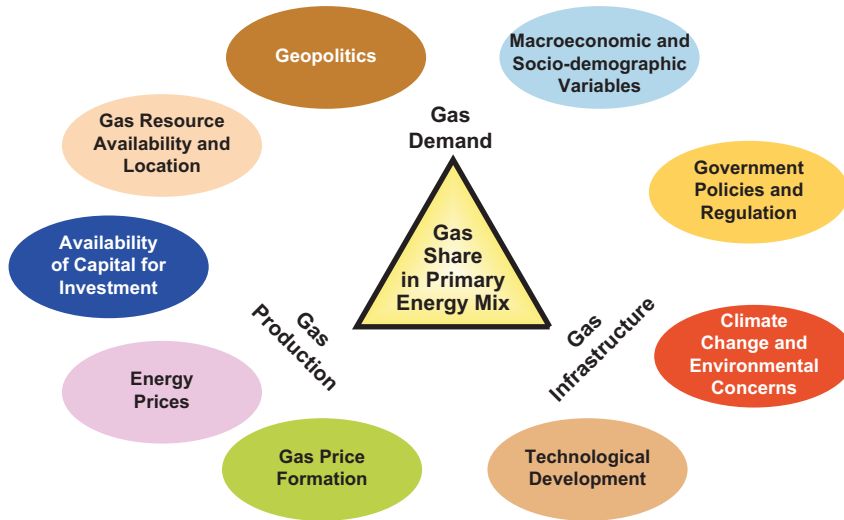
**Exhibit 9**  
**Gas Demand by Region, 2006–2030**



Source: IGU.  
90813-7

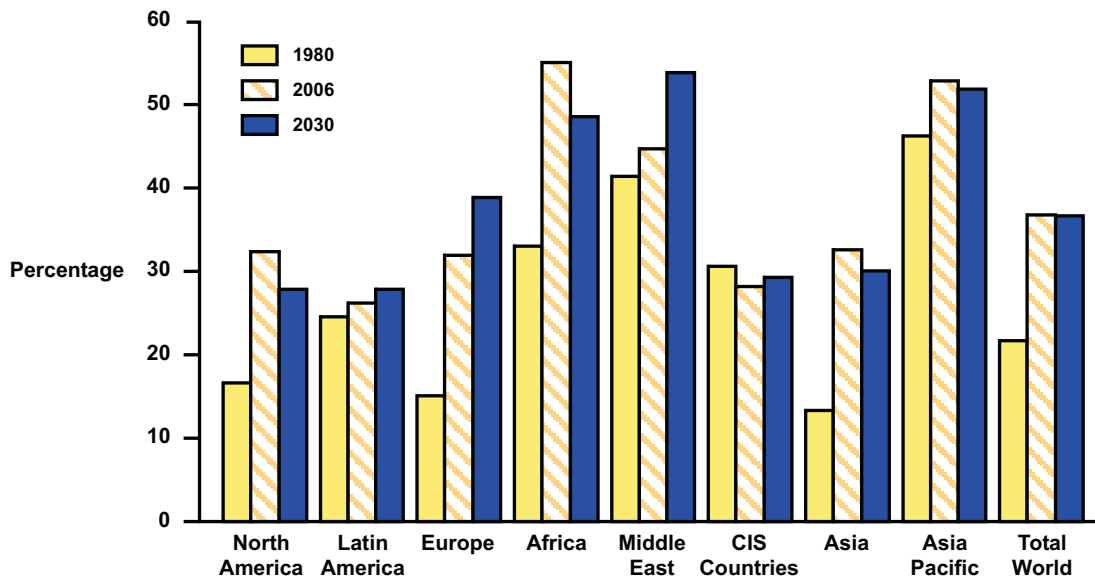
\*This is not happening in all countries and regions. Indeed to meet political targets for renewable energy, governments often consider subsidies to increase renewable sources for power generation. In Europe, for example, this might unduly displace, or at least significantly reduce, running hours of all forms of thermal power plants, including gas-fired plants.

**Exhibit 10**  
**Main Drivers Influencing Gas Market Development**



Source: IGU.  
 90813-24

**Exhibit 11**  
**Share of Power Sector in Gas Demand, 1980–2030**



Source: International Energy Agency (historical), IGU (projections).  
 90813-8

### ***Gas-to-power: Expected Trends***

The most dynamic sector for gas demand growth will continue to be the power generation sector. Total gas use in the power sector is expected to reach 1.7 Tcm in 2030, a 2.5 percent average annual increase over 2006 levels. As a result, the power sector's share of global gas demand will increase from 35 percent in 2006 to 39 percent in 2030.

In most regions, the power sector demand for gas is expected to grow faster than total gas demand, as shown in Exhibit 11 (a growing share of the power sector demand in total gas demand indicates that the power sector grows faster than other sectors). The most notable exceptions are North America and the CIS, where the power sector's share in total gas demand actually falls slightly, indicating that the industrial and residential sectors are growing faster than the power sector in these regions.

### ***Other Traditional Gas-using Sectors***

#### **Residential/Commercial Sector**

Total gas demand in the residential and commercial sector is expected to increase from 0.7 Tcm in 2005 to 0.9 Tcm in 2030. Globally the share of this sector in total gas demand is expected to decrease slightly during that period, from 25 to 21 percent, with a significant increase only in Asia, from 15 to 21 percent, as downstream gas networks expand, bringing natural gas to more than 100 million additional end-users by 2030.

Gas consumption in the residential and commercial sector is driven by population growth, or more precisely growth in the number of households and commercial buildings, as well as improvements in lifestyle and comfort levels. Growth in the number of customers is offset by technological improvement in gas-burning devices and in building insulation. In some countries, such as the United States, consumption can also be affected by internal migration from colder to warmer regions, thus diminishing average heating loads.

In developing countries, and in particular in new emerging gas markets, the expansion of the natural gas transportation and distribution networks will allow gas to be brought to cities and towns that previously relied on more polluting fuels. New residential connections are expected to increase in line with the expansion of the distribution grids. In China, for example, where there are at least 20 cities with more than 20 million people each, gasification will generate enormous demand. Although many developing countries have a tropical climate, and thus little need for space heating, gas is expected to be used increasingly for space cooling and refrigeration in place of electricity production from other sources.

In developed countries, where populations are roughly stable, the number of connections is still increasing because the number of dwellings increases as the number of people per household decreases. But the increased pressure for energy conservation and efficient use of resources is reducing the energy consumption per individual dwelling or commercial building. We expect continued downward pressure on the amount of natural gas used for residential space heating. Furthermore, in new highly efficient buildings, where the demand for heating is low, electric space heating is likely to be preferred to gas heating because of lower capital costs.

Energy saving in the air-conditioning field is expected advance rapidly. Conventional types of air-conditioning systems using fossil fuels will start to be replaced by electric heat pumps or gas heat pumps using geothermal heat or heat from ambient air.

Conventional fuel-based water heating systems are expected to be substituted by high efficiency systems such as micro-combined heat and power (CHP), fuel cell, latent heat recovery water heaters, and heat pump-type water heaters, as is already happening in new homes in Japan and northern Europe.

Photovoltaic (PV) power generation systems will continue to be adopted rapidly all over the world in the residential and commercial sector, and these are often complemented by natural gas. The cumulative installed number of residential PV power generation systems increased more than four times in the past five years. It is expected that the cost of PV power generation systems will start falling towards 2030, enabling the spread of such systems without subsidies.

To reduce CO<sub>2</sub> emission of commercial buildings and individual houses, many European countries are increasingly introducing renewable energy, especially biomass such as sewage sludge, garbage, agricultural waste, wood chips, or biogas, as the heat source in small district heating or CHP systems in place of coal. In order to use biogas more efficiently, it will increasingly be purified into bio-natural gas, and delivered to individual households through the natural gas pipeline system, as a complement to natural

gas. This is already happening in some European countries and in Japan, although volumes are still very small in proportion to conventional natural gas supply.

The combination of gas and renewable energy has greater economic benefits in larger buildings as the appliance and installation cost per user can be much lower, and there may be better opportunities to combine the two energies in a compatible package. This is valid for both thermal solar and PV in combination with natural gas. Although the combination of gas and solar has much potential in the residential sector, it will not amount to large gas demand growth in this sector.

### Industrial Sector

Total gas demand in industry is expected to increase from 0.9 Tcm in 2005 to 1.6 Tcm in 2030. The share of the industrial sector in the world's gas demand is expected to remain at around 35 percent. This trend is more or less uniform in all regions, with some regions registering small increases and others small decreases.

Where natural gas infrastructure is developed, the better combustibility and lower CO<sub>2</sub> emissions will continue to allow natural gas to displace oil products in the industrial sector and to expand its market share. Electricity and natural gas are expected to become the primary forms of energy for heating furnaces toward 2030.

A trend that is already starting and will continue is the movement of gas-intensive industries, in particular industries using gas as a feedstock, closer to the source of production, particularly in the Middle East. This can yield economic advantages, but whether the resulting emissions would be less depends on, amongst other factors, the environmental rules or financial incentives to limit GHG emissions in producing countries.

Natural gas CHP systems can be very efficient, and their penetration is expected to expand. Industrial CHP applications bring to the user further potential economic advantages, not only through improved efficiency and CO<sub>2</sub> reductions, but also in power supply stability. However, the economics of such schemes depend on the relative fuels costs and the value placed on environmental benefits.

Policy implementation can have an important impact on whether or not a CHP project is viable. To clarify the correct approach, in August 2007 the World Business Council for Sustainable Development adopted the thermal power average for the marginal coefficient to calculate CO<sub>2</sub> reduction. The IGU supports this approach: using the marginal coefficient as the correct basis for any project impact assessment shows the effect of a change. The use of average coefficients (i.e., based on the average emissions from all power plant) is useful for policy planning purposes, but it does not correctly represent the benefits of installing gas-fired CHP if that results in, for example, less electricity being generated from the coal-fired power plants that the project would displace at the margin. Nevertheless, certain interest groups in some countries urge the use of the average coefficient of all power sources, leading to fewer apparent environmental benefits for CHP schemes. Furthermore, in countries where nuclear power generation has a large share and the full costs of nuclear energy might not be included in the electricity price, the widespread introduction of CHP systems that rely on imported natural gas will remain challenging.

To promote adoption of small and medium-size gas engine CHP, the generation efficiency needs to be improved and the initial cost reduced, providing systems with high electric generation efficiency and total efficiency.

Spreading out from Asia and Asia Pacific, as well as expanding in parts of Europe, food manufacturers, garbage processing plants, and sewage plants will increasingly introduce biogas generation systems to reduce industrial waste and garbage, whilst acquiring a considerable quantity of biogas at the same time. If this biogas can be used efficiently at the factory without subsidy then a CHP system might be the most profitable way for the customer to obtain economic and environmental-merit benefits. This trend will increase for small and medium-size gas dual-fuel engines in which biogas and natural gas can be burnt.

An increasing proportion of gas supply in the industrial market will be used as a supplementary or backup fuel for renewable energy, for example in the introduction of wood chip boiler advances at sawmills or in the paper industry. In the IGU Expert View scenario the use of wood chips, city garbage, and sewage sludge will increase to some extent. Bioenergy and the development of gasification conversion technology from biomass such as methane fermentation and pyrolysis gasification will be promoted, and reduction of equipment cost will also be pursued. Highly efficient gas-fired engines and charcoal-fired boilers will develop spurring the advancement of the Stirling engine generation systems that can burn these biomasses directly.

Automotive Sector

The automotive sector is expected to register the fastest gas demand growth of all sectors in the next 20 years, although volumes are expected to remain small in absolute terms compared with other sectors.

Today there are about 10 million compressed natural gas (CNG) vehicles in the world, of which 55 percent are concentrated in just three countries: Pakistan, Argentina, and Brazil (see Exhibit 12).<sup>\*</sup> Of the total 10-12 Bcm used globally in the transport sector, Latin America accounts for 7 Bcm.<sup>\*\*</sup> Looking ahead, a conservative estimate, compatible with the IGU Expert View scenario, would be for a total NGV fleet of 35 million in 2030, which would use some 60 Bcm of natural gas and 5–10 Bcm of biogas. A more optimistic estimate which requires the right policies to support a much faster network development is for an NGV fleet of 100 million in 2030, requiring 200 Bcm of fuel, of which about 30 Bcm could be biogas.

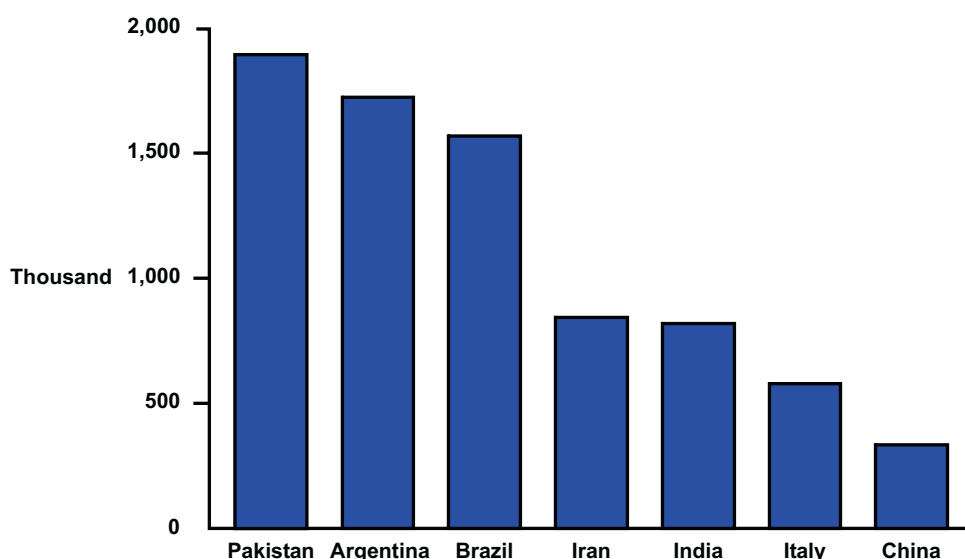
The two regions where the use of CNG is expected to grow faster are Latin America, where it is expected to double to 15 Bcm, and the Middle East, where there is currently no CNG use but gas use in the automotive sector is expected to reach 17 Bcm by 2030.

Gas as a Chemical Feedstock

Producing countries could increase their GDP by developing gas as a chemical feedstock for higher value goods such as synthetic liquid fuels and oils, methanol, ammonium, and fertilisers, but successful development of technologies for producing polyolefins is challenging.

The use of natural gas as a chemical feedstock depends greatly on economic drivers, both global and local. Currently some 110–160 Bcm of natural gas is used, but this represents only about 5 percent of all fossil fuel feedstock.

**Exhibit 12**  
**Countries with the Largest Fleets of Natural Gas Vehicles, 2008**



Source: International Association for Natural Gas Vehicles.  
90813-9

<sup>\*</sup>Source: International Association of Natural Gas Vehicles (IANGV) *Gas Vehicles Report—December 2008*.

<sup>\*\*</sup>IANGV estimates that consumption of gas in the transport sector worldwide (by cars, busses, and trucks) is much higher than this because of incomplete or incorrect reporting in many countries (some gas used by natural gas vehicles [NGVs] could be reported as industrial use, for example if the NGV fleet is an industrial energy fleet). IANGV estimates that global use of gas in the transport sector is around 26 Bcm (IANGV, *Gas Vehicles Report—December 2008*).

The current norm is to produce polymer plastic from ethylene obtained from cracking naphtha, with oil as its raw material. However ammonia, methanol, and hydrogen (H<sub>2</sub>) are usually obtained from natural gas. The share of natural gas is more than 90 percent in the methanol manufacturing process and is more than half in the ammonia manufacturing process. Manufacturing hydrogen from natural gas is the best option until at least 2030.

The amount of ammonia manufacturing increases in proportion to population growth, because most ammonia is used to produce chemical fertilisers. In our IGU Expert View scenario, assuming a population in 2030 of 8 billion people, the demand for natural gas for ammonia rises by 23 percent by 2030.

One third of all methanol consumption is used for methyl tertiary butyl ether (MTBE) and for the biodiesel used in the transportation sector. When biodiesel fuel is manufactured, 3 litres of methanol are required for each litre of colza or Jatropha oil of raw material. Therefore, the demand for natural gas will increase along with the introduction of biodiesel fuel.

Overall the demand for natural gas as a chemical feedstock is expected to expand by 20 percent by 2030.

Natural gas can also be used as a raw material to manufacture synthetic liquid fuels for vehicles through the Fischer-Tropsch (FT) GTL method. Because of its high cost, GTL is expected to remain as a sizeable niche technology that is useful in cases where certain geographic, technical, and economic factors converge.

### New Gas Uses\*

New markets for natural gas are expected to derive from new as well as existing but only marginally deployed technologies, including

- **Hybrid power generation systems.** Though residential hybrid systems will have little impact on total gas demand even if their use becomes more widespread, large-scale hybrid solar and natural gas power generation plants may have a more significant effect. Europe's first of such plants went into operation in Spain in 2008: Andasol I is a parabolic solar trough power plant, with natural gas as a back-up fuel, so that power supply can be maintained even in the event of a long stretch of rainy or overcast days.
- **Micro-CHP.** Micro-CHP can compensate for the intermittent power output from renewable generation technologies such as PV and wind on site. It can enable the use of distributed generation linked to the local grid. Micro-CHP can use gas-fired engines, turbines, and fuel cells, all technologies that are already in use.
- **Fuel cells.** The polymer electrolyte fuel cell (PEFC) technology, which can use either natural gas or hydrogen (the latter usually obtained from natural gas), has already been made available for household use in Japan as of March 2009. Japanese gas companies are also developing the high temperature solid oxide fuel cell (SOFC) technology, which has higher efficiency than the PEFC, and they expect to commercialise it in 2020.
- **LNG as a maritime and road fuel.** The heavy road transport and the shipping industry are responsible for a large part of harmful pollutant emissions and CO<sub>2</sub> emissions; therefore substitution of liquid fuels with gas would yield significant environmental benefits. Though CNG-fuelled trucks, locomotives, and ships already exist, the use of LNG as a fuel offers the advantage of loading more fuel and enabling longer travel distances between re-fuelling. LNG is already used as a fuel for heavy road transport for one route in China and on the M1 in the United Kingdom. Norwegian ship owners have been forerunners for LNG-fuelled ships.
- **Mixing hydrogen into natural gas at grid level.** In a similar development to mixing bio-methane into the natural gas grid, the possibility of injecting pure hydrogen into natural gas pipelines is currently being investigated in the European Union (the NATURALHY R&D project). Current studies estimate that it may be possible to transport in excess of 30 percent hydrogen in existing high-pressure transmission networks. However, given that many domestic appliances in use today are not new, are not of the pre-mixed design, and are not subject to rigorous maintenance, the maximum allowed percentage of hydrogen in natural gas may turn out to be 10 percent or less.

\*The IGU report "Natural Gas Unlocking the Low Carbon Future" offers a comprehensive analysis of the technologies available today to reduce GHG with the help of natural gas.

The extent to which these technologies will be deployed or used more widely in more countries depends not only on technological and economic factors, but also on adoption of the appropriate policies and regulations (e.g., tighter limits on local pollutant emissions, stricter energy-efficiency regulations, or new climate-related commitments). The IGU Expert View scenario projects the gradual implementation in a few countries of these new technologies in a few countries.

### *Is Hydrogen a Threat or an Opportunity for Natural Gas?*

The further end-use decarbonisation of energy will ultimately depend on switching to hydrogen (H<sub>2</sub>), together with a higher use of carbon-neutral renewables. Hydrogen is a young and thriving industry. Globally some 50 million tonnes (mt) of hydrogen are produced annually and transported over a network of nearly 3,000 kilometers of hydrogen pipelines, equally shared between North America and Europe. This is equivalent to about 170 million tonnes of oil equivalent (mtoe), or about 7 percent of global natural gas production. Today very little hydrogen is used directly for energy purposes; it is used extensively in the petrochemical, fertiliser, and refinery industries. About half is used to produce ammonia for fertilisers via the Haber process. The other half is used to convert heavy petroleum sources into lighter fractions suitable for use as vehicle fuels.

Currently about half of global hydrogen production is from natural gas, 30 percent is from oil, and most of the rest is from coal. Water electrolysis, contrary to widespread belief, accounts for only 4 percent.

In the medium term, as hydrogen use increases, an increase in the use of gas to produce hydrogen can be expected. If the natural gas could be converted into hydrogen directly at the processing plant, this could lead to the conversion of substantial parts of existing natural gas infrastructure to hydrogen systems as well as to the development of new, purpose-built 'hydricity' systems (see below) based on natural gas as the hydrogen feedstock. In the longer term, however, it is expected that hydrogen will be produced mainly using non-carbon sources such as renewables and nuclear. At the same time, as discussed in the previous section, hydrogen can be used as a direct substitute for gas or to complement it.

### Hydricity

Since hydrogen, like electricity, does not produce CO<sub>2</sub> or pollutants at the point of use and can be produced, like electricity, from a variety of sources, both renewable and non-renewable, hydrogen could be used in the future in the same way as electricity: an energy carrier linking energy sources with energy-consuming services. This concept is called 'hydricity'.

Natural gas is both a source of hydrogen and a source of electricity. So natural gas is likely to play an important role in any hydricity system. Furthermore the delivery of hydrogen could be achieved through adapting or expanding parts of the gas pipeline system.

The IGU Programme Committee A (PGC-A) on Sustainable Development has analysed the prospects for hydricity system and concluded that a full implementation of hydricity systems will not happen before 2030, because it would require the construction of costly new infrastructure and the solution of many technical problems, from cheap production to safe storage and use of hydrogen. In Japan, for example, the deployment of a local hydrogen network is expected between 2030 and 2040 in order to achieve a 70–80 percent reduction of GHG by 2050.

Our IGU Expert View scenario assumes that the development of hydricity systems will be limited to some small local areas or pilot schemes that globally will not require more than 10 Bcm of natural gas by 2030. The expected impact on the size or activities of the gas market in 2030 is therefore not significant.

A wider deployment of hydricity systems would require adequate political and economic incentives to support a global drive toward low-emission hydricity technology. Currently there is little sign of the political will required to accomplish this.

### **Natural Gas Production to 2030**

Proven natural gas reserves have grown in tandem with natural gas demand and production. The reserves-to-production (R-P) ratio has remained remarkably stable in the past two to three decades, at around 60–65 years. Although geopolitical challenges related to access and transportation remain, natural gas reserves are sufficiently abundant from a geological perspective to serve a much larger gas market, and the recent developments to exploit unconventional gas—tight sands, CBM, and shale—located



near large consuming markets suggest that commercially viable gas resources may be both significantly more prolific and more widespread across the globe than believed previously.

### Natural Gas Production by Region

In the IGU Expert View scenario, global gas production capacity is expected to reach 4.4 Tcm in 2030, including both conventional and unconventional gas.

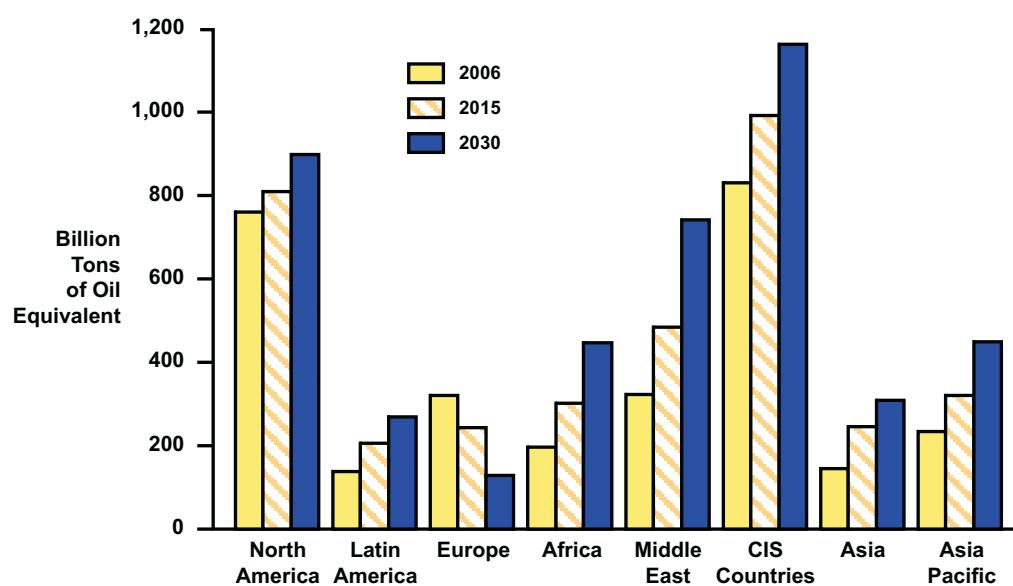
Exhibit 13 shows our regional outlook for natural gas production. The key drivers that are expected to determine natural gas production growth in the various regions are

- the level of remaining reserves and prospects for new gas discoveries
- the location of reserves relative to main markets
- the level of domestic and regional market development and the export opportunities
- a stable political and legal framework and predictable policies
- availability of capital and attractiveness for investment

Unconventional gas—and particularly shale gas—has led to large revisions for prospectivity in North America, the world's most mature and explored region. Indeed, North America was the fastest growing region in production additions in 2008, faster even than Qatar.

An increasing proportion of gas supply, particularly in North America but also in Asia and Africa, will come from more challenging reservoirs and unconventional gas sources (tight gas, CBM, shale reservoirs). According to the Energy Information Administration (EIA), unconventional gas (in particular shale gas) is expected to account for more than 55 percent of US gas production in 2030, compared with around 40 percent today.

**Exhibit 13**  
**Gas Production by Region, 2006–2030**



Source: IGU.  
90813-13

The potential for unconventional gas in other parts of the world is significant, although unproven. The challenge for large-scale unconventional gas development outside North America is that the conditions that enabled a rapid development in the United States—a large, integrated, open-access pipeline system; private ownership of the mineral rights; a large market; and a group of independent producers willing to experiment and take risks—are less evident elsewhere.

CBM also has significant potential, as coal is abundant and very widely distributed. There was recently a significant upward re-evaluation of Australian gas reserves based on CBM activity. There is significant potential for CBM in Asia and Africa. However, since CBM has strong water disposal implications, its development will likely differ among countries according to their environmental conditions and policies.

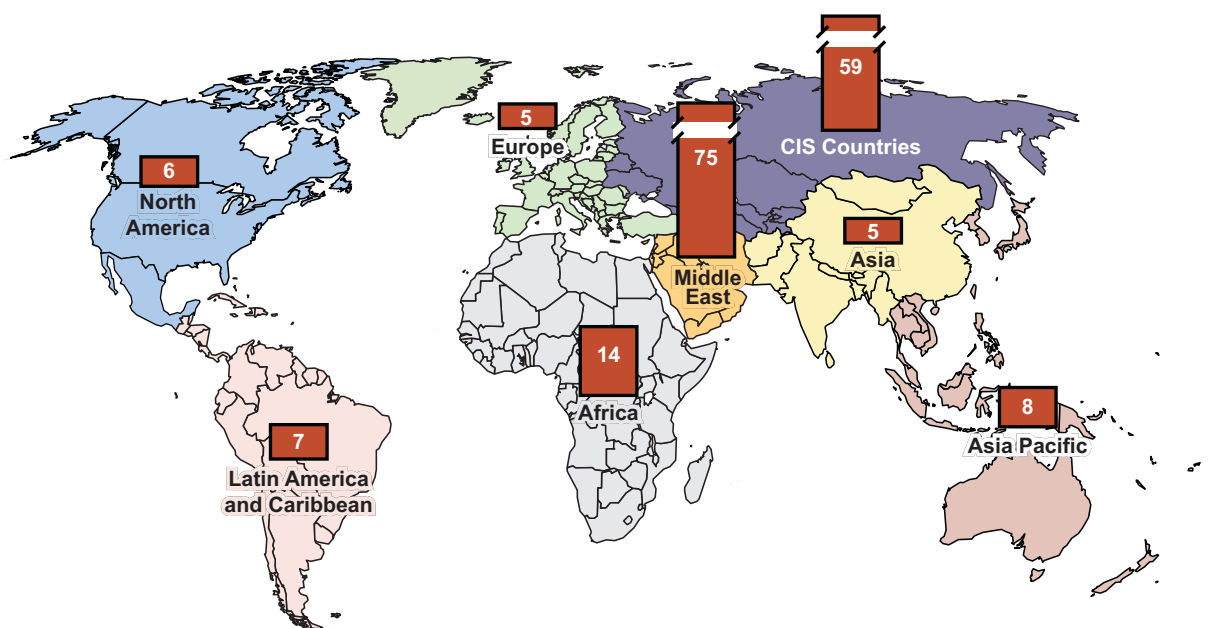
Finally, gas hydrates are a vast potential resource that can contribute to gas supply in the longer term. However, the IGU Expert View scenario considers that other sources of gas will be sufficient to meet demand, and therefore significant commercial exploitation of methane hydrates will not be required before 2030.

**Natural Gas Reserves and Remaining Resources**

Current proven reserves are more than sufficient to guarantee future production to 2030 and beyond. The production outlook in the previous section represents a total reserve draw of about 87 Tcm, equivalent to 3,045 trillion cubic feet (Tcf), between 2008 and 2030, well below today’s total proven natural gas reserves, which are estimated at 181 Tcm (6,635 Tcf) as of the end of 2007.

But exploration for natural gas will not stop today, and we expect that many gas reserves not yet proven or even discovered today will be in production in 2030.

**Exhibit 14**  
**Distribution of Proven Gas Reserves**  
 (trillion cubic meters)



Source: IGU.  
 90813-20

In addition to the above numbers, the quantities of gas that may ultimately be accessible from shales worldwide are enormous, though defining the reserves levels of gas shales is difficult (see the text box ‘The Challenge of Assessing Shale Gas Resources’).

Though the amount of reserves may not be a concern, their location may be. Exhibit 14 shows that gas reserves are very concentrated regionally: the CIS and the Middle East account for 75 percent of total natural gas proven reserves, and 55 percent of reserves are concentrated in just three countries (Russia, Iran, and Qatar). Unconventional gas resources, however, are more evenly distributed than conventional gas reserves. Hence, their increasing development is likely to reduce security of supply concerns arising from the high geographical concentration of conventional reserves.

Another problem is that new conventional gas reserves are discovered increasingly far from demand centres. Currently an estimated 86 Tcm (3,000 Tcf) of proven reserves are considered ‘stranded’; i.e., located too far away from pipeline infrastructure or population centres for its transportation to be economical. Even reserves that are not stranded are discovered in increasingly difficult environments: new discoveries of conventional gas are increasingly offshore and at increasing depth. By 2030 it is estimated that roughly half the world’s gas supplies will be produced from offshore reservoirs, compared with 26 percent in 1995 and 39 percent in 2005.

### Biogas Production\*

Biogas is produced from the anaerobic fermentation of biomass and solid wastes. Included in this category are sewage gas, landfill gas, sludge gas, and other biogas manufactured from the anaerobic fermentation of agricultural waste, animal manure, and wastes from abattoirs, breweries, and other agro-food industries. Biogas can be combusted ‘as is’ to produce heat and/or power locally or it can be purified into bio-methane that can be injected into the gas grids.

According to IEA statistics, in 2006 the biogas produced globally contributed around 13.6 mtoe to global energy supply, equivalent to approximately 0.5 percent of global natural gas supply.\*\* Of total biogas, 70 percent was produced in OECD countries and 30 percent in developing countries, practically all in China. The drivers, technology, and segment of use of biogas are very different between developed and developing countries.

China is the reference country in biogas production; it began biogas production in 1958 to solve the problem of manure disposal and improve hygiene. Today, China has the largest number of biogas plants, but these are mainly very small farm-based units aimed at supplying the cooking gas needs of a family or a small rural community. Though the individual production may be small, the technology is widespread (some 50 million families are expected to use biogas in 2010) and very worthwhile economically (if a family or community produces biogas from its own wastes, it can save between 25 and 50 percent of the liquefied petroleum gases [LPG] it uses for cooking). It is a worthwhile example that can and should be duplicated elsewhere in the developing world. China plans to increase investments in this area and could well export the technology outside its borders.

#### The Challenge of Assessing Shale Gas Resources

The large-scale production of gas from the non-permeable shales in North America in the past two years poses fundamental questions about the process of defining reserves and assessing likely future trends. Producibile gas reserves are now no longer limited to the permeable stratigraphic formations that have conventionally been deemed to hold ‘reserves’ but can be extended to the source rocks whose producibile volume cannot readily be assessed because they do not ‘flow’ gas in the absence of fracturing. The area extent of these shales is enormous, but the fracture characteristics are not uniform. So far, there is no reliable basis for estimating what the reserve base may be in the shales, either in North America or elsewhere. This poses new challenges both in valuing the assets of companies that have access to these reserves and in defining the future volumes of gas that may be available to market.

Worldwide the quantities of gas that may ultimately be accessible from the source rocks are enormous. They may be significantly larger than figures cited above.

\*In the statistics presented in this report, biogas is included in the renewables, not the natural gas, category.

\*\*See Section on Frame-breaking Markets for more information on the Chinese biogas experience.

China also plans to increase the number of large-scale biogas power plants connected to the grid. According to the Chinese Academy of Sciences and Geography, China's total annual production of manure and night soil could theoretically generate about 130 Bcm of methane, which could replace 93 mt of coal used in power generation.

Biogas production in developed countries is mainly large scale, derived from waste and sewage, and used to produce electricity (75 percent) and in industry (20 percent). Europe currently dominates large-scale biogas production, although there is a growing biogas industry in other developed countries such as the United States, Japan, New Zealand, and Australia. Europe uses biogas to fuel power generation (there are currently 3,500 biogas plants able to fuel about 1.1 gigawatts of power). There are also examples of waste-produced biogas that is used to fuel a fleet of CNG waste trucks.

Biogas can be purified and upgraded to natural gas quality for injection into the natural gas grids. This way biogas can be used (mixed with natural gas) more widely. Some examples of purified bio-methane injected into the pipeline grid already exist. In 2008 in the European Union there were about five plants in Switzerland, four in Sweden, and five in Germany injecting bio-methane into gas grids, with others following planning stages. The main barrier to large-scale bio-methane production is the lack of biogas resources close to gas grids, but future technological developments (i.e. biogas produced from designer algae or other microbes) may help to overcome the resource problem.

Opinions as to the potential and real opportunities for biogas growth in the next two decades vary considerably, ranging from a very conservative 34 Bcm (which might refer mainly to the prospects in developed countries) to an ultra-optimistic 220 Bcm in 2030 (where analysts are including the biogas potential of China and other developing countries).\*

While biogas competes with natural gas to a certain extent, we believe that it constitutes more of an opportunity than a threat for the gas industry. Mixing biogas with natural gas helps to 'decarbonise' the gas chain, further 'greening' the image of natural gas, which is essential if natural gas is to survive in a low-carbon world. On the other hand, it is clear that biogas production will never reach the scale necessary to replace a large proportion of natural gas supply, but biogas will benefit from the infrastructure and markets created for natural gas: in this sense natural gas is an 'enabler' for biogas, as it is for other renewable energy sources.

Biogas in developing countries does not threaten natural gas at all, as it replaces LPG and biomass solid fuel and eventually offers an avenue for the development of pipeline gas.

## Gas Trade Flows and Infrastructure to 2030

### *Inter-regional Trade Flows*

The regional distribution of natural gas production and demand in the IGU Expert View scenario implies that an increasing volume of gas will be traded across country borders and between regional blocks.

It is important to recall that the methodology used to establish the IGU Expert View scenario is based on a regional analysis and results in a potential global mismatch between total gas supply and demand. For example the IGU Expert View scenario outlook is for global gas supply of 4,415 Bcm and global gas demand of 4,331 Bcm in 2030. In practice supply will balance with demand through either lower production or higher demand, with price being a balancing factor. We have assumed in this section that gas production is reduced when necessary to match demand rather than gas demand increasing. The trade flows shown in this section are therefore only one of several possible outcomes, even for the specific data of the IGU Expert View scenario. Which gas is turned down and which gas reaches the consuming market will depend on relative prices, in particular where the consuming market has a choice between local production, flexibility in pipeline import contracts, and LNG cargoes.

In Europe domestic production will decline and import dependency will increase significantly. In 2030 imports from outside Europe are expected to represent over 80 percent of supply by 2030, with LNG accounting for about 38 percent of this volume.

In North America conventional gas production is expected to decline, but the large increase in unconventional production will more than compensate. The large increase in LNG imports that was projected even as recently as two to three years ago is no longer in sight owing to the shale boom and the lower demand levels resulting from the economic downturn. Nevertheless the

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\*Differences can also be due to the fact that biogas can be measured in Bcm of biogas or in Bcm of natural gas equivalent. Non-purified biogas has a much lower calorific value than natural gas: as low as 50 percent in some cases.

United States is a liberalised market with gas-to-gas competition, so the competition between unconventional gas and LNG imports will depend on prices.

The CIS, the Middle East, and Africa are exporting regions, with the CIS providing the bulk of the additional demand for exports, now and in the future. Despite rising domestic demand, the share of their exports over production will increase: in 2030 the CIS, Middle East, and Africa will export 23 percent, 32 percent, and 51 percent of their respective production, compared with 19 percent, 20 percent, and 53 percent in 2007. However, huge investments are necessary to increase gas production and export infrastructure in the three regions, and geopolitical factors (including transit issues, that can potentially jeopardise reliability of supply) are a further concern.

Asia and Asia Pacific are very diversified regions that include both large gas exporters and large importers. Asia has the largest share of world population and rapidly rising energy needs. Asia's dependence on imported gas is expected to increase from the current 8 percent to 37 percent of total demand by 2030, owing mainly to the large and expanding markets of China and India. Huge investments in pipelines, LNG terminals, and distribution networks will be necessary.

Pipeline imports into Asia will compete with European demand. To the extent that greater volumes are delivered by pipeline to Asia from the CIS, more LNG will necessarily move from the Middle East into Europe to replace the shortfall. Within the Atlantic Basin, LNG balances the pipeline supplies from Africa and the Middle East to Europe.

Asia Pacific, conversely, will turn from being a small net importer in 2007 (5 Bcm) to exporting 30 Bcm to Asia by 2030, owing mainly to the substantial increase in Australia's gas production and exports. Gas production is expected roughly to keep up with gas demand, with a small net deficit. Towards 2030 a push for new gas sources (e.g., methane hydrates), particularly by Japan and Korea, will be responsible for increasing gas production. The region will need large investments in LNG liquefaction plants, ships, and LNG regasification terminals.

Latin America and the Caribbean constitute a diversified region with gas importers and exporters, and some flows are expected to change direction. Net gas exporters such as Mexico and Argentina are set to become net importers soon. The region as a whole is currently a small net exporter (mainly because of Trinidad and Tobago) but will become a net importer before 2025, although the Caribbean is expected to continue to be a net LNG exporter. To guarantee regional supply security and market integration, substantial investments are needed.

The current and expected inter-regional gas trade flows are shown in the maps in Exhibits 15 and 16, where the black arrows represent LNG flows and the red arrows show pipeline trade flows.

Overall the trade flows shown for 2030 tend to indicate that local production will be preferred to imported LNG, but if the costs of local production are not competitive then LNG imports would increase, for example into North America. In practice we would expect seasonal and indeed shorter-term price variations that would increase the variety of LNG trade routes for 2030 and make the trade patterns more complex.

### **Pipeline Flows and Infrastructure**

Pipelines will continue to meet a large portion of the international transportation requirement of natural gas, particularly into Europe and Asia. But even in these regions, the share of LNG imports is expected to increase as LNG contributes to improving supply diversity and flexibility, as a complement to intercontinental pipeline trade.

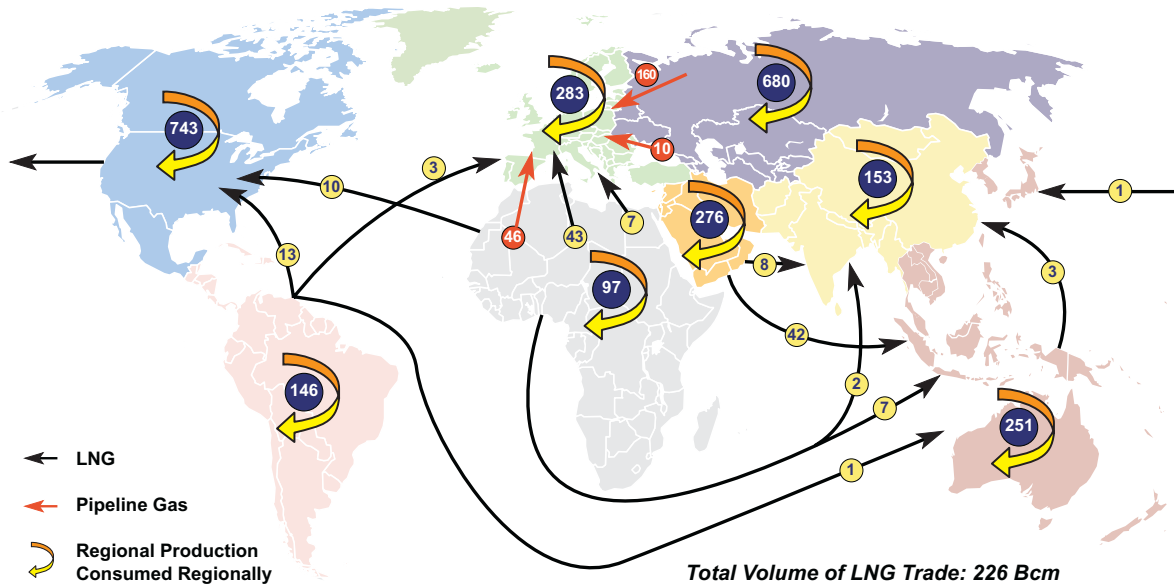
Pipeline trade is of two types:

- within regions (shorter, mostly bi-national, pipelines)
- between regions (much longer cross-continental and undersea pipelines)

In the second case, the main exporting regions are the CIS, North Africa, and the Middle East; and the main importers are Europe and Asia (see Exhibit 17).

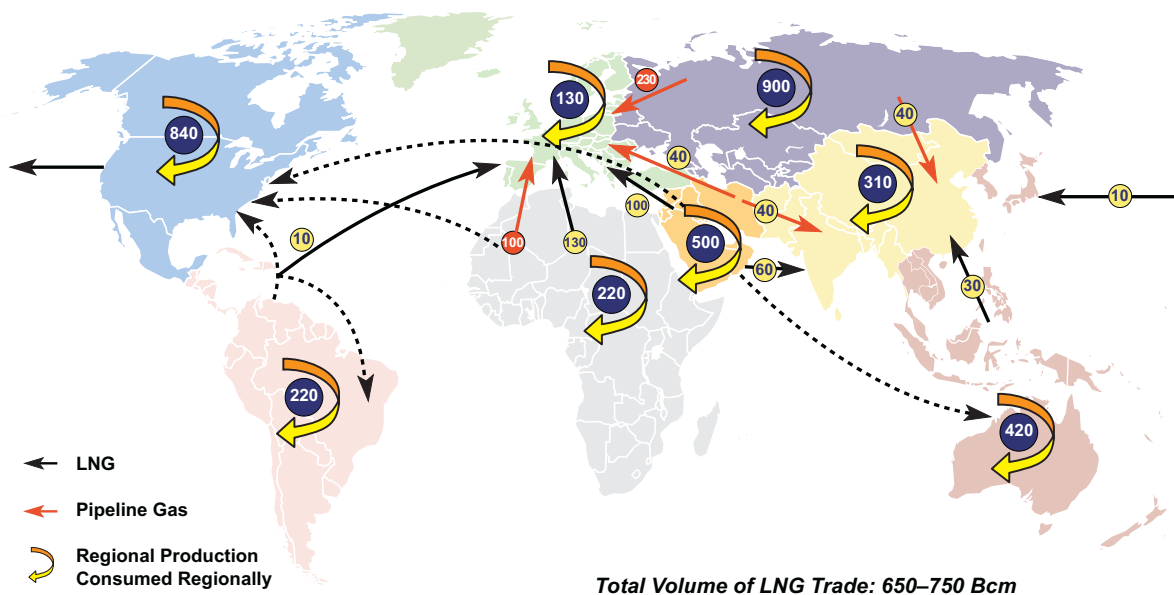
Gas transportation companies are likely to consider developing pipelines for hydrogen or for sequestered CO<sub>2</sub> for storage, as the gas industry plays a new role in energy security and climate change mitigation. Pipelines are expected to alter and expand gas's role and to become a key infrastructure element in realising the energy system of the future, a 'smart energy network', in

**Exhibit 15**  
**Inter-regional Gas Flows, 2007**  
 (billion cubic meters)



Source: IGU.  
 90813-21

**Exhibit 16**  
**Estimated Inter-regional Gas Flows, 2030**  
 (billion cubic meters)



Source: IGU.  
 90813-22

## Exhibit 17

## Inter-regional Pipeline Flows in 2030

(billion cubic meters)

Exporters	Importers		Total Pipeline Exports
	Europe	Asia	
CIS	230	40	270
Africa	100		100
Middle East	40	40	80
<b>Total Pipeline Imports</b>	<b>370</b>	<b>80</b>	<b>450</b>

Source: IGU.

which the integration of distributed generation and renewables increases the efficiency, flexibility, safety, reliability, and quality of gas and power networks.

### LNG Flows and Infrastructure

In the IGU Expert View scenario some 650–750 Bcm of LNG will be traded in 2030, compared with 226 Bcm in 2007. Roughly half of future LNG trade is expected to be take place intra-regionally, particularly in Asia Pacific, and the rest will be traded between the regions, as shown above.

The main LNG-exporting regions will remain the Middle East, Africa, and the CIS, while the main LNG-importing regions will be Europe and Asia. Asia Pacific is expected to be both an important LNG exporter (from Australia) and an important LNG importer (into Japan and Korea).

The Latin America and Caribbean region is expected to remain roughly in balance, exporting LNG from Peru and possibly from Venezuela and importing LNG into Argentina, Chile, Uruguay, and possibly Colombia. Brazil is likely to simultaneously import and export LNG.

North America is now expected to remain roughly in balance but with the capability to accept large increases in LNG imports if LNG cargoes are available at prices below local production costs. Seasonal variations and geographic price variations (allowing exports of small volumes from its Pacific coast) could cause gross North American LNG trade to significantly exceed the small net quantities indicated here.

Europe has a mature gas market and is already a major importer of pipeline gas and expecting more LNG. Security of supply issues may drive LNG imports, which are expected to jump from 53 Bcm in 2007 to 230 Bcm in 2030 and to come from Africa and the Middle East.

Asia is competing with Asia Pacific for global LNG supply. In 2007 Asia's LNG demand was 13 Bcm and by 2030 it is expected to increase to 100 Bcm, which will come from Middle East and Asia Pacific.

In the Middle East, Qatar has the largest potential for increasing gas production and exports, as it has the largest (by far) known gas field. Iran also has large reserves. LNG exports from the Middle East are expected to rise from 57 Bcm in 2007 to 160 Bcm in 2030. The Middle East's main markets are Asia Pacific, Asia, and Europe.

Africa becomes South and North Americas' primary LNG supplier. The region currently exports 62 Bcm of LNG to North America, Latin America and the Caribbean, and Europe and is expected to export 130 Bcm by 2030.

Regasification capacity is expected to expand globally, especially in Europe, Asia, and Asia Pacific. Despite difficulties in obtaining planning permissions in some locations, the availability of regasification terminals is not expected to be a bottleneck in the global LNG chain. Indeed, we expect that LNG regasification capacity will continue to exceed LNG production capacity through

2030. Regasification terminals are relatively cheap to build (compared with liquefaction) so that they may be constructed to increase diversity of supply even if their expected average utilisation is relatively low. The industry has demonstrated the ability to quickly build regasification facilities as they are required.

Floating regasification is expected to grow. Floating solutions offer three potential advantages over traditional regasification terminals. First, they can be built offshore in cases where environmental sensitivities make the siting of onshore terminals problematic. Second, they can be built more quickly and may therefore provide a fast-track solution to LNG imports. Third, they require a lower upfront outlay of capital, though they have higher operating costs over time.

Shipping is not expected to be a bottleneck in the capacity build-up to 2030. Today's shipping fleet comprises 255 ships (2007). To transport 750 Bcm of LNG per year will require 425 ships on 100 percent utilisation, or 500 ships at normal utilisation (less than 100 percent utilisation is more likely, as it enables global LNG suppliers to meet changing demand requirements in the markets). We assume that by 2030, 300 ships will be of the conventional size of 135 to 160 thousand cubic metres (Mcm) and the remainder will be larger, more efficient ships on the order of 175 to 265 Mcm.

Regarding liquefaction, small-scale LNG liquefaction plants (capacity of less than 1 mt per year) can be a good match for smaller fields (of less than 1 Tcf). More than 1,500 fields worldwide fit this range; hence significant growth is anticipated. Small-scale projects currently in operation, under construction, and proposed add up to approximately 6 mt per year by 2011/12. As these projects generally have a shorter development phase than the larger-scale LNG plants, a growth factor of over three by 2030 does not seem unrealistic (20–25 mt per year). A range of 15–30 mt per year by 2030, depending on whether the LNG market development scenario is weak or strong, seems plausible.

No floating LNG liquefaction facilities are in operation yet (as of August 2009). If the current market pull and energy prices remain favourable, 5–10 mt per year of floating LNG could be in operation by 2015. By 2030 this could be increased by a factor of one to three. This outlook is highly speculative.

LNG trade is becoming more flexible, which will benefit customers as well as suppliers. Allowing the markets to work naturally will ensure that LNG makes its way to the customers that need it the most. There will be adequate terminals and ships to deliver the LNG in the future and a reasonable balance by market between LNG supply and demand, which will lead to lower-cost transportation.

### Storage Infrastructure: Its Future Role in Flexibility and Security

In the IGU Expert View scenario, not only does gas demand increase, but import dependency of the largest markets also increases. We expect this to lead to an increase in demand for storage capacity both for security-of-supply reasons and as an economic option to moderate price volatility: when gas prices fall, more gas can be put into storage with the intention that it be taken out later when prices and gas demand are higher. Declining conventional production close to markets (for example in Europe) will drive an increased need for storage, because imports of pipeline gas are generally delivered with less volume flexibility than local production.

The expected increase in LNG trade will not necessarily reduce demand for storage. It may in fact require increased storage capacity, both at the LNG reception terminals and in the downstream markets, for economic optimisation and security of supply reasons.

Based on the initial assumptions for the IGU Expert View scenario that were sent to all IGU Committees, the IGU Storage Committee developed in 2008 a regional and global assessment of the future storage capacities and the related incremental investment required (see Exhibit 18).

Although these detailed projections were carried out before the full effects of the economic downturn emerged, which warrants a slight downward revision for the short to medium term, they do provide a good guide to the long-term investment implications of the IGU Expert View scenario. Global demand for gas storage capacity is expected to rise from 333 Bcm in 2005 to 543 Bcm in 2030, or 63 percent. The term storage capacity as used in this report is the same as what is sometimes called working gas volume (WGV). WGV is the total amount of gas that could be put into storage, and then taken out during a storage cycle. Storage capacity is usually sold as a bundled product, taking account of the injection rate and withdrawal rates that can be achieved for the particular type of storage facility. Very fast withdrawal rates can be achieved from LNG storage, but underground reservoirs



## Exhibit 18

## Expected Evolution of Underground Gas Storage Demand, 2005–2030

## Demand for Working Gas Volumes (Bcm)

Region	2005	2010	2015	2020	2025	2030
Europe	79	93	109	121	129	135
CIS Countries	136	148	156	165	173	177
Asia Pacific	2	2	4	8	10	12
Asia	1	2	5	12	20	21
North America	116	134	153	162	172	187
Latin America & C.	0	1	1	2	3	4
Middle East	0	0	0	2	3	4
Africa	0	0	0	1	2	3
<b>World</b>	<b>333</b>	<b>379</b>	<b>428</b>	<b>473</b>	<b>513</b>	<b>543</b>

## Cumulative Incremental Working Gas Volumes (Bcm)

Region	2010	2015	2020	2025	2030
Europe	14.0	30.0	42.0	50.0	56.0
CIS Countries	12.0	20.0	29.0	37.0	40.0
Asia Pacific	0.5	2.3	6.0	9.0	11.0
Asia	1.5	4.5	12.0	20.0	20.0
North America	18.0	37.0	46.0	57.0	71.0
Latin America & C.	0.4	0.8	1.9	2.9	4.2
Middle East	0.3	0.4	1.7	2.9	3.9
Africa	0.1	0.3	0.8	1.9	3.4
<b>World</b>	<b>46.0</b>	<b>95.0</b>	<b>139.0</b>	<b>180.0</b>	<b>209.0</b>

Source: IGU.

provide the largest WGV storage capacities. The demand for incremental deliverability may result in an increased withdrawal rate of an additional 200 million cubic metres per hour by 2030.

Storage of gas in gaseous form also generally requires ‘cushion gas’ which remains in the store when the working volume is withdrawn. The amount of cushion gas required depends on the type of storage and has a significant proportionate impact on project economics, as shown in Exhibit 19. Demand for cushion gas in the scenario period is expected to be in the order of 230–320 Bcm, which would need to come from world gas supplies, or existing reservoirs, prior to 2030.

When oil and gas prices are high, upstream companies have a greater incentive to develop new exploration and production (E&P) projects. The demand for rigs, engineering competencies, steel, and other E&P requirements increases, with the consequence that the price for all these materials and services, which are also required to build new storage capacities, also increases.

Good locations for storage sites will be increasingly difficult to find and will face conflicting political and economic pressures (e.g., the cost of cushion gas is lowest in producing countries, but transportation costs imply that storage should be close to the market).

## Exhibit 19

## Relative Capital Costs of Underground Gas Storage Projects

Capital Costs for	Type of Underground Storage		
	Salt Caverns	Aquifers	Depleted fields
Cushion Gas Cost	15%	40%	0–40%
Well & Caverns	30%	40%	15–50%
Surface Facilities	55%	20%	40–60%

Source: IGU.

Technologies to improve the capacities and performance of existing underground gas storage (UGS) facilities will be of major interest. Focus on improving flexibility of operational response will increase, reducing the environmental impact and increasing the lifetime of storage facilities.

### Frame-breaking Markets

China, India, and Brazil are large economies with the potential to develop sizeable gas markets in the medium to long term, although today their gas industry and infrastructure are still at an early stage of development. These countries are expected to dominate their respective regional gas markets by 2030, and while increases in gas production are expected in all three countries, demand is likely to grow faster, with a significant impact on global gas flows.

China and India are especially important because their energy mix is currently dominated by coal; hence a significant penetration of gas in substitution for coal would have considerable effects on the region's CO<sub>2</sub> emissions.

In Brazil gas will displace fuel oil in the industrial sector and will compete with other hydrocarbons for thermal power generation. Although hydropower will continue to be the main source of power, thermal generation will increasingly be needed as cost-effective insurance against the weather-related variability of hydropower.

In all three countries, the penetration of gas in the primary energy mix in general, and in the power generation mix in particular, will depend crucially on relative fuel prices and environmentally related government policies.

### China

China currently accounts for nearly 40 percent of Asia's gas demand, compared with 70 percent of the region's total primary energy demand and 63 percent of GDP. The share of natural gas in the primary energy supply is still very low (3 percent), compared with the rest of the world (21 percent in 2006). However, China's long-term plans for natural gas's share in primary energy demand, set out in the National Energy Policy and Strategy Report (2004), are for a 10 percent share by 2020.

Natural gas consumption has been particularly strong since 1999 (17 percent per year on average). Industry is the main consumer (44 percent of total gas demand). Power generation's share of total gas demand is still low, at 15 percent.

Official government projections are for natural demand to increase to 220–250 Bcm in 2020 and to 320–360 Bcm in 2030, driven mainly by the industrial and residential/commercial sectors. IEA's forecast is more conservative, projecting gas demand at 140 Bcm in 2020 and 200 Bcm in 2030.

The 2004–20 energy programme adopted in 2004 has three priorities: energy conservation, the development of coal-based electricity capacity, and the development of the oil and gas assets. Higher demand growth for electricity, oil, and gas is centred in the richer, more dynamic coastal regions. In the central, western, and northern areas, coal will continue to provide most of the energy.

Current production is still modest (70 Bcm in 2007), but it has been growing at an average rate of 12 percent per year since 1997, with a significant acceleration in the past few years (18 percent in 2007). Four areas in China are gas rich: the Tarim Desert, Shaanxi-Gansu-Ningxia, Sichuan, and Qinghai. China's natural gas proven reserves are estimated at 1880 Bcm (CEDIGAZ 2007).

The Chinese government projects domestic production of 150–180 Bcm in 2020 and 250 Bcm in 2030, though this is generally regarded as very ambitious. Indeed the IEA's World Energy Outlook (WEO) 2008 suggests that production may rise to 115 Bcm in 2030. Yet, the government's targets are not totally unrealistic, considering the significant estimated resource base and the impressive growth in production of the past five years. Production is located in the centre and the western part of the country, and bringing the gas to the southern and eastern provinces where demand is concentrated will require huge investments in pipelines and storage facilities.

It is not surprising that China, given its vast coal reserves, also has great expectations about the potential of coal-bed methane. To date, production of CBM is very small, and there are great uncertainties surrounding this resource's potential.

China is the reference country in biogas production and plan to increase investments in this market. China began biogas production in 1958 to solve the problem of manure disposal and improve hygiene. By the end of 2006, biogas production averaged 8.5 Bcm, equivalent to approximately 5.5 Bcm of natural gas. The goal of China's 2003–10 National Rural Biogas Construction Plan is to increase biogas-using households by a further 31 million to a total of 50 million by 2010, meaning that 20 percent of total rural households would use biogas.

China also plans to increase the number of large-scale biogas power plants connected to the grid. According to the Chinese Academy of Sciences and Geography, China's total annual production of manure and night soil could theoretically generate about 130 Bcm of methane, equivalent to 93 mt of coal. Eighty percent of industrial wastewater can also be used to produce methane.

Pressed by shortages of peak-load capacity and growing concern about pollution from coal burning, China has begun to import LNG for electricity generation. A number of regasification facilities were built and more are under construction or planned, especially in the eastern part of the country, where access to coal resources is limited. Though China holds great potential for LNG use, the growth of the LNG market may be limited by competition with cheaper coal. Investments in infrastructure are fundamental to developing the gas market there.

Significant new imports of pipeline gas will also be required, to satisfy the forecasted demand. During summer 2009, however, there have been reports of stalled negotiations between Russia and China on this issue.

## India

India accounts for another 24 percent of Asia's gas demand. India's energy demand is dominated by coal and biomass, and the share of natural gas is still relatively low (6 percent). India's natural gas demand was 45 Bcm in 2007. By 2030 gas demand is expected to reach 116 Bcm, with an unchanged share in the primary energy mix. The industrial sector will still dominate the demand structure, but with a decreasing share. The share of residential/commercial gas demand is expected to double by 2030 as a result of expanding gas distribution networks.

Energy prices including gas prices are heavily subsidised for power and fertiliser feedstock or CNG vehicles fuel. About 50 percent of the gas is sold under the "Administrated Pricing Mechanism" (APM). Gas from LNG or that produced locally from fields under production-sharing contracts is not covered by APM.

The policy framework for natural gas includes intensifying domestic exploration efforts (including CBM); facilitating projects to address emerging supply-demand gaps; promoting a rational tariff and pricing policy; and creating a policy framework that supports more environmentally friendly energy sources. Midstream, the government's major priority is the construction of a National Gas Grid (NGG) entailing 14 long-distance pipelines across 15 states, with a total combined pipeline length of 7,900 kilometres.

Natural gas production, which was almost negligible when India attained independence, is currently around 38 Bcm (2008) and expected to grow steadily to reach 81 Bcm in 2030. Though the potential for gas growth exists, the main challenge is the low price gas fetches on the local market.

Like China, India too has substantial potential for CBM. But unlike China, India does not yet have significant biogas production. Nevertheless, China's biogas experience could be reproduced in India and would be aligned with the government's environmental policies.

LNG imports will be needed to guarantee supply security. By 2030 imports are expected to meet 30 percent of India's gas requirements.

### **Brazil**

Currently Brazil accounts for 8 percent of gas production and 17 percent of gas demand in the Latin America and Caribbean region. However, Brazil is expected to become a major player in the region by 2030, accounting for one third of the region's gas production and more than 40 percent of the region's gas demand. This would be due in large part to the recent, very large oil and gas discoveries in the subsalt play which are strategically located offshore from the country's two largest energy demand centres, the states of São Paulo and Rio de Janeiro.

The Brazilian government expects the country's natural gas demand to increase from 22 Bcm in 2008 to 97 Bcm by 2030, driven mostly by power sector demand, which is expected to grow to 46 percent of total demand. Gas demand in the industrial sector has the potential to increase substantially, displacing fuel oil, but this will depend on relative prices and infrastructure development.

Gas production is expected to grow 7 percent per year, from 22 Bcm in 2008 to 92 Bcm in 2030. Given that demand is expected to reach 97 Bcm in the same year, Brazil is expected to remain a small net gas importer (5 Bcm is roughly half the volume of gas imported today from Bolivia at full capacity).

Given the great uncertainty concerning the success of exploration and the timing and scale of production from the recently discovered Presalt oil and gas resources, it is highly speculative whether Brazil will turn into a minor LNG importer or an LNG exporter. The country already has two regasification terminals, and two others are under discussion. However, there are also rumours of a plan to build a liquefaction project.

### **Pricing Mechanisms**

The price of most natural gas in international trade and in domestic wholesale markets is established either in locally traded gas markets or in contracts with indexation to competing fuels (mainly crude oil or oil products), or it is set by a government or regulatory authority. The IGU Programme Committee on Strategy, Economics, and Regulation (PGC-B) undertook a survey of the various ways around the world in which gas is priced. The results are summarised in Exhibit 20.

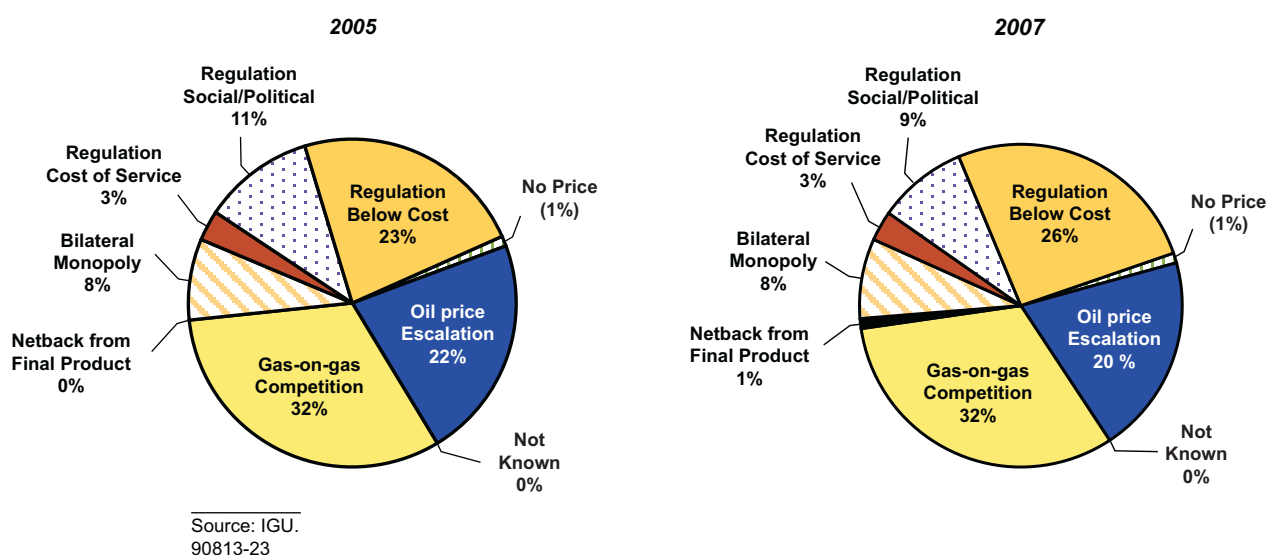
Six main categories of pricing approach were defined:

- gas-on-gas competition
- oil price indexation
- regulation (cost of service or below cost)
- bilateral monopoly
- netback from final product
- no price

Three of these—gas-on-gas-competition, oil price indexation, and regulation (cost of service or below cost)—accounted for almost 90 percent of world gas pricing (defined on a consumption basis).

Just over 50 percent of total consumption is currently priced either through oil price indexation or in gas-on-gas competitive markets, while slightly less than 40 percent is subject to some form of regulatory control. This includes regulation of the price below cost, where gas is subsidised.

**Exhibit 20**  
**World Natural Gas Price Formation, 2005 and 2007**



The respective shares of total world consumption for the categories ‘gas-on-gas competition’ and ‘regulation’ principally reflect the dominance of domestic production consumed locally. Oil price indexation becomes more important because of its dominance in long-term inter-regional gas trade.

The small amount of ‘netback from final product’ pricing is in Latin America (Trinidad to methanol plants), while ‘no price’ (gas effectively given away) is principally in the CIS (Turkmenistan), in the Middle East, and in North America (in Mexico, where PEMEX refineries and petrochemical plants use gas as a ‘free’ feedstock).

In 2007 compared with 2005, gas-on-gas competition-based pricing gained some ground, mostly at the expense of oil price escalation—largely because of growth in spot LNG imports to Japan, Korea, Taiwan, and Spain and in the trading on Continental Europe’s emerging gas hubs. The share of gas transactions at prices reflecting ‘regulation on a social and political basis’ declined from 2005 to 2007, owing mainly to policy changes in Brazil, Argentina, Ukraine, and Malaysia.

### **Evolution of Pricing Mechanisms**

The relative importance of each of these pricing mechanisms in the world’s gas industry could change significantly between now and 2020.

Countries and regions that have adopted gas-to-gas competition-based pricing—North America, the United Kingdom, Australia, and Northwest Europe, where significant volumes are traded on gas indices—are not likely to turn away from this mechanism as long as confidence in the liquidity of the markets is maintained. The remaining oil-linked contract volumes in the United Kingdom and part of Northwest Europe are likely to decline further over time as some buyers find opportunities to insist on competitive gas.

In Continental Europe and in Japan, Korea, and Taiwan, various pricing mechanisms co-exist, with oil indexation playing a dominant role. Opinions on the sustainability of this situation differ but, looking forward, oil indexation provides a reliable basis of liquid markets and, perhaps most importantly, oil markets are independent from the influence of either party in the gas transaction. Both parties can hedge positions—with forward oil contracts or with physical storage provisions—if they wish. Oil indexation is a practical mechanism to enable both buyer and seller to manage their commercial risks and is therefore unlikely to disappear soon. Its relative importance may begin to decline where gas-on-gas competition and traded gas markets develop and the existing contracts present opportunities to change, as for example in Europe:

- Continental European buyers have signed medium- to long-term contracts for an estimated 350–350 Bcm of gas per year, and a very high share of these contracts are of the standard oil-linked type. Annual commitments start declining from around 2015.
- By 2007 existing medium- to long-term contracts corresponded to more than 80 percent of Continental European gas consumption (with the rest being short-term purchases). This share will tend to decline over time. PGC-B estimates that on certain assumptions already contracted supply will meet around two thirds of Continental European gas demand by 2015 and less than a quarter of demand by 2025.
- Take-or-pay provisions in most contracts give the purchaser the option to offtake less than 100 percent of annual contracted volumes, allowing further flexibility if a buyer becomes increasingly inclined to move away from oil indexation.

The European Commission is likely to continue to press for changes in the direction of gas-to-gas competition-based pricing, but it cannot push very hard until trading platforms develop further, offering reliable price information and the full range of trading facilities and services. Continental Europe's gas hubs are likely to take on these characteristics and functions, but this will take time. The difficulties of the banking sector in 2008/09 have highlighted the issue of counterparty risk that is involved in the trading platforms for most commodities and their derivatives.

Similar considerations of stable commercial relations and risk management will be conducive to preserving crude oil indexation in Japan, South Korea, and Taiwan. Alternative pricing models are likely to make only minor inroads.

Legislation to make these countries' domestic gas markets somewhat more competitive has been passed, and their recurrent needs to purchase spot LNG will constantly bring them into contact with the Henry Hub (HH) or National Balancing Point (NBP) price levels (see Glossary in Annex 9). However, there are no champions anywhere in the region for dramatic reforms.

- Like their counterparts in Continental Europe, buyers in Japan, South Korea, and Taiwan have entered into a large number of oil-linked medium- to long-term gas import contracts that limit the pace of potentially introducing alternative pricing principles.
- PGC-B estimates that the ratio of already-contracted supply to future demand could fall from around 80 percent in 2007 to around 66 percent by 2015 and around 25 percent by 2025. But there is no sign that replacement for these volumes will be found entirely in world spot markets.

China and India are in the midst of adjustments to world-level gas prices. These adjustments are driven by a growing need for imported gas and a need to stimulate gas discoveries that will allow significant growth in indigenous production in both countries.

These countries are proceeding, broadly speaking, by introducing competitive pricing for customers that can afford the steep gas cost increases while retaining price regulation for everybody else, but in a differentiated manner, and with the aim of gradually increasing prices across the board. This route offers a pragmatic transition from domestic pricing systems that are dominated by below-cost regulation to alternatives that are characterised by a mixture of below-cost regulation, a type of cost-based regulation, and gas-to-gas competition-based pricing. Pricing will shift incrementally from the first to the second and third pricing principles.

Many other countries than China and India—including the majority of countries in Asia and Latin America, apart from the richest ones, and the gas-importing CIS republics—are aiming to accomplish transitions similar to those of China and India. The timelines vary and are difficult to forecast. Factors such as the pace of economic growth, inflation, and the current government's perception of its freedom of manoeuvre will guide both the timing and the outcome.

Russia appears to be on a broadly parallel course although from a different starting point as the world's biggest gas producer and exporter. Russia's traditionally low domestic gas prices have over-stimulated domestic gas use and limited the incentives for Gazprom and the country's independent gas producers to invest in new fields and new supply infrastructure. The Russian authorities have therefore taken steps to make opportunity costs the guiding principle for domestic gas pricing. Over a period of four to five years prices to commercial, industrial and power sector consumers are to be raised to make producers indifferent between domestic and export sales of gas—the so-called netback parity.

To the extent that European border prices—the starting point for netback calculations—remain oil linked, Russian wholesale prices will come to reflect oil prices too. This could transfer the problems of oil-linked pricing into a Russian market poorly prepared to deal with them, possibly leading to delays, exemptions, and special arrangements that would reduce the transparency of the process.

Many non-OECD countries—in particular those in the Middle East and North Africa that are domestic oil and gas producers—may seek to continue subsidising domestic gas prices. Cheap electricity, gas, and transport fuels can be seen as obligatory government deliverables. Raising gas prices could also make their feedstock-based industries less attractive to investors.

On the other hand, with many North African and Middle Eastern countries beginning to feel the pinch of stagnant indigenous gas supply, intraregional gas exports and imports look set to increase, and this trade will not be at subsidised prices. Qatar is aiming to raise the netback of its LNG sales to Kuwait and Dubai to equal that of its other LNG sales, and if it sells additional pipeline gas to its Middle Eastern neighbours, the United Arab Emirates or Oman, it will do so at international market prices. This will increase subsidisation burdens in the importing countries and could eventually pave the way for domestic price adjustments.

### Price Volatility

A striking aspect of recent gas price developments is that prices seem to have become much more volatile. This impression may be slightly misleading. In absolute terms price gyrations have become stronger. In relative terms—i.e., if one takes into account that prices in recent years have fluctuated around higher averages—volatility appears to have been roughly constant since 2000.

Short-term wholesale price volatility is a feature of gas-on-gas competition-based pricing, but long-term contracts that average the short-term gas price already exist. This mechanism has a similar volatility-dampening effect as the typical Continental European pipeline gas import contract that links the gas price to a basket of oil product prices in an averaged and lagged way that moderates the impact of oil price fluctuations. A typical Asian LNG import contract is structured in the same way, only with the gas price indexed to a basket of crude oil prices.

Gas-on-gas pricing is a symptom, not a cause, of price volatility; market tightness is the other precondition. The recent big gas price changes have been due to supply and demand intersecting with each other at very steep segments of either the supply curve or the demand curve or both. Oil price volatility also plays a role.

The impact of price volatility on investment and efficient markets is unclear. Although some investors pursuing low-risk activities with correspondingly low returns need stable, predictable prices, others thrive on price instability because of the arbitrage opportunities associated with a dynamic environment. Moreover, volatility also acts as a price signal, helping to direct the commodity to its most economically efficient use.

As the gas industry globalises and trade in LNG increases, questions arise about the likely impact of growth in global trade on the volatility of individual regional markets. LNG under traditional long-term take-or-pay contracts is not much different from pipeline gas under similar contracts in its capacity to aggravate or dampen price volatility. However, a material shift to more flexible LNG would imply further commoditisation of gas and different volatility patterns across countries. If, as we expect in the IGU Expert View scenario, an increased volume of LNG can respond to price signals, then the overall trend will be for flexible LNG to dampen volatility.

To some extent this happened in 2008 when Asian buyers had to negotiate at high prices to attract numerous flexible cargoes from the Atlantic Basin. Without this flexible LNG, the Asian prices would have risen even higher, while US prices would have been even lower than they were.

In general the 2008 experience suggests that by making local supply curves less rigid, the advent of flexible LNG is likely to reduce average price volatility over time.

### Changes in Business Models

The structure and business strategies of the gas industry have undergone substantial changes in the past two decades, and we expect that they will continue to change to allow companies to satisfy shareholders (whether public or private) in a shifting commercial and/or political environment. Some of the changes occur in response to specific government policies and regulation,

but others are a result of evolving corporate strategies and objectives. The most important trends that have already started and can be expected to intensify or to spread across the world are the following:

- **Globalisation.** International markets present new opportunities to gas companies, many of which have expanded from their home territories to join the increasing number of companies active in the global market. Though this trend will continue, at the same time the linkage of the gas markets, the lengthening of the gas supply chains, the scale of financial investment required, and integration across the industry tend to favour very large companies. We therefore face a very dynamic global market in which there will be continuous change through expansion, mergers, acquisitions, de-mergers, failures, and successes. Many companies will be involved, though the number of very large global players in the gas industry may decrease. Will national mid-stream companies, focussed on intermediate roles between source owners/developers and the markets, be squeezed as the industry integrates and globalises?
- **Vertical integration** The boundaries between the different roles along the gas value chain are blurring and dissolving. Gas resources owners are moving downstream; downstream players are trying to secure long-term and direct access to resources through a combination of merger and acquisition (M&A) activity and asset investment. Vertical integration is generally viewed in the industry as a positive development that improves supply security and operational flexibility and reduces economic risk in the face of price volatility or illiquid markets. The owners of the major gas sources are increasingly looking to extend their participation in the gas volume chain through partnerships, the development of competencies and technologies, or asset investments to link resources with markets. Likewise, downstream gas retailers may increasingly seek to move further up the value chain to diversify their gas supply portfolios by securing direct access to new gas sources or supply routes.
- **Consolidation of retail.** The retail supply business is likely to vary substantially among regional markets—those markets with very active retail level competition will see periods of new entry followed by consolidation, whereas markets with limited or no retail competition are likely to continue with local monopolies insulated from this trend.
- **Changing role of NGCs versus IGCs.** Governments' priorities/attitudes towards local and international gas companies (IGCs) are changing, with a general trend towards fortifying national gas companies (NGCs). The effect of this trend is difficult to project, as NGCs could either pursue regional market integration or prioritise domestic production. Experience suggests that the successful development of the gas industry will continue to require political and commercial cooperation. The behaviour of NGCs and IGCs may well converge, as in the long term both are driven by economic considerations. Stronger partnerships or other arrangements between IGCs, NGCs, and other types of energy companies seem likely to develop, particularly for the challenges of developing remote and difficult gas resources.
- **Convergence of gas and power.** The convergence of gas and power continues in generation, retail supply, and the evolving traded wholesale markets. Gas remains the preferred lower-carbon fossil fuel for power generation, and delays in new nuclear and renewables projects may increase the operation of gas-fired power plants. Retail suppliers will increasingly combine gas and electricity supply in order to deliver efficiencies of scale, but implementing this model will depend on local conditions and will not always be successful.
- **Market liberalisation.** Removal of traditional regulatory protections (such as cost of service rates), and efforts to introduce increased industry competition can lead to mandates and incentives to restructure the gas industry. This may lead to various company-level reactions, such as convergence of the gas industry with power and other energy sectors, and other strategic responses from companies, including mergers, acquisitions, or disposals of newly regulated assets to place them and ultimately their gas business in new market contexts. We would also expect to see more regionalisation and globalisation of commercial and regulatory activities across international borders.
- **Changes in gas supply patterns.** The maturing of some production areas and the development of new ones will continue to result in changed roles for existing players and various roles for new players in the industry.



- **Investment scale.** Changes in the global gas supply chains and new and renewed infrastructure investment have placed significant pressure on incumbent players, with the recent upheavals in the financial markets sparking issues about debt raising, cost of capital, and optimal levels of gearing.
- **Local industry maturity.** The maturity of local gas industry has been and will be a significant driver of the local gas business model. The use of monopoly and integrated business models has generally been favoured as infrastructure is being constructed, so as to reduce economic risk and increase control over economic return. Once the local gas industry reaches maturity, it may be more resilient to different business models, forms of economic regulation, restructuring, and other factors.

## ENABLING A LOW-CARBON FUTURE: THE IGU GREEN POLICY SCENARIO

The IGU Expert View gas supply and demand scenario described in the previous section is consistent with the dual imperatives of maintaining global economic growth in the longer term and establishing energy security through robust national and international markets for the supply, demand, and trade of natural gas. The third global objective toward which the gas industry must contribute is mitigating environmental damage and climate change.

Anthropogenic emissions of GHGs, and in particular CO<sub>2</sub>, are widely held to be a significant cause of global warming. Whilst there are many sources of CO<sub>2</sub>, the production and use of hydrocarbon fuels is variously estimated to result in 75–90 percent of anthropogenic CO<sub>2</sub> emissions.

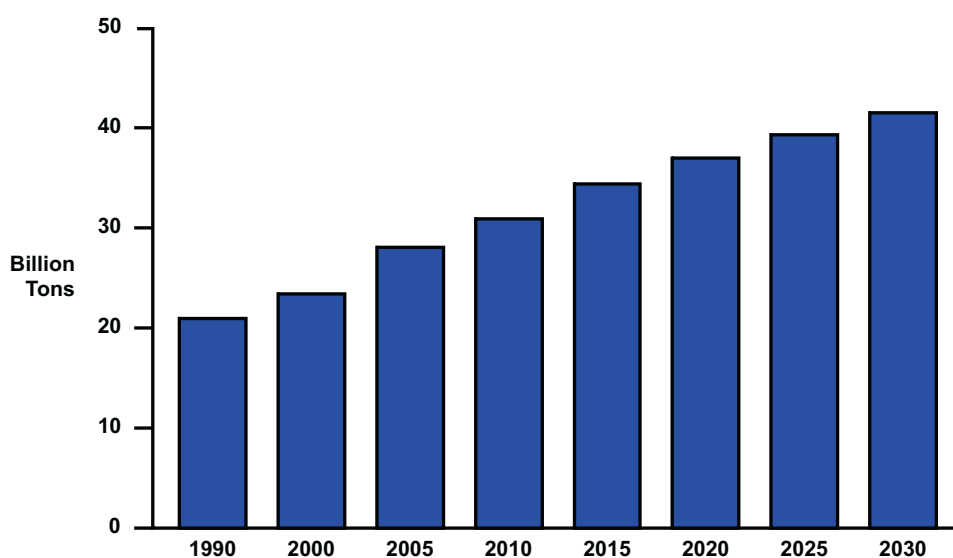
### CO<sub>2</sub> Emissions in the IGU Expert View Scenario

Exhibit 21 shows the projected emissions of CO<sub>2</sub> caused by the use of energy in the IGU Expert View scenario. Given our assumptions on expected population growth, limited changes in consumer behaviour, modest technological progress, and unchanged international policies on climate change, and despite the recent downturn in global economic activity, total CO<sub>2</sub> emissions from energy use will continue to grow from 28 mt in 2006 to 41 mt in 2030, almost doubling the emission levels of 1990. Is such an outcome sustainable?

In the IGU Expert View scenario, total primary energy demand grows at an average annual rate of 1.5 percent between 2006 and 2030, while CO<sub>2</sub> emissions increase 1.6 percent per year, reflecting the fact that the fuel mix does not change significantly. Exhibit 22 shows the distribution of CO<sub>2</sub> emissions by fuel. Indeed, the share of coal in global primary energy demand is projected to increase due to the faster energy demand growth of large coal-using countries such as China and India.

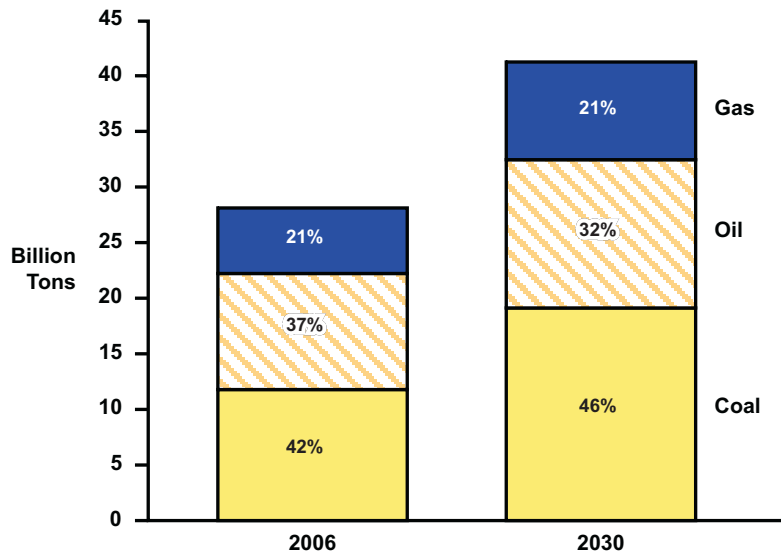
Most of the increase in CO<sub>2</sub> emissions is projected to occur in the developing world, due to stronger economic growth and expected continued heavy reliance on fossil fuels for most of the developing economies (see Exhibit 23). Despite the increase of gas and renewables demand in Europe and other developed countries, CO<sub>2</sub> emissions also continue to increase in the developed world, but at a lower rate than PEC growth (see Exhibit 24).

**Exhibit 21**  
**Global CO<sub>2</sub> Emissions Outlook, 1990–2030**  
(IGU Expert View Scenario)



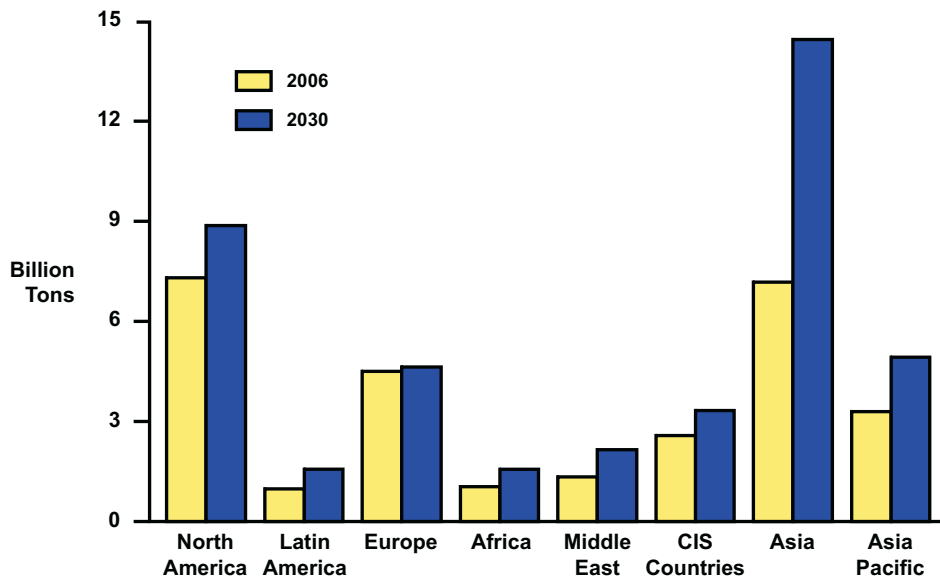
Source: International Energy Agency (historical), IGU (projections).  
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**Exhibit 22**  
**Global CO<sub>2</sub> Emissions by Fuel, 2006 and 2030**  
 (IGU Expert View Scenario)



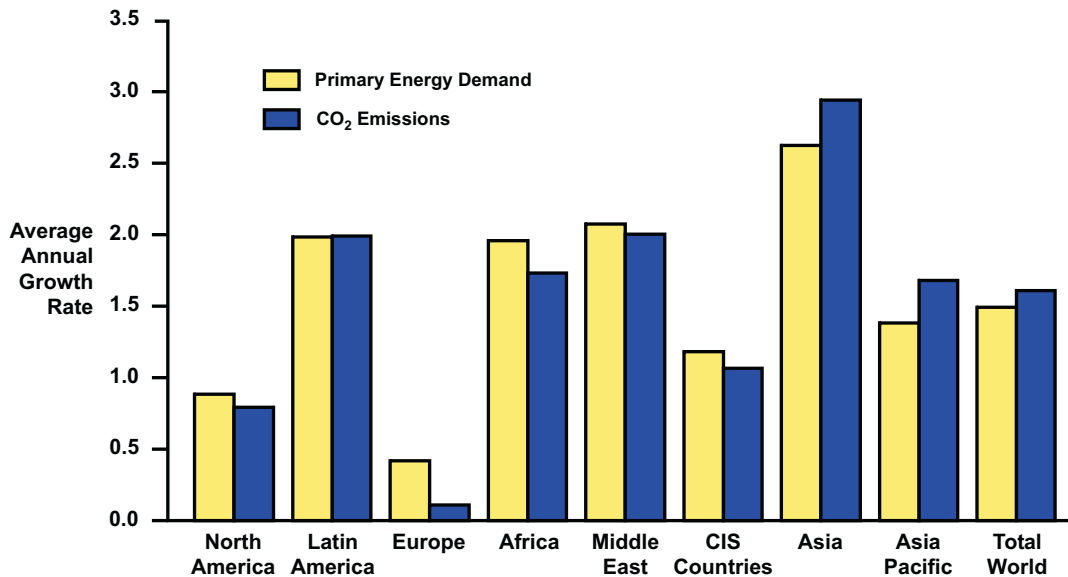
Source: IGU.  
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**Exhibit 23**  
**CO<sub>2</sub> Emissions by Region, 2006 and 2030**  
 (IGU Expert View Scenario)



Source: IGU.  
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**Exhibit 24**  
**Primary Energy Demand and CO<sub>2</sub> Emissions, 2006–2030**  
 (IGU Expert View Scenario)



Source: IGU.  
90813-12

## The Climate Change Debate

During the first decade of the twenty-first century, politicians around the globe have been responding to growing scientific evidence and public concerns about climate change. Increasingly ambitious political targets have been released to the press, for example to 'stabilise' CO<sub>2</sub> emissions at 1990 levels' or to 'cut' CO<sub>2</sub> emissions by 10, 20, 50, or even 80 percent below 1990 levels. In the IGU Expert View scenario not only are even the smallest of these cuts not achieved, but there is no indication that CO<sub>2</sub> emissions can start decreasing before 2030. Our estimates for this scenario indicate that CO<sub>2</sub> emissions will almost double by 2030, compared to 1990.

There is no way of knowing what the maximum tolerable level of CO<sub>2</sub> and other GHGs in the atmosphere will be. But changing consumer behaviour is proving to be very difficult, and it seems inevitable that CO<sub>2</sub> concentrations will rise above 500 parts per million (ppm), and maybe well beyond. If the CO<sub>2</sub> levels in the atmosphere are to stabilise at one of the benchmark levels cited by the Intergovernmental Panel on Climate Change (say, 450 ppm or 550 ppm) by 2100, then at some point well before 2040 there must be a turning point in the emissions curve.\* What policy decisions would enable the energy industry to contribute significantly to reducing CO<sub>2</sub> emissions without compromising the other objectives of economic growth and energy security?

We anticipate that global leaders will seek an overall directional limitation in the emissions of GHGs and in particular will agree that within the next 20 years the world must start to reduce its anthropomorphic CO<sub>2</sub> emissions. To make such an aspiration practical and economically effective, there would need to be some overarching mechanism. Our assumption therefore is that a carbon market will be established either through the development of a global cap-and-trade CO<sub>2</sub> emissions trading scheme (as already exists in the European Union) or through equivalent progressive CO<sub>2</sub> taxation so that a global 'cost of carbon' is established.\*\*

\*This is equal to about 550 ppm and 650 ppm of CO<sub>2</sub> equivalent for all GHGs, in terms of radiating force.

\*\*For our modelling purposes we have assumed the same effects for either approach, but we recognise that the impact on wholesale energy price formation might be different when comparing a direct carbon tax and an emissions trading scheme. This is one of the issues that we recommend for analysis in the next IGU triennium.

Whatever the mechanism, the gas industry supports the principle that there should be a global cost on carbon. Indeed, this is the primary mechanism that drives the IGU Green Policy scenario, described further down in this chapter.

## Gas's Contribution to Sustainable Development

The gas industry can also make a more direct contribution to reducing carbon emissions through its commitment to sustainable development as expressed in the IGU's "Guiding Principles for Sustainable Development".

IGU's approach to sustainable development is not restricted only to **environmental** considerations, adopting a much more comprehensive standpoint encompassing also **social** issues, **economic** development and **integrity**. In 2003, IGU prepared a document entitled "Guiding Principles for Sustainable Development", containing a set of principles proposed for the global gas industry, with the objective of aligning their practices with the environmental and principles of corporate social responsibility. These principles were revised and updated during the 2006–2009 triennium (see Annex 6 for more details).

The most significant challenge in terms of sustainable development related to energy supply is finding the way to balance two major global needs which are currently opposed: the increasing demand of energy and the imperative to reduce the effects on climate change. Gas can play an important role to bring together these two opposing imperatives. This role can be summarised through the five ABCDE 'strategic axes' described below:

**A as Access.** Big gains in carbon reduction can be achieved if *access to gas* is made more widely available in the major energy consuming countries, especially in those where coal today is the dominant fuel in electricity generation. India, China, and the US offer the largest potential. Greater access to global trade in gas, and greater access to conventional and unconventional domestic gas resources in these countries, will enable the same kind of substantial reductions in carbon dioxide emissions that have been achieved by gas-for-coal substitution in Europe [and elsewhere] since 1990.

**B as Bridge to the Future.** The transition toward sustainable energy supply will need several decades. But the world cannot wait to begin the process of reducing the rate of growth of carbon emissions into the atmosphere. *A bridge to the future is needed*, and the natural gas industry can provide that bridge by promoting higher efficiency in end-use, by fostering the use of gas into transport, heating and electricity generation in substitution for higher carbon-content fuels and electricity, and by incorporating biogas in the energy balance alongside natural gas.

**C as Complementarity with Renewables.** Renewable forms of electricity generation, notably wind and solar power, can only fulfil their potential if they are *complemented by a fast-response, readily storable alternative* for when the wind stops blowing and clouds pass across the sun. Natural gas in turbine technology is ideal for complementing the intermittency of these carbon-free renewables. Investment in the expansion of gas storage and in 'smart grids' will be needed to enable the most efficient complementary use of gas with renewable electricity generation.

**D as Decarbonisation.** In the longer term, deeper carbon reductions can be obtained by removing carbon altogether as a combustion product from natural gas. Two technological routes can be envisaged towards almost complete *decarbonisation*: carbon capture and storage (CCS), and the development of hydrogen from natural gas as a new, carbon-free energy carrier. Hydrogen in combination with electricity offers carbon-free energy use in the very long-term.

**E as Efficient Use of All Forms of Energy including Natural Gas.** Energy intensity has been fortunately declining in most of the major global economies. The IEA allocates about half of the reduction in energy intensity to efficiency improvements in the major IEA countries and globally. Future energy scenarios rely heavily on a continued reduction in energy intensity without which achieving carbon reduction will be nearly impossible.

## Adequate Government Policies Are Key

National and local policy decisions can help create an environment in which the gas industry can invest to make its contribution to meeting the world's energy and climate challenges. Policies need to be oriented to support such investment without undue regulatory and political risk, and to enable the development of necessary new technology if more far-reaching CO<sub>2</sub> reductions in the longer term (post 2030) are to be achieved.

In order for the IGU's Guiding Principles for Sustainable Development to be implemented with maximum effect, policies should include provisions for each part of the value chain:

### Downstream

- **Pricing policies.** In countries where gas prices are regulated, especially where they are regulated below cost, policies should be oriented towards ending price subsidies in the interest of promoting more efficient use of gas. Economic efficiency and improved resource allocation would also be a benefit of such a policy.
- **Fuel substitution in transport.** Because it has a lower carbon content than gasoline and diesel, natural gas can reduce the transport sector's carbon emissions by substituting oil products, as has already been done in heating and power generation. Tax policies can be structured—in terms of the *relative* taxation of natural gas and oil products—to encourage the penetration of NGVs.
- **Technology innovation.** Policies should be oriented towards supporting the development of micro-CHP schemes and distributed energy in the interest of efficiency gains and lower carbon output. Investment in smart grids will improve the opportunity for distributed energy generation.

### Midstream

- **Complementing zero-carbon power generation.** Supporting investment in adequate gas-fired generating capacity and sufficient gas deliverability (pipeline capacity and storage) will enable the development of large quantities of intermittent wind generation and solar power. In countries where transmission tariffs are regulated, the regulatory authorities should take a long-term perspective that acknowledges the necessary contribution of reinforced gas grids to making zero-carbon power generation possible.
- **Regulatory support for carbon-footprint reduction.** Many companies wish to invest to reduce the impact of their own activities on emissions of CO<sub>2</sub>. In the gas industry this may involve investment in new compressor equipment or other renewables-related investment in retrofits to reduce environmental impact. Regulators should encourage such investment plans and accept the inclusion of such assets in the cost base.
- **Pipelines for new technology.** Policy support for pipeline companies' research and development (R&D) activities is essential to enable the gas industry to develop in a timely way tomorrow's technologies, notably to transport CO<sub>2</sub> to carbon storage, as well as to advance toward the development of a hydrogen economy.

### Upstream

- **Unconventional gas.** Exploration and development of source rock reserves from gas shale deposits or methane from coal seam (CBM) in regions where conventional close-to-market reserves are declining should be promoted. Environmental standards associated with the infrastructure needs for hydro-fracturing activities in these areas should be monitored and developed.
- **Licensing and taxation policies.** Adequate policies are needed to ensure that all conventional gas resources that are actually technically viable can be accessed and economically developed so that, for example, accumulations of natural gas in small reservoirs can be produced.
- **Trade policies.** Open markets for international gas trade should be maintained in the interest of obtaining the economic and environmental benefits from individual nations' comparative advantages. Enhancing global gas trade will be particularly important in widening the access of the electricity sectors of large coal-consuming countries to the low-carbon benefits of natural gas.

Policies such as these are not applied in all nations in the IGU Expert View scenario, but they will be essential if the world is to make an effective transition to a sustainable future. National governments will need to align their local policies with global agreements if the best sustainable solutions are to emerge. An ambitious but practical way forward to implement a global solution is examined in the next section with the name of IGU Green Policy scenario.

## Gas as Part of the Solution: The Green Policy Scenario

The IGU Green Policy scenario looks at the possible consequences for the world's energy balance of introducing a cost of carbon and combining this with vigorous implementation of the IGU's sustainability principles. These would need to be supported by appropriate government policies, as described above, that favour investment and technology innovation.

The relative effect of this cost of carbon is to increase the economic cost of energy in proportion to its CO<sub>2</sub> emissions. In practice we have taken this to mean that by 2030 the relative economic cost of coal has increased by 100 percent, of oil by 75 percent, and of natural gas by 60 percent above their respective wholesale energy prices. Renewable energy is assumed not to bear any of these costs and therefore has a big economic advantage at the wholesale level.

This cost of carbon has the greatest benefit for renewable energies but also benefits natural gas in comparison with oil, and oil in comparison with coal. The high efficiency of gas appliances further increases the differential with other fuels at the final point of use. Higher energy prices will also reduce energy demand or slow its growth.

Other low-carbon energy systems, for example using nuclear power, benefit from the avoided cost of carbon. In the time frame of the 2030 study even maintaining nuclear's market share is technically difficult given the current age of nuclear plants and the lead times and resources involved in the development of new capacity. Schemes to remove CO<sub>2</sub> from the combustion (or pre-combustion) of fossil fuels, particularly in CCS for coal, would also benefit from a high global cost of carbon once the large-scale CCS plants have been sufficiently developed and proven.

In summary then, the policy assumptions in our IGU Green Policy scenario are

- An overarching agreement that CO<sub>2</sub> emissions must start to decline within the next 10–15 years and that emissions from energy consumption must fall back roughly to 2000 levels by 2030.\* This goal is to be achieved in the first instance by a global CO<sub>2</sub> trading scheme, or equivalent tax that is implemented progressively over the period. By 2030 the economic cost of coal has increased by 100 percent, of oil by 75 percent, and of natural gas by 60 percent above their inherent wholesale energy prices.
- A continuing emphasis on improved energy efficiency and reduced CO<sub>2</sub> emissions, through incentives or certification of only the most efficient proven technology that is economically available. This should apply not just to power generation but also to the transportation and heating sectors, where the efficiency-in-use and low emissions of natural gas can be encouraged by relative tax rates.
- Policies that support the role of natural gas as the natural complement to renewable energy.
- Policies that facilitate the development and international trade of natural gas, thereby enabling an increase in the share of renewable energy in PEC.
- Policies that encourage the growth of distributed energy. This would include for example CHP fuel cells, which are fed by hydrogen converted from natural gas distributed through existing networks to homes and businesses in parts of Europe, North America, and Asia.
- The assumption that biogas benefit from the same economic incentives as other renewable energy and is increasingly integrated with natural gas, or developed for stand-alone systems.
- Subsidies that enable some pilot hydricity systems start to develop, using natural gas as the source of hydrogen.
- Support by local authorities to encourage companies to implement local solutions that involve the innovative supply or use of gas—for example, CNG use in truck fleets or the delivery of LNG by tanker or trucks to remote urban communities where the quality of life can be greatly enhanced.

More concretely, the IGU Green Policy scenario assumes that a global climate change policy will be agreed in Copenhagen in 2009, as a starting point towards an agreement on a global approach to establish the cost of carbon. Governments will need to acknowledge that such a policy needs to be consistent with the maintenance of energy security and the encouragement of optimum economic choices.

This will lead to a reinforcement of global climate change policy around 2020, leading to further change towards the end of our study period. Technical advances, economic incentives, and public pressure lead to policies for a carbon-neutral world. By the beginning of 2025 the gradual 'decarbonisation' of natural gas is a realistic and material issue.

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\*This applies only for the 450 ppm CO<sub>2</sub> scenario. For 550 ppm, CO<sub>2</sub> emissions can continue to increase up to the 2035–40 period.

We expect that the resulting global political agreement will lead to the following trends:

- Natural gas grids will take an increasing quantity of suitably treated biogas, and in some areas may convert to hydrogen grids, albeit on a small scale.
- Momentum will gather for increased use of biogas as a main fuel for pipeline distribution in towns that are remote from natural gas transmission grids.
- Technology improvements will drive the economic implementation of high-efficiency gas-fired CHP and micro-CHP for businesses and homes already connected to the gas grid, reducing overall energy consumption.
- The complementarity with gas that allows increasing use of renewables, particularly wind and solar power, which in turn will decrease global primary energy demand because each kilowatt-hour delivered by renewables would have required about three times the amount of primary energy if it had been generated in a thermal power plants.
- Penetration of electric or hybrid cars will rise to 10 percent of the vehicle fleet in 2030, reducing primary energy demand by another 5 percent, since electric cars are about three times more energy efficient than gasoline cars. Total efficiency gains could approach 10 percent by 2030.
- The global natural gas vehicle (NGV) fleet will reach 100 million by 2030, and 15 percent of the fuel used will be sourced from biogas.
- More widely available gas will mean that gas can become the fuel of choice for power generation in a wider range of countries, with high-efficiency CCGT providing the best balance of economic, efficient, and secure operation.
- Industrial-scale trials of carbon capture and storage (CCS) for gas-fired CCGTs will take place.

The IGU Green Policy scenario also makes global assumptions that affect the role of non-gas fuels in the energy balance, notably

- CCS receives sufficient funding in its current development phase for industrial-scale projects to be proven by 2015. Confidence in the global cost of carbon results in the application of CCS technology at a steadily increasing pace and in an increase over time in the efficiency of carbon capture:\*
  - by 2020: 5 percent of new coal plants; 85 percent carbon capture
  - by 2025: 10 percent of new coal plants; 90 percent carbon capture
  - by 2030: 20 percent of new coal plants; 95 percent carbon capture
- Despite ongoing concerns about nuclear waste and the problem of proliferation, ageing nuclear power plants are replaced and there is additional growth so that nuclear power retains its overall market share.
- Tax advantages are progressively introduced for small, efficient cars, leading to an increasing share of electric, hybrid, and natural gas/biogas-fuelled cars, such that there is no net increase in oil product use for transport.

The next few graphs illustrate our high-level assessment of how primary energy demand and CO<sub>2</sub> emissions might evolve at global level if there is a global agreement on climate change and the policies described above are implemented.\*\* Though these policies—both for gas and for other fuels—are potentially applicable anywhere in the world, there are likely to be significant regional differences, both in how they are implemented and in their impact on the gas industry and gas market sectors. The differences are likely to be especially marked between developed and emerging countries. This warrants further analysis, and we recommend that this should be pursued in the next IGU triennium.

\*The energy losses associated with the process are assumed to stay constant at 20 percent.

\*\*The economic and demographic assumptions of the IGU Green Policy scenario are identical to those of the IGU Expert View scenario.



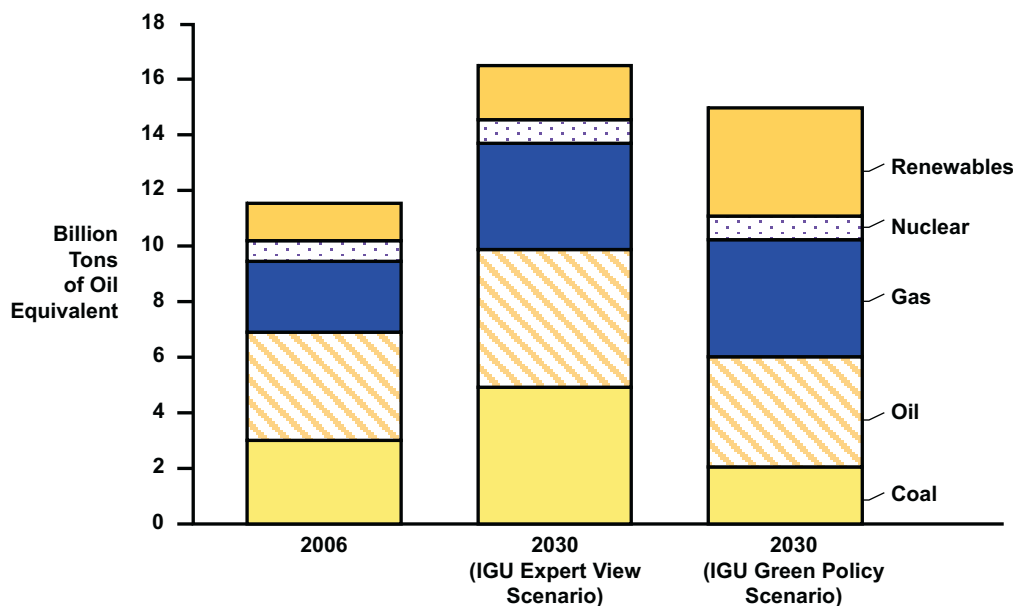
Global primary energy consumption stops increasing in the mid-2020s and remains below 15,000 mtoe in 2030. This is about 10 percent lower than in the IGU Expert View scenario. While a reduction of primary energy of 10 percent may not seem a lot, the shares of the various energy sources in total primary energy consumption are completely different between the two scenarios, with coal share at 14 percent compared to 30 percent in the IGU Expert View scenario, renewables share at 26 percent compared to 12 percent and gas share at 28 percent compared to 23 percent.

The results of this lower energy demand and different supply mix on CO<sub>2</sub> emissions are dramatic. Emissions start to fall between 2015 and 2020. By 2030 emissions are down to the level in 2005. In 2030, CO<sub>2</sub> emissions are projected to be 27 billion tonnes per year, 35 percent less than in the IGU Expert View scenario, and on a clear downward trajectory.

In the IGU Green Policy scenario, the overall size of the global natural gas market in 2030 reaches 4.8 Tcm, which is approximately 10 percent higher than in the IGU Expert View scenario.

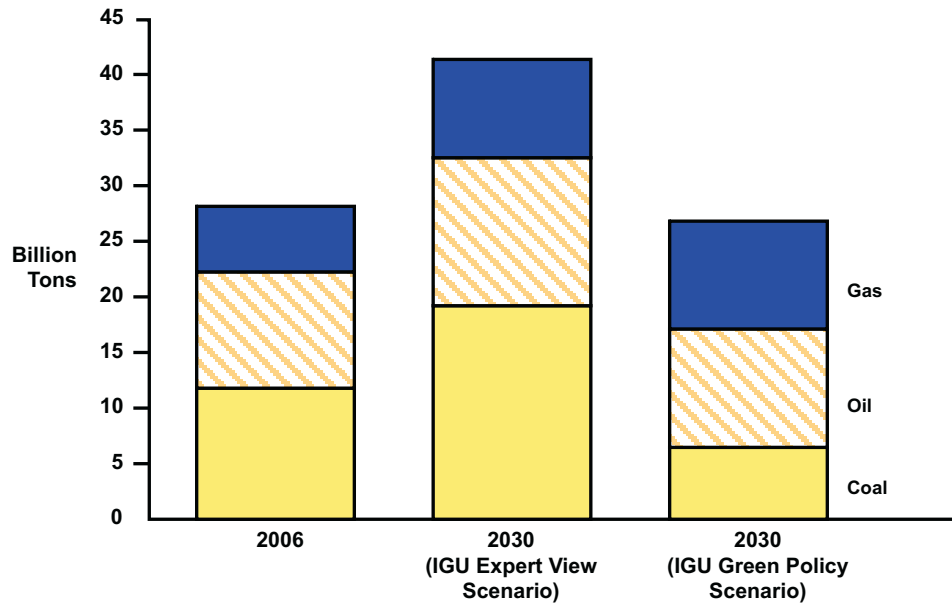
This exercise shows that with adequate policies to sustain a global commitment to mitigate climate change, a sustainable outcome can be achievable, despite the needs of a growing world population. An increase in the share of natural gas, in combination with renewable energy, could result in the stabilisation of global energy consumption and in setting global CO<sub>2</sub> emissions on a downward path within the next ten years.

**Exhibit 25**  
**Total Primary Energy Consumption by Scenario**



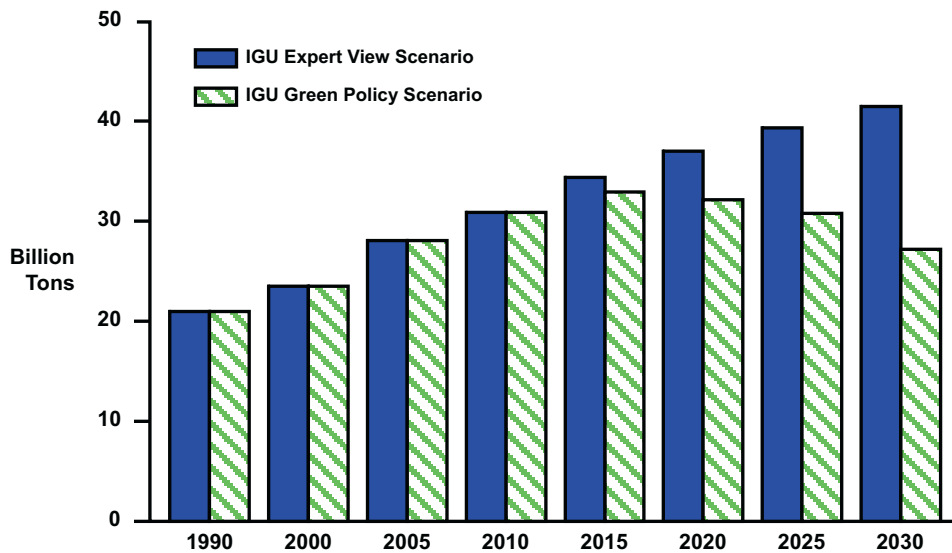
Source: IGU.  
90813-15

**Exhibit 26**  
Global CO<sub>2</sub> Emissions by Scenario



Source: IGU.  
90813-16

**Exhibit 27**  
Global CO<sub>2</sub> Emissions Outlook: A Comparison



Source: International Energy Agency (historical), IGU (projection).  
90813-17

## MAKING IT HAPPEN: CHALLENGES AHEAD

### Financing and Investment

According to IEA's latest World Energy Outlook (WEO 2008), cumulative investment in energy supply infrastructure in 2007–30 is projected to amount to US\$26.3 trillion (in 2007 dollars), of which the gas sector is expected to account for US\$5.4 trillion. This includes investment in the whole gas chain: from exploration and development (61 percent) to LNG liquefaction, regasification, and shipping (8 percent), to transportation, distribution and storage (31 percent), as shown in Exhibit 28. The WEO takes into consideration the investment needed not only to expand supply capacity, but also to replace supply facilities that become obsolete or resources that are exhausted.

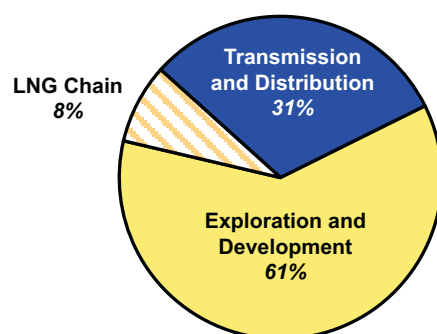
The IEA has continuously raised its investment projections since its first calculation of energy investment needs in the WEO 2003. Although the period is now five years shorter than in the WEO 2003, the estimated investment needs for the gas sector grew from US\$3.1 to US\$5.4 trillion (a 74 percent increase) owing to rapidly increasing unit costs—particularly in the upstream oil and gas industry. The 2008/09 financial crisis and the sharp drop in oil prices may now start to reverse this trend: there are signs already that unit costs are gradually decreasing. Also, the sharp reduction in demand growth expectations will probably mean that several supply projects are put on hold, delayed, or cancelled.

Investment in the future expansion of the gas industry worldwide will depend—as it has in the past—on a combination of private equity finance, state-provided capital, and commercial debt finance. The gas industry is expected to continue to provide attractive opportunities for all these sorts of finance, at every stage of the value chain, and in most parts of the world, assuming that the pricing mechanisms described in the previous chapter maintain the prospect of positive returns on investment for private or state entities. Given the scale of the investment needed to meet the expected demand for gas in the next 20 years, it is important that these conditions remain in place.

The gas industry in most parts of the world has traditionally been an attractive sector for commercial bank finance. This is the result of three particular characteristics of the business:

- strong customer-supplier relationships, with distinct business models, robust contracting practices, and assurances about pricing
- liquid markets against which a diverse set of companies are prepared to take price risk, confident that volumes can reliably be sold or will be reliably available

**Exhibit 28**  
**Cumulative Investment in Gas Supply Infrastructure, 2007–30**



Source: Redrawn from International Energy Agency, *World Energy Outlook 2008*. 90813-18

- strong willingness of governments—local and national—to be engaged, because of clear policy benefits such as local environmental improvements, energy diversity, contributions to export trade, and resource and tax revenues

A particular feature of past successes is the way in which internationally these elements are often combined to help with the promotion of new gas supply or distribution projects. They remain key to continuing to meet tomorrow's finance and investment challenges.

The challenges for the future include:

- the sheer scale of the identifiable need for new investment
- new risks associated with the changing nature of regulation in some parts of the world
- the consequences of the financial crisis of 2008/09

At the time of writing, the extent of the impact of the contraction in the availability of commercial debt from private financial institutions remains unknown. There are no particular reasons for the gas industry to be disproportionately affected compared with other sectors of economic activity. In fact, the industry's long investment cycle can provide a relative safe haven in periods of financial distress. Nevertheless, any capital-intensive industry will be affected by dislocations in capital markets, and the impact of the current crisis remains uncertain.

There are two areas that look to be of particular note in 2009: finance for the further development of transmission infrastructure and interconnections, and finance for international trade in gas.

### ***Finance for Transportation Infrastructure and Interconnections***

The changing nature of regulation in some parts of the world—notably in Europe—provides signposts to changes in the way that the financing of the industry midstream may need to develop in the future. Vertically integrated companies with transmission assets on their balance sheet will have less control over these assets. They may begin to regard them as a financial asset only, and one that faces a significant regulatory burden, with a lower level of authorised return than they expect or need from their energy supply or production activities. In order to maximise shareholder value these companies may reconsider the amount of money they are prepared to tie up in the regulated transmission assets. Other forms of financing—through state ownership or private bond structures—may become a more appropriate mechanism for these assets in the future.

The unbundling of midstream assets into alternative financial structures has been under way in North America for the past 25 years. Whether or not the 'pure play' model of midstream investment gains a foothold in other regions remains to be seen. Large demand growth from developing economies and the potential development of unconventional gas resources worldwide by 2030 will make the need for midstream infrastructure all the more urgent. New gas resources and new demand centres will need to be connected. The regulatory climate and the health of financial markets will ultimately determine the terms under which these new assets will be owned and operated and which entities will provide the capital.

### ***Finance for International Trade***

If international trade in natural gas is to grow, then particular attention will need to be paid to the conditions under which major LNG projects can continue to be financed. Despite the increased project costs in recent years, resource holders such as host governments and international oil and gas companies have so far been prepared to take higher equity positions—and to depend less on project-specific commercial or export credit finance. This willingness has been consistent with the development of a flexible approach to marketing LNG—targeting it at the highest-value markets whether in Asia Pacific, the Americas, or Europe—rather than dedicating individual projects to fixed bilateral trade.

The changes in internationally traded oil, gas, and in particular LNG prices over the past two years suggest that forecasts of future earnings may now carry a greater uncertainty; for some this has increased the perceived risk in assessing the value of future projects. The industry, governments, and the financial community will need to remain alert to changes in the business environment that may require flexibility in the way that such projects are financed. As the scenarios in this report show, however,

the demand for internationally traded gas is on a strong upward trend, and it can be only those projects that go ahead that will make the returns for their investors.

## Geopolitics

Energy is of concern to politicians, and this is particularly true for natural gas with its increasing use in power generation and its favourable properties for industrial and residential use. Whatever the political system and whatever the structures of the gas industry, the widespread use of natural gas and the international aspects of the market make government interest inevitable.

Government intervention or changes in national policies that affect the energy industry can occur quite frequently and will continue to occur over the coming decades. But the true geopolitical issues are based on the interaction between governments, usually in different parts of the gas chain. The commercial concerns of the gas seller, the gas transporter, and the gas buyer become embroiled in geopolitical issues because of the physical location of the supply chain. When the economic drivers affect governments as well as companies, then the pressures for government intervention can become intense.

Geopolitics not only affects the decisions about new resources and infrastructure, it also affects the continuing operation of existing supply routes. In a world where gas trade and interdependence between producing and consuming countries are increasing, concerns about security of supply and of demand are set to become more and more important. Furthermore, as the gas market becomes more integrated globally, regional events may have global effects.

A key factor in the geopolitics of gas is the heavy concentration of reserves in a relatively small number of producing countries. This can lead to security-of-supply concerns in the importing countries. As shown in Exhibit 29, the top five gas producers (Russia, Iran, Qatar, Saudi Arabia, and the United Arab Emirates) hold nearly 67 percent of the world's proven hydrocarbon reserves. National oil companies control more than 80 percent of the oil and gas resources, and there appears to be a trend towards resource nationalism affecting gas as well as oil.

The expected changes in the future distribution of production, implied in the distribution of proven reserves today, suggests a perspective of potential changes in the economic balance for gas supply and demand that will interact with geopolitical decisions and future agreements.

To what extent will competition for, control of, and access to hydrocarbon resources and markets set the political agenda? Will strategic manoeuvring pit major powers, IOCs, NOCs, and consuming countries against each other in the pursuit of gas supply security and gas demand security? Or will mutual interdependence lead to intergovernmental agreements to support or promote new infrastructure, jointly explore and exploit new gas reserves, and help establish robust and secure markets for the benefit of all parties?

### Exhibit 29

#### Countries with Largest Gas Production and Reserves

World Ranking	Share of Global Gas Production		Share of Global Proven Gas Reserves	
	Country	(percent)	Country	(percent)
1	Russia	19.6	Russia	23.4
2	United States	19.3	Iran	16
3	Canada	5.7	Qatar	13.8
4	Iran	3.8	Turkmenistan	4.3
5	Norway	3.2	United States	3.6

Source: BP 2009 World Energy Statistics.

A full examination of the challenges of geopolitics is beyond the scope of this study, but it is clear that the imbalance in gas supply and demand is potentially of such proportions that some governments consider this a threat to their ability to execute their planned projects for the next few years, and thus to meet gas demand. Recognising the importance of these challenges, the IGU has singled out the geopolitical issue as one of key issues to be developed in the next triennium (2009–12) under the Malaysian presidency, and has set up a special task force to examine the geopolitics of natural gas.

## The Role of Technology and Innovation

Though economic and environmental factors are key drivers of our energy future, it is possible to implement new strategies and new policy measures, whether at a corporate or government level, only if the necessary technology exists. The development of innovative technological improvements and establishing best applications of technology on a global basis is an immense challenge for the gas industry in the period up to 2030.

### *The Future Outlook for Research and Development*

Though governments and industry will continue to recognise the value of technological development, economic pressures are likely to restrict gas-related research and development (R&D) budgets so they only grow in line with inflation and remain, typically, in the range 0.5–1.0 percent of turnover. Although natural gas will continue to be recognised as the cleanest hydrocarbon fuel, greater focus and funding will be dedicated to renewable or ‘clean’ technologies. Gas R&D will still benefit where the focus is the development and widespread application of hybrid energy systems in which gas and renewable energy are complementary. Overall, we expect that R&D investments will aim to optimise production, supply, and energy use; assure safety and reliability of delivery systems; focus on cost effectiveness and productivity; and reduce impacts on the environment throughout the gas chain.

The future focus of local R&D efforts will depend on national energy positions, with companies operating in countries with no indigenous gas reserves focussing on efficient utilisation, while those with large gas production potential will focus R&D on new production and treatment technologies. The focus on cost efficiency and reduced operating costs while enhancing reliability will continue.

New investors will emerge in gas R&D, particularly for the exploitation of unconventional reserves and the production of Synthetic Natural Gas (SNG) and coal Gasification in markets where conventional supplies are in decline.

Despite intellectual property issues, collaboration on R&D within the industry and in partnership with other energy sector participants will increase as the focus toward greater integration of community energy systems and smart grids is pursued. This would drive investments and technologies in CHP and micro-CHP. Investment in R&D throughout the gas chain by a single company will occur only with the very largest companies.

R&D will continue to prove that gas technology can provide more efficient energy conversion, heating, and transportation options, but what would be brought to the mass market will depend on economic and other factors.

Some of the main drivers behind our expectation for gas R&D are

- **Safety concerns.** Improving the safety and integrity of gas supply systems remain one of the main drivers for R&D. The safe and reliable operation of both transmission and distribution assets will be an area of continued focus.
- **National circumstances and policy approaches.** R&D priorities are expected to continue to vary depending on national circumstances (whether a country is a gas producer or a gas importer) and on policy approaches and industry structures (whether the gas industry in a certain country is mainly private or public, vertically integrated or unbundled, etc.).
- **New gas production regions.** The majority of already discovered big gas fields are located in northern regions with severe natural and climate conditions, which requires development of a new production, treatment, transmission, and processing methods and technologies.

- **Stranded gas.** Some countries or regions have significant volumes of gas that are not economic to exploit by conventional routes. This will stimulate R&D to reduce production, treatment, and subsea pipeline costs or to find cost-effective scale of LNG and GTL facilities.
- **Unconventional gas resources.** The need to develop cost-effective access to non-traditional reserves (shale gas, CBM, methane hydrates) will also drive R&D efforts.
- **Climate change and GHG emission caps.** International commitments and local policies to reduce GHG emissions will promote R&D on low-carbon technologies and CCS.
- **Energy efficiency targets.** Improvements in the efficiency of energy use, for example gas-fired CHP, will be required to maintain competitiveness and meet government targets for reductions in overall energy intensity and environmental emissions.
- **Energy prices.** Increased oil and gas prices are a further incentive for new technology development to use energy more efficiently.
- **New technologies mainly in the area of renewable energy.** R&D on renewable energy and also on the utilisation of hydrogen will drive industry development. The increased availability and reduced costs of new technologies in the utilisation of renewable energy and possibly hydrogen may have both positive and negative impacts on gas demand:
  - **Negative impacts.** Regulations and fiscal reforms that favour biofuels, water, wind, and geothermal energies will slow further development of the natural gas market.
  - **Positive impacts.** Natural gas could be the natural complement to renewables in multi-fuel systems. The experience and knowledge gained concerning natural gas transmission and distribution may be at least partially adopted for hydrogen systems. Competition is often a powerful factor in promoting development.

### **Potential Technological Breakthroughs**

Spotting which new technology will be important in the future is as difficult as predicting the oil price. But there are longer-term trends that we expect will have varying impacts in the period out to 2030.

### **Widening the Horizon for Gas Resources**

- Technology developments will broaden production capabilities in difficult reservoir environments (high water depths, high reservoir depths, and difficult reservoir properties), bringing new gas resources into proven reserves.
- The 'shale revolution' has expanded the concept of natural gas reserves, as explained in the section on gas production in the chapter "A Look into the Future: The IGU 2030 IGU Expert View Scenario."
- GTL technology will continue to develop for applications in niche geographic markets where conventional gas resources are not economic to export by pipeline or as LNG.
- Small-scale and floating LNG will allow the exploitation of smaller fields and stranded reserves.
- New technologies will enable unconventional manufacture of natural gas (from coal, for example) and cost-effectively access to unconventional gas sources.

### **Responding to Environmental Imperatives**

Costs associated with CO<sub>2</sub> capture and storage (CCS) will decrease, and the gas industry will be involved in this technology to maintain a competitive position with other technologies such as clean coal. In addition, chemical transformation of CO<sub>2</sub> may have a significant impact.

Biogas technology development (from sewage, sludge, wood chips, etc. in high efficiency digesters) will occur as stand-alone projects in remote areas and in areas where integration with the natural gas grid is possible. Large biogas digesters at wastewater treatment plants, landfill gas installations, and industrial bio-waste processing facilities will increase. But by 2020 the largest volume of produced biogas will come from farms and large co-digestion biogas plants, integrated into the farming and food-processing structures. Technology development is also expected to allow production of biogas from designer algae or other microbes.

Developments in other energies that will have indirect influence on the gas business might include

- significant advancement of all electric smart grids, zero emission homes, and zero carbon footprint communities
- new advancements in nuclear and battery technologies, particularly to enable a leap forward in electric road vehicle usage.

### Technology Alone Is Not Enough: The Example of CHP

Aggressive technological advancement and commercialisation of CHP, including hybrid systems and natural gas fuel cells, is important.\* In OECD countries, CHP systems tend to be an economically viable solution, but there can also be obstacles for the introduction of CHP systems.

- The customers that adopted CHP systems might have to pay high back-up charges to the power utilities.
- The guideline to connect to the power grid might not be suitable for CHP users.
- Initial cost and maintenance costs for a CHP system can be high.
- Fuel cost can change rapidly, altering economic viability,
- In many cases, special technicians or engineers are needed for customer service.

In many developing countries where gas infrastructure is not well developed, gas-fired CHP systems are rarely installed. In these countries electricity tends to be generated in coal-fired plants, and the local coal price is relatively cheap compared with international gas or oil prices. For example in inland China, almost all power plants are coal fired. Large industrial customers use coal-fired boilers and power from the local electricity company because a gas-fired CHP system is relatively unattractive. But for customers located near the coast, where almost all energy supplies for the factories are natural gas or oil, the use of a gas-fired boiler CHP system is a sound economic option.

So in developing countries, the opinions about CHP systems are divided into two groups. In gas-producing countries such as Malaysia, Algeria, and Thailand, where the cost of natural is low for local customers and gas supplying infrastructure is well equipped for the special industrialised area, a CHP system is attractive. But CHP project economics are more difficult in other countries, such as India and South Africa.

The situation is similar for micro-CHP. In OECD countries, such as Russia and the CIS, where gas pipelines for domestic and commercial users are well equipped, a micro-CHP system is very attractive for both customers and gas suppliers. But for developing countries where gas networks for domestic and commercial users are not well developed, a micro-CHP system cannot compete.

The improvements in efficiency of micro-CHP that will undoubtedly occur in the coming decades will enable a somewhat wider market for this technology, but these technical developments alone will not be sufficient if the infrastructure and pricing challenges cannot also be met. For countries or cities where low-pressure gas distribution is not well established, the best economic and environmentally efficient option may well be for gas companies to supply natural gas to centralised, high efficiency CCGT plants, provided the housing stock is sufficiently well insulated and modernised to enable all-electric housing to be efficiently supplied.

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\*In this report we denote micro-CHP as 100 kW or less (most micro-CHP are in the 30 kW category). Small CHP are 200 kW or less; medium CHP are 200–2000 kW; and large CHP is 2,000 kW or more. However, there is no international standard classification. Classification varies throughout the world, and indeed within individual countries.



Apart from intellectual property issues, there are three main challenges with respect to natural gas technological transfer from the development phase to commercialisation, both in local markets and across the globe:

- **A reallocation of financial investment.** The significant focus on renewables, the transition to less carbon intensive economies, and government goals of greater self-sufficiency are drawing significant funding resources, attention, and commercialisation efforts away from natural gas. The traditional players that have helped grow the natural gas markets are now being pushed to focus on renewables and their potential for significant market opportunities. The natural gas industry is considered a mature industry while renewables are at the early adoption stage, and significant advantage will go to the early movers. To this end, alliances with governments, universities, and industries will have to be reshaped both nationally and internationally in order to ensure that a flourishing natural gas industry remains one of the priorities for sustainable development.
- **Attracting and retaining R&D staff.** To the extent that R&D funding in natural gas will pale in comparison to the funding that is being made available for renewables and clean coal technologies, there will be a significant drain on the human intellectual capacity in natural gas R&D. The education of engineers and technology experts will shift away from traditional gas technologies and towards renewable and ultimately hydrogen. The attraction of new graduates to work on natural gas technologies will be challenged as renewable research, at least on the surface, is viewed as offering the brightest and most promising future.
- **Making technology available internationally.** It is unlikely that sufficient natural gas R&D funding and incentives from governments towards the commercialisation of new natural gas technologies will be secured, making technological transfer into the marketplace more challenging. New mechanisms would need to be established to ensure coordination and maximum leverage of investments, and the industry focus will ultimately need to move from a regional to a global one. This will include greater international standardisation of codes and technologies but will require sensitivity to the intellectual property rights of the creators of the new technologies.

### *Encouraging Technological Transfer*

There is a natural dynamic in the development and transfer of technology. For example a technological breakthrough might occur in a major importing country that is trying to exploit its dwindling gas reserves more efficiently. This same new technology can then be applied to improve the extraction of large gas reserves in other countries. The challenge is how to ensure the optimum transfer of technology so that there is a balance between the incentives and rewards for technology development and the improved global use of best available technology where this provides economic benefits. Often, solutions can be found through political agreements that set the framework for technology transfer through establishing trust and confidence in longer-term relationships. Technology transfer is also likely to be facilitated by greater openness in markets, or at least a mutual understanding of the costs and benefits to all participants in the proposed transfer of technology and how that fits with international agreements and free trade.

Against a background of increasing international gas trade and exploitation of ever more challenging gas resources, the imperative for fair and efficient technology transfer will need to be one of the key issues addressed jointly by political leaders and gas industry management in the coming years.

### **The Human Resource Challenge**

The growth of the natural gas industry as described in both our scenarios will require a substantial addition of new skilled human resources, both to grow the business and to replace retiring employees. Training and indeed retaining high-calibre people will be major challenges for the gas industry in the period up to 2030.

The oil and gas industry is already facing a shortage of qualified labour, and this trend is likely to further intensify unless steps are taken to attract young people into technical careers in general, and into the oil and gas industry in particular.

The industry's longest serving and most experienced experts—the 'knowledge workers'—are retiring in large numbers, causing a so-called 'big crew change'. And in many countries, there is a lag in the entry of young talent willing to develop a career in the gas industry. The result is a diminishing number of workers with the experience to make autonomous decisions on critical projects

and operations across the entire value chain. In addition, brand new skills, previously not required, are becoming necessary to address new issues associated with oil and gas production and supply; e.g., climate change, unconventional gas resources, LNG projects, and energy efficient technologies.

While there is a lack of comprehensive and updated statistics to ascertain the magnitude of the gaps in the various disciplines and regions, several recent surveys among industry leaders and human resource executives around the world confirm that companies are struggling to attract, retain, and develop a sufficient number of employees in recent years, and that the increasing human capital deficit and talent void is considered one of the highest strategic risk to the industry. The problem appears to be particularly acute for the maintenance and development of major infrastructure (e.g. in E&P, in high pressure gas pipeline transportation, and in the LNG chain). Despite the global economic downturn, engineer and project management personnel are in short supply, and the human resource constraint could seriously hamper long-term projects.

The shortage of oil and gas workers is the result of a slow and evolving build-up of several factors that are expected to continue to hinder future corporate recruitment efforts. Some of the most worrying challenges are

- **Negative public perception.** Does natural gas appear in public perception alongside oil, with implications that we could be a 'sunset industry', as hydrocarbon reserves will eventually dry up and be replaced by other energy sources, rather than a 'sunrise industry' that complements newer and environmentally friendly energy sources?
- **Negative career perceptions.** Is this a difficult industry offering few prospects for career growth and advancement?
- **Industry consolidation.** Has the ongoing reduction in the workforce since the 1980s created a permanent loss of expertise and added to the negative career perception?
- **Industry cyclicality.** The ups and down of energy prices have resulted in cycles of hiring and layoff. Has this added to the negative employment perceptions?
- **High average age of workforce.** Why is the average age in the oil and gas industry among the oldest of any industry?
- **Required nationalisation of workforce.** Should requirements for a national workforce in gas activities be reconsidered?
- **Financial crisis.** Recruitment and retention problems are further complicated by cutbacks of both capital projects and human resources.

The imbalance in supply and demand of knowledgeable workers is potentially of such proportions that it is considered a threat to the industry's ability to execute its planned projects for the next few years, and thus on its ability to meet demand in the market. There is no quick or easy solution, though clearly the gas industry needs to re-brand itself as a high-technology, environmentally friendly industry that offers interesting careers. Addressing the human resource challenge today in a comprehensive and collaborative manner is the only way to ensure the industry's future sustainability.

Recognising the importance of the challenge, the IGU has singled out the human resource issue as one of the four Strategic Guidelines to be developed in the next triennium (2009–12) under the Malaysian presidency. Under the heading Ensuring adequate human capability to enable growth and integrity of the industry, two Task Forces are being launched.

Task Force 1—Building Strategic Human Capital—aims to understand the key issues affecting the attraction and retention of talent in the gas industry. The project will in particular

- map critical talent and human resources requirements across the whole gas value chain.
- identify issues affecting the gas industry's recruitment and retention capacity.
- analyse the factors contributing to the shortages of skilled workers.
- compile best practices across the gas value chain segments and regions.
- assess the potential roles of governments, industry associations, universities, and private companies

Task Force 2—Nurturing the Future Generations—aims to develop a comprehensive approach to encourage future generations to take an interest in science and technology and eventually to direct them towards the oil and gas industry, drawing upon experiences and best practices of different organisations and countries.

## CONCLUSIONS

The world energy system is in a critical and uncertain phase, with severe economic, environmental, and security challenges to face. The global economic downturn has had major effects on energy demand and raised questions about the availability of finance for the investment needed to secure energy supply in the longer term. At the same time, the demands for a cleaner, climate-friendly, secure, and affordable energy supply are intensifying, and the decisions to be taken by governments in Copenhagen in November 2009 will show the extent to which policymakers are willing to move in the direction of a greener future.

The results presented in this study show that natural gas can make a very strong contribution towards meeting these local, regional, and global challenges. Looking ahead to 2030, the global gas market is expected to expand by some 50 percent, from just under 3 Tcm now to over 4.3 Tcm in 2030. Under a continuation of current policies the share of gas in the global fuel mix should rise slightly from 21 percent today to 23 percent by 2030, helping to bring economic and environmental benefits to homes and businesses across the planet. But this will not be sufficient to deliver the GHG reductions consistent with many policy aspirations. Indeed, in our IGU Expert View scenario, CO<sub>2</sub> emissions continue to increase year on year.

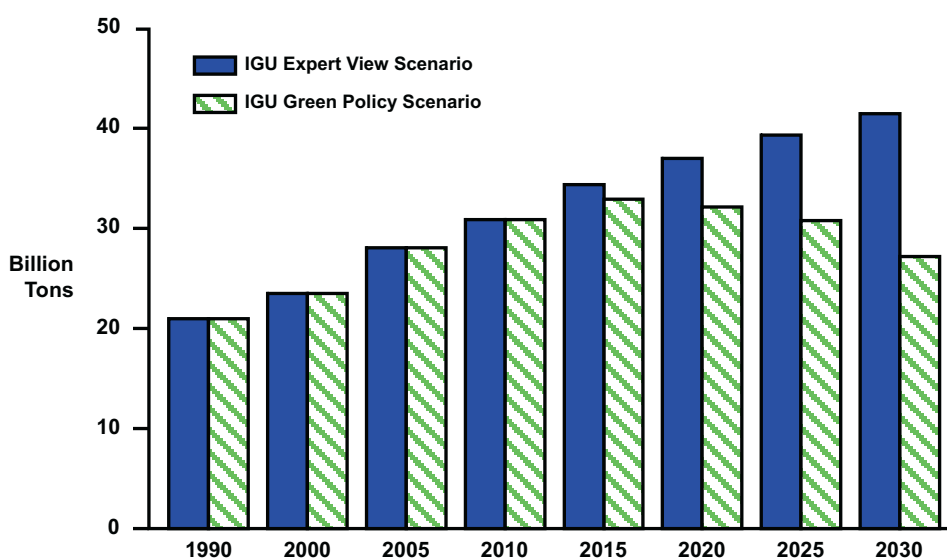
A political agreement to drive towards a low-carbon global economy would require a significant increase in the use of renewable energy sources. The best economic approach would be to put a price on carbon emissions so that renewable energy sources and efficient, low-carbon fuels such as natural gas can achieve their full economic potential. In the IGU Green Policy scenario, global energy consumption in 2030 would be lower and CO<sub>2</sub> emissions would start to fall by 2020, reaching a level in 2030 that is 35 percent lower when compared with a continuation of current trends. To achieve these environmental benefits, gas would need to attain a 28 percent share of the energy market by 2030.

None of these outcomes is guaranteed. To get there, the approaches in terms of sustainability, investment, and policy need to be well aligned among the various stakeholders:

### Sustainability

- The environment is an important dimension of sustainability, and the impact of different energy sources should be assessed through life-cycle analysis. But sustainability also means ensuring energy security and a sufficient flow of investment (availability of capital at an affordable cost).

**Exhibit 27**  
**Global CO<sub>2</sub> Emissions Outlook: A Comparison**



Source: International Energy Agency (historical), IGU (projection).  
90813-17

- Gas is part of the solution. In both good times and bad, increasing the share of gas in primary energy is a no-regrets solution.
- Gas's contribution to a more sustainable future is not only its lower carbon content, but also the higher energy efficiency of gas-using technologies. Gas can reduce the primary energy intensity of final energy demand.

### Investment

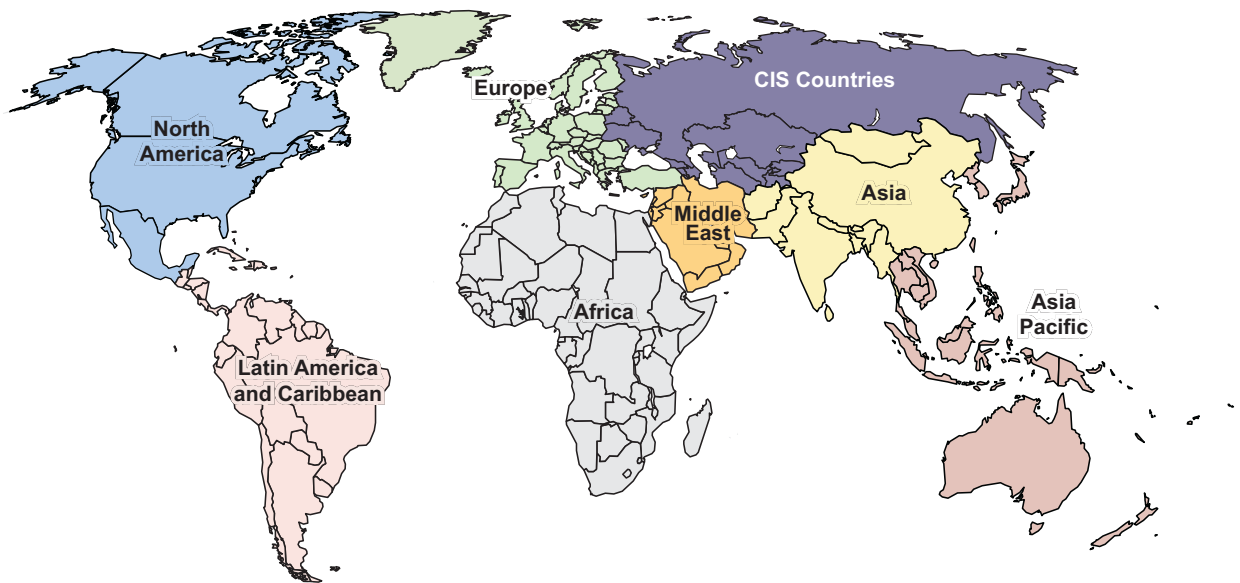
- Managing the risks and uncertainties in the future evolution of natural gas supply and demand will be a key challenge for the industry. Governments influence these risks and uncertainties.
- Availability of financing for investments was already a key issue for the gas industry before the current global financial crisis and will continue to be an issue in the long term.
- The sheer physical scale of the investment that will be needed is immense, not only globally but also in some individual large markets, such as Russia, China, and Brazil. The gas business can be commercially structured in several ways, but there is always a need for large capital investments, from drill bit to burner tip, in a synchronised way along the whole gas chain.

### Policy

- The future of the gas industry will be characterised by increasing interdependence. This implies a need to increase dialogue and trust and to maintain openness to trade. Both governments and industry will have a role to play in adapting policies and business models to foster increased trust and interdependence.
- Policies can be stronger drivers than prices. One of the effects of the current global financial crisis will be that much of what will come on stream in the next decade will now depend on government funding and timely policy decisions.
- Policymakers should not take gas for granted. The increase in gas use and the transition to a gas/renewable world needed to ensure the extent of CO<sub>2</sub> reduction that we assumed in our IGU Green Policy scenario will not happen spontaneously. The right policy measures will have to be put in place at the right time, and that means starting now.

## ANNEX 1: DEFINITION OF IGU REGIONS

### Exhibit A-1 IGU Regions



Source: IGU.  
90813-19

North America: USA, Mexico, Canada.

Latin America and Caribbean: All countries of South and Central America, with the exception of Mexico, but including the Caribbean.

Europe: All Western and Eastern Europe. Also includes Estonia, Latvia, Lithuania and Republic of Moldova.

CIS Countries: Azerbaijan, Kazakhstan, Kyrgyzstan, Republic of Belarus, Russia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan.

Middle East: Bahrain, Iraq, Israel, Iran, Jordan, Kuwait, Qatar, Syria, Sultanate of Oman, Saudi Arabia, United Arab Emirates, Yemen.

Africa: All countries of North Africa, Sub-Saharan Africa and Southern Africa.

Asia: Bangladesh, China, India, Myanmar (Burma), Mongolia, Nepal, Pakistan, Sri Lanka, Taiwan.

Asia Pacific: Australia, Brunei, Cambodia, Indonesia, Japan, Korea, Laos, Malaysia, New Zealand, Papua New Guinea, Philippines, Singapore, Thailand, Vietnam.

## ANNEX 2: SUMMARY TABLES

### 2A. The IGU Expert View Scenario

WORLD		2000	2005	2006	2010	2015	2020	2025	2030
Primary Energy Demand	Mtoe	9,888	11,286	11,565	12,382	13,674	14,724	15,685	16,525
Total Gas Demand	Bcm	2,427	2,777	2,820	3,088	3,419	3,762	4,069	4,331
- Residential/Commercial	Bcm	626	691	698	740	807	864	906	944
- Power Generation	Bcm	573	970	1,039	1,102	1,222	1,357	1,467	1,592
- Automotive	Bcm	3	8	9	18	32	42	52	59
- Industry/Other	Bcm	731	1,098	1,075	1,228	1,358	1,499	1,644	1,736
Gas Production	Bcm	2,526	2,790	2,953	3,242	3,608	3,891	4,178	4,415
CO <sub>2</sub> Emissions	Mt	22,658	28,098	28,300	30,914	34,424	37,056	39,439	41,556

NORTH AMERICA		2000	2005	2006	2010	2015	2020	2025	2030
Primary Energy Demand	Mtoe	2,705	3,059	3,035	3,185	3,334	3,475	3,614	3,752
Total Gas Demand	Bcm	733	717	714	769	798	817	823	841
- Residential/Commercial	Bcm	251	242	223	243	259	269	272	277
- Power Generation	Bcm	180	214	231	241	243	238	230	235
- Automotive	Bcm	0	1	1	1	1	2	2	2
- Industry/Other	Bcm	302	260	259	284	295	308	319	327
Gas Production	Bcm	763	722	761	805	810	820	870	900
CO <sub>2</sub> Emissions	Mt	6,588	7,419	7,335	7,597	7,923	8,200	8,494	8,874

LATIN AMERICA		2000	2005	2006	2010	2015	2020	2025	2030
Primary Energy Demand	Mtoe	460	500	530	601	676	734	793	850
Total Gas Demand	Bcm	99	112	122	149	171	184	206	219
- Residential/Commercial	Bcm	11	13	13	17	20	20	23	26
- Power Generation	Bcm	26	28	32	37	41	47	53	61
- Automotive	Bcm	2	5	6	8	11	12	15	16
- Industry/Other	Bcm	58	66	71	87	99	106	115	116
Gas Production	Bcm	104	139	139	176	207	224	249	270
CO <sub>2</sub> Emissions	Mt	862	964	981	1,124	1,279	1,384	1,488	1,577

EUROPE		2000	2005	2006	2010	2015	2020	2025	2030
Primary Energy Demand	Mtoe	1,885	2,005	2,011	1,949	2,067	2,140	2,193	2,223
Total Gas Demand	Bcm	462	549	545	581	634	681	722	742
- Residential/Commercial	Bcm	183	218	216	220	230	240	245	250
- Power Generation	Bcm	125	171	174	198	228	254	278	289
- Automotive	Bcm	0	0	0	0	1	1	2	2
- Industry/Other	Bcm	154	159	155	163	175	187	197	201
Gas Production	Bcm	318	300	320	270	244	201	165	130
CO <sub>2</sub> Emissions	Mt	4,198	4,451	4,512	4,147	4,348	4,500	4,596	4,633

**ANNEX 2:  
SUMMARY TABLES (continued)**

**2A. The IGU Expert View Scenario (continued)**

AFRICA		2000	2005	2006	2010	2015	2020	2025	2030
Primary Energy Demand	Mtoe	507	363	376	412	473	522	564	599
Total Gas Demand	Bcm	60	81	87	111	142	173	197	220
- Residential/Commercial	Bcm	4	5	7	8	12	12	14	14
- Power Generation	Bcm	30	45	48	53	61	84	96	107
- Automotive	Bcm	0	0	0	1	2	2	3	3
- Industry/Other	Bcm	26	31	32	49	67	75	84	96
Gas Production	Bcm	133	173	198	224	303	382	419	447
CO <sub>2</sub> Emissions	Mt	695	1,008	1,046	1,127	1,290	1,413	1,514	1,581

MIDDLE EAST		2000	2005	2006	2010	2015	2020	2025	2030
Primary Energy Demand	Mtoe	389	503	526	543	626	700	784	862
Total Gas Demand	Bcm	174	244	261	281	318	375	441	504
- Residential/Commercial	Bcm	22	36	41	34	37	41	46	50
- Power Generation	Bcm	73	113	117	135	161	197	236	272
- Automotive	Bcm	0	0	0	2	7	11	14	17
- Industry/Other	Bcm	79	95	103	110	113	126	145	165
Gas Production	Bcm	204	289	324	402	484	561	654	742
CO <sub>2</sub> Emissions	Mt	967	1,271	1,329	1,365	1,576	1,754	1,955	2,143

CIS		2000	2005	2006	2010	2015	2020	2025	2030
Primary Energy Demand	Mtoe	907	1,063	1,086	1,070	1,150	1,263	1,375	1,441
Total Gas Demand	Bcm	602	681	675	682	725	796	856	896
- Residential/Commercial	Bcm	110	112	128	136	144	154	165	175
- Power Generation	Bcm	0	214	244	227	236	248	251	263
- Automotive	Bcm	0	0	1	0	0	0	0	0
- Industry/Other	Bcm	0	345	302	319	345	394	441	458
Gas Production	Bcm	722	804	831	906	994	1,050	1,107	1,166
CO <sub>2</sub> Emissions	Mt	2,184	2,535	2,583	2,506	2,670	2,915	3,166	3,332

ASIA		2000	2005	2006	2010	2015	2020	2025	2030
Primary Energy Demand	Mtoe	1,785	2,396	2,590	3,094	3,676	4,128	4,504	4,833
Total Gas Demand	Bcm	79	131	140	218	304	382	442	494
- Residential/Commercial	Bcm	9	20	23	37	56	74	84	90
- Power Generation	Bcm	28	46	46	63	83	106	124	149
- Automotive	Bcm	0	2	0	4	8	12	14	16
- Industry/Other	Bcm	42	64	71	113	158	190	220	239
Gas Production	Bcm	89	132	144	188	247	293	314	310
CO <sub>2</sub> Emissions	Mt	4,429	6,704	7,203	8,974	10,899	12,298	13,465	14,474



**ANNEX 2:  
SUMMARY TABLES (continued)**

**2A. The IGU Expert View Scenario (continued)**

ASIA PACIFIC		2000	2005	2006	2010	2015	2020	2025	2030
Primary Energy Demand	Mtoe	1,251	1,397	1,411	1,529	1,671	1,761	1,859	1,964
Total Gas Demand	Bcm	218	261	276	298	327	354	383	415
- Residential/Commercial	Bcm	36	45	47	45	50	54	58	62
- Power Generation	Bcm	111	138	146	149	168	183	199	216
- Automotive	Bcm	0	0	1	2	2	2	3	3
- Industry/Other	Bcm	71	78	82	103	106	113	123	134
Gas Production	Bcm	194	232	235	271	320	360	400	450
CO <sub>2</sub> Emissions	Mt	2,735	3,747	3,311	4,074	4,439	4,594	4,762	4,942

**2B. The IGU Green Policy Scenario**

WORLD		2000	2005	2006	2010	2015	2020	2025	2030
Primary Energy Demand	Mtoe	9,888	11,286	11,565	12,382	13,637	14,275	14,965	14,991
Total Gas Demand	Bcm	2,427	2,777	2,820	3,018	3,438	3,908	4,363	4,760
CO <sub>2</sub> Emissions	Mt	22,658	28,098	28,300	30,914	33,018	32,204	30,861	27,198

Source: IGU.

### ANNEX 3: KEY MESSAGES FROM THE IGU COMMITTEES

This Annex summarises the main points made by each of the IGU committees as derived from their input to the Natural Gas Industry 2030 study. The persons who were responsible for each Committee's many contributions during the last three years are also acknowledged in each section. Their expertise and knowledge has been the foundation of this report.

The overall view from the IGU Committees is that the global energy challenge is an opportunity for gas, but far more will be expected of the gas business in terms of quantity, flexibility, and sustainability. Success will require increased investment, improved technology, and international agreements. The key strategic and development issues revolve around politics and prices.

Further details of the work of all IGU Committees and their various study groups are available in their individual reports, which can be found in the proceedings of the 25th World Gas Conference, October 2009.

#### 1. Working Committee: Exploration and Production

Focal point: Kamel Eddine Chikhi; Chair: Vladimir Yakushev; Secretary: Sergey Leonov.

Other main contributors: Ilhane Dib Nataliya Makhonina.

- Globally, the expansion of world gas supply to satisfy 2.5 percent per year average growth in global gas demand is within the capability of the E&P business and underlying gas resources.
- An increasing proportion of gas supply, particularly in North America but also in Asia and Africa, will come from unconventional resources (CBM, shale reservoirs, etc.). By 2030 unconventional gas could constitute 12–15 percent of global gas supply, compared with less than 5 percent today.\* [FTN: \*Gas production from high pressure/high temperature and sour reservoirs is not included in these figures as unconventional gas.]
- Global gas reserves, if developed and delivered to market, are sufficient not to require significant commercial exploitation of methane hydrates before 2030, but hydrates could provide around 2–3 percent of global production in the event of overriding energy security or other considerations in a major market like the United States, Japan, China, or India.
- There is an increasing proportion of new discoveries of conventional gas offshore (with 43 percent of new offshore gas discoveries in Asia Pacific during the past five years). By 2030 roughly half the world's gas supplies will be produced from offshore reservoirs (compared with 26 percent in 1995 and 39 percent in 2005).
- Consistent with the IEA WEO 2008, we estimate that to grow gas production levels to over 4,500 Bcm per year by 2030, including bringing new fields on stream and sustaining output at existing fields, will require approximately US\$3.3 trillion (in 2007 dollars) in E&P investment.
- Remaining giant fields are less likely to be discovered in in-fill areas where past giants have been clustered and are more likely in frontier, or new, areas that correspond to the predominant tectonic settings of past giants.
- We agree with the IEA assessment that more than one half of undiscovered conventional natural gas is expected to come from the CIS, the Middle East, and North Africa; and about one fourth is expected to come from North America and Latin America combined.

#### 2. Working Committee: Gas Storage

Focal point: H  l  ne Giouse; Chair: Vladimir Onderka; Secretary: Petra Grigelova.

Other main contributors: Joachim Walbrecht, Georg Zangl, Emmanuelle Wicquart, Gerard Martinus.

- In the IGU Experts View scenario, not only does gas demand increase but there is increasing import dependency which will tend to lead to an increasing demand for storage capacity to prevent undue rises in price volatility or risks to security of supply.

- Investment in gas storage must at least keep pace with increased gas demand if supply security is to be maintained and price volatility mitigated.
- Storage capacity (working gas volume) is expected to rise from 333 Bcm in 2005 to 543 Bcm in 2030, or 63 percent. The demand for incremental deliverability may result in an increased withdrawal rate of an additional 200 MMcm per hour by 2030.
- In addition we would expect a demand for cushion gas on the order of 230–320 Bcm that would need to come from world gas supplies prior to 2030.
- Good locations for storage sites will be increasingly difficult to establish and will face conflicting political, economic, and environmental pressures (e.g., the cost of cushion gas is lowest in producing countries, but transportation costs imply that storage should be close to the market).
- Higher demand and mounting costs for rigs, engineering expertise, steel, etc. will increase the capital expenses and price of the services necessary to build and operate new underground gas storage capacities. This will have a feedback effect to further increase the gas price.
- Technologies to improve the capacities and performance of existing UGS will be of major interest. There will also be an increasing focus on improving the flexibility of operational response, reducing environmental impact, and increasing the lifetime of storage facilities.
- Market developments will ask more from UGS operators (e.g., in responsiveness and efficiency), and we expect the increasing installation of high-level decision support (expert) systems connected to the existing monitoring framework to allow better proactive UGS management.
- The gas industry will have to promote itself as high technology, environmental friendly, and offering interesting careers to attract young people to avoid a skills shortage in the design and operation of future UGS in several parts of the world.

### 3. Working Committee: Gas Transmission

Focal point: Eric Dam; Chair: Helge Wolf; Secretary: Uwe Klass.

Other main contributors: Lillian van den Bos, Sigve Apeland, Peter Flosbach, Arman G. Gulagian, Cynthia Silveiral, Hisao Hotto, Yuji Hosokawa, Shinkai Hajime, Takashi Akiyama, Young Keun Kim, Sung Baek Hong.

- Existing high-pressure gas transmission pipelines have a typical lifespan of 50–70 years, suggesting there will be some major pipeline investment towards 2030. New pipelines are likely to have greatly increased capacity owing to far higher operating pressures. Reducing pressure on old pipelines to prolong their life may also be a cost-effective alternative to replacement, which is very expensive in built-up areas.
- Expansion of markets and exploitation of new sources of gas will require major investment in gas transmission. For example, in Iran the projected investments to implement just the required gas transmission infrastructure by 2030 are estimated to be in excess of US\$30 billion.
- New gas transmission pipelines and increased access to capacity will improve regional market integration and build stronger trade and common business practices. For example new pipelines will open new markets, and in general cross-border transmission will increase.
- There is a danger that regulatory controls over pipeline development and access will place increasing uncertainty on investment in new projects, while at the same time there will be pressure on operational budgets that are needed to maintain safe and secure pipeline systems.
- As pipelines age, smart pigging tools and other new equipment should be developed to detect degradation mechanisms at a very early stage. Monitoring of gas quality and impurities and technologies to prevent third-party damage are expected to improve so that remedial actions can be taken more quickly.
- Due to stricter environmental and safety codes (e.g., to comply with stricter standards regarding earthquake risk or highly populated areas) potentially adding costs to pipeline system construction and operation,

technology developments and new materials will increase transmission costs overall.\* [FTN: \*The pipeline system includes pipelines and compressor stations.]

- By 2030 an increasing number of transmission pipelines that currently carry natural gas will be carrying unconventional gas or a proportion of biogas. In the Green Policy scenario these proportions would be higher and, in addition, a few pipelines would carry hydrogen, or captured CO<sub>2</sub> for storage, as the gas industry plays a new role for energy and the environment.

#### 4. Working Committee: Gas Distribution

Focal point: Alessandro Soresina; Chair: Jeremy Bending; Secretary: Steven Vallender.

Other main contributors: Andreas Hennig, Fergal Geoghegan, Svend Bomholt, Steve Vick, Kevin Knapp.

- Investment in distribution networks will increase, with a greater safety focus on renewal and maintenance of existing networks in mature markets. The estimated annual replacement level of networks will settle at around 1.6 percent of their total length.
- Investments will concentrate on smart technology and other information technology/technical systems, personnel training, and material development/testing.
- Condition-based proactive maintenance will predominate by 2030, with safety and leakage control the main concerns; and asset management strategies will be increasingly influenced by regulations.
- Global leakage rates will decline by 10–20 percent as cast iron in distribution networks is replaced, locally reducing leakage by 85 percent or more, and improved risk management strategies are applied.
- The low leakage rates from extensive plastic, PE and PVC, networks are not expected to change before 2030.
- Significant developments in new technologies, attention to human factors, and enhanced data quality will reduce third-party damage, offering environmental, safety, and cost benefits, particularly in densely populated areas.
- Establishing a proper understanding by regulatory authorities to ensure that distribution network operators are able to continuously maintain and improve the integrity of their pipeline systems will be fundamental for the expansion of safe and sustainable retail gas markets.

#### 5. Working Committee: Gas Utilisation

Focal point: Tatsuo Kume; Chair: Jean Schweitzer; Secretary: Aksel Hauge Pedersen.

Other main contributors: Guy Verkest, Martin Wilmsmann, Davor Matic, Sergey Shilnikov, Michael Hermann, Eugene Pronin, Peter Seidinger, Peter Boisen.

- Up to 2030 the biggest improvement to global GHG emissions is likely to be possible through efficiency gains. Gas can make a major contribution to global energy efficiency because of its combustion technologies, including potential flue gas utilization.
- High energy costs and climate change concerns provide a strong global impetus towards improved combustion efficiency and reduced GHG emissions. Although there will be regional differences, both these pressures result in an overall global benefit for the natural gas market and for the use of gas in combination with renewable energy, in particular solar power.
- The transport sector is expected to be the fastest growing sector in the next 20 years. Natural gas and bio-methane from organic waste streams will be used to fuel tens of millions of NGVs with optimised engines using a higher compression ratio than gasoline engines by 2030. A low estimate, compatible with the IGU Expert View scenario, would imply a total NGV fleet of 35 million vehicles in 2030, compared with 10 million today, which would use some 60 Bcm of natural gas and 5-10 Bcm of biogas. A more optimistic estimate, which requires the appropriate policies to support a much more rapid network development,

projects a fleet of 100 million vehicles in 2030, requiring 200 Bcm of fuel, of which about 30 Bcm could be biogas.

- In the residential markets of OECD countries, improved insulation and higher-efficiency appliances could reduce overall gas demand in this sector by 20–30 percent, but gas sales might be counterbalanced by increased distributed energy fired by natural gas. Grid expansions and new technologies, particularly for the Asian markets (e.g., high efficiency gas-fired absorption chillers) could also increase sales volumes in the residential gas market by 2030.
- In the industrial sector, gas market growth is expected across the world, including China, India, and Korea, where energy saving will be increasingly important to remain globally competitive and as further efficiency advances are made in industrial gas appliances, including CHP.
- Despite high fuel costs, advances in technology will enable gas to continue to displace oil and coal for power generation. Large-scale CHP applications will increase, but extremely challenging advances in efficiency would be needed for CHP to be widely competitive in many small-scale applications.

## 6. Programme Committee: Sustainability

Focal point and Chair: Juan Puertas; Secretary: Kari Hunsbedt.

Other main contributors: Jordi Canet, Elbert Huijzer.

- Wider application of gas technologies and gradual displacement of other fossil fuels will contribute to reduced GHG emissions.
- But the gas industry will need to take special environmental responsibilities:
  - Co-operate throughout the gas chain to maximise efficiency and minimise environmental impacts (e.g., losses, leakage, etc.).
  - Support efficient and combined use of renewable energy and natural gas by investing in R&D pilot programmes.
  - Promote transfer of high efficiency and low emission technologies to developing countries.
- More rapid development of zero/low carbon technology will be needed, leading the power generation sector to increase its reliance on flexible gas combined-cycle as a complementary support technology.
- Local pollution controls should help promote long-term investments in gas infrastructure particularly in Asia, but industry might also face new emission reduction caps on transport and distribution of gas and in gas extraction activities.
- Collaboration between gas and electricity sectors will increase, as a hydricity energy system starts to take shape.

## 7. Programme Committee: Strategy, Economics, and Regulation

Focal point: Colin Lyle; Chair: Pedro Moraleda; Secretary: Francisco Sichar.

Other main contributors: Runar Tjersland, Mike Fulwood, Antonin Mantz, Floris Merison, Enrique Jose Lopez Romero-Avila, Olga Shchekina, Ottar Skagen, Meg Tsuda, Jaap Hoogakker, Mark Robinson, Carlos Eduardo de Freitas, Saeed Pakseresht, Saeed Ghavampour, Hamed Ali Hamed Korkor, Tatiana Mitrova, Michel Valette, Xiaoli Liu, Hiroshi Hashimoto, Abd Rahim Mahmood, David Sweet, Margot Loudon, Rene Snijder, Jayesh Parmar.

- General expectations in the industry suggest that the global gas market will maintain a slight supply surplus over the coming years, with demand rising to 4330 Bcm per year, and that global supplies on average will maintain a level some 100 Bcm higher than demand through to 2030.

- If supported by government policy and by the right economic conditions, additional production of both conventional and unconventional gas reserves is possible and could meet increased demand (including displacing more polluting fuels) in several market sectors.
- Whether the transition to renewables is slow or fast, there will be an increasing need for natural gas. The economic and environmental outcomes for mankind and for gas industry development both benefit from a high market cost of CO<sub>2</sub>.
- The global prevalence of government-controlled or -regulated prices will diminish, but ‘oil price escalation’ for imports, particularly to Asia, will co-exist with pricing based on traded gas markets. In the longer term increasing international LNG trade and market integration will strengthen developments towards gas-on-gas pricing.
- Political decisions will be increasingly implemented through regulatory changes that affect industry structure, with an impact on the gas business from drill bit to burner tip.

## 8. Programme Committee: Developing Gas Markets

Focal point and Chair: Farid M. Amin; Secretary: M. Rashdan M. Radzi.

- The natural gas industry has reached most countries in the world, but the majority of the world’s homes and businesses still do not have the benefit of connection to a gas supply or heat, cooling or power produced and delivered efficiently from gas-fired plant.
- Some of the countries where we the biggest growth in their energy demand are also those that currently have a low share of natural gas in their national fuel mix.
- Over the next two decades the most rapid gas market growth is expected to be in Asia, followed by Africa, the Middle East and Latin America.
- Within those regions, the extent to which gas markets continue to develop in China, India and Brazil will have a particular impact on global trends, not only for energy but also for the environment.

## 9. Programme Committee: LNG

Focal point: Alaa Abu Jbara; Chair: Seiichi Uchino; Secretary: Yutaka Shirakawa

Other main contributors: Cater Crites, Abdulla Ahmad Al-Hussaini.

- Despite the slowdown of the LNG market in 2008, in the IGU Expert View scenario we expect 650–750 Bcm per year of LNG production by 2030, requiring up to 800 Bcm per year of nameplate capacity with average capacity growth of 4 percent per year between 2010 and 2030.
- At normal utilisation rates the global LNG shipping fleet will grow from 255 ships in 2007 to about 500 ships by 2030.
- Despite concerns about planning permission in some locations, the availability of regasification terminals is not expected to be a bottleneck in the global LNG chain.
- If greater volumes are delivered by pipeline to Asia from the CIS, more LNG will move from the Middle East into Europe.
- Within the Atlantic Basin, LNG balances the pipeline supplies from Africa and the Middle East to Europe.
- By 2030 there will be sufficiently flexible market-based LNG trade to allow global optimisation of gas supply and demand.

## 10. Task Force: Gas Market Integration

Focal point and Chair: Jorge Doumanian; Secretary: Javier Fernandez Gonzalez.

- Interconnecting pipelines will help to build and empower regional market development, but this integration will often need governments to actively facilitate the required international investments, by defining clear rules and promoting cooperation among government and enterprises.
- Potentially the geographic spread of gas resources, infrastructure, and consumption could lead to four super-regions covering much of Eurasia, North America, South America, and Asia Pacific.\* [FTN: \*These super-regions denote primarily the physical interconnection and are not single price zones. Indeed a super-region might comprise several demand centres and well as other areas of supply.]
- Globally LNG will make interregional flows more flexible and increase gas-on-gas competition, but wholesale gas prices will continue to vary both between and within the regions.
- Though gas contracts may de-link from oil prices, actual gas prices will remain economically linked via inter-fuel competition.
- The economic imperative to develop global gas resources to satisfy the world's growing energy needs will create geopolitical tensions but may also drive increased international co-operation and regional gas market integration.
- There are uncertainties about whether integration will be achieved by private or public capital and about the degree to which the key political considerations of climate change and national security of energy supply will accelerate or delay the process.

## 11. Task Force: Research and Development

Focal point: Mel Ydreos; Chair: Marc Florette; Secretary: Marie-José Fourniguet

While governments and industry will continue to recognise the value of new technology, economic pressures will restrict gas R&D budgets so they only grow in line with inflation and remain, typically, in the range 0.5 – 1.0 percent of turnover.

- The future focus of R&D will depend on national energy positions, with companies operating in countries with no indigenous gas reserves focussing on efficient utilisation while those with large gas production potential will focus R&D on new production and treatment technologies.
- Overall, R&D investments will aim to optimise production, supply and energy use, assure safety and reliability of delivery systems, and reduce impacts on the environment throughout the gas chain.
- New investors will emerge in gas R&D, particularly for the exploitation of unconventional reserves and the production of SNG in markets where conventional supplies are in decline.
- Investment in R&D throughout the gas chain by a single company will be led by only the largest entities, such as Gazprom.
- GTL technology will develop, but only in niche geographic markets where conventional gas resources are not economic to export by pipeline or as LNG.
- R&D will continue to prove that gas technology can provide more efficient energy conversion, heating, and transportation options, but there is doubt about what could be brought to the mass market.
- Costs associated with CCS will decrease, and it will be important for the gas industry to be involved in this technology to maintain a competitive position with clean coal.
- Successful R&D programmes will lead to the wide application of hybrid energy systems in which gas and renewable energy are complementary.

**ANNEX 4: MATRIX OF DRIVERS AND LIMITING FACTORS BY INDUSTRY SEGMENT**

EXPLORATION & PRODUCTION		HOW WOULD A CHANGE IN THIS DRIVER AFFECT STUDY OUTCOMES/EXPECTED TRENDS?	WHICH OTHER PARTS OF THE GAS INDUSTRY MIGHT BE AFFECTED?
MAIN DRIVERS/LIMITING FACTORS			
Level of remaining reserves and prospects for new gas discoveries	In the Middle East, the high level of already discovered reserves will lead to low exploratory efforts, and a slow growth in proved reserves, despite high prospects for new gas finds. In North America, the low level of remaining reserves and low prospects of new finds (unless far away from demand centres, e.g. Arctic) will lead to a shift to unconventional resources exploration.	Transmission, LNG. R&D for unconventional gas resources; R&D for co-utilisation with renewables.	
Location of reserves relative to main markets	In Europe, the low level of remaining reserves and low prospects of new finds (including unconventional gas) will lead to increasing imports (low prospects for unconventional gas). Asia Pacific still has potential reserve growth, but big markets with low reserves and low prospects, like Japan and Korea, will push for unconventional gas development if the gas price stays high. In Africa and South America, large prospects for new finds will lead to high exploratory efforts and rapid increase in proved reserves.	Transmission, LNG; R&D for co-utilisation with renewables. R&D for unconventional gas resources, Transmission, LNG. R&D (deep and ultra deep water technology); Transmission; LNG.	
Level of market development	In Asia Pacific (namely Australia and Oceania), the large distance between markets will delay exploratory efforts and slow down growth of proven reserves, despite high prospects for new finds. Same for the reserves in the Arctic (FSU and North America). In South America and Africa the low level of market development will slow down exploration and production, even in presence of significant prospects. Conversely, countries and regions with a high level of market development will tend to promote E&P.	Transmission, LNG. All gas supply chain.	
Political stability and predictable policies	Political stability and predictable policies will affect the willingness of companies to invest in gas production infrastructure, e.g. political instability is expected to delay investment in Africa, Middle East and South America.	All gas supply chain.	
Availability of capital and attractiveness for investment	Availability of capital (locally) and/or attractiveness for foreign investment will also affect growth of gas production infrastructure.	All gas supply chain.	



## ANNEX 4: MATRIX OF DRIVERS AND LIMITING FACTORS BY INDUSTRY SEGMENT (continued)

MAIN DRIVERS/LIMITING FACTORS	HOW WOULD A CHANGE IN THIS DRIVER AFFECT STUDY OUTCOMES/EXPECTED TRENDS?	WHICH OTHER PARTS OF THE GAS INDUSTRY MIGHT BE AFFECTED?
<b>STORAGE</b>		
Level of gas import dependence	A higher level of cross-border gas trade and import dependence will generate generally a higher demand for storage, for security of supply reasons.	Utilisation, transmission and distribution.
Level of security of supply requirements	National or international/geopolitical issues might increase the level of security of supply requirements will increase the level of storage.	Utilisation, transmission and distribution.
Level of gas prices	Higher gas prices will increase the cost of storage thus reducing demand for storage.	Utilisation, transmission and distribution.
Level of gas price volatility	Higher gas price volatility will increase demand for storage.	Utilisation, transmission and distribution.
Availability and cost of new technologies for unconventional UGS	A lower cost of unconventional UGS will increase options for storage and thus total demand for storage.	R&D
Cost of raw materials	Higher costs will promote more maintenance and life extension of existing pipelines and less replacements.	E&P
Technological development linked to sub-sea pipeline installation	Technological development Leading to lower costs for installation of sub-sea pipeline installation will promote new sub-sea routes. Competition with LNG.	R&D, E&P, LNG, GTL
<b>TRANSMISSION</b>		
Cost of LNG transportation	Lower LNG transportation costs will make LNG more widely competitive with pipelines.	LNG, Transmission, GTL, etc
Technological developments (high pressures pipes)	Will increase capacity of new pipelines, reducing the amount of pipeline needed.	R&D
Increased safety concerns	Will promote either increased maintenance or earlier replacement, when this is the economic option.	R&D
Market regulation	Gas market regulation or deregulation may affect pipeline investment and gas demand, although the kind of impact (positive or negative) will depend on the direction of regulation.	All gas chain
Wider range of gas quality - biogas	Wider quality range could affect maintenance and future construction standards. But also creates new business opportunities.	
Geopolitics	Geopolitics, and in particular political tensions between countries and regions (including transit countries), may delay pipeline construction, or favour alternative supply options (LNG, unconventional gas, other fuels/energy types).	E&P; LNG, Effects will be felt downstream too (price)
Foreign investment availability	Will determine the ability of companies and countries to build new pipelines.	E&P; LNG

**ANNEX 4: MATRIX OF DRIVERS AND LIMITING FACTORS BY INDUSTRY SEGMENT (continued)**

ANNEX 4: MATRIX OF DRIVERS AND LIMITING FACTORS BY INDUSTRY SEGMENT (continued)		WHICH OTHER PARTS OF THE GAS INDUSTRY MIGHT BE AFFECTED?
MAIN DRIVERS/LIMITING FACTORS	HOW WOULD A CHANGE IN THIS DRIVER AFFECT STUDY OUTCOMES/EXPECTED TRENDS?	
<b>DISTRIBUTION</b>		
IT development and asset management knowledge	Higher IT development and increased asset management knowledge will result in a deeper knowledge of the networks, which will help allocate investment where they are really needed most.	IT suppliers, equipment suppliers
Safety regulation	Stricter safety standards will increase replacement investment needs, will require more complex civil engineering works (capex) and result in higher taxes on leakages (opex/capex).	TSO, equipment suppliers, civil engineering subcontractors, R&D
Technological development	Significant enhancements in characteristics of materials will result in a decrease in the number of damages due to gas leaks.	R&D, Producers of materials, contractors
Market regulation	Influences costs recovery in tariffs, which has a direct effect on replacement investment capacity.	TSOs (Transmission System Operators); equipment suppliers; civil engineering subcontractors
Gas price competitiveness	Lower gas price competitiveness will result in a lower gas demand as well as lower network development.	Equipment suppliers, house heating installers
Natural gas price	Sharp gas price increases will reduce competitiveness of gas against oil products and against coal or nuclear based electricity. The spread of gas-fired CHP will be delayed. The impact of the LNG price is especially large because of the extra costs of operation and maintenance of the regasification facilities.	Production, transmission, and distribution.
Taxation and other policies	The use of differential taxation and other policies promoting introduction of natural gas will increase natural gas use, particularly in sectors where oil is the dominant fuel, such as industrial heating furnaces and vehicles.	Production, transmission, and distribution.
Carbon tax	The effect of introducing a carbon tax will be different in different countries. In many countries, a carbon tax will help increase gas utilisation; promote the spread of gas-fired CHP and highly efficient gas appliances; as well as gas use for vehicles. But a carbon tax will have an adverse effect on gas in countries where the shares of hydro power, wind power or nuclear power are high and the average CO <sub>2</sub> emission intensity of electricity is low (e.g. Canada, Japan and France).	Production, transmission, and distribution.
Level of power price and taxes in relation to gas prices	If the power price (including taxes) increases faster than that of gas, than as an example more gas-heat-pumps will be installed.	Providers of heating appliances.
Blending with biogas	Increase supply security, energy efficiency and reduces emissions. Adds a 'green image' to natural gas, especially useful to promote gas use in vehicles.	NGV producers; biogas producers; transmission.
<b>UTILISATION</b>		

**ANNEX 4: MATRIX OF DRIVERS AND LIMITING FACTORS BY INDUSTRY SEGMENT (continued)**

SUSTAINABILITY		GAS MARKET INTEGRATION	
MAIN DRIVERS/LIMITING FACTORS	HOW WOULD A CHANGE IN THIS DRIVER AFFECT STUDY OUTCOMES/EXPECTED TRENDS?	WHICH OTHER PARTS OF THE GAS INDUSTRY MIGHT BE AFFECTED?	
Level of international cooperation on climate change (including Kyoto Protocol)	Adoption of more stringent emission reduction goals for developed countries (and adoption of some emission reductions commitments by selected developing countries) will promote lower-carbon technologies and energy efficiency. This should: <ul style="list-style-type: none"> <li>- favour gas over other fossil fuels;</li> <li>- promote renewable energy (including those with co-utilisation with gas);</li> <li>- favour nuclear power in some countries.</li> </ul>	All gas supply chain.	
Technology transfer to developing countries	Promoting transfer of high efficiency and low emission technologies to developing countries will contribute to wider application of gas technologies and more rapid displacement of other fossil fuels in developing countries.	All gas supply chain.	
Local pollution controls	Adoption of more stringent local pollution controls should help promote long-term investment in gas infrastructure, in particular in Asia.	E&P, transmission, distribution.	
Security of supply concerns – geopolitical issues	Can work both ways: can lead to promoting regional gas market integration (e.g. Europe) or to regional market “disintegration” (e.g. Southern Cone)	E&P, Transmission, LNG	
Changing role of NOCs versus IOCs	The governments’ priorities/attitude towards local and international gas companies are changing, with a general trend towards fortifying national companies (NOCs). The effect of this trend is difficult to predict as NOCs could either pursue regional market integration or could privilege domestic production.	E&P, Transmission, LNG	
Location of reserves relative to main markets	Whether a country has or not availability of gas reserves close to its main markets will determine its stance towards regional integration. In general, the development of reserves further away from markets (and the increase of gas dependency) should contribute to promote gas market integration, unless there are geopolitical problems.	E&P	

**ANNEX 4: MATRIX OF DRIVERS AND LIMITING FACTORS BY INDUSTRY SEGMENT (continued)**

STRATEGY, ECONOMICS AND REGULATION		LNG	
MAIN DRIVERS/LIMITING FACTORS	HOW WOULD A CHANGE IN THIS DRIVER AFFECT STUDY OUTCOMES/EXPECTED TRENDS?	WHICH OTHER PARTS OF THE GAS INDUSTRY MIGHT BE AFFECTED?	
Population growth	Population growth affects total energy demand and gas demand. It also influences the need for transmission and distribution expansion.	All gas value chain.	
Economic growth	Acceleration in economic growth in Asia will increase energy/gas consumption.	All gas value chain.	
High energy/gas prices	The current high cost of energy (including gas) could contribute to a reduction in economic growth leading to a reduced demand forecast. A potential impact on all markets, especially the emerging markets.	All gas value chain.	
Regulatory and fiscal stability	Any increase in regulatory and fiscal instability will reduce investment in infrastructure that is required. Changes in tax regimes on IOCs; interference in the natural market forces can affect all elements of the value chain.	All gas value chain.	
Supply-demand balance	Periods of supply and capacity constraints can lead to price increases and volatility. This then leads to regulatory and/or political response variously to improve security of supply and perhaps to control market/price, which in turn can undermine liberalisation agendas where they are initiated.	All segments with risk being affected, albeit in different ways.	
Environmental concerns / climate change / CO <sub>2</sub> pricing	Global commitments to regulate GHG emissions will increase need for clean fuels, such as natural gas. On the other hand, price structures designed to improve energy efficiency and provide incentives to renewables can dampen demand for natural gas. We could see an increase in gas for power generation, while the use of gas in homes, especially in new-build, will be detrimentally affected. This in turn will impact on distribution operations.	All gas value chain.	
Tightening environmental controls / standards	While climate change is overall a factor that could increase gas attractiveness versus its competing fossil fuels (coal), its implementation is a potential threat to gas market growth. Increased reporting and legislation may increase costs, delay infrastructure and reduce demand growth.	All gas value chain.	
Transition to renewable energy world	Increased reliance on renewable fuels can lead to efforts to blend natural gas service with renewables to offset intermittency of solar and wind (hybrid gas/renewable systems). Gas is the ideal bridge to renewable energy supply. On the hand, technology to improve reliability of renewable energy and/or enable electricity to be stored more effectively would reduce the need for gas.	R&D	
Location of reserves relative to main markets	The development of increasingly remote gas reserves, and the development of new market further away from reserves will lead to a substantial increasing in transoceanic gas trade.	E&P, Market Integration	
Security of supply concerns – geopolitical issues	Increasing concerns about security of gas supply, leading to the need to diversify gas supply sources and routes, are driving investment in LNG regasification facilities even where pipeline gas is available	Market Integration	
Need for flexibility	The increasing demand for gas supply flexibility is driving LNG demand.	Gas utilisation	
Technological improvements	Technological improvements are reducing costs and diseconomies of scale thus allowing for smaller cost-effective facilities.	R&D	

## ANNEX 4: MATRIX OF DRIVERS AND LIMITING FACTORS BY INDUSTRY SEGMENT (continued)

MAIN DRIVERS/LIMITING FACTORS	HOW WOULD A CHANGE IN THIS DRIVER AFFECT STUDY OUTCOMES/EXPECTED TRENDS?	WHICH OTHER PARTS OF THE GAS INDUSTRY MIGHT BE AFFECTED?
National circumstances and policy approaches	R&D priorities are expected to continue to vary substantially across countries, depending on national circumstances (whether a country is a gas producer or a gas importer) and on policy approaches / industry structures (whether the gas industry in a certain country is mainly private or public, vertically integrated or unbundled, etc).	All gas chain
Stranded gas	The existence of significant volumes of stranded gas in some countries or regions with increasing gas demand / gas deficits will stimulate R&D in particular to reduce costs or cost-effective scale of LNG and GTL facilities. Also to reduce costs of sub-sea pipelines.	LNG, transmission
Climate change and GHG emission caps	International commitments and local policies to reduce GHG emissions will promote R&D on low-carbon technologies and carbon capture/sequestration	
New technologies mainly in the area of utilisation of hydrogen and renewables	The increased availability and reduction of costs of new technologies in the area of utilisation of hydrogen and renewables may have both positive and negative impacts on gas demand. Negative impacts: Commercial utilisation of new methods of hydrogen production not using natural gas, wide implementation of hydrogen energy, will both automatically decrease interest in natural gas. Regulations and fiscal simplifications concerning biofuels, water, wind, geothermal energies, high investments on these areas, will slower further development of natural gas market Positive impacts: Natural gas may be the natural supplement for renewables in multi-fuel systems. The experience, knowledge, solutions etc. concerning natural gas transmission and distribution may be at least partly adopted for hydrogen systems. Competition is usually a great factor supporting development!	
Oil and gas prices	Increased oil and gas prices are seen as a major incentive for new technology development.	
Safety concerns	Improving the safety and integrity of gas supply systems remain one of the main drivers for R&D. The safe and reliable operation of both transmission and distribution assets will be an area of continued focus.	
Unconventional gas resources	The need to develop cost effective access to non traditional reserves (shale gas, coal bed methane, methane hydrates) will also be drive R&D efforts.	

R&amp;D

**ANNEX 5: MATRIX OF DRIVERS AND LIMITING FACTORS BY REGION**

REGION/COUNTRY	MAIN DRIVERS FOR GAS MARKET GROWTH	MAIN LIMITING FACTORS	
NORTH AMERICA	USA	<ul style="list-style-type: none"> <li>Declining conventional plays</li> <li>Low cost unconventional reserves, primarily shale, unlocked by technological progress</li> <li>Growing power demand from economic growth, new electrical applications and plug-in hybrids</li> <li>Substantial under-utilisation of gas-fired generation and LNG regasification capacity</li> <li>Effect of climate policy (uncertainty of final policy makes this an opportunity and a threat)</li> </ul>	<ul style="list-style-type: none"> <li>Effect of climate policy (uncertainty of final policy makes this an opportunity and a threat)</li> <li>Impact of renewables on gas generation</li> <li>Higher efficiency standards for gas and electric appliances</li> <li>Long-term decline of heavy industry</li> <li>Restrictions on gas development related to environmental concerns</li> <li>Increased federal taxes on production</li> <li>Shift of population to warm weather states</li> </ul>
	CANADA	<ul style="list-style-type: none"> <li>Consumption of gas in oil sands production</li> <li>Shut-down of Ontario coal-fired generation</li> <li>Effect of climate policy (uncertainty of final policy makes this an opportunity and a threat)</li> <li>Transition to unconventional gas production</li> </ul>	<ul style="list-style-type: none"> <li>Effect of climate policy (uncertainty of final policy makes this an opportunity and a threat)</li> <li>Long-term decline of heavy industry in Ontario and Quebec</li> </ul>
	MEXICO	<ul style="list-style-type: none"> <li>Growing gas penetration mainly in power generation</li> <li>Growing LNG demand because of security of supply concerns</li> </ul>	<ul style="list-style-type: none"> <li>Declining indigenous production</li> <li>Limited private sector participation allowed in upstream</li> </ul>
	BOLIVIA	<ul style="list-style-type: none"> <li>Large reserves</li> <li>Large growing markets in neighbouring countries (Brazil and Argentina)</li> </ul>	<ul style="list-style-type: none"> <li>Political and legal instability are delaying investment in E&amp;P and transportation</li> </ul>
SOUTH AMERICA	BRAZIL	<ul style="list-style-type: none"> <li>Large new discoveries close to main market</li> <li>Growing economy, growing share of gas in energy mix</li> </ul>	<ul style="list-style-type: none"> <li>Need for huge infrastructure growth</li> <li>Hydropower dominant in power generation</li> </ul>
	ARGENTINA	<ul style="list-style-type: none"> <li>Low prices drive up demand</li> </ul>	<ul style="list-style-type: none"> <li>But low prices also discourage exploration</li> </ul>
	VENEZUELA	<ul style="list-style-type: none"> <li>Huge reserves</li> <li>Good location for LNG exports</li> </ul>	<ul style="list-style-type: none"> <li>Instability of legal and regulatory framework</li> <li>Large gas use for reinjection to increase oil production</li> <li>Low prices in domestic market</li> </ul>

## ANNEX 5: MATRIX OF DRIVERS AND LIMITING FACTORS BY REGION (continued)

REGION/COUNTRY	MAIN DRIVERS FOR GAS MARKET GROWTH	MAIN LIMITING FACTORS
EUROPE	<ul style="list-style-type: none"> <li>• High share of gas-fired power generation and growing power generation needs</li> <li>• Downstream competition</li> <li>• Effect of EU 2020 targets</li> <li>• Security of supply concerns may promote LNG</li> </ul>	<ul style="list-style-type: none"> <li>• Declining indigenous production</li> <li>• Security of supply concerns may promote alternative fuels to natural gas</li> <li>• Diversification of fuel mix in power generation</li> <li>• Effect of EU 2020 targets</li> <li>• Higher efficiency standards</li> </ul>
RUSSIAN FEDERATION	<ul style="list-style-type: none"> <li>• Large, diversified reserve base</li> <li>• Large internal market</li> <li>• Improved commercialisation and pricing in domestic market</li> <li>• Large available pipeline infrastructure</li> <li>• Highly competitive cost of supply</li> <li>• Access (or potential access) to most major export markets, both via pipeline and LNG (Europe, Pacific, Asia, and North America)</li> </ul>	<ul style="list-style-type: none"> <li>• High level of government regulation and inconsistent policies, both upstream and downstream</li> <li>• Limited access for independent producers to markets and pipeline infrastructure</li> <li>• Transit issues</li> </ul>
CENTRAL ASIA	<ul style="list-style-type: none"> <li>• Large reserves</li> <li>• Existing pipeline infrastructure</li> <li>• Existing pipeline connections to export markets in Russia and Ukraine, Iran, and now China</li> </ul>	<ul style="list-style-type: none"> <li>• Long distances to major markets in all directions</li> <li>• Limited market access; high cost of new infrastructure</li> <li>• High level of government regulation and poor investment climate</li> <li>• Limited commercialisation and low prices in domestic markets</li> <li>• Multi-country transit issues</li> <li>• Land-locked, so no opportunity to develop LNG</li> </ul>
CAUCASUS	<ul style="list-style-type: none"> <li>• Ample reserves and sizable production potential; Existing pipeline connections to export markets in neighbouring countries (Georgia, Russia, Turkey, and Iran)</li> </ul>	<ul style="list-style-type: none"> <li>• Long distances to major markets</li> <li>• Multi-country transit issues</li> <li>• High cost of new pipeline infrastructure</li> <li>• Land-locked, so no opportunity to develop LNG</li> </ul>

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**ANNEX 5: MATRIX OF DRIVERS AND LIMITING FACTORS BY REGION (continued)**

REGION/COUNTRY	MAIN DRIVERS FOR GAS MARKET GROWTH	MAIN LIMITING FACTORS
NON-OECD	<ul style="list-style-type: none"> <li>• Energy diversification favours natural gas</li> <li>• Strong power demand growth</li> <li>• Environmental factors</li> <li>• Many countries relatively under-explored for gas</li> <li>• Unconventional gas (CBM) in some countries (Vietnam, India, Indonesia, China)</li> </ul>	<ul style="list-style-type: none"> <li>• Institutional barriers</li> <li>• Pricing policies (upstream and retail, depending on the country)</li> <li>• Competition from coal in power generation</li> <li>• Insufficient transmission infrastructure</li> </ul>
OECD	<ul style="list-style-type: none"> <li>• Power demand growth</li> <li>• Environmental factors</li> </ul>	<ul style="list-style-type: none"> <li>• Vertical integration of utilities (South Korea, Japan, Taiwan)</li> <li>• Linkage to oil prices (South Korea, Japan, Taiwan)</li> <li>• Resource depletion (New Zealand)</li> <li>• Location of resources (Australia)</li> </ul>
GULF AND IRAQ	<ul style="list-style-type: none"> <li>• Large reserves</li> <li>• Push for industrialisation (energy-intensive industries) coupled with low prices</li> <li>• Strong power sector growth</li> <li>• Need for post-war reconstruction (Iraq)</li> </ul>	<ul style="list-style-type: none"> <li>• High level of reserves deters further exploration</li> <li>• Tight sour gas</li> <li>• Contractual/legal uncertainties</li> <li>• Infrastructure needs: inexistent or in need of major refurbishment (Iraq)</li> </ul>
IRAN	<ul style="list-style-type: none"> <li>• Large reserves</li> <li>• growing demand from residential demand and industrialisation</li> <li>• Maturing oil sector needing more gas for reinjection</li> </ul>	<ul style="list-style-type: none"> <li>• Difficult political landscape and complex institutional set-up</li> <li>• Tense International relations</li> <li>• Need for additional investment in infrastructure</li> <li>• Problem of deliverability</li> </ul>
EAST MEDITERRANEAN COUNTRIES	<ul style="list-style-type: none"> <li>• Transit countries</li> <li>• Proximity to Europe</li> <li>• Low prices</li> </ul>	<ul style="list-style-type: none"> <li>• Small reserves</li> <li>• Political risk</li> <li>• Slow investment in infrastructure</li> </ul>

ASIA & ASIA PACIFIC

MIDDLE EAST



## ANNEX 5: MATRIX OF DRIVERS AND LIMITING FACTORS BY REGION (continued)

REGION/COUNTRY	MAIN DRIVERS FOR GAS MARKET GROWTH	MAIN LIMITING FACTORS
NORTH AFRICA	<ul style="list-style-type: none"> <li>• Big reserves and strong exploration push</li> <li>• Proximity to Europe (suppliers or transit)</li> <li>• Strong power demand growth</li> <li>• Industrialisation (Algeria)</li> <li>• Post-embargo (Libya)</li> </ul>	<ul style="list-style-type: none"> <li>• Inefficiencies (Libya)</li> <li>• Contractual/legal uncertainty</li> <li>• Infrastructure bottlenecks</li> </ul>
SUB-SAHARAN AFRICA	<ul style="list-style-type: none"> <li>• Many countries still underexplored, with potential discoveries</li> <li>• Gas sector still in its infancy, huge gas flaring: potential for monetisation</li> <li>• Development needs</li> </ul>	<ul style="list-style-type: none"> <li>• Lack of infrastructure and capital</li> <li>• Political unrest (Niger Delta)</li> <li>• Power generation dominated by hydro and coal</li> <li>• Fragmentation of regional markets</li> </ul>

AFRICA

## ANNEX 6: IGU'S GUIDING PRINCIPLES FOR SUSTAINABLE DEVELOPMENT

In 2003 the International Gas Union prepared a document entitled "Guiding Principles for Sustainable Development," containing a set of principles proposed for the global gas industry. The objective was to align gas industry practices with environmental preservation and principles of corporate social responsibility.

Four years after this document was published, one of IGU's technical committees (Programme Committee A – Sustainable Development) was asked to carry out a survey to determine the extent to which the principles were actually being implemented by the gas industry. The survey also aimed at collecting feedback regarding their current applicability.

The IGU Principles are guided by the following declarations:

- The Universal Declaration of Human Rights, 1948
- The International Labour Organisation's Declaration on Fundamental Principles and Rights at Works, 1998
- The Rio Declaration on Sustainable Development and its Agenda for the 21st Century, 1992
- The United Nations Global Compact, 1999
- The OECD Principles of Corporate Governance, 1999
- The Millennium Summit, 2000
- The United Nations Convention against Corruption (UNCAG in December 2005)

The approach to sustainable development was not restricted to environmental considerations, but adopted a much more comprehensive standpoint encompassing also social issues, economic development, and integrity. Some of the key aspects considered in the IGU Guiding Principles for Sustainable Development are:

### Environmental Aspects

- Consider the climate change impact.
- Use environmental criteria in business management.
- Take actions beyond the continuous enforcement of applicable regulations, taking into account international standards and legislative trends.
- Employ awareness, good practices, and technologies that enable activities to be conducted to the maximum benefit of the environment.
- Integrate the environmental variable in selecting and evaluating suppliers and contractors.
- Encourage clean and efficient gas utilisation.
- Promote any solution combining the efficient use of natural gas and renewable energies.
- Promote continuous improvement by means of environmental management systems and communicate in an open, transparent, and objective manner on environmental matters to stakeholders: employees, authorities, customers, shareholders, and the public

### Social Aspects

- Assess the social impacts of the company's activities.
- Effectively implement environment, health, and safety management systems and leading-edge employment standards and practices.

- Improve awareness of working conditions, human rights, discrimination, labour standards, and training.
- Prioritise local employment and suppliers, and develop an open dialogue with interested parties such as customers, employees, governments, and nongovernment organisations.
- Promote technology transfer, taking advantage of the Clean Development Mechanisms of the Kyoto Protocol.

#### Economic Aspects

- Support employment fairness.
- Develop transparent, non-discriminatory pricing policies.
- Maintain economically viable conditions for necessary investments.
- Promote innovation and research oriented to competitiveness and long-term social responsibility.

#### Integrity Aspects

- Reject and fight corruption in all its forms.
- Support the principles of the United Nations Global Compact as well as the OECD Principles of Corporate Governance.
- Respect all the aspects of the United Nations' Universal Declaration of Human Rights.

To ensure future implementation and improvement, the IGU will support a dynamic approach, based on a “plan, do, check, and act” approach, including the following objectives:

- Integrate environmental, social, and economic considerations into the process of planning, construction, and operation.
- All employees receive education on environmentally sound, socially responsible, and economically viable behaviour and decision-making to assure effective implementation of a sustainable development approach.
- Evaluate, using a comprehensive view from “cradle to grave,” the impacts and benefits of the activities, when establishing and implementing corporate policies, goals, programmes, and procedures.
- Assess compliance with company procedures, guaranteed by regular audits and relevant reports provided to government, employees, and other interested parties.
- Measure and report sustainable development using performance indicators as a reference for improvements

## ANNEX 7: ABBREVIATIONS AND UNITS

a	annum (year)
bbbl	barrel (of oil)
Bcf	billion cubic feet
Bcm	billion cubic metres
Bcm/a	billion cubic metres per annum
bd	barrels per day
Brent	Brent crude oil
btoe	billion tons of oil equivalent
Btu	British thermal units
CBM	coal-bed methane
CCGT	combined-cycle gas turbine
CCS	carbon capture and storage
CDM	clean development mechanism
CFCs	chlorofluorocarbons
CHP	combined heat and power
cif	carriage, insurance, and freight
CIS	Commonwealth of Independent States
CNG	compressed natural gas
CO <sub>2</sub>	carbon dioxide
CTL	coal to liquids
d	day
DOE	Department of Energy (USA)
E&P	exploration and production
EC	European Commission
EIA	Energy Information Administration (USA)
ETS	European trade scheme
EU	European Union
FE	Far East
fob	free on board
FSU	Former Soviet Union
FT	Fischer-Tropsch
GDP	gross domestic product
GHG	greenhouse gas
GJ	gigajoules or 10 <sup>9</sup> joules
GTL	gas to liquids
GW	gigawatt
HFO	heavy fuel oil
HSFO	high-sulphur fuel oil
IEA	International Energy Agency
IGCs	international gas companies
IGU	International Gas Union
IOCs	international oil companies
IPP	independent power producer
km	kilometre
kWh	kilowatt-hour or 0.036 GJ
LFO	light fuel oil

LNG	liquefied natural gas
LSFO	low-sulphur fuel oil
M or m or MM	million
m <sup>3</sup> /h	cubic meters per hour
mdb	million barrels per day
MMBtu	million British thermal units
mt	million metric tonnes
mt/a	million tonnes per annum
MTBE	methanol tertiary butyl ether
Mtoe	million tonnes of oil equivalent
Mtoe/a	million tonnes of oil equivalent per annum
mtpa	million metric tonnes per annum
NBP	National Balancing Point (UK)
NGCs	national gas companies
NGG	national gas grid
NGV	natural gas vehicle
NOCs	national oil companies
NO <sub>x</sub>	nitrogen oxides
NW	Northwest
O&M	operations and management
OECD	Organisation for Economic Co-operation and Development
OPEC	Organisation of Petroleum Exporting Countries
PEC	primary energy consumption
PED	primary energy demand (same as PEC)
PEFC	polymer electrolyte fuel cell
ppm	part per million
PV	photovoltaic
PVC	polyvinyl chloride
R&D	research and development
S	sulphur
SNG	synthetic natural gas
SO <sub>2</sub>	sulphur dioxide
SOFC	solid oxide fuel cell
SO <sub>x</sub>	sulphur oxides
t	metric tonnes or 106 grammes
tce	tonnes of coal equivalent (or 29.31 GJ net)
Tcf	trillion cubic feet
Tcm	trillion cubic metres
toe	tonnes of oil equivalent (or 41.87 GJ)
UAE	United Arab Emirates
UGS	underground storage
UK	United Kingdom
US or USA	United States of America
VAT	value-added tax
VLCC	very large crude carrier
WBCS	World Business Council for Sustainable Development
WEO	World Energy Outlook (published by the IEA)
WGV	working gas volume
WTI	West Texas Intermediate

## ANNEX 8: GLOSSARY

**Associated gas:** Gas reserves found in reservoirs that hold a large percentage of liquid hydrocarbons.

**Biogas:** A mixture of methane and carbon dioxide produced by bacterial degradation of organic waste from domestic, industrial, and agricultural sewage) and used as a fuel.

**Biomass:** Biomass energy or bioenergy is defined as any plant matter used directly as fuel or converted into other forms before combustion. It includes wood, vegetal waste (including wood waste and crops used for energy production), animal wastes, sulphite lyes, also known as “black liquor” and other solid biomass.

**Brent:** One of the major classifications of oil consisting of Brent crude, Brent Sweet Light crude, Oseberg, and Forties. Brent Crude is sourced from the North Sea. A benchmark price for oil production from Europe, Africa, and the Middle East flowing West.

**British thermal unit (Btu):** A standard measure of heat energy contained in a given fuel; commonly used to compare consumption and production volumes of energy sources with varying units of measure (oil, gas, coal, nuclear); 1 Btu is equal to the amount of heat required to raise the temperature of 1 pound of liquid water by 1 degree Fahrenheit at its maximum density, which occurs at a temperature of 39.1 degrees Fahrenheit.

**Carbon capture and storage (CCS):** A process of separating carbon dioxide (CO<sub>2</sub>) emissions from large stationary sources (power plants, factories, etc.), transporting the gas, and storing it in geologic or ocean reservoirs. Potential geologic reservoirs for storage include active oil fields where the CO<sub>2</sub> is used for enhanced oil recovery, depleted oil and gas fields, unmineable coal seams, and deep saline formations (also called carbon capture and sequestration).

**Chlorofluorocarbons (CFC):** Any of various compounds consisting of carbon, hydrogen, chlorine, and fluorine used as refrigerants.

**Clean Development Mechanism (CDM):** A Kyoto Protocol program that enables industrialised countries to finance emissions-avoiding projects in developing countries and receive credit for reductions achieved against their own emissions limitation targets.

**Coal-to-liquids (CTL):** A chemical process whereby carbon monoxide and hydrogen are converted into liquid hydrocarbons, using coal as feedstock.

**Combined-cycle gas turbine (CCGT):** An electric generating technology introduced from the 1980s that has a much higher transformation efficiency than the traditional steam turbines and the single-cycle gas turbines, reducing the amount of fuel input necessary per unit of power output. CCGT however can normally only use cleaner fuels, such as gas, gasoil and naphtha.

**Combined heat and power (CHP):** A plant designed to produce both heat and electricity from a single heat source.

**Demand-side management:** The planning, implementation, and monitoring of utility activities designed to encourage consumers to modify patterns of electricity usage, including the timing and level of electricity demand.

**Emissions trading scheme (ETS):** An emissions trading system set up by the European Union for the period of 2005–07 as a test designed to help its member states change to a system that leads to compliance with their emission reduction targets set under the Kyoto Protocol which covers the period 2008–12.

**Enhanced oil recovery (EOR):** The recovery of oil from a reservoir using means other than the natural reservoir pressure. EOR generally results in increased amounts of oil being removed from a reservoir in comparison to methods using natural pressure or pumping alone.

**Feedstock:** Natural gas, which is used as essential component of a chemical product, e.g. fertiliser.

**Fischer-Tropsch (FT) process:** The Fischer-Tropsch process is a catalyzed chemical reaction in which carbon monoxide and hydrogen are converted into liquid hydrocarbons of various forms. Typical catalysts used are based on iron and cobalt. The principal purpose of this process is to produce a synthetic petroleum substitute for use as synthetic lubrication oil or as synthetic fuel.

**Flue gas desulphurisation (FGD):** Equipment used to remove sulphur oxides from the combustion gases of a boiler plant before discharge to the atmosphere. Also referred to as scrubbers. Chemicals such as lime are used as scrubbing media.

**Foreign Direct Investment (FDI):** Investment of foreign assets into domestic structures, equipment, and organisations.

**Gas-to-liquids (GTL):** A chemical process whereby carbon monoxide and hydrogen are converted into liquid hydrocarbons, using gas as feedstock.

**Greenhouse gases (GHGs):** Gases of natural or anthropogenic source that absorb infrared radiation produced by solar warming of the Earth's surface. Earth's most abundant greenhouse gases are: water vapour, carbon dioxide, methane, nitrous oxide, ozone, CFCs.

**Gross/net calorific basis:** The difference between the "net" and the "gross" calorific value is the latent heat of vaporisation of the water vapour produced during combustion of the fuel. For natural gas, the net calorific value is 10 per cent lower than the gross calorific value.

**Integrated gasification combined-cycle (IGCC):** A type of power generation technology that gasifies fuels such as petroleum residues or coal internally to allow the burning of these fuels in a gas turbine in a combined cycle.

**Joint Implementation (JI):** Agreements made between two or more nations under the auspices of the Framework Convention on Climate Change whereby a developed country can receive "emissions reduction units" when they help to finance projects that reduce net emissions in another developed country (including countries with economies in transition).

**Liquefied natural gas (LNG):** Natural gas (primarily methane) that has been liquefied by reducing its temperature to -260 degrees Fahrenheit at atmospheric pressure.

**Liquefied petroleum gas (LPG):** A group of hydrocarbon-based gases derived from crude oil refining or natural gas fractionation. They include ethane, ethylene, propane, propylene, normal butane, butylene, isobutane, and isobutylene. For convenience of transportation, these gases are liquefied through pressurisation.

**Local distribution company (LDC):** A legal entity engaged primarily in the retail sale and/or delivery of natural gas or electricity.

**Long-run marginal cost:** Marginal cost is the change in total cost that arises when the quantity produced (or purchased) changes by one unit. Long-run marginal cost allows all inputs, including capital items (plant, equipment, buildings) to vary.

**Methanol tertiary butyl ether:** An ether intended for gasoline blending.

**Midstream:** Segment of the natural gas chain that includes transmission and storage. Sometimes midstream is included into downstream, as opposed to upstream.

**Natural gas liquids (NGLs):** Liquid hydrocarbons found in association with natural gas, such as natural gasoline and other products including ethane, butane, and propane.

**Non-associated gas:** Gas reserves found in reservoirs that contain mostly gaseous hydrocarbons.

**Photovoltaic:** Energy radiated by the sun as electromagnetic waves (electromagnetic radiation) that is converted into electricity by means of solar (photovoltaic) cells.

**Photovoltaic cell:** An electronic device consisting of layers of semiconductor materials fabricated to form a junction (adjacent layers of materials with different electronic characteristics) and electrical contacts, and capable of converting incident light directly into electricity (direct current).

**Photovoltaic (PV) power generation systems:** Energy radiated by the sun as electromagnetic waves (electromagnetic radiation) that is converted into electricity by means of solar (photovoltaic) cells.

**Polymer electrolyte membrane :** A hydrogen/oxygen proton exchange membrane fuel cell, a proton-conducting polymer membrane, (the electrolyte) separates the anode and cathode sides. Most commonly used in transportation applications (also called proton exchange membrane).

**Production-sharing agreements:** Agreements used primarily to determine the share a private company will receive of the natural resources (usually oil) extracted from a particular country.

**Proven reserves:** Those reserves that geological and engineering information indicates with reasonable certainty can be recovered in the future from known reservoirs under existing economic and operating conditions.

**Steam turbine:** A type of power generation technology that uses steam heat from fuel combustion to drive an electric generator.

**Unconventional gas:** Gas produced from unconventional source: i.e. tight sands gas, coal-bed methane, and shale gas.

**Upstream:** Segment of the natural gas chain that includes exploration, development, production, gathering and purification. The term is used in opposition to downstream or to midstream and downstream.

**West Texas Intermediate:** A light, low-sulphur crude oil that serves as the benchmark oil price in the United States.



## Conversion Factors:

FROM:	TO: (multiply by)							
	1 cubic metre (gas)	1 cubic foot (gas)	1 MMBtu	1 therm	1 gigajoule	1 cubic metre LNG	1 metric ton LNG	1 barrel crude oil
1 cubic metre (gas)	1.00	35.3	0.038	0.38	0.040	0.00171	0.00073	0.00611
1 cubic foot (gas)	0.028	1.00	0.001	0.011	0.0011	0.00005	0.00002	0.00017
1 MMBtu	26.32	929	1.00	10.00	1.06	0.05	0.02	0.17
1 therm	2.63	93	0.10	1.00	0.1055	0.0048	0.0019	0.0172
1 gigajoule	25.0	883	0.95	9.48	1.00	0.045	0.018	0.163
1 cubic metre LNG	584	20,624	21.04	210.4	22.19	1.00	0.41	3.59
1 metric ton LNG	1,379	48,699	52	520	54.80	2.47	1.00	8.98
1 barrel crude oil	164	5,781	5.8	58	6.1	0.28	0.11	1.00

Quick Conversion:	1 MMBtu	= 28 cubic metres	= 1 thousand cubic feet
	1 million cubic meter	= 38 thousand MMBtu	= 35 million cubic feet
	1 million cubic meter per annum	= 2.7 thousand cubic meter per day	
	1 million cubic feet per annum	= 2.7 billion cubic feet per day	

## Assumptions:

The cubic metre and cubic feet are volume measures, while Btu, joules, kWh, and therms are energy content units. The cubic meter to Btu conversion depends on the specific gas calorific value and on the temperature and pressure at which is it measured.

The difference between the "net" and the "gross" calorific value is the latent heat of vaporisation of the water vapour produced during combustion if the fuel. For natural gas, the net calorific value is 10 per cent lower than the gross calorific value.

The IGU statistics are in cubic metres, based on the following assumptions:

- temperature: 0 degrees Celsius
- pressure: 1 bar
- energy content: 40 MJ/m<sup>3</sup> (gross calorific value)



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